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CONTRIBUTING PAPERS

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Climate Change and Agricultural Production-Adapting Crops to Climate Variability and Uncertainty

(April 6-8, 2017)

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PREFACE

Climate Change and its extremes are increasingly one of the most serious national food security threats, which will have significant impacts on agriculture, natural resources, ecosystem and biodiversity. Agriculture is strongly influenced by weather and climate. The nature of agriculture and farming practices in any particular location are strongly influenced by the short and long-term mean climate. These changes are likely to threaten food production, increase water stress and decrease its availability, result in sea-level rise that could flood crop fields. Water is vital to plant growth, so varying precipitation patterns will have a significant impact on agriculture. Precipitation not the only influence on water availability but increasing evaporation demand owing to rising temperatures and longer growing seasons could increase crop irrigation requirements globally by between 5 and 20 per cent, or possibly more. Changes in short-term temperature extremes can be critical, especially if they coincide with key stages of plant development. Projections indicate the possibility of loss of 4–5 million tonnes in wheat production with every rise of 1°C temperature throughout the growing period . Only a few days of extreme temperature at the flowering stage of many crops can drastically reduce yield. The impact of high temperatures on final yield can depend on the stage of crop development. Rising atmospheric CO_2 and climate change may also impact indirectly on crops through effects on pests and disease. Indications suggest that pests and disease will may result in more lossess and can put challenge for management. These interactions are complex and as yet the full implications in terms of crop yield are uncertain. Climate variability and climate change can force farmers to adopt new agricultural practices in response to altered climatic conditions. The potential effect of climate change on agriculture is the shifts in the sowing time and length of growing seasons geographically, which would alter planting and harvesting dates of crops and varieties currently used in a particular area. The Indian agriculture will experience lots of ups and downs in the coming years due to natural resource depletion and changing climate events. Understanding the climate changes over a period of time and adjusting the management practices towards achieving better harvest is a challenge to the growth of agricultural sector as a whole.

There is urgent need to have planned research with cordianted efforts of agriculture university, institutes of Indian Council of Agricultural Research and international research organization to overcome the challenge of climate change. Therefore, Bihar Agriculture University, Sabour in collaboration with Indian Ecological Society has organized a National Conference–Climate Change and Agricultural Production-(Adapting Crops to Climate Variability and Uncertainty (April 6-8, 2017) at Sabour Bhagalpur Bihar. The conference was programmed in around 5 broad themes as follows:

1.Climatic Uncertainties, impact and Adaptation in Agriculture
2. Weather Based Information, Crop Simulation Modeling and Remote Sensing Applications in Climate Change
3. Natural Resource Management, Information & Communication Management Concerning Climate Smart Agriculture
4. Crop Weather Pest Dynamics and Innovative Agronomic and Breeding Practices
5. Climate Change and Livestock, Fisheries and Poultry

In addition, 2 special session namely, "Abiotic Stress Tolerant Rice for Adaptation to a Climate Change" with IRRI (International Rice Research Institute), and "Sustainable Intensification and Climate Smart agriculture for Smallholders" with CIMMYT (International Maize and Wheat Improvement Center) were also organized during the conference.

The first issue of Indian Journal Ecology conatains 61 research papers out of 300 submitted by the policy planner, scientists, students and extension specialist from various universities, institues and organizations. Information on various aspect of impact of climate on agriculture will be useful not only for students, teachers and researchers in agricultural but also for administrators, planners and field level extension functionaries.

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Exposed to Global Warming-Challenges, Opportunities and Future Directions

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Abstract: Global warming and climate change is one of the most extensively researched and discussed topical issues affecting the environment. Food security threatened by climate change is one of the most important challenges in the 21st century to supply sufficient food for the increasing population while sustaining the already stressed environment. There is growing evidence that, as a result of climate change, temperature increase is likely to be 1.8-5.0°C. There will be a 10-percent increase in annual mean monsoon intensity, a 15-per cent increase in year-to-year variability in monsoon precipitation. This would lead to more frequent hot extremes, floods, droughts and cyclones and gradual recession of glaciers in India over the next 20-50 years, which in turn would result in greater instability in food production. Of the total annual crop losses in agriculture, many are due to direct weather and climatic effects such as droughts, flash floods, frost, storms, hail, heat and cold wave. It is estimated that crop production loss in India by 2100 AD could be 10-40% despite the beneficial effects of higher CO_2 on crop growth. The impact of climate change on water availability will be particularly severe for India. About 54 percent of India's groundwater wells are decreasing, with 16 percent of them decreasing by more than one meter per year. Dynamic of pests and diseases will be significantly altered leads to the emergence of new patterns of pests and diseases which will affect crops yield. A wide variety of adaptation and mitigation options have been identified as having the potential to reduce vulnerability of agricultural systems to risks related to climate change. The paper aims to discuss (i) increasing temperature trends causing the agro-meteorological risks, (ii) their impact on crop production and, (iii) strategies for management of these climatic risks for better crop production.

Keywords: Global warming, Impact, Crop production, Adaptation

Global warming is and will continue to be a "significant obstacle" to efforts to eradicate poverty. Global warming is the term used to describe a gradual increase in the average temperature of the Earth's atmosphere and its oceans, a change that is believed to be permanently changing the Earth's climate. There is great debate among many people, and sometimes in the news, on whether global warming is real (some call it a hoax). But climate scientists looking at the data and facts agree the planet is warming. While many view the effects of global warming to be more substantial and more rapidly occurring than others do, the scientific consensus on climatic changes related to global warming is that the average temperature of the Earth has risen between 0.4 and 0.8°C over the past 100 years (Qin *et al*., 2013). The increased volumes of carbon dioxide and other greenhouse gases released by the burning of fossil fuels, land clearing, agriculture, and other human activities, are believed to be the primary sources of the global warming that has occurred over the past 50 years.

Global warming impacts on agriculture are being witnessed all over the world, but countries like India are more vulnerable in view of the high population depending on agriculture and excessive pressure on natural resources. Annual surface air temperatures over India have shown increasing trends of 0.84ΩC over the period 1901–2014 (Annual Climate Summary, 2014). Various studies conducted to study the effects of climate change on the crop production showed that the effect of climate change on crop production varied with the climate change scenario used, current climate, cropping systems, management practices and also from region to region (Islam *et al*., 2014; Ko*et al*., 2011).Kumar *et al.,* (2013) reported decrease in irrigated rice yields in India by about 4, 7, and 10 % during the 2020s (2010–2039), 2050s (2040–2069), and 2080s (2070–2099), respectively. Whereas, 6–23 and 15–25 % reduction in the wheat yield in India during 2050s and 2080s, respectively has been reported by Kumar *et al*., (2014) under projected climate change scenarios. These results indicate that projected impacts are likely to further aggravate yield fluctuations with impact on food security, prices, access, stability and utilization.In addition, water requirement of crops is also likely to go up with projected warming and extreme events are likely to increase. Besides crops, climate change will effect on thegrowth of livestock, fish and aquaculture enterprises, forest and pasture in different ways. It will also have an impact on the incidence of pests and diseases, biodiversity and ecosystems.

Hence, there is a need to address the whole issue of climate change and its impacts on Indian agriculture in totality so as to cope with it through adaptation and mitigation.This paper considers the likely changes that climate change will bring in temperature, precipitation and the impact on agriculture. Needed based adaptation measures including changes needed for mitigation to improve agriculture sector have also been discussed. It is intended to provide useful background information for scientists as well as policy makers who are interested in understanding the impacts of climate change on agriculture and food security and to devise suitable adaptation options.

Global Green House Gas Emission

Global carbon emissions from fossil fuels have significantly increased since 1900. Since 1970, CO_2 emissions have increased by about 90%, with emissions from fossil fuel combustion and industrial processes contributing about 78.5% of the total greenhouse gas emissions increase from 1970 to 2014. Agriculture, deforestation, and other land-use changes have been the second-largest contributors (IPCC, 2014). The six largest emitting countries/regions in 2014 were: China (with 30%), the United States (15%), the European Union (EU-28) (9.6%), India (6.6%), the Russian Federation (5.0%) and Japan (3.6%). Remarkable trends were seen in the top three emitting countries/regions, which account for 54% of total global emissions. In China and the United States, emissions increased by 'only' 0.9%. The European Union saw a large decrease of 5.4% in 2014, compared to 2013, which offset the 7.8% growth in India. The Russian Federation and Japan saw their CO_2 emissions decline by 1.5% and 2.6%, respectively (Netherlands Environmental Assessment Agency, 2015).

Emission of GHGs in Indian Agriculture

It is also important that role of agricultural activities in increasing the levels of GHGs is often overlooked. The updated inventory for the year 2010 showed that the agricultural sector, including crop and animal husbandry, emitted 406 Mt of CO_2 eq. (Table 1), the enteric fermentation constituted 52% of the total CO2 eq. emissions from this sector. Agricultural soils emitted 23% of the total CO_2 eq. emission from agriculture, whereas rice cultivation contributed 17%. Livestock manure management contributed 6% of the emissions and 2% was attributed to the burning of crop residues in field. The direct and indirect N_2O emissions from Indian agricultural soils were 259 Gg and 45 Gg (94 Tg CO2 eq.), respectively in 2010. Fertilizer was the largest source contributing 77% to the total direct nitrous oxide emissions.

Warming temperatures trends

Warming due to climate change is now reality as evident from the significant increase in the CO_2 concentration (404.48 ppm as on January 6, 2017) which has caused most

Table 1. Greenhouse gas emissions from Indian agriculture in 2010

Source	GWP (CO_2 eq.)
Enteric fermentation	211
Manure management	27
Rice cultivation	68
Agricultural soil	94
Crop residue burning	6
Total	406

of the warming and has contributed the most to climate change (NOAA, 2017).Yet again, year 2016 set a global heat record for the third year in a row according to NOAA and NASA. To put this in perspective, it also means 16 of the 17 hottest years on record have occurred since 2000. A record El Nino lasting from 2015 into 2016 played a role in further pushing the planet's temperature higher. El Ninos are weather phenomena that warm the Pacific Ocean and pump lots of excess heat into the atmosphere, raising global temperatures. To come up with its figures the World Meteorological Organization (WMO) combined different global temperature datasets from various sources, including NOAA, NASA, the UK Met Office and the European Weather and Climate Senter. Despite using different methods to compile and analyze the temperatures, all those agencies reached the same conclusion, that 2016 continued the long-term trend of warming that has been seen since the 1970s. Additionally, scientists from the Intergovernmental Panel on Climate carrying out global warming research have recently predicted that average global temperatures could increase between 1.4 and 5.8 °C by the year 2100 (IPCC, 2014).

In India, annual surface air temperatures also have shown increasing trends of similar magnitude during the period 1901-2016, making 2016 the warmest year in the period of instrumental data. The year 2016 was warmer than last year by 0.24 Degree Celsius. The annual mean land surface air temperature averaged over the country during 2016 was +0.91 Degree Celsius above the 1961-1990 average, thus making the year 2016 as the warmest year on record since nation-wide records commenced in 1901. The other 5 warmest years on record in order were: 2009 (anomaly +0.84°C), 2010 (+0.81), 2015 (+0.72), 2003 (+0.67), and 2002 (+0.61). It is important to note that 13 out of 15 warmest years were during the recent past fifteen years (2002-2016). Past decade (2001-2010/ 2007-2016) was also the warmest decade on record with anomalies of 0.53°C /0.58°C. The annual mean temperature during 1901-2016 showed an increasing trend of 0.65°C/100 years (Figure 3) with significant increasing trend in maximum temperature (1.06°C/100 years), and relatively lower increasing trend

(0.25˚C/100 years) in minimum temperature (IMD, 2016). However, during the recent years, minimum temperatures (nighttime) have increased more than daytime temperatures, suggesting the possible role of moisture and the greenhouse gases (Annual Climate Summary, 2015).The changes in mean value or variance in temperatures may cause increase in extreme temperatures and therefore occurrence of extreme events (Qin, 2013). Two drought years in south central India created panic and for the first time in the history and special trains were put in place to provide drinking water. The reason being attributed to most of the El Nino years which have either led to droughts or below normal rainfall in India (Prasad *et al*., 2014; Rishma and Katpatal, (2016). Since 1871, El Nino caused 8 prominent droughts in India. Recent droughts occurred in 2002, 2009, 2014 and 2015, low rainfall during an El Nino year severely affects crop production. According to the World Meteorological Organization, in 135 years from 1880 to 2015, about 90% of all El Nino years have led to below normal rainfall and 65% has led to droughts.

Climate Change Impacts on Major Crops Yield

Impacts of climate change on food production are global and local. Climate change will affect agricultural food systems in all countries, including exporters and importers as well as those at subsistence level. Warming related extreme weather events are already a significant challenge for grain producers and are predicted to increase under future climate scenarios (Zheng *et al*., 2012). Since 1980 there has been a progressive increase in temperatures in all of the major cropping countries with the exception of the United States (Lobell *et al.,* 2011). A world‑wide analysis by Teixeira *et al*. (2013) to determine the potential ′hot‑spots′ predicted that continental lands in the high latitudes (between 40 and 60Ω N), particularly Central and Eastern Asia, Central North America and the Northern part of the Indian subcontinent were the key cropping areas facing heat stress risk.

India is considered to be vulnerable to climate change impacts in view its high population depending on agriculture and excessive pressure on natural resources. Cereal productivity is projected to decrease by 10‑40% by 2100 and greater loss is expected in winter. There are already evidences of negative impacts on yield of wheat and paddy in major parts of India due to increased temperature, increasing water stress and reduction in number of rainy days. However, climate change impacts are likely to vary in different parts of the country. For example, Parts of western Rajasthan, Southern Gujarat, Madhya Pradesh, Maharashtra, Northern Karnataka, Northern Andhra Pradesh, Utter Pradesh, Bihar and West Bengal are likely to be more vulnerable in terms of climate change and its extreme events (Mall *et al*., 2006; Rao *et al*., 2016). Whereas, the districts in Punjab and Haryana are having low vulnerability due to their higher adaptive capacity to recover from the climatic stresses (Sehgal*et al*., 2013).

Temperature during ear emergence and anthesis is considered an important factor limiting yield of cereal crop (Luo, 2011). For example in wheat, the optimum temperature for anthesis and grain filling ranges from 12 to 22°C. Exposure to temperatures above this can significantly reduce grain yield. Heat stress during anthesis increases floret abortion and during the reproductive phase can cause pollen sterility, tissue dehydration, lower CO_2 assimilation and increased photo respiration. Therefore, when temperatures are elevated between anthesis to grain maturity, grain yield is reduced because of the reduced time to capture resources (Figure 1, Farooq *et al*., 2011). Low temperature spell (below 10°C) in cereals also may disturb the formation of pollen mother cells and can thus cause sterility resulting in yield loss or crop failure (Chawade *et al.,* 2013). For example, prevalence of very cold weather during the anthesis period of wheat (*aestivum* and durum var.) can cause pollen sterility as high as 98% (Subedi *et al.,* 1998). In India, a study of Chakrabarti *et al*. (2011) has found wheat varieties where an thesis and flowering took place in the month of December and January (sown in October) experienced very low temperature leading to more number of sterile pollens and in turn, pollen germination has been found to be positively correlated with yield (R^2= 0.65) as higher pollen germination (85.2%) obtained at temperature of 18.4 °C has resulted in better grain setting (Figure 2). These findings indicate that time of sowing can be an important management strategy to avoid the chilling and terminal heat stress losses in wheat. Timely planting may avoid both chilling and terminal heat stress so that grain filling occurs during optimum temperatures.

Higher temperature risks can be addressed by integration of different components like building resilience of crops, soils and farmers. Appropriate technologies including crop diversification; developing crop genotypes with high and stable yields coupled with abiotic and biotic stress tolerance; location specific soil and water conservation measures, alternate land use systems and integrated farming systems have to be evolved further and promoted through a participatory approach.

Climate change impact through crop simulation modelling

The likely impacts of climate change on crop yield can be determined either by experimental data or by crop growth simulation models. To predict future impacts on crop yields, crop models present valuable approaches. A number of crop simulation models, such as CERES-Maize (Crop Environment Resource Synthesis), CERES-Wheat, SWAP (soil–water–atmosphere–plant), and Info Crop have been widely used to evaluate the possible impacts of climate variability on crop production, especially to analyze crop yield-climate sensitivity under different climate scenarios. Table 2 shows a summary of the crop growth models used to study climate change impacts on crop yields in recent studies. The studies about wheat production affected by climate change are mainly concerned with future CO_2 concentrations. Ortiz *et al*. (2008) discussed how wheat can adapt to climate change in Indo-Gangetic Plains for 2050s and suggested that global warming is beneficial for wheat crop production in some regions, but may reduce productivity in critical temperature areas, so it is urgent to develop some heat-tolerant wheat germplasm to mitigate climate change. Krishnan *et al*. (2007) analyzed the impacts of elevated CO_2 and temperature on irrigated rice yield in eastern India by ORYZAI and Info Crop-rice models, and the result shows that increased CO_2concentration can increase the rice yield of about 30.73 to 56.37% by INFOCROP rice. Results also suggested that the limitations on rice yield imposed by high CO_2 and temperature can be mitigated, at least in part, by altering the sowing time and the selection of genotypes that possess higher fertility of spikelets at high temperatures.

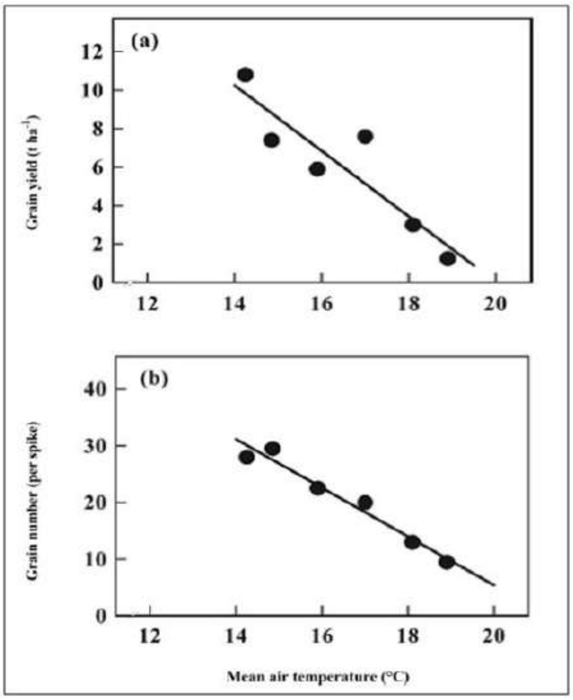

Fig. 4. Influence of mean temperatures from anthesis to Harvest maturity on(a) grain yield and (b) number of grains per year in winter wheat

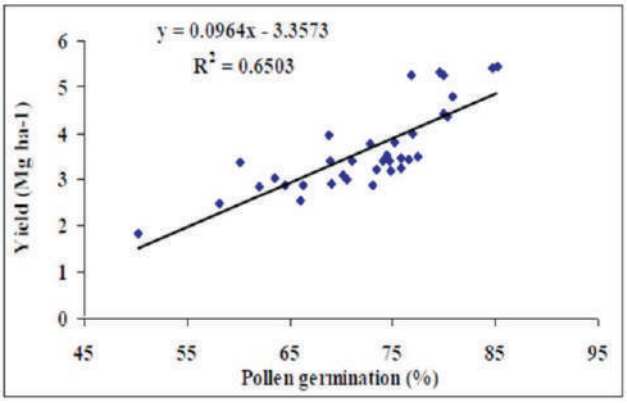

Fig. 5. Relationship between pollen germination and yield percentage of wheat crop

Impacts on Crop Pests and Diseases

Pests and pathogens are weather-dependent, and many thrive in hotter, wetter climates, which is exactly the sort of change that global warming is predicted to create over the coming decades. There has been only limited research on impact of climate change on plant diseases under field conditions or disease management under climate change. However, some assessments are now available for a few countries, regions, crops and particular pathogens which concern with food security. According to Cruz *et al*., (2007), some studies have shown that higher temperatures and longer growing seasons could result in increased pest populations in temperate regions of Asia. Warmer winter temperatures would reduce winter kill and increase insect populations. Overall temperature increases may influence crop pest and disease interactions by increasing pest and disease growth rates which would then increase the number of reproductive generations per season and by decreasing pest and disease mortality due to warmer winter temperatures, would make the crop more vulnerable. Enhanced CO_2 may affect insect pests through amount and quality of the host biomass (higher consumption rate of insect herbivores due to reduced leaf N).

Changing disease scenario due to climate change has highlighted the need for better agricultural practices and use of ecofriendly methods in disease management for sustainable crop production (Boonekamp, 2012). In addition, appropriate Decision Support System (DSSs) using forewarning models will provide lead time for managing pest attacks and thus minimize crop loss. Model based DSSs for pest management in major crops such as rice and cotton will help in rational pesticide usage. Weather, crop phenology and pest/ pathogen biology are integrated in developing such DSSs.

Table 2. Summary of crop models used for the study of climate change impacts

Crop model	Objective crop	Predicted impacts	References
CERES-Maize	Maize	Dry matter	Cuculeanu *et al*., 2002
	Maize	Sustainable production	Walker and Schulze (2006)
	Maize	Planting date and different weather	Soler *et al* .(2007)
	Maize	Precise and deficit irrigation	Popova and Kercheva (2005)
CERES-Wheat	Wheat	CO_2 levels	Eitzinger*et al* .(2003)
	Wheat	CO_2 levels	Luo*et al*. (2003)
CropSyst	Wheat	Rainfall and warming temperature	Anwar *et al*. (2007)
CERES-Rice	Rice	CO_2 levels	Yao *et al* .(2007)
SWAP	Rice	CO_2 levels	Droogers*et al*. (2004)
Info Crop	Rice	Elevated CO_2 and temperature	Krishnan *et al* .(2007)
	Rice and wheat	Climate change	Aggarwal*et al* .(2006)
IBSNAT-ICASA	Cereal/soybean	Climate change	Parry *et al* .(1999)
GLAM	Peanut	Climate uncertainty	Challinor and Wheeler (2008)
GLYCIM	Soybean	Temperature rainfall and CO_2 concentration	Reddy and Pachepsky (2000)
SWAT	Maize	Climate vulnerability	Xie and Eheart (2004)

Impacts on Fisheries

India, the second largest producer of fish is contributing about 5.43% of the global fish production and ranks second in aquaculture, thus providing livelihood of 14 million people in the country (Das *et al.,* 2014). Impacts of climate change on Indian fisheries have been reported in the earlier studies (Vivekanandan and Jeyabaskaran, 2010, Salagrama, 2012). For fisheries, an increased frequency of El Nino events could likely lead to measurable declines in fish larvae abundance in the coastal waters of South and South-East Asia (Cruz *et al*., 2007). This and other factors are expected to contribute to a general decline in fishery production in the coastal waters of East, South and South-East Asia. There is a potential to substantially alter fish breeding habitats and fish food supply and therefore the abundance of fish populations in Asian waters due to the response to future climate change to the following factors: ocean currents; sea level; sea-water temperature; salinity; wind speed and direction; strength of upwelling; the mixing layer thickness; and predator response

Impact of Climate Change Water Resources

India is one of the most water-challenged countries in the world, by 2030, demand in **India** will grow to almost 1.5 trillion m^3, driven by domestic demand for rice, wheat, and sugar for a growing population, a large proportion of which is moving toward a middle-class diet. Against this demand, India's current water supply is approximately 740 billionm^3. As a result, most of India's river basins could face severe deficit by 2030 unless concerted action is taken, with some of the most populous-including the Ganga, the Krishna, and the Indian portion of the Indus-facing the biggest absolute gap. According to Cruz *et al*. (2007), the decline in precipitation and droughts in India has led to the drying up of wetlands and severe degradation of ecosystems. About 54 percent of India faces high to extremely high water stress. Large parts of north-western India, notably the states of Punjab and Haryana, which account for the bulk of the country's rice and wheat output, are extremely water-stressed (Shiao *et al*., 2015).

About 54 per cent of India's groundwater wells are decreasing, with 16 percent of them decreasing by more than one meter per year (Rao *et al*., 2013) North-western India again stands out as highly vulnerable; of the 550 wells studied in the region, 58 percent had declining groundwater levels. With increased periods of low precipitation and dry spells due to climate change, India's groundwater resources will become even more important for irrigation, leading to greater pressure on water resources. These observations indicate that there is a need to invest substantially by central and state governments on the issue of ground water use. A detailed analysis considering the anticipated changes in water availability due to changes in land uses, climate change, changing choices for crops, population pressure could form the basis for watershed management programmes in future.

Impact on Food absorption

There are many potential impacts of climate change on food absorption but there is a dearth of quantitative studies on the subject which focus on India. Overall, the global threat is that climate change could lead to a reduction of production and consumption of certain foods that play a critical role in the diets of poor rural and indigenous populations such as fish, fruits and vegetables, and wild foods (FAO, 2016). Change in climatic conditions could lead to a reduction in the nutritional quality of foods (reduced concentration in proteins and minerals like zinc and iron) due to elevated carbon dioxide levels. In India, where legumes (pulses) rather than meat are the main source of proteins, such changes in the quality of food crops will accelerate the largely neglected epidemic known as "hidden hunger" or micronutrient deficiency (Mayers *et al*., 2014). It is also argued that micronutrient deficiencies increase the risk of acquiring an infectious disease which in turn worsens the problem of under nutrition, creating a vicious circle (Phalkey, 2015). Evidence from Botswana suggest that changes in climate that lead to an increase in temperature and a decrease in precipitation are associated with an increase in diarrhoeal disease in children (Alexander, 2014). In India, children living in poor rural areas and urban slums are at higher risk of morbidity and mortality from diarrhoeal diseases. Projections made by Moors *et al*., (2013) say that climate change will lead to an average increase of about 13.1 percent in diarrhoeal in the Ganga basin. Ramachandran (2014)also argues that climate change could lead to a reversal of India's achievements in reducing diarrhoeal-related deaths.

Adaptation strategies to increased climate risks

Use of stress tolerant crop varieties or climate ready crops: Development of new crop varieties with higher yield potential and resistance to multiple stresses (drought, flood, salinity) will be the key to maintain yield stability (Lobell *et al*., 2008). In India, some of candidate genotypes has been tested and screened for resilience to different stresses using 'Mother' and 'Baby trials' and the promising varieties/genotypes were identified through 'Participatory Varietal Selection' (PVS) approach and are being promoted among farmers, as the adaptation strategy to reduce vulnerability. Genotypes in this context are(i) 'Swarna Sub 1' and 'IR 64 Sub 1' of rice, which were found best under submergence conditions during flood. Swarna Sub 1 has been reported to yield 3.20 t/ha even after 10 days of submergence compared to yield of control variety (1.70 t/ha) under eastern conditions of India (Yamano *et al*., 2013; Dar *et al*., 2013). (ii) ShushkSamrat, a drought tolerant rice variety has been found to perform better under drought conditions. With one irrigation the average yield of ShushkSamrat was found to be 3.12 t/ha, compared to only 1.43 t/ha of Moti-local and 2.75 t/ha of Sarju 52-local (DRR, 2011).(iii) CSR-1 and K-3119, salt-tolerant rice varieties; KRL 19 high salt tolerant variety of wheat; KRL 213 and KRL 210, mild salt tolerant varieties of wheat have been found to perform better under varied salinity condition. (iv) Similarly, for heat stress tolerance, NDW 1014, Halna, WR 544 and PBW 154 have been found to be highly productive and stable (Singh and Singh, 2013).

Although the current research has divulged several key genes, gene regulatory networks and quantitative trait loci (QTLs) that mediate plant responses to various abiotic stresses, the comprehensive understanding of this complex trait is still not available. The discovery of genomic variations and genes associated with climate adaptation found in wild relatives of crop plants via whole-genome re-sequencing may be directly relevant for implementing breeding approaches to develop environmentally adapted crops (Garg *et al*., 2014).

Adjusting cropping season

Adjustment of planting dates to minimize the effect of temperature increase induced spikelet sterility can be used to reduce yield instability, by avoiding of having the flowering period to coincide with the hottest period. There exists a strong correlation between yield declines in rice and wheat and the shortening of crop duration under high temperature, whereas shifting the transplanting date seems to be an effective measure to reduce the shortening of crop duration for both crops (Jalota *et al*., 2013). The study further confirms that yield declines are found to be smaller (in the range of -2.4 percent for 2020, -13.3 percent for 2050, and -26.6 percent for 2080, when the transplanting date is shifted by +7 days for rice in comparison to the yield declines (in the range of -4.6 percent for 2020, -16.1 percent for 2050, and -29.1 percent for 2080 under A2 SRES scenario. Likewise, yield declines were found to be smaller in wheat (in the range of -4.3 from -8.8 percent for 2020, -13.6 from 22.5 percent for 2050, and -28 from 41 percent) when the transplanting date is shifted by +15 days under same emission scenario. Sorghum yields which were projected to decline by 16 percent in Madhya Pradesh and Karnataka and by 4-5 percent in Andhra Pradesh by 2020 are now expected to decline by only 1-2 percent with low cost adoptive measure and shifting in sowing dates (Srivastava *et al*., 2010).

Conservation agriculture (CA)

CA practices, considering the three main components, i. Minimal soil disturbance(disturbed area must be less than 15 cm wide or 25% of cropped area), ii. Soil cover (ground cover must be more than 30%). iii. Crop rotation (rotation should involve at least three different crops) is steadily gaining acreage worldwide to about 124 million hectare (Friedrick *et al.,* 2012) and in south Asia to about 3.90 million hectares (Jat *et al.,* 2011). CA has been adopted in tropics/sub-tropics and temperate regions of the world for both rain-fed and irrigated eco-systems in view of its pronounced effects to mitigate the greenhouse gases emission and adaptation to climatic variability (Malik *et al.,* 2005; Gupta *et al.,* 2010; Pathak *et al.,* 2011). By adopting CA practices, agricultural soils in the world are estimated to have the potential to sequester 0.4–0.8 Pg C per year (Lal, 2004). Improved agricultural management practices such as conversion from conventional to no-till or reduced tillage, residue retention, conversion to permanent pasture, crop rotation and fertilizer application have shown to increase soil C in various countries, including India (West and Marland 2002; Lal 2004; Patle *et al*., 2013). However, contradictory results are common in the literature. For example, a meta-analysis based studies in North America and South America indicated that adoption of no-till did not increase soil C stock down to 40 cm (Luo *et al*., 2010). This is true under Indian conservation agriculture, where CA sequesters maximum soil organic carbon near soil surface layer up to 10 cm (Patle, 2013). Review suggests that soil at 0–10 cm depth is most responsive to the targeted management practices, what we did in CA. Increase in soil C as a result of these management practices can be attributed to enhanced biomass production, litter fall and hence returns of crop residues to the soil and also to improved soil aggregation that protects the C compounds from rapid decomposition. Carbon accumulation can be increased in the surface 0–10 cm of soil, but that is also the layer from which it can be most readily lost from agricultural soils. It is therefore necessary to examine whether an agricultural practice sustains surface soil C over time or not. Does it mean that potential for C sequestration in Indian agricultural soils is technically limitedΩ More in-depth analysis is therefore required in this aspect.

Crop diversification

Crop diversification has proven to be one of the most popular farm level responses to climatic variability and change particularly in countries which are predominantly of rural economics and are at most risk (Bradshaw *et al.,* 2004). Apart from *b*uffering crop production from the effects of greater climate variability and extreme events, crop diversification improves resilience by engendering a greater ability to suppress pest outbreaks and dampen pathogen transmission, which may worsen under future climate scenarios, (Lin, 2011). In India, review from the published reports suggested, that fewer attempts have been made to quantify the benefits of diversification in relation to coping with climate change and its risks. Diversification is commonly studied to meet demand fluctuations and stabilize farmer's income. Attempts are needed to identify least impacted cropping systems and promote those which improve carbon sequestration, like maize-wheat and agroforestry systems had 65–88% higher soil organic carbon stocks than the rice-wheat system, Benbi *et al*. (2012), under other conditions it can add to them (Waha *et al.,* 2013). Results from study by Saha, (2013) has shown that crop diversification in India has taken place in western and south-western states, while as crop specialization has occurred in states like West Bengal, Assam, Manipur and Mizoram. Because of changing rainfall patterns and water resources depletion, the traditional cropping pattern is becoming less productive. Thus crop intensification, through mixed cropping and integration of high-value crops such as horticultural production, is gaining prominence as a climate change adaptation strategy. A re-evaluation of cropping patterns can provide higher risk security.

Local weather information

Local weather information and its early warning systems will be very useful in minimizing risks of climatic adversaries. But having access to relevant and easily understandable weather and climate information is essential to effectively managing the risk and optimizing agricultural production. Examples of the successful utilization of meteorological information for the benefit of food production can be seen from the results of a case study in Mali, Africa (Hellmuth *et al.,* 2007) and Kalyani, India (Maini and Rathore, 2011), where crop yields and farm incomes were compared for farmers taking management decisions with and without agro-meteorological information (Table 3). Results revealed that crop yields and farmer's incomes were significantly higher in fields where agro-meteorological information was used compared with those where it was not used. The increase in income was substantial, notably for maize in Mali, (where farmers earned 80% more income from agro-meteorologicalfields) and for oilseed mustard in India, (where, farmers earned 12% more income from farmers using agro-meteorological advisory services). Likewise, in Finland, early information to farmers on prevalence of extreme low temperature has prevented the loss of more than 50% of citrus yield, which was vulnerable to the premature fruit drop disease caused by fungus under low temperature (Tolat, 2013).

Improved pest management

Healthier crops are more likely to withstand the adverse effects of increased temperatures, droughts and unreliable or more intense precipitation. Changes in temperature and variability in rainfall would affect incidence of pests and disease and virulence of major crops, like at higher temperature, declined survival rate of brown plant hopper and rice leaf folder has been observed in rice ecosystem. (Karuppaiah and Sujayanad, 2012). In Sub-Saharan Africa, changes in rainfall patterns are driving migratory patterns of the desert locust (Cheke and Tratalos, 2007). It is because climate change will potentially affect the pest/weed-host relationship by affecting the pest/weed population, the host population and the pest/weed-host interactions. Some of the potential adaptation strategies in this context could be: (i) developing cultivars resistance to pests and diseases; (ii) adoption of integrated pest management with more emphasis on biological control and changes in cultural practices, (iii) pest forecasting using recent tools such as simulation modelling, and (iv) developing alternative production techniques and crops, as well as locations, that are resistant to infestations and other risks.

Water saving technologies

Water saving / conservation technologies acts as buffer against production risk in the face of climate change and its variability (Kato *et al.,* 2011), and could be part of the country's climate proofing strategy. In view of increasing frequency of droughts, warm days and warm nights which are likely to increase further in the next decades (IPCC, 2013 for India), water-saving technologies (WST) are going to contribute substantially against production risks. In addition, WST reduces the greenhouse gas emissions, which can ease the negative effects of climate change on agricultural production (Karimi *et al*., 2012). However, In India, the cost and effectiveness analysis of using WST to cope with climate change has remained few in literature and same is important factor relevant to the willingness of farmers to adopt.

Precision nutrient Management

Improving the efficiency and effectiveness of fertilizer use by crop can reduce N_2O emission by reducing the potential for elevated residual NO_3-N in soil profile and also increases C sequestration through enhanced biomass production. Recent advances in development of precision nutrient prescription tools like Nutrient Expert (NE) decision support system, Green Seeker hand held sensors and simple tools like Leaf Color Chart has shown promise to increase nutrient use efficiency of crops thereby reducing fertilizer related cost of production, increase farm profitability and minimizing environmental footprint. Experimental result at BAU showed that SPAD (Soil Plant Analysis Development) N management strategy can save N fertilizer up to 24% in rice and 27% in wheat without deteriorating the grain yield over conventional N management practice.

Green Seeker: It is a handheld, easy to use crop sensor that is easily calibrated locally. Here, crop vigor, measured as normalized difference vegetative index (NDVI), is used as the basis for N prescription rates Using Green Seeker, farmers optimize the fertilizer N use increase crop yield and profit as well as reduce environmental footprints. We have developed an android phone based application for Green Seeker guided N application (*Urea Calculator*). Results of experiment conducted at BAU, Sabour revealed that SSNM based nutrient expert and green seeker guided N management saved 15-20 % N fertilizer in addition to 6% higher wheat grain yield compared to RDF.

Decision support system for nutrient management: Site specific nutrient management (SSNM) being knowledge intensive concept limits its on-farm applications on large scale. Decision support tools like computer can be useful for analyzing complexity of nutrient dynamics in soil and providing recommendation for nutrient management specific for the site. The Nutrient Expert (NE) developed by International Plant Nutrition Institute (IPNI) and CIMMYT is interactive software and is available for free use on websites. NE for Maize and Wheat developed and validated over the last seven years has helped farmers for efficient nutrient management under the current scenario of escalating fertilizer prices (Satyanarayana *et al*., 2012).

Table 3. Crop yields and farm incomes for farmers taking management decisions with and without agro-meteorological information in Mali, Africa and Kalyani, India

Country	Crop	Field type	Average yield (kg/ha)	Gross income US$/ha	Income gain in agro-met fields (%)
Mali, Africa	Pearl millet	Agromet	1, 204	175	26
		Non Agromet	957	139	
	Sorghum	Agromet	1, 427	193	42
		Non Agromet	1, 005	136	
	Maize	Agromet	1, 984	249	80
		Non Agromet	1, 105	139	
	Groundnut	Agromet	874	237	25
		Non Agromet	702	190	
Kalyani, India	Oil seed mustard	Agromet	1, 595	666	10
		Non Agromet	1, 468	604	
	Jute	Agromet	7, 871	1140	8
		Non Agromet	6, 943	1059	
	Winter rice	Agromet	9, 999	837	12
		Non Agromet	9, 625	747	

Adopted from Hellmuth *et al.,* 2007; Maini and Rathore, 2011

Nanotechnology applications

Nanotechnology has a significant potential to solve or mitigate the problem of climate change.Some of the specific applications of nanotechnology are as under:−

Alleviation of drought: Novel super absorbent nanopolymeric hydrogel having equilibrium water absorbency (ranging from 350 g g^{-1} to 500 g g^{-1}) is good materials under moisture stress condition. Products are biodegradable, can withstand high salinity level (100 Mm NaClsolutions).

Input use efficiency: Nano fertilizers (P, K, Zn, Fe *etc.*) with higher use efficiency and greater diffusion rate in rhizosphere as well as within plant system would bring cost effective nutrient formulation in changing climate scenario. Mode of nutrient transport *via* diffusion is temperature and moisture controlled which could be effectively controlled by nanoformulations.

Agrochemical formulation: Shift in pest dynamics and population is anticipated in changing climate scenario. Novel Nanopesticides (Nano silver, cu and chitosan) with minimal dose, more biodegradability and cost effectiveness would of great interest in changing climate scenario.

Carbon sequestration: Nano titanium dioxide (TiO_2) particles are reported to increase carbon sequestration potential in soil by escalating degree of aromatization and polycondensation of carbon. Increased C storage would facilitate in combating global warming.

Photosynthetic radiation use efficiency: Silicon nanowires, a solar cell for Mg and Ti nanoparticles that increases photosynthetic radiation use efficiency. Silica nanoparticles as a tool for fluorescence collection efficiency enhancement would be of great use in changing climate scenario. Temperature sensors for managing radiation use efficiency would be of good use.

Increasing shelf life: Nanosilicon, Silicon dioxide and Nanopolymeric coating materials would enhance shelf life of fruits and vegetables in changing temperature scenario. Nanobiosensors and nanosensors for intelligent packing materials development and determination of contaminants in packaged food materials are of great help.

However, agricultural application of nanotechnology is its infancy stage. Systematic scientific researches on long−term basis needs to be done following interdisciplinary approach with due consideration in nanotoxicology for its wide scale application.

Future Researchable Issues: Agriculture offers promising opportunities to combat the effects of climate change and mitigating GHGs emissions largely through carbon sequestration, soil and land use management, and biomass production. Smart weather forecasting and ICT application would be significant tool for adaption in agriculture under future climate change scenario. Therefore, research policy should be formulated to encourage farmers for adopting the mitigation technologies without compromising production and income. Some of the research and policy options are suggested as under:−

- Intensify utility initiatives to promote energy efficiency actions by end users, especially in agriculture, domestic & commercial sectors. Promoting hydro and renewable energy.
- Undertake national/collaborative research programme in Mission Mode for advanced biomass based technologies.
- Integrated systems simulation modeling to integrate other components like natural resources, livestock, poultry and fishery sectors evolving a systems modeling approach. Down−scaling the global climate models to regional and district level and linking with crop simulation models to arrive at crop−specific and region−specific impacts is an immediate need.
- Integrated analysis of climate change impacts and vulnerabilities, including impacts of extreme weather events and climate variability at regional and smaller geographical scale required to be taken up. These impact and vulnerability analyses need to include the assessment of the economic consequences of climate change.
- Developing simple methodologies for quantifying and minimizing GHGs emission from agriculture, live stocks and reducing uncertainties in emission coefficients. In addition, developing simulation models for integrated, regional assessment of GHGs emission and mitigation coupling with remote sensing, GIS and web−enabled reporting tools.
- Further promote CDM implementation in PSUs, Central and States/UT Govt./Municipalities.
- Planning and Investment for Urban mass transport.
- Intensify afforestation for carbon sequestration programmes.
- Better water resource infrastructure planning and restoration of water bodies in rural areas
- Enhancing the research capability in climate science and establishment of climate change research centre's at regional level.

CONCLUSION

In conclusion, it is important for us to stick to the principle of common but differentiated responsibility in our negotiations and to take forward the concept of equalizing per capita emissions of countries proposed by the Prime Minister of India. At the same time, we should be tactfully showcasing our efforts to conserve use of fossil fuels and reducing GHG emissions. In accordance with the Paris Agreement on 12 December 2016, countries, regions must cooperate with one another to promote sustainable development, improve the ability to adapt to climate change, enhance resilience, and reduce vulnerability. Countries must also develop national and regional adaptation plans, assess climate change impacts and vulnerability, monitor and evaluate adaptation plans, and enhance the resilience of society, economy, and ecological systems. In India, more certain assessment of the impacts and vulnerabilities of rain fed agriculture sector and a comprehensive understanding of adaptation options across the full range of warming scenarios and regions would go a long way in preparing the nation for climate change. A multi-pronged strategy of using indigenous coping mechanisms, wider adoption of the existing technologies and or concerted R&D efforts for evolving new technologies are needed for adaptation and mitigation. Policy incentives will play crucial role in adoption of climate ready technologies in rain fed agriculture too as in other sectors. Policymakers need to understand the local climate change impacts pertaining to their constituencies and accordingly develop locally relevant and comprehensive low-carbon plans and strategies. The state agricultural universities and regional research centers will have to play major role in adaptation research which is more region and location specific while national level efforts are required to come up with cost effective mitigation options, new policy initiatives and global cooperation.

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Application of *RAPD and ISSR* Markers for Fingerprinting of Promising *Myrobalan* Accessions (*Terminalia chebula Retz*.): An Indigenous Minor Agroforestry Tree Species

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Abstract: Six selected accessions of *Terminalia chebula* from the previous study in the department were used for *molecular characterization* to know genetic diversity among selected six *accessions using* two marker systems *viz.,* Random amplified polymorphic DNA (RAPD) and Inter simple sequence repeat (ISSR) markers. In which, 25 RAPD and 12 ISSR primers were effective in revealing polymorphisms among different accessions of *T. chebula*. RAPD exhibited 96.76 per cent polymorphism among six accessions, out of the total, 124 scorable bands, 120 showed polymorphism and 4 bands exhibited monomorphism. *Total numbers of amplified and polymorphic fragments generated for ISSR primer revealed 97.92 per cent polymorphism among* accessions. Accession Paragpur 2 (G_3) came as outliner as revealed by both ISSR study and combined data (RAPD and ISSR).

Keywords: Accessions, *Fingerprinting,* Indigenous, ISSR, RAPD*, Terminalia chebula*

The genus *Terminalia* includes about 200 species of trees and shrubs distributed in the tropical and subtropical regions of the world. In India, 20 species have been reported to be distributed in the tropical and subtropical states *(*Srivastava, 1993*)*. Amongst these *Terminalia chebula* is one of the very important indigenous multi-purpose tree species (Warrier, 1997) *T. chebula* tree improvement projects are in progress around the South East Asia because of its multifarious uses. Forest geneticists lesser extent, use genetic markers to study patterns of genetic diversity in forest trees. The unusually high phenotypic diversity evident within the species at the morphological and physiological levels, both within populations and between geographical regions, is further substantiated by the degree of genotypic diversity evident from biochemical and molecular analysis. Molecular markers successfully developed during the last two decades have largely overcome the problems that are associated with phenotype-based classification. PCR based techniques developed in recent years such as Random Amplified Polymorphic DNA (RAPDs) and Inter Simple Sequence Repeats (ISSR) provide DNA markers that are dispersed throughout plant genomes and are easier to reproduce and analyze. ISSR markers, which show dominant inheritance, use SSR repeat-anchored primers and are being used as an alternate tool in diversity studies. ISSR markers are useful in detecting genetic polymorphisms among accessions by generating a large number of markers that target multiple microsatellite loci distributed across the genome. Further, they are simpler to use than the SSR technique as prior knowledge of the target sequences flanking the repeat regions is not required (Awasthi *et al.,* 2004). However, an extensive search of literature failed to reveal any useful information on characterization of the clones selected in the present study keeping these points in view selected six candidate plus trees from the natural population of Himachal Pradesh based on the previous study in the department. Further, these selected accessions were vegetatively propagated and planted in the field. The present investigation was carried out on these accessions for fingerprinting of promising Myrobalan accessions to know genetic diversity and relatedness using two marker systems.

MATERIAL AND METHODS

Six selected accessions of *T. chebula* from the previous study in the department *viz*., Kothi (G_1), Paragpur-1 (G_2), Paragpur-2 (G_3), Kallar (G_4), Bhella (G_5) and Tamber (G_6) which are grown at (lat. 32° 18′ N, long. 75° 65′ E and altitude 428 m) Regional Horticultural Research Station, Jachh, Kangara, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan Himachal Pradesh were used for study during 2010–12 for molecular characterization among six accessions. The molecular markers technique was used to reveal the genetic relatedness among six accessions of *T. chebula* with help of two marker systems. Random amplified polymorphic DNA (RAPD) and Inter simple sequence repeats (ISSR) were used for revealing polymorphism among accessions. Fresh disease free young leaves were collected from these six selected accessions and used for genomic DNA extraction from a modified protocol (Doyle and Doyle, 1990) using cetyl –trimethyl ammonium bromide method (CTAB) for molecular variability studies. PCR amplification, electrophoresis, data analysis and clustering was done by unweighted pair group mean average (UPGMA) using SAHN module of NTSYSpc., Version 2.02e (Rohlf, 1998).

RESULTS AND DISCUSSION

Characterization of accessions using 25 decamer RAPD primers: Genetic variation among six accessions of *T. chebula* was investigated using 25 arbitrary RAPD primers and produced RAPD profiles with intense banding pattern, which detected polymorphism among six accessions used in the study each primer generated a unique set of amplification products. RAPD analysis revealed high levels of genetic diversity within the reference set of six *T. chebula* accessions and the inference of Table 2 depicts the informative RAPD markers specific for a particular accession. The number of bands recognized by the software, Alpha Imager for each primer ranged from 2 (OPC −06) to 9 (OPF−16). All the 25 primers used in this analysis yielded a total of 124 scorable bands with an average of 4.96 bands per primer. Out of the total 124 scorable bands, 120 bands showed polymorphism and 4 bands showed monomorphism (Table 1).

RAPD pattern with 25 decamer primers: RAPD analysis with 22 primers out of 25 showed 108 scorable bands with 100 per cent polymorphism (No monomorphic band was

Table 1. Total numbers of amplified and polymorphic fragments generated by PCR using RAPD primers

Primers name	Total no. of scorable bands (y)	Total no. of polymorphic bands (x)	Total no. of monomorphic bands	Polymorphism (%) $\frac{x}{y} \times 100$	Size range of amplified products (bp)
OPC−01	6	6	0	100.00	150 – 900
OPC−04	3	3	0	100.00	150 – 450
OPC−06	2	2	0	100.00	300 – 600
OPC−08	5	5	0	100.00	150 – 2,050
OPC−11	6	6	0	100.00	150 – 950
OPC−12	4	4	0	100.00	200 – 850
OPC−13	3	3	0	100.00	200 – 550
OPF−06	6	6	0	100.00	150 – 2,100
OPF−08	6	6	0	100.00	250 – 800
OPF−10	5	5	0	100.00	200 – 1,050
OPF−11	3	3	0	100.00	150 – 2,000
OPF−12	7	7	0	100.00	250 – 2,150
OPF−14	3	3	0	100.00	300 – 950
OPF−15	6	6	0	100.00	150 – 1,350
OPF−16	9	9	0	100.00	150 – 1,850
OPF−20	6	6	0	100.00	200 – 1,050
OPS−03	2	2	0	100.00	150 – 950
OPS−07	6	4	2	66.67	250 – 1,000
OPS−10	6	6	0	100.00	200 – 1,150
OPS−11	6	6	0	100.00	500 – 1,000
OPS−12	6	6	0	100.00	150 – 1,400
OPS−13	4	4	0	100.00	300 – 600
OPS−14	3	2	1	66.67	100 – 400
OPS−15	7	6	1	85.71	250 – 850
OPS−18	4	4	0	100.00	100 – 800
Total	124	120	4	96.76	100 – 2,150

Table 2. Informative RAPD markers specific for a particular accessions

Primers	Approximate size	Accessions
OPF-10	200 bp	Tamber (G_6)
OPF-12	200 bp	Paragpur-2 (G_3)
OPF-14	750 bp	Kallar (G_4)
OPF-15	1350 bp	Kallar (G_4)
OPF-16	1850 bp	Kothi (G_1)
OPS-11	350 bp	Paragpur-2 (G_3)
OPS-13	200 bp	Paragpur-2 (G_3)
OPS-14	100 bp	Paragpur-2 (G_3)
OPS-15	300 bp	Kallar (G_4)

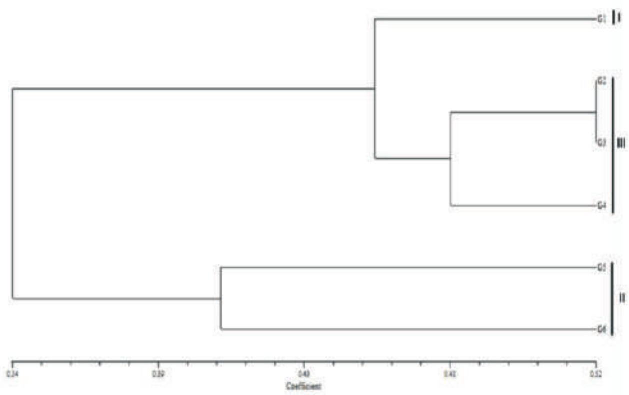

Fig. 1. Dendrogram based on UPGMA analysis among six accessions of *T. chebula* using RAPD markers

identified) with products size ranged from 100 bp to 450 bp. In which OPF-12 RAPD marker yielded highest (7) informative bands with amplified bands size ranged from 250 bp to 2,150 bp and lowest (2) scorable bands reported for two primers *viz*., OPC-06 and OPS-03 with size ranged from 300 bp to 600 bp and 150 to 950 bp respectively. Whereas, rest of three (OPS-07, OPS-14 and OPS-15) markers out of 25 produced total of 16 scorable bands out of which four monomorphic bands observed with amplified products size ranged from 250 to 1,000 bp, 100 to 400 bp and 250 to 850 bp which lead to 66.67 to 85.71 per cent polymorphism (Table 1).

Molecular techniques are useful and accurate for determination of both interspecific and intraspecific genetic variation in plants. RAPD markers, in particular, have been successfully employed for determination of intraspecies genetic diversity in several plants. RAPD analysis has proved useful for estimating genetic diversity particularly to assist in the conservation of rare species and plant genetic resources (Anderson and Fairbanks, 1990). In the present investigation RAPD markers has been used for assay in genetic variation at molecular level of six accessions using 25 decamer primers designed from Genei Bangalore, India limited. Results showed that RAPDs were highly informative for revealing relationship based upon similarity with in reference set of accessions. Out of 25 primers, 22 were polymorphic and amplified the genomic DNA of six accessions of *T. chebula* successfully. From the results of RAPD profiling number of RAPD markers generated per primer varied from 2 to 9 with an average of 4.96 markers per primer and it was because of primer sequence and due to individual accession (Table 1). All 25 primers produced distinct banding pattern for all the six accessions. 124 amplified products were detected out of which 96.76 per cent were polymorphic. Such a high level of polymorphism reflects the outcrossing nature of the species. This is consistent with the studies carried out in *T. chebula* that, genetic diversity among the thirty accessions of *T. chebula* using 48 random decamer primers (RAPD). In which only 31 primers were able to amplify the genomic DNA and all primers were polymorphic in nature (Sood 2007). Each of the 31 primers generated a unique set of amplification products with size ranging from 200-2,500 bp. Total number of amplified bands were identified to be 257, depicted 100 % polymorphism whereas average number of polymorphic bands per polymorphic primer was 8.29 (Sood 2007). This is also in consistent with the results obtained after testing five taxonomically critical *Terminalia* L. species and analysed with 31 random primers to evaluate genetic diversity and species relationships. From the total 31 primers screened, 26 primers amplified across all species scoring 336 bands of which 305 were polymorphic. On average 12.92 bands per primer were scored. The average polymorphism was 90.77% and eight primers were reported to produce 100% polymorphism. Dendrogram based on RAPD data grouped five *Terminalia* species in two distinct clusters. Cluster-I comprised 3 species *viz*. *T. arjuna*, *T. bellerica* and *T. chebula*, while cluster-II comprised 2 species *T. tomentosa* and *T. catappa* (Deshmukh *et al*., 2009). This result supports the finding of Qi *et al*. (2003), Wang *et al*. (2011) and Narayanan *et al*. (2007) in jute, *Dalbergia sissoo* and teak respectively. The number of polymorphic primers and fragments generated were not of similar range for tree species. They can vary significantly in different plant species. This is understandable as product amplification depends upon the sequence of random primers and their compatibility within genomic DNA. The number of markers detected by each primer depends on primer sequence and the extent of genetic variation which is accession specific (Hossain *et al*., 2002).

RAPD analysis with primer OPF-10 exhibited polymorphism in all 5 bands scored. This primer produced one conspicuous unique band of size approximately 200 bp, which was unique to Tamber. The size of amplified bands ranged between 200 to 1,050 bp (Table 1). The total number and polymorphic bands amplified with OPF–12 primer was 7. This primer produced one 2,150 bp (Table 2). In Kallar primer OPF–14 yielded a unique band of size 750 bp. Primer OPF–15 produced unique band for accessions Kallar and Bhella with the size of the bands were 1,350 and 750 bp respectively. RAPD analysis with OPF–16 primer yielded 9 bands and all bands exhibited 100 per cent polymorphism. The product size ranged between 150 to 1,850 bp. This primer yielded two unique bands (1,850 and 1,000 bp) for accession Kothi and one unique band (150 bp) for Paragpur 2. The total number of bands amplified with OPS–07 primer was found to be six and per cent polymorphism revealed was 66.67 per cent as two out of six bands exhibited monomorphism. The size of amplified bands ranged between 250 to 1,000 bp. The total number of bands recorded and showed 100 per cent polymorphism with primer OPS–11 was six. The size of amplified products ranged between 500 to 1000 bp. This primer produced one conspicuous unique band of size approximately 350 bp, which was unique to Paragpur–2 (Table 2). With primer OPS–13 total number of bands amplified was 4 and all were polymorphic. The product size ranged between 300 to 600 bp. This primer yielded one conspicuous unique band of size approximately 200 bp, which was unique to Paragpur–2. Primer OPS–14 yielded 3 bands out of which 2 were polymorphic and 1 band was monomorphic. Per cent polymorphism recorded for this primer was 66.67 per cent. The amplified bands ranged from 100 to 400 bp. This primer produced one conspicuous unique band of size approximately 100 bp, which was unique to Paragpur–2. The total number of bands amplified with OPS–15 primer was found to be 7 and per cent polymorphism revealed was 85.71 per cent as six out of seven bands exhibited polymorphism and one band exhibited monomorphism. The size of amplified bands ranged between 250 to 850 bp. This primer produced one conspicuous unique band of size approximately 300 bp, which was unique to Kallar. RAPD analysis with primer OPS–18 exhibited polymorphism in all the four bands amplified; therefore per cent polymorphism was 100 per cent. The size of bands ranged between 100 to 800 bp.

Informative RAPD markers specific for a particular accession: The informative RAPD markers specific for a particular accession were obtained. Primer OPF–10 produced unique band for the accession Tamber (G_6) and the size of the band was 200 bp. Primer OPF 12 produced one conspicuous unique band of size approximately 200 bp, which was unique to Paragpur – 2 (G_3). OPF–15 produced unique bands for accessions Kallar (G_4) and Bhella (G_5) with the size of the bands were 1,350 bp and 750 bp respectively. OPF 16 primer yielded two unique bands (1,850 and 1,000 bp) for accession Kothi and one unique band (150 bp) for Paragpur 2. OPS 11 primer yielded one conspicuous unique band of size approximately 350 bp, which was unique to Paragpur–2. Thus primers producing unique bands for particular accessions can be specifically used for the study of particular accession.

RAPD data analysis: Jaccard's similarly correlation coefficient ranged from 0.34 to 0.52 (Figure 1). This suggested a good range of variability in the similarity coefficient values indicating a broad genetic base of six *T. chebula* accessions. The highest value (0.52) was observed between Paragpur 1 and Paragpur 2, which shows that they almost have the same genetic constituents. Lowest similarity (was exhibited between Bhella) and Kothi. It may be attributed to the fact that both Bhella and Kothi belong to different districts with different origin. The mean coefficient value of any accession may give an idea about its overall relatedness with all other accessions in the study.

Dendrogram based on RAPD banding pattern: Dendrogram was created using the similarity coefficient and unweighted pair group mean average (UPGMA) method in order to visualize genetic differentiation among various accessions of *T. chebula* and to see their clustering pattern. The UPGMA dendrogram based on RAPDs exhibited three clear clusters (Figure 1). Cluster II is a second major cluster having two accessions *viz.,* Bhella and Tamber. Overall cluster II exhibited 41 per cent similarity with cluster III. Cluster III is a major cluster comprised of three accessions *viz*., Paragpur 1, Paragpur 2 and Kallar. Cluster III expressed 45 per cent similarity with cluster I. The similarity between accessions showed that there is a degree of DNA conservation. The observed differences between Kallar and other two accessions in cluster could be ascribed to the fluctuating climatic habitat conditions and may be accession specific besides both were from different districts of Himachal Pradesh *viz.,* Bilaspur and Kangra respectively. Cluster I comprise of only one accession Kothi and was found to be 41 per cent similar to rest of the clusters. The placement of this accession in one cluster is may be due to the human intervention which makes partitioning and distribution as *T. chebula* is the important multipurpose tree species in Himachal Pradesh. Hence, this accession came as outliner and was the most divergent which could be easily being exploited for hybridisation programme in different combinations. It is utmost essential to select most divergent parents so that maximum heterosis is obtained in the shortest possible time, which could easily be done by selecting the parents from two divergent clusters used in a variety of combinations.

Characterization of accessions using 12 ISSR primers: Molecular characterizations of six accessions of *T. chebula* were investigated using an initial screening of 12 ISSR primers. ISSR markers are based on size‑polymorphism of inter‑microsatellite spacers, which are amplifiable by a single‑primer. This technique is similar to that for RAPD, except that ISSR primers consist of a di‑ or trinucleotide simple sequence repeat with a 5′ or 3′ anchoring sequence of 1 to 3 nucleotides. ISSR is considered to achieve higher reproducibility than RAPD markers and is reported to detect a high portion of genomic variation than RFLP (Zietkiewicz *et al*., 1994). Out of 12 ISSR primers eleven primers produced ISSR profiles with intense banding pattern, which showed polymorphism between six accessions used in the study. Each primer generated a unique set of amplification products. ISSR analysis revealed high levels of genetic diversity within the *T. chebula* accessions. Out of the total 48 scorable bands 47 showed polymorphism and 1 band exhibited monomorphism with an average of 4.00 bands per primer. Total numbers of amplified and polymorphic fragments generated per ISSR primer revealed 97.92 per cent polymorphism among accessions (Table 3).

ISSR banding pattern with 12 primers: The ISSR molecular analysis using 12 primers revealed that 11 primers were 100 per cent polymorphism and out of total 48 scorable bands reported 47 were polymorphic bands with products size ranged from 100 bp to 1,300 bp (Table 3). Among the 12 ISSR markers two ISSR markers 840 8YT and 841(GA)8YC yielded highest (8) informative bands with amplified bands size ranged from 100 to 600 bp and 100 bp 1,000 bp respectively. While lowest (2) scorable bands observed for again two primers *viz*., 876 (GATA)2 and 844 (CT)8RC and produced bands with size ranged from 300 to 400 bp and 100 to 700 bp respectively. Whereas, other ISSR marker 836 (AG) 8YA yielded total of 3 scorable bands out of which two were polymorphic and one was monomorphic bands observed with amplified products size ranged from 350 to 1,000 bp which lead to 66.67 per cent polymorphism.

A summary of amplified, polymorphic and monomorphic fragments obtained from ISSR study revealed that eleven out of 12 primers were polymorphic and amplified the genomic DNA of different accessions of *T. chebula* successfully. The number of ISSR markers generated per primer varied from 2 to 8 with an average of 4.00 markers per primers and it was because of primer sequence and due to individual accession (Table 3). All the eleven ISSR primers were found to produce distinct banding pattern for six accessions of *T. chebula*. Forty eight amplified products were detected out of which 97.92 per cent were found to be polymorphic. The accessions obtained from different districts are of wide genetic base. Presently there are no such studies conducted in *T. chebula.* The ISSR primers revealed more DNA polymorphism (97.92%) among the accessions of *T. chebula* than RAPD primers (96.76%). This can be attributed to the hyper variable nature of the ISSR markers, which are expected to reveal high levels of variation (Srivastva et al. 2004). However, in this study polymorphism was higher using ISSR primers (91.72%) than earlier studies in *Bauhinia blakeana* (Lau *et al*., 2005) and in *Eucalyptus grandis* Okun *et al*. (2007) observed 46.7% and 65.9% polymorphism. Because the ISSRs indicated higher polymorphism among different accessions it can be anticipated that the results of

Table 3. Total numbers of amplified and polymorphic fragments generated by PCR using ISSR primers along with nucleotide sequences

Primers name	Base sequences (5′‑3′)	Total no. of scorable	Total no. of polymorphic	Total no. of monomorphic	Polymorphism (%) $\frac{x}{y} X100$	Size range of amplified
808 $(AG)_8C$	AGAGAGAGAGAGAGAGC	3	3	0	100.00	300‑650
823 $(TC)_8C$	TCTCTCTCTCTCTCTCC	4	4	0	100.00	150‑650
836 $(AG)_8YA$	AGAGAGAGAGAGAGAGYA	3	2	1	66.67	350‑1,000
840 $(GA)_8YT$	GAGAGAGAGAGAGAGAYT	8	8	0	100.00	100‑1,000
841 $(GA)_8YC$	GAGAGAGAGAGAGAGAYC	8	8	0	100.00	100‑600
842 $(GA)_8YG/TG$	GAGAGAGAGAGAGAGAYG/TG	5	5	0	100.00	100‑350
844 $(CT)_8RC$	CTCTCTCTCTCTCTCTRC	2	2	0	100.00	100‑700
845 $(CT)_8RG$	CTCTCTCTCTCTCTCTRG	7	7	0	100.00	150‑1,300
868 $(GAA)_6$	GAAGAAGAAGAAGAAGAA	4	4	0	100.00	200‑650
873 $(GACA)_4$	GACAGACAGACAGACA	3	3	0	100.00	250‑450
876 $(GATA)_2$	GATAGATAGACAGACA	2	2	0	100.00	300‑400
TOTAL		48	47	1	–	100‑1,300

ISSR based study will play a major role in the management, conservation and improvement of this tree crop.

Informative RAPD markers specific for a particular accession: With primer 836, a total of 3 scorable bands were produced, 1 was monomorphic and the other 2 were polymorphic. The size of amplified bands ranged between 350 to 1,000 bp. Primer 823 produced two unique bands in accession Paragpur 2 and sizes of the bands were approximately 400 and 200 bp. ISSR analysis with primer 840 and 841 yielded highest number of bands (8) and all the bands exhibited polymorphism. The size of amplified bands ranged between 100 to 1,000 bp in primer 840 and produced 3 unique bands in accession Paragpur 2 and size of the bands were approximately 1,000, 800 and 400 bp. Whereas, the primer 841 yielded the size of amplified bands ranged between 100 to 600 bp and produced 4 unique bands in accession Paragpur 2 and size of the band varied may be because of its divergent nature and uniqueness of the accession. In the primer 842, a total of 5 scorable bands were produced and all were polymorphic exhibiting 100 per cent polymorphism. The size of amplified band ranged between 100 to 350 bp and produced 1 unique band in accession Paragpur 2 and size of the band was approximately 350 bp. ISSR analysis with primer 845 yielded second highest numbers of bands (7). In which, all the bands showed polymorphism revealing 100 per cent polymorphism among six accessions. The size of amplified bands ranged between 200 to 1,300 bp and produced highest unique bands (6) in accession Paragpur 2 and size of the bands varied may be because of its divergent nature and uniqueness of the accession. ISSR analysis with primer 868 yielded 4 bands and 100 per cent polymorphism was recorded with bands size s between 200 bp to 650 bp and produced unique bands (2) in accession Paragpur 2 and with size of 650 and 500 bp (Table 4). These markers may be converted into accession−specific probes for identification purposes. Similarly ISSR markers study in *Populus* spp. twenty-five markers, unique to 10 of the cultivars. These markers may be converted into cutivars-specific probes for identification purposes. Each of the selected primers produced fingerprint profiles unique to each of the 28 cultivars, and it was possible to distinguish all cultivars (Gao *et al*., 2006).

ISSR data analysis: Jaccard′s similarity correlation coefficient value for ISSR *r*anged from 0.11 to 0.50 (Figure 2). This indicated a good range of variability in the similarity coefficient values suggesting a broad genetic base of six accessions included in the experiment. The highest value (0.50) was between Kothi and Tamber, the genetic similarity coefficients revealed substantial amount of genetic similarity among the accessions, though the accessions were collected from different districts [Bilaspur and Kangra] climatic conditions. The lowest value of 0.10 was exhibited between Bhella and Tamber revealing that the accessions were more diverse to each other. This result supports the finding of Srivastva *et al*. (2004), Balasaravanan *et al*. (2005) and Narayanan *et al*. (2007) in *Morus alba, Eucalyptus* spp. and teak, respectively.

Table 4. Informative ISSR markers specific for a particular accessions in *T. chebula*

Primers	Approximate size of DNA bands (bp)	Accessions
823 $(TC)_8C$	200	Paragpur-2 (G_3)
840 $(GA)_8YT$	1,000	Paragpur-2 (G_3)
841 $(GA)_8YC$	600	Paragpur-2 (G_3)
842 $(GA)_8YG/TG$	350	Paragpur-2 (G_3)
845 $(CT)_8RG$	1,300	Paragpur-2 (G_3)
868 $(GAA)_6$	650	Paragpur-2 (G_3)

Dendrogram based on RAPD banding pattern; Dendrogram was created using the similarity coefficient and unweighted pair group mean average (UPGMA) method in order to visualize genetic differentiation among various accessions of *T. chebula* and to see their clustering pattern. A critical perusal of dendrogram reveals that the distribution of various accessions into clusters and within cluster was according to their geographic distribution and genetic constitution. The dendrogram exhibited three clear clusters (Figure 2). Cluster I consist of only one accession namely Paragpur 2. According to dendrogram at similarity index value 0.20 Paragpur 2 was separated from the rest of all accessions giving information about its most diverse nature, which is categorized as cluster I. Overall cluster I exhibited 20 per cent similarity with cluster II and III. Cluster II is second major cluster having two accessions viz., Bhella and Tamber. Overall cluster II exhibited 33 per cent similarity with clusters I

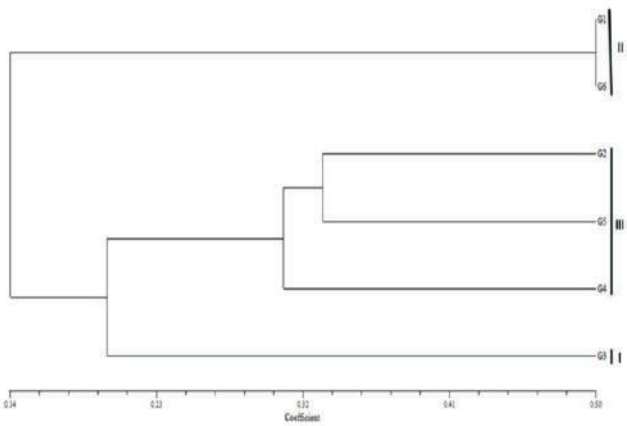

Fig. 2. Dendrogram based on UPGMA analysis among six accessions of *T. chebula* using ISSR markers

and cluster III. Cluster III is a major cluster comprised of three accessions *viz.,* Kothi, Paragpur 1 and Kallar. According to dendrogram within in the cluster III accession Kothi exhibited 40 per cent similarity to Paragpur 1 and Kallar.

The distribution of the accessions into the clusters was random and can be attributed to the fact that these accessions appeared to be selected from populations that share maximum common alleles which may have resulted from frequent movement of seeds/planting stocks across these localities regions. In the work is the first report where ISSR markers have been used in the analysis of genetic variation and determination of genetic relationships between different accessions of *T. chebula*. The ISSR technique was found very reproducible and polymorphic in detecting genetic variability. The present findings are in agreement with earlier work in *Eucalyptus grandis* (Okun *et al*., 2007).

Cluster analysis using RAPD and ISSR data: The RAPD and ISSR data were combined for UPGMA cluster analysis. The dendrogram and cluster analysis gave a similar clustering pattern to that of RAPD and ISSR analysis separately, with Jaccard′s similarity coefficient ranging from 0.32 to 0.47 and the dendrogram exhibited three clear clusters (Figure 3). Cluster I consist of single accession namely Paragpur *2* and expressed 39 per cent similarity with cluster III. According to dendrogram at similarity index value 0.39 Paragpur 2 was separated from the rest of all accessions giving information about its most diverse nature, which is categorized as cluster I. while the remaining accessions exhibited in two clear clusters. Cluster II a second major cluster having two accessions consists. Cluster II consisted of accessions *viz*., Bhella and Tamber showing 34 per cent similarity with rest of clusters I and III. Cluster III a major cluster comprised of three accessions *viz*., Kothi, Paragpur 1 and Kallar. Within in the cluster III accession Kothi exhibited 40 per cent similarity to Paragpur 1 and Kallar. The dendrograms based on RAPD and ISSR combined markers showed partially different genetic distance levels when used individually. But when used together, ISSR‒based cluster is similar to the combined cluster than RAPD‒based cluster. These results are in agreement with the studies in *Ficus* species (Hadia *et al*., 2008). Similarly, in Old World Lupin (*Lupinus* sp.) had found that ISSR‒based cluster is more similar to the combined cluster than RAPD‒based cluster study by Yorgancilar *et al*. (2009). In *Jatropha curcas* also reported similar result when RAPD and ISSR dendrogram patterns were combined than when ISSR and RAPD based patterns were combined (Gupta *et al*. 2008).

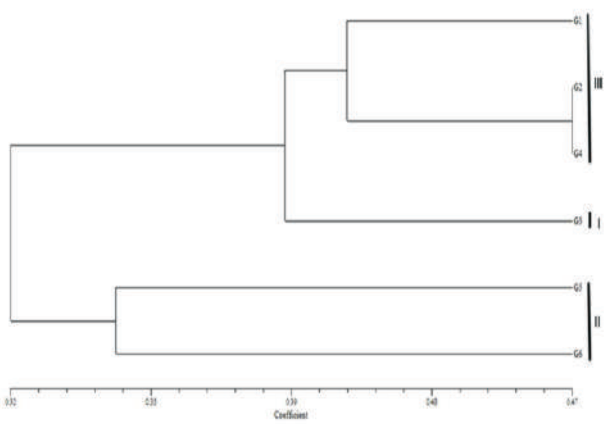

Fig. 3. Dendrogram based on UPGMA analysis among six accessions of *T. chebula* using RAPD and ISSR markers

Hence, both the marker systems RAPD and ISSR either individually or combined can be effectively used in determination of genetic relationships among *T. chebula* accessions. However, various reports suggested ISSR being a better tool than RAPD for phylogenetic studies (Ajibade *et al*. 2000; Galvan *et al*. 2003). The similarity index for combined markers RAPD and ISSR ranged from 0.21 to 0.47. This range is similar to ISRR and RAPD based marker.

CONCLUSIONS

Genetic diversity among selected six accessions of *T. chebula* was evaluated using two marker systems *viz.,* RAPD and ISSR markers. The study revealed that, about twenty five RAPD and twelve ISSR primers were effective in revealing polymorphisms among different *accessions* of *T. chebula*. In RAPD analysis Cluster I comprise of only one accession Kothi and was found to be 41 per cent similar to rest of the clusters and came as an outliner. Whereas ISSR and combined data (RAPD and ISSR) analysis revealed accession Paragpur 2 came as outliner. Hence this accession was the most divergent and unique accession which could be easily being exploited for hybridisation programme in different combinations.

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Assessment of Vulnerability to Agriculture in Kosi Region of Bihar

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Abstract: The present study was conducted to assess the vulnerability to agriculture in Kosi region of Bihar. The study was based data from 1976 to 2015 and divided into four different periods. Data pertaining to contribution of sources of vulnerability as well factors affecting vulnerability showed that the agricultural sector played a significant role in construction of vulnerability followed by occupational, climatic indicator and demographic indicators in all most all period which was selected for the study. Kisanganj district ranked first in the overall vulnerability to climate change followed by Khagaria, Saharsha and Purnea. The vulnerability indices constructed by unequal weight method re-establishing Kisanganj as the most vulnerable district followed by moderately vulnerable districts like Supaul, Saharsa, Madhepura, Purnea and Khagaria and the Araria district was found least vulnerable to climate change. Therefore, the study on climate change on various aspects needed to be addressed urgently due to its devastating impacts on agriculture and linkages among poverty, livelihood and environment.

Keywords: Climate Change, Sensitivity, Adaptive Capacity, Vulnerability, Kosi Region

Climate is the primary determinant of agricultural productivity. It has multi-dimensional effect on humanities in terms of several socio-economic parameters like agriculture and human health, poverty, etc. In the developing countries like India, the small and marginal farmers are more vulnerable to both to the current and future climate change impacts, given their high dependence on agriculture, strong reliance on ecosystem and rapid population growth. Year to year variability in climate contributes to rural poverty where the exposure is high and adaptive capacity is low. The effects of climatic variability on farming is prominent as witnessed by delayed sowing, changes in cropping patterns, higher evidence of pest and diseases, frequent and persistent droughts, less availability of water in tanks and canals for irrigation, reduced profits due to increased prices of inputs and wages as well as stagnation of output prices, shift towards non-farm occupations, migration, asset disinvestment (Singh *et al.*, 2009). Most of the models predict that the damages will adversely affect the small farmers, especially in the rain-fed areas.

Bihar is one of the most disaster prone states of the county. To cope up with changes in the production system virtual stagnation of the crop yield, floods, droughts, heat/cold waves etc. are various forms of disasters prevalent in the state. Among natural disasters, flood is the most common and a regular annual phenomenon in Bihar resulting in enormous loss of life and property. In addition to floods, Increasing population pressure, high density of buildings and their poor construction quality, the settlement in vulnerable areas and inadequate or no investment on mitigation/ Preparedness measures has further increased the vulnerability need to be assessed. The Kosi River (The Sorrow of Bihar) is well known in India for rapid and frequent avulsions of its course and the extensive flood damages it causes almost every year. The Kosi is one of the major tributaries of the Ganga River, and rises in the Nepal Himalayas .This study has been planned to assess the vulnerability keeping in view the extent of damage due to natural calamities and other parameters like social and economic factors directly or indirectly responsible for damage in the Kosi region which is most important component of vulnerability and also need to know which factors or sources should be strengthen. For assessing the major contributory sources no study has been carried out so far in our state.

MATERIAL AND METHODS

The present study was conducted to **assess of vulnerability to agriculture** in Kosi region of Bihar**. The** study was based data from 1976 to 2015 and study period was divided into four periods from 1976-1985, 1986-1995, 1996-2005 and 2006-2015. The secondary data were collected from various published source like Indian Meteorology Departments (IMD), DES, Patna, Ministry of Agriculture, Government of India. For the construction of vulnerability index several sub-indicators were used and so only those indicators relevant to study site were identified. The districts were taken as the unit for computing vulnerability indices in the present study. Keeping in view of the availability of data, eight districts (Supaul, Saharsa, Madhepura, Araria, Purnea, Katihar, Khagaria, and Kishanganj) of Kosi region of Bihar were selected. The method of simple average method, Patnaik and Narayanan's method of equal weight, expert judgement method were employed for the construction of vulnerability index. The expert judgement method is based on opinion of the experts. In order to obtain figures which are free from the units and also to standardize their values, first of all they were normalized so that they all lie between 0 and 1. For normalization of the variables having increasing functional relationship with vulnerability, the normalization was done using the formula

$$U_{ij} = \frac{X_{ij} - \text{Min } X_{ij}}{\text{Max } X_{ij} - \text{Min } X_{ij}} \text{.......... ......} \quad (1)$$

Where,

X_{ij} is the value assigned by i^{th} respondent on j^{th} component

Min X_j is minimum score on j^{th} component

Max X_j is maximum score on j^{th} component

U_{ij} is unit value of i^{th} respondent on j^{th} component

And for those variables have decreasing functional relationship with vulnerability and the normalization was done by using the formula

$$U_{ij} = \frac{\text{Max } X_{ij} - X_{ij}}{\text{Max } X_{ij} - \text{Min } X_{ij}} \text{.......... ......} \quad (2)$$

After computing the normalized scores the index was constructed by giving equal weights to all indicators/components or unequal weights.

Simple Average of the Scores: When equal weights were given to all the variables, simple average of all the normalized scores to construct the vulnerability index

$$VI = \frac{\sum_j U_{ij}}{k}$$

Finally, the vulnerability indices were used to rank the different regions in terms of vulnerability. A region with highest index was said to be most vulnerable and it is given the rank1, the region with next highest index was assigned rank 2 and so on.

Patnaik and Narayanan Method: In this method (Patnaik and Narayanan, 2005), possible sources of vulnerability were identified and for each source several sub-indicators are identified. Sources of vulnerability were demographic, climatic, agricultural and occupational, after normalization, the average index (AI) for each source of vulnerability was worked out and then the overall vulnerability index was computed by employing the following formula:

$$VI = \frac{\left[\sum_{i=1}^{n} (AI_i)^{\alpha}\right]^{\frac{1}{\alpha}}}{n}$$

Where, AI= Average index, *n* is the number of sources of vulnerability and α= *n*.

After the values of the index were calculated for all the districts for different period of time and they were compared to assess the changes in vulnerabilities a ranking of the various districts can be carried out to identify the most vulnerable districts in terms of the indicators used for measurement.

Expert Judgement Method : The weights are assigned based on the basis of expert opinion. The experts in this field were asked to rank these four components according to vulnerability. Each component was ranked in the descending order according to their relative importance. Garrett's ranking technique was involved to reveal the importance of each component based on their unit value after normalization. The percentage positions thus obtained were transformed into scores on a scale of 100 points by using Garrett's table. From the scores, the average score was derived. This is termed as scale value (Sj) of each component. The unit values (Uij) for each combinations and category of experts were multiplied by respective component scale value, summed up and divided by total scale value to get vulnerability Index (VI) of each of the combinations in different categories of experts. The value of SI is in percentage. Higher the VI higher will be the vulnerability of that district (Rahaman *et al*., 2016).

$$VI = \frac{\sum_{i=1}^{n} U_{ij} * S_j}{\sum_{i=1}^{n} S_j}$$

Garrett's Ranking Technique: In this method, respondents were asked to rank the specific problems faced by them according to their own perception. The assigned rank was converted into percentage position which was subsequently transferred into Garrett score using Garrett's table. For each constraint, scores of individual respondents were added together and then divided by total number of respondents. Thus, mean score for each constraint was ranked by arranging them in descending order.

$$\text{Percentage position} = \frac{100\,(R_{ij} - 0.50)}{N_j}$$

Where, R = Rank given for the i item by the j individual and N = Number of items ranked by the j individual.

Thus after constructing the vulnerability index by method of unequal weight, the different districts of Kosi region were categorized according to high, moderate and low :

Highly vulnerable :> (Standard Deviation + Mean); Low vulnerable :< (Standard Deviation − Mean) moderately vulnerable: Between (Standard DeviationMean).

RESULTS AND DISCUSSION

The vulnerability indices as well as component-wise contributions to the overall vulnerability to climate change for selected districts of Kosi region for the different periods have been done using Patnaik and Narayanan method (Table 1) by including four major sources of vulnerability. These included the demographic factors, climatic factors, agricultural factors and occupational factors. Weight of each factor was estimated and the vulnerability index of agriculture to climate change in the districts of Kosi region was developed. The Kisanganj district of Kosi region was most vulnerable, whereas the Katihar and Araria districts was assessed to comparatively least vulnerable due to having higher adaptive capacity i.e. high literacy rate, better yield of crop, high cropping intensity etc. to recover from the climatic stresses and it was noticed that agricultural and occupational sources of vulnerability was major sources with respect to overall vulnerability to climate change in period one i.e. for1976-85.However climate and demographic was third and fourth main indicators of vulnerability respectively for all most all district. Spatial variation of vulnerability indicated that in Katihar district climatic factors contributed about 33 percent amongst all selected district of Kosi region, and occupational vulnerability was contributed maximum in Supual district of Bihar. However, demographic indicator was contributed maximum in Katihar i.e. 23 percent of overall vulnerability.

Out of the eight districts the district of Kishanganj ranked first and Araria ranked last in the overall vulnerability to climate change. The agricultural sector played a significant role in ranking Kishanganj district at the first position by contributing to the tune (46.12) per cent to the overall vulnerability however demographic and climatic sources were contributing only 6 and 13% respectively towards the overall vulnerability. The second important sources of vulnerability was occupational vulnerability in all most all selected district of Bihar but it contributed more in Khagaria i.e. about 25 percent, It was mainly due to recurrent occurrences of flood every year, people are migrating for other occupation rather than farming. So therefore it may be concluded that, occupational vulnerability was also one of important sources of vulnerability in these district next to

Table 1. Source wise percentage contribution of vulnerability index (P-I) during 1976-1985

District	Demographic	Climate	Agricultural.	Occupational	Overall	Rank
Kishanganj	6.26	13.46	46.12	34.16	14.27	1
Khagaria	12.17	10.16	41.72	35.95	12.47	2
Saharsa	16.68	28.67	25.03	29.62	10.03	3
Purnea	16.57	29.99	37.38	16.06	9.65	4
Madhepura	16.84	27.94	21.07	34.16	9.28	5
Katihar	23.14	32.94	36.19	7.73	9.14	6
Supaul	14.5	15.28	18.82	51.4	8.41	7
Araria	8.2	31.34	44.35	16.11	6.72	8
Overall	13.92	22.45	34.67	28.96	100	

Source: Field Survey, 2016

Table 2. Source-wise percentage contribution of vulnerability index (p-II) during 1986 -1995

District	Demographic	Climatic	Agril.	Occupational	Overall	Rank
Kishanganj	7.64	8.6	49.66	34.1	14.3	1
Khagaria	14.16	10.19	40.45	35.21	12.74	2
Purnea	23.92	16.39	43.8	15.89	9.75	3
Saharsa	20.47	17.59	31.33	30.61	9.70	4
Supaul	10.44	17.63	24.43	47.5	9.10	5
Araraia	16.01	29.25	41.23	13.51	8.01	6
Katihar	32.21	6.91	51.34	9.53	7.42	7
Madhepura	18.28	14.5	24.03	43.19	7.34	8
Overall	16.82	14.49	39.13	29.56	100	

Source: Field Survey, 2016

agricultural vulnerability. Their adaptive capacity was also not enough to overcome with the existing problem. Among four sources of vulnerability agricultural sources was contributed about 39 per cent followed by occupational sources, climate and demographic factor as observed by Chaturvedi *et al*., 2014. Moreover, vulnerability due to climatic factors like rainfall, diurnal temperature, change in maximum temperature was also observed maximum in Katihar district due to agricultural vulnerability production of food grains (tones) was maximum in Saharsa followed by Katihar and least production of food grains in Khagaria district productivity of food grains) in Katihar was maximum and Madhepura was minimum Livestock population (no. ha^{-1} of net sown area) was maximum in Araria district (3.71) followed by Purnea, Supaul and least livestock population was found in Khagaria district (1.68).

In the year1986–1995, Kishanganj district was placed again in first position with agricultural and occupational indicators yet again being major contributors towards the overall vulnerability to climate change. It was followed by Khagaria and Purnea districts. However demographic sources was also took place important sources of vulnerability as mentioned contributed about 17 percent which was accounted more than that of climatic factor (15 percent)with respect to overall vulnerability. However district wise vulnerability with respect to each sources indicated that vulnerability to agriculture sources was accounting highest percentage i.e. about 51 per cent in Katihar district followed by Kishanganj (50 %), Purnea (43 %) and Araria (41%) respectively for the period under reference. Another sources of vulnerability was occupation in which Supual was accounted highest 48% percentage followed by Madhepura district and it was accounted high due to lack of opportunities of any industry in that area where people got job, despite of the fact that due to flood famers were not able to cultivate cop in entire period /season.

In the year 1996–2005, Khagaria district retained its first position with demographic and agricultural indicators being major contributors towards the overall vulnerability to climate change. It was followed by Kishanganj and Supaul districts. Katihar was least vulnerable district with respect to overall vulnerability to climate change in mentioned period. The contribution of demographic indicators towards overall vulnerability was 31.77 per cent, followed by agricultural (30.13%), occupational indicators (25.22%) and climatic factors (12.87%). The values of vulnerability indices varied

Table 3. Source wise percentage contribution of vulnerability index (P–III) during 1996–2005

District	Demographic	Climatic	Agricultural	Occupational	Overall	Rank
Khagaria	62.76	4.32	17.87	15.06	29.78	1
Kishanganj	9.71	13.74	43.87	32.69	14.92	2
Supaul	20.18	15.77	17.04	47.01	9.19	3
Purnea	23.74	18.19	40.62	17.46	8.87	4
Araria	26.58	24.92	35.27	13.23	8.18	5
Saharsa	15.85	16.71	29.88	37.57	7.91	6
Madhepura	13.10	16.42	27.94	42.54	7.45	7
Katihar	12.15	15.18	59.86	12.81	5.52	8
Overall	31.77	12.87	30.13	25.22	100.00	

Source: Field Survey, 2016

Table 4. Source wise percentage contribution of vulnerability index (P–IV) during 2006 –2015

District	Demographic	Climate	Agricultural	Occupational	Overall	Rank
Kishanganj	4.74	14.50	46.28	34.48	14.14	1
Khagaria	11.59	9.93	42.59	35.89	12.49	2
Purnea	22.25	25.00	36.89	15.86	9.77	3
Saharsa	21.12	18.15	26.90	33.82	8.78	4
Supaul	12.95	19.43	17.99	49.63	8.71	5
Madhepura	16.27	15.53	27.04	41.17	7.70	6
Katihar	31.20	9.42	48.91	10.47	6.75	7
Araria	14.57	26.25	43.04	16.14	6.70	8
Overall	15.47	16.80	36.87	30.86	100	

Source: Field Survey, 2016

from 0.30 (Madhepura) to 0.59 (Kishanganj) in 1996–2005 indicating that there exists a wide variability in the factors influencing climate change. Hence to reduce the climate change impact, the policy makers must focus on generating better employment opportunities including income diversification options for the people in the regions where the incidences of outmigration are high. The result was supported by the similar findings obtained in assessment of vulnerability in Gujarat of (Hiremath *et al.*, 2013).

Source wise contribution of vulnerability from 2006 to 2015 also indicated that agricultural and occupational indicators were the main source / factors of vulnerability accounted 36.87 per cent and 30.86 per cent respectively. Kisangani again placed as most vulnerable district followed by Khagaria and Purnea. However highest occupational vulnerability was observed in Supaul (49 %) district of Bihar. It was mainly due to frequent occurrence of flood leads no occupation even in farming and due to lack of capital, taking other subsidiary enterprises was also a big problem in study district during mention period. Thus, it may be concluded that, the agricultural indicators contributes more towards vulnerability followed by occupational indicators in all most all decades under study. It was seen that a high value of this variable implied more literates in the region and so greater awareness to cope up with climate change impacts (Palanisami *et al.,* 2009).

Climatic vulnerability was assumed to be positively related to the indicators. This indicated increase in the variability of these climatic indicators would increase the vulnerability of the districts to climate change. Any change in climatic variables like temperature and precipitation could induce vulnerability of food production in a big way. For instance, the climatic abnormality during the 1970s caused relatively small fluctuations in the world cereal supplies (Glantz and Wigley, 1986). Yield is more uncertain with unfamiliar technology. Quite often the objective risks are uncertain due to weather fluctuations, susceptibility to pests, uncertainty regarding timely availability of crucial inputs etc. However, it could be seen that higher yields of crops led to higher incomes of the farmers and thereby increasing their risk bearing ability to various shocks. Lastly, all the occupational indicators were hypothesised to have a negative functional relationship to climate change as greater employment meant more secure incomes which would in turn increase the risk bearing capacities of the people. It may be concluded that, emphasis must be on the priorities setting

Table 5. Source wise percentage contribution of vulnerability index during 1976 –2015

District	Demographic	Climate	Agricultural	Occupational	Overall	Rank
Kishanganj	6.71	10.52	46.18	36.59	12.98	1
Khagaria	13.2	14.82	36.62	35.35	12.85	2
Supaul	11.32	20.52	25.53	42.64	10.69	3
Purnea	20.35	26.72	36.22	16.71	9.12	4
Madhepura	17.37	24.57	22.62	35.44	9.00	5
Saharsa	19.36	16.07	32.42	32.14	8.99	6
Araria	9.75	24.48	42.67	23.1	5.89	7
Katihar	36.13	27.92	23.43	12.53	5.83	8
Overall	15.42	19.41	33.92	31.25	100	

Source: Field Survey, 2016

Table 6. Comparative analysis of vulnerability index during 1976 –2015

District	P-I (1976-85)		P-II (1986-95)		P-III(1996-05)		P-IV(2006-15)		1976-2015	
	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank
Kishanganj	0.89	1	0.89	1	0.024	1	0.59	1	0.81	1
Khagaria	0.78	2	0.8	2	0.021	3	0.51	4	0.8	2
Supaul	0.53	7	0.57	5	0.021	2	0.54	2	0.67	3
Purnea	0.6	4	0.61	3	0.019	4	0.52	3	0.57	4
Madhepura	0.58	5	0.46	8	0.012	8	0.3	8	0.56	5
Saharsa	0.63	3	0.61	4	0.014	7	0.37	6	0.56	6
Araria	0.42	8	0.5	6	0.015	6	0.36	7	0.37	7
Katihar	0.57	6	0.46	7	0.016	5	0.38	5	0.36	8

Source: Field Survey, 2016

and policies for rural youth to be part of agriculture diversification and could act as an agent for rural development.

Among the different factors of overall vulnerability in 1975–2015, agriculture and occupational vulnerability were contributing 34 per cent and 31 per cent respectively to the climate change. Other factors were the climate and demographic factors having contribution of 19.41 per cent and 15.42 per cent respectively. Data pertaining to district wise analysis of percentage contribution of different factors indicated that, in Kishanganj district agricultural factors (46 %) were the main indicators of vulnerability followed by occupational factors in the district of Supaul.

Comparative analysis of vulnerability to climate change over different period indicated that, in period I (1976–85) period II and period IV (2006–2015) the value of vulnerability index was comparatively more than that of period III. It means higher the value of indices greater will be the vulnerability. Component wise vulnerability to climate change indicated that among four indicators agriculture followed by occupational indicators were the major indicators towards vulnerability. However climatic factors were the third factor which affects the vulnerability. It clearly indicated that agricultural vulnerability was most common phenomenon in selected districts of Bihar. Climate played important role in production of crop therefore strategies for selection of crop according to the prevailing situation as well selection of suitable subsidiary enterprises to cope with the existing situation is need of hour. To check out migration suitable policy related to employment generation for rural youth is also need to be developed, because to mitigate the challenges engagement of rural youth in agriculture is necessary. District wise vulnerability indices indicated that among selected district Kisanganj followed by Khagaria and Supaul was found to be most vulnerable district and Katihar, Araria followed by Saharsa was ranked as comparatively less vulnerable district. It may be concluded that those district which was found to be most vulnerable had lower adaptive capacity (agricultural component) and most sensitive towards the danger (climatic component) and vice–versa.

Degree of vulnerability: Component wise indicators for assessment of vulnerability indicated that Kisanganj was highly vulnerable towards exposure whereas Purnea and Katihar were highly vulnerable towards sensitivity (Table 7). Data pertaining to adoptive capacity indicated that Kisanganj was again placed under highly vulnerable district towards the adaptive capacity as productivity of major crop was comparatively low, people were not aware about proper method of cultivation and due to change in maximum and minimum temperature several consequences due to these are observed as delayed sowing ,insect attack, less productivity of crops and farming was less profitable in that area that's why government has already established Agricultural collage to overcome all the issues related with farmers. Therefore special package and practices is required to develop coping mechanism against the vulnerability for highly vulnerable district.

Table 7. Ranking of indicators using expert judgment method during 1996–2005

Scale	Level	Name of district
	Exposure	
≥47.744	Highly	Kishanganj
26.82–47.74	Moderate	Supaul, Saharsa, Madhepura, Khagaria, Purnea, Araria
≤26.82	Least	Katihar
	Sensitivity	
≥66.2866.28	Highly	Purnea ,Katihar
36.79–66.28	Moderate	Saharsa, Madhepura, Kishanganj, Khagaria, Araria
≤36.79	Least	Supaul
	Adaptive Capacity	
≥73.58	Highly	Kishanganj
28.32–73.58	Moderate	Supaul, Saharsa, Madhepura, Araria, Purnea, Khagaria
≤28.32	Least	Katihar

Source: Field Survey, 2016

The district of Saharsa, Supaul, Purnea, Khagaria followed by Araria, and Madhepura was placed under moderate vulnerability. However, from the sensitivity component out of eight district, Purnea, **Katihar** was highly vulnerable district

CONCLUSION

Kosi region of Bihar is the boosting the economy of the state. It is rapidly expanding its production and consumption activities. Thus, the region not only contributes to climate change but is equally vulnerable to its impacts. Since the agricultural sector has the greatest bearing there is a need to shift focus towards investments in adaptation of research for these districts of Bihar. The occupational indicators were the second largest contributors towards overall vulnerability, thus, to reduce the climate change impact, the policy makers must focus on generating better employment opportunities including income diversification options for the people in the regions where the incidences of outmigration are high. So Kosi region of Bihar requires a development strategy that integrates climate change policies with sustainable development strategies to effectively combat climate change issues.

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System of Root Intensification in Mustard: Climate Change Mitigation and Climate Resilience Strategy

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Abstract: A field experiment was conducted at Bihar Agricultural University, Sabour during *rabi* season during 2013-14, 2014-15 and 2015-16 to evaluate the yield, root depth and economics of mustard varieties under SRI as well as conventional sowing. Experiment was laid out in split plot design comprised of twelve treatments having three varieties i.e. Rajendra suflam, Pusa bold and Rajendra anukul in main plot while planting geometries i.e. SRI spacing at 30x30 cm, 45x45 cm, 60x60 cm and conventional spacing at 30x15 cm placed in sub plots replicated thrice. Rajendra suflam exhibited significantly highest grain yield (14.5 q ha^{-1}) over Rajendra anukul and Pusa bold. Maximum grain yield (15.4 q ha^{-1}) under 45x45 cm SRI spacing was found significantly superior over rest of the spacings and recorded 26.2% higher grain yield over conventional spacing. Root depth was not significantly influenced by varieties. However, SRI spacing at 60x60 cm registered maximum root depth (57.6 cm). Significantly maximum net return (Rs. 38895 ha^{-1}) was obtained from Rajendra suflam, however, SRI spacing at 45x45 cm exhibited significantly maximum net return (Rs. 42005 ha^{-1}). Rajendra suflam variety at 45x45 cm spacing can prove step ahead in realizing the yield potential of the crop through root intensification.

Keywords: Climate change, Climate resilience, Mustard, System of root intensification, Yield

Optimum planting time for rapeseed mustard in south Bihar is second fortnight of November, but it often gets delayed to December particularly after *kharif* season crop especially rice. Hence the productivity of mustard becomes declined due to shorten interval between vegetative and reproductive phases of the crop. Moreover, the productivity potentiality of rapeseed-mustard has become static under conventional sowing, which may not be further enhanced, until or unless we could not emphasize to explore the possibility of some agronomical manipulations in achieving better production to fulfil the basic pre-requisite demand of present and future growing population for edible oil consumption in the country. System of root intensification (SRI) is best option for early establishment of seedling in main field to solve the problem of late sown mustard and also mitigate the ill effects of climate change with minimum use of water and better root proliferation to survive under water stress (Mirza and Karim, 2007). SRI is based on basic principles *viz.*, transplanting of young seedlings (8 days old), avoiding trauma to roots by quick and shallow planting, planting single seedling at wider spacing, use of organics, mechanical weeding and alternate wetting and drying. Yield enhancement in SRI mustard might owe to reduce competition among individuals for light, nutrient, space, water etc. under changing climate. SRI enhances root spread area which favours water stress condition more efficiently and little emission of green house gases from the field of alternate wetting and drying and also from organic manures instead of chemical fertilizers (Adhya *et al*., 2014). It is intended to help small and marginal farmers with limited resources to produce more for them and to gain more financially. Root intensification through transplanting might be better alternative in rainfed rapeseed-mustard growing zones but it requires standardization for further recommendation. However, the information on raising the seedling of mustard crop by transplanting is scanty so far. Varieties also differ in their yield potential which is largely dependent on growing habit, canopy architecture and different phenophases and that needs to be studied.

Keeping these issues in view, the present study was undertaken to investigate the yield potentiality and spatial requirement of mustard varieties (*Brassica juncea* L.) in system of root intensification (SRI) under existing climate change scenario of Bihar.

MATERIAL AND METHODS

Experimental site: A field experiment was conducted at Bihar Agricultural University farm, Sabour (25˚50′ N, 87˚19′ E; 52.73 m above mean sea level) during *rabi* season 2013-14, 2014-15 and 2015-16. Soil of the experimental site was sandy loam, low in available nitrogen and phosphorus and medium in available potassium with normal soil reaction.

Experimental details: The experiment was laid out in split-plot design with three replications. Main plot consisted of three varieties (Rajendra suflam, pusa bold and Rajendra anukul). The sub plots include four planting geometry (S_1:

30x15 cm as conventional, S_2: 30x30 cm as SRI, S_3: 45x 45 cm as SRI and S_4: 60x60 cm as SRI).

This experiment was undertaken to find out the yield, root depth and economic analysis of mustard varieties under system of root intensification as well as conventional sowing. Mustard in conventional sowing was fertilized uniformly with 80:40:40 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. Half N along with full P and K was applied as basal. Remaining N was top dressed in two equal splits, at 25 and 45 days after sowing in conventional sowing at 30 cm x 15 cm distance in lines. In SRI method of sowing, sprouted seeds emerged after proper soaking of seeds treated with jaggery, cow urine and vermicompost slurry were raised into poly bags for initial 8 days in nursery bed after use of organic manures like vermicompost and bio-pesticide like *Trichoderma.* Frequent sprinkling of water were given after emergence of crop on the basis of visual moisture stress symptoms. Seedlings were transplanted manually as per intended geometry after application of bulky organic manures like vermicompost, biozymes, PSB and other composts supplemented with little amount of inorganic fertilizers like urea, di-ammonium phosphate and muriate of potash in region where young seedlings established after its transplantation. Normal package of practices for crop husbandry like intercultural operations, weeding/hoeing, alternate wetting and drying, compost and organics application, plant protection measures etc. were also followed for successful raising of SRI mustard. Field data for yield attributes (siliquae $plant^{-1}$, seeds $siliqua^{-1}$ and grain weight $plant^{-1}$) and yield (grain and stover), root depth and economics of mustard were recorded at harvest. Statistical analysis of the data was performed by applying ANOVA technique of split plot design (Cochran and Cox, 1985). The significance of different sources of variations was tested by F′ test at probability level 0.05. Standard error of mean (SEm±) and critical difference (CD) at 5% level of significance were worked out to compare the difference between the treatment means.

RESULTS AND DISCUSSION

Yield attributing parameters like number of siliqua per plant, length of siliqua, number of seeds per siliqua and grain weight per plant were significantly influenced by varieties and planting geometries in all the branches of mustard crop except number of siliqua per plant in tertiary branch (Table 1 and 2). Among the varieties, Rajendra suflam produced more number of primary, secondary and tertiary branches as compared to the other two varieties except secondary branch. Rajendra anukul variety also recorded more number of primary, secondary and tertiary branches over that of Pusa bold variety.

Number of siliqua $plant^{-1}$: Number of siliqua per plant was significantly more in the transplanted crop than that of conventional sown crop owing to more number of primary, secondary and tertiary branches in the transplanted crop than that of conventional sown crop (Table 1), which was largely attributed due to more branching taking place from the basal part of the main shoot in transplanted crop. These findings are in agreement with the results of Satpathy (2007). Number of siliqua per plant is a function and resultant of the number of branches per plant. Varieties significantly influenced the number of siliqua per plant. Rajendra anukul variety produced significantly more total number of siliqua per plant over the other two varieties, however, in case of number of siliqua per plant in different branches was concerned, it was found maximum under Rajendra suflam variety in all the branches except in secondary branch where Rajendra anukul variety exhibited maximum number of siliqua per plant. The varietal characters in yield attributes has also been reported by various researchers including Prakash *et al*. (2000) and Singh *et al*. (2001).

Different varieties caused significant variation in number of siliqua per plant in all the branches except in tertiary branches. Primary and secondary branches exhibited maximum number of siliqua per plant under different varieties. Rajendra suflam exhibited maximum number of siliqua per plant followed by Rajendra anukul for primary branches. However, it was found maximum value under Rajendra anukul followed by Rajendra suflam for secondary branches. Similar trend was found in case of total number of siliqua per plant. So far as spacing by SRI method was concerned, number of siliqua per plant was highest towards significant increasing trend with increase in spacing from 30x30 cm to 60x60 cm by SRI method as compared to conventional spacing at 30x15 cm distance in primary, secondary and tertiary branches as well as total number of siliqua per plant. Length of siliqua, numbers of seeds per siliqua and grain weight per plant were observed highest under Rajendra suflam followed by Rajendra anukul except in case of length of siliqua where Rajendra suflam exhibited superiority over rest of the varieties. As far as spacing was concerned, maximum length of siliqua, number of seeds per siliqua and grain weight per plant was found under 60x60 cm spacing by SRI method which was found superior over rest of spacing treatments.

Number of seeds $siliqua^{-1}$: The conventional planting caused a significant reduction in the average number of seeds per siliqua (Table 2). Among the different varieties, Rajendra suflam variety produced significantly more number of seeds per siliqua which may be a varietal character. This varietal character is also reported by Kumar (2003).

Table 1. Effect of different treatments on number of siliqua plant^{-1} and length of siliqua in mustard

Treatment	Number of siliqua per plant				Length of siliqua (cm)
	Primary branch	Secondary branch	Tertiary branch	Total	
Varieties					
V_1–Rajendra Anukul	131.8	156.1	72.8	361.6	4.3
V_2–Pusa bold	124.9	147.0	73.1	338.4	4.2
CD (p=0.05)	6.8	4.6	NS	14.6	0.1
Planting geometry					
S_1−30×15 cm Conv.	51.4	66.0	21.5	134.2	3.9
S_2−30×30 cm SRI	77.9	111.9	40.5	223.9	4.2
S_3−45×45 cm SRI	160.2	174.7	95.4	433.3	4.6
S_4−60×60 cm SRI	231.0	258.6	136.0	617.5	4.9
CD (p=0.05)	7.7	5.7	4.0	14.7	0.1
Interaction					
CD (p=0.05)	NS	NS	NS	NS	NS

Table 2. Effect of different treatments on number of seeds per siliqua, grain weight plant^{-1}, grain, stover yield and harvest index of mustard

Treatment	Number of seeds per siliqua	Grain weight per plant (g)	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Harvest index (%)
Varieties					
V_1–Rajendra Anukul	13.8	25.5	14.2	32.3	30.7
V_2–Pusa bold	13.4	23.5	13.9	32.8	29.4
V_3–Rajendra Suflam	14.1	26.5	14.5	34.9	29.8
CD (p=0.05)	0.3	1.3	0.2	1.7	0.5
Planting geometry					
S_1−30×15 cm Conv.	11.3	5.0	12.2	28.1	30.4
S_2−30×30 cm SRI	13.0	12.7	14.7	34.6	29.8
S_3−45×45 cm SRI	14.9	30.9	15.4	36.5	29.7
S_4−60×60 cm SRI	16.0	52.1	14.4	34.1	29.9
CD (p=0.05)	0.5	1.3	0.3	1.6	0.9
Interaction					
CD (p=0.05)	NS	NS	NS	NS	NS

Grain weight plant^{-1}: Among the varieties, Rajendra suflam produced higher grain weight per plant over the other two varieties (Table 2). SRI sowing at 60x60 cm distance produced higher grain weight per plant, while the conventional sowing ended up with the lowest weight of grain per plant. More accumulation of dry matter resulted in better accumulation of photosynthates in the transplanted crop, which resulted in more number of siliqua per plant and grain weight per plant in transplanted crop than that of direct seeded mustard crop. These findings corroborated the results of Kumar (2003).

Grain yield: Among the planting geometries, transplanting with 45 cm x 45 cm spacing produced the maximum grain yield (15.4 q ha^{-1}) being significantly superior over the other planting methods (Table 2). The lowest grain yield (12.2 q ha^{-1}) was achieved in conventional sowing which remained significantly inferior to SRI transplanting. The differences in the plant population between 45x45 cm and 60x60 cm made the difference in the grain yield significantly. ATMA (2013) and Singh *et al*. (2006) also reported higher grain yield under transplanting system of mustard. Rajendra suflam variety out yielded (14.5 q ha^{-1}) the other two varieties being significantly superior in terms of grain yield. Indian mustard variety ′Rajendra suflam′ also remained significantly superior over Pusa bold variety which registered the lowest grain yield (13.9 q ha^{-1}) among the three varieties.

The highest grain yield in case of Rajendra suflam variety might be due to more number of branches, siliqua, and the grain weight per plant. The varietal differences in grain yield have also been reported by Raquibullah *et al*. (2006) and Razzaque *et al*. (2007). Among the different varieties of mustard, Rajendra suflam variety accumulated significantly more dry matter followed by Rajendra anukul and Pusa bold possibly due to higher uptake of N and a longer duration time taken by this variety, which is truely indicative of the total photosynthate production (Prakash *et al*., 2000). Different varieties and spacing caused significant variations in grain yield of mustard. Rajendra suflam exhibited significantly highest grain yield over Rajendra anukul and Pusa bold. It was found maximum (15.4 q ha^{-1}) under 45x45 cm spacing and was found significantly superior over rest of the spacings and recorded 26.2% higher grain yield over conventional spacing. The differences among the varieties could be attributed to their growth behaviour, biomass production and the crop duration, the transplanted crop accumulated significantly more dry matter over conventional sown cop. Maximum dry matter accumulation per plant was at 45x45 cm distance SRI transplanting, which remained significantly superior over rest of the transplanting geometries.

Stover yield: Stover yield, too, was significantly highest (36.5 q ha^{-1}) in 45x45 cm SRI transplanting geometry over the other planting geometries (Table 2). Transplanting at 60x60 cm and 45x 45 cm on SRI pattern remained significantly varied and was found significantly superior over the conventional sowing. The highest stover yield in 45x45 cm SRI spacing could be taken as a function of more plant population, number of branches per plant and more vegetative growth. Among the different varieties, Rajendra suflam variety produced significantly higher stover yield (34.9 q ha^{-1}) over the other two varieties.

Harvest index: Conventional sowing resulted in maximum harvest index (30.4%), which was statistically on a par with that of all other transplanting geometry (Table 2). Among the various varieties, Rajendra anukul variety had significantly higher harvest index (30.7%) over Rajendra suflam and Pusa bold varieties.

Root depth: Root depth of mustard was significantly influenced by different spacing treatments (Table 3). The transplanting of mustard was associated with vigorous growth of the crop. Root depth was measured more (57.6 cm) in case of transplanted crop at 60x60 cm SRI spacing, which remained significantly superior over rest of the planting geometries. The transplanted crop attained significantly more root depth over the conventional sown crop which might be due to more vigorous root system and more spacing under the transplanted crop letting it derive more water and nutrients for its growth and development. Root studies in mustard at harvest indicated that root depth was not significantly influenced by varieties. However, SRI spacing caused significant variation in root depth which provides tolerance against drought.

Al-Doori (2013) also reported the significant differences in root proliferation of the particular varieties over the other mustard varieties. More root depth and root proliferation in case of the transplanted crop could be owed to more exploration of soil for nutrients and water by the transplanted crop. The direct sown crop produced significantly lowest root depth (42.9 cm), which may be due to low dry weight of roots due to less growth of conventional sown crop.

Table 3. Effect of different treatments on root depth and economics of mustard

Treatment	Root depth (cm)	Cost of cultivation	Net return (Rs. ha^{-1})	B:C ratio
Varieties				
V_1-Rajendra Anukul	52.0	21104	36925	1.70
V_2-Pusa bold	52.7	21104	36253	1.67
V_3-Rajendra Suflam	53.3	21104	38895	1.80
CD (P=0.05)	NS		1317	0.06
Planting geometry				
S_1−30×15 cm Conv.	42.9	18726	31098	1.65
S_2−30×30 cm SRI	54.2	23061	37745	1.58
S_3−45x45 cm SRI	56.0	21666	42005	1.88
S_4−60×60 cm SRI	57.6	20965	38582	1.78
CD (P=0.05)	0.9		1552	0.07
Interaction				
CD (P=0.05)	NS		NS	NS

Economics: Among the SRI spacing, mustard crop transplanted at 45x45 cm spacing registered the maximum benefit: cost ratio (1.88) which was significantly superior over rest of the spacings (Table 3). Other spacing combinations could also register benefit: cost ratio greater than unity. Maximum net return (Rs. 38895 ha^{-1}) and B: C ratio (1.80) was obtained from Rajendra suflam which was significantly superior over rest of the varieties. However, SRI spacing at 45x45 cm distance exhibited maximum net return (Rs. 42005 ha^{-1}) which was found significantly superior over rest of the spacing treatments. Similar findings are in agreement with Mirza and Karim (2007). The interaction between the varieties and the planting geometrics was found to be non significant with respect to yield, yield attributes, root depth and economics of mustard.

Transplanting of Rajendra suflam variety at 45x45 cm spacing could realize the yield potential of the crop through root intensification at Sabour region of Bihar. Therefore, it could be best alternative crop adaptation for farm beneficiaries of Bihar state in perspective of climate resilient farming for mitigating global warming ill effects.

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Statistical Modelling for Forecasting of Pearl Millet (*Pennisetum glaucum*) Productivity Based on Weather Variables

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Abstract: A timely and reliable forecast of yield of crop needs little emphasis for monsoon dependent country like India where, the economy is mainly based on agricultural production. Weather is a major factor affecting crop production in advanced agricultural systems. The large variation due to climate change in yield from year to year and place to place is dominated by the weather parameters. In view of fluctuating climate, a timely and reliable forecast of crop productivity could help in deciding the policies. To estimate the effect of weather variables and technological advances, 34 years productivity data of summer pearl millet from 1980 to 2013 were collected. The weekly averages of weather variables *viz.,* bright sunshine hours (BSS), maximum temperature (MAXT), minimum temperature (MINT), morning relative humidity (RH_1), afternoon relative humidity (RH_2) and weekly total rainfall (RF) from 5^{th} to 16^{th} standard meteorological week of the respective year were considered in the study.Among the equations fitted under this approach, for 11 and 12 weeks of 27 years, for 11 weeks R^2 was (54.50 percent) and 12 weeks (62.40percent) model and deviations of simulated forecasts ranged from 0.86 to 10.91 percent and from 3.71 to 20.93 percent for 11 and 12 weeks models, respectively. In case of 11 and 12 weeks models using data for 28 years, R^2 was 67.20 percent for 11 weeks with deviation ranging from 2.24 to 10.55 percent from observed data and for 12 weeks, R^2 was 63.00 percent with deviations ranging from 2.19 to 21.91 percent. For data of 29 years, the R^2 was 57.00 percent (11 weeks), having deviation from 2.75 to 10.19 per cent and R^2 was 65.00 percent for 12 weeks with deviation ranging from 0.36 to 11.37 percent from observed data. Looking to higher adjusted R^2 (61.60 percent), lower S.E. (170.72), deviations (2.24 to 10.55), RMSE (158.28) and MAE (123.46) in prediction among all models, the model of 11 weeks using data of 28 years could be considered as pre harvest forecast model which can predict the productivity at 2 weeks before harvest with R^2 value 67.20 percent.

Key words: MLR model, Forecasting, Weather variables, Pearl millet yield

Global food security threatened by climate change is one of the most important challenges in the 21st century to supply sufficient food for the increasing population while sustaining the already stressed environment. Agriculture is sensitive to short-term changes in weather and to seasonal, annual and longer-term variations in climate. Crop yield is the culmination of a diversified range of factors. The variations in the meteorological parameters are more of transitory in nature and have paramount influence on the agricultural systems. Analysis of the food grains production/productivity data for the last few decades reveals a tremendous increase in yield, but it appears that negative impact of vagaries of monsoon has been large throughout the period. In this context, a number of questions need to be addressed as to determine the nature of variability of important weather events, particularly the rainfall received in a season/year as well its distribution within the season. These observations need to be coupled to management practices, which are tailored to the climate variability of the region, such as optimal time of sowing, level of pesticides and fertilizer application. Agriculture now-a-days has become highly input and cost intensive area without judicious use of fertilizers and plant protection measures, agriculture no longer remains as profitable as before because of uncertainties of weather, production, policies, prices *etc.* that often lead to losses to the farmers. Under the changed scenario today, forecasting of various aspects relating to agriculture are becoming essential.

Pearl millet *(Pennisetum glaucum)* is one of the most extensively cultivated cereals in the world has wide adaptability to local environments. It is a hardy crop and can be grown in areas which are very hot and dry and on soils too poor for crops like maize and sorghum is considered more efficient in utilization of soil moisture and has a higher level of heat tolerance than sorghum and maize. Crop yield forecast provided useful information to farmers, marketers, government agencies and other agencies and useful in formulation of policies regarding stock, distribution and supply of agricultural produce to different areas in the country. However, statistical techniques employed should be able to provide objective crop forecasts with reasonable precisions well in advance before harvests for taking timely decisions. Various approaches have been used for forecasting such agricultural systems.The forecasting of crop yield may be done by using three major objective methods (i) biometrical characteristics (ii) agricultural inputs and (iii) weather variables. The importance of crop forecasting is more relevant in semi-arid state like Gujarat where the precipitation is confirmed to short period of four months. Crop modeling can play a significant part in systems approaches by providing a powerful capability for scenario analyses.However, such forecast studies based on statistical models need to be done on continuing basis and for different agro-climatic zones, due to visible effects of changing environmental conditions and weather shifts at different locations and area.

MATERIAL AND METHODS

The present study was undertaken to investigate the feasibility of estimating the productivity of pearl millet based on combined effects of weather parameters and technological advancement, using past weather records for Kheda district of middle Gujarat state using MLR models.

Source of data: Pearl millet productivity data forsummer Pearl milletand historical weather data including bright sunshine hours (BSS), maximum temperature (MAX T), Minimum temperature (MIN T), weekly total rainfall (RF), morning relative humidity (RH_1), afternoon relative humidity (RH_2) of Kheda district of middle Gujarat for the years 1980 to 2013 were collected from Directorate of Agriculture, Gandhinagar, Gujarat and Department of Agricultural Meteorology, B. A. College of Agriculture, Anand Agricultural University, Anand. For studying the effect of important weather variables on productivity of pearl millet crop, weather variables with time trend includes Y:average pearl millet productivity (kg/ha) of the Kheda district; T: time trend, year number included to correct for upward and downward trend in yield; X_1: bright sunshine hours (hrs); X_2: maximum temperature (^{0}C); X_3: minimum temperature (^{0}C); X_4: weekly total rainfall (cms); X_5andX_6: morning and afternoon relative humidity (%). Due to technological advancement in agriculture from year to year here we have assumed the presence of trend effect (T).

Multiple Linear Regression models: For selecting the best regression equation among number of explanatory variables, the stepwise regression procedure was adopted using SPSS statistical Software. Three sets of multiple linear regression equations were obtained separately for 27, 28 and 29 years data for both 11th and 12th week. Since the variables entered in the individual model were not consistent over the models, a full regression model was fitted considering common significant variables obtained from individual stepwise regression analysis and Pearl millet productivity for the subsequent years were predicted. Attempt has been made to formulate a relationship for predicting the pearl millet productivity (Y) of Kheda district of middle Gujarat by investigating the influences of important weather variables (X_i's) on the pearl millet crop.

Development of weather indices using correlation as weight: Following the methodology suggested by ICAR–Indian Agricultural Statistical Research Institute (Agrarwal, 1980), New Delhi was used to express the effects of changes in weather variables on productivity as function of respective correlation coefficients between yield and weather variables. Under this assumption, the models were developed for studying the effects of weather variables on productivity of pearl millet crop. For each weather variable, two weather indices were developed, one as simple accumulation of weather variable and other one as weighted accumulation of weather variable, weights being correlation coefficients of weather variable in respective weeks with yield (adjusted for trend effect, if present). Similarly, for interaction of weather variables, indices were generated using weekly products of weather variables taking two at a time. The correlation coefficients between the crop productivity and different weather variables were worked out and used as weight and new variables Z_{ij} and $Z_{ii'j}$ (taking interactions of variables) were generated using following formula

$$Z_{ij} = \Sigma_{w=1}^{m} r_{iw}^{j} x_{iw} \ and \ Z_{ii'j} = \Sigma_{w=1}^{m} r_{iiw}^{j} x_{i'w}$$

Z_{ij} and $Z_{ii'j}$ are generated first order and second order variables,where,

m = number of weeks up to the time of forecast.

w = week identifications for summer pearl millet, (w = 1, 2 …m = 11 and 12).

X_{iw} = value of ith weather variable in wth week.

r_{iw}^{j} = correlation coefficient of yield with ith weather variable in wth period.

$r_{ii'w}^{j}$ = correlation coefficient (adjusted for trend effect) of yield with product of ith and i'th weather variables in wth period

The details of first order (Z_{ij}) and second order ($Z_{ii'j}$) generated variables obtained from this way and included in analysis are given in Table 1.

In order to explore the possibility of early forecasts before 1 and 2 weeks of harvest of pearl millet crop, two models were fitted using generated weather variables for summer pearl millet for the period of 11 and 12 weeks crop periods. Forty two explanatory variables comprising of 12 first order generated variables (Z_{ij}) and 30 second order generated variables ($Z_{ii'j}$) along with time trend variable (T) were subjected to stepwise regression analysis using the following model.

Table 1. First and second order generated variables using correlation coefficient as weight

First order generated variables (Z_{ij})

Zij	Z_{1j}	Z_{2j}	Z_{3j}	Z_{4j}	Z_{5j}	Z_{6j}
Z_{i0}	Z_{10}	Z_{20}	Z_{30}	Z_{40}	Z_{50}	Z_{60}
Z_{i1}	Z_{11}	Z_{21}	Z_{31}	Z_{41}	Z_{51}	Z_{61}

Second order generated variables ($Z_{ii'j}$)

$Z_{ii'j}$	$Z_{ii'0}$	$Z_{ii'1}$	$Z_{ii'j}$	$Z_{ii'0}$	$Z_{ii'1}$	$Z_{ii'j}$	$Z_{ii'0}$	$Z_{ii'1}$
Z_{12j}	Z_{120}	Z_{121}	Z_{13j}	Z_{130}	Z_{131}	Z_{14j}	Z_{140}	Z_{141}
Z_{15j}	Z_{150}	Z_{151}	Z_{16j}	Z_{160}	Z_{161}	Z_{23j}	Z_{230}	Z_{231}
Z_{24j}	Z_{240}	Z_{241}	Z_{25j}	Z_{250}	Z_{251}	Z_{26j}	Z_{260}	Z_{261}
Z_{34j}	Z_{340}	Z_{341}	Z_{35j}	Z_{350}	Z_{351}	Z_{36j}	Z_{360}	Z_{361}
Z_{45j}	Z_{450}	Z_{451}	Z_{46j}	Z_{460}	Z_{461}	Z_{56j}	Z_{560}	Z_{561}

$$Y = A_0 + \sum_{i=1}^{p} \sum_{j=0}^{2} a_{ij} z_{ij} + \sum_{i \neq i'=1}^{p} \sum_{j=0}^{2} a_{ii'j} z_{ii'j} + cT + e$$

Where,

Y = average crop productivity of the district kg ha^{-1}.

A_0 = constant.

T = Year number included to correct for long term upward or downward trend in yield.

a_{ij}, $a_{ii'j}$ and c are partial regression coefficients associated with z_{ij}, $z_{ii'j}$ and time trend respectively.

p = Number of weather variables

Comparison of efficiency of models: The model was selected as the suitable pre-harvest forecast model based on the earliness in forecast before harvest of the crop and higher value of coefficient of determination (R^2). The efficiency of developed models is checked by using goodness of fit of the models. The models are validated in terms of the forecast errors *i.e.* the root mean square error (RMSE) and mean absolute error (MAE). The fitted models, which had lower values of these estimates, were considered to be better.

$$R^2 = 1 - \frac{\Sigma_{i=1}^{n} (Y_i - \tilde{Y})^2}{\Sigma_{i=1}^{n} (Y_i - \bar{Y})^2}$$

$$\bar{R}^2 = 1 - \frac{(n-1)(1-R^2)}{(n-k-1)}$$

$$\mathrm{RMSE} = \left[\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2 / n \right]^{1/2}$$

$$\mathrm{MAE} = \sum_{i=1}^{n} \left| Y_i - \hat{Y}_i \right| / n$$

RESULTS AND DISCUSSION

In order to investigate the possibility of yield forecasts up to 11 and 12 weeks of harvest for *summer* pearl millet the weather variables related to 11 and 12 weeks crop period were considered. The variables included in the fitted multiple regression equations were determined based on stepwise regression procedure utilizing 27, 28 and 29 years data. To have the idea about the stability of the model, coefficient of determination, root mean square error (RMSE) and mean absolute error (MAE) were used. Apart from this, pre-harvest forecast of pearl millet productivity for 3 to 5 sub-sequent years were also made. The results for different approaches are presented and discussed in the subsequent section.

Fitting of Multiple Linear Regression model: The generated weather variables using correlation coefficient as weight were utilized to fit the model.The results related to 11 weeks crop period based on generated variables (Table 2) revealed that the variables entered were Z_{121} (weight of correlation coefficient to cross product of bright sunshine and maximum temperature) and trend (T) for 27 years model explained about 54.50 percent of variation in productivity of summer pearl millet crop. The results indicated that the partial regression coefficients for Z_{121} and trend (T) were positive and highly significant. Similarly, for 28 years′ data, the equation comprised of the variables *viz.*, $Z_{121,}$ trend (T), Z_{251} (weight of correlation coefficient to cross product of maximum temperature and morning relative humidity) and Z_{360} (weight of correlation coefficient to cross product of minimum temperature and evening relative humidity). The variation explained by these variables was 67.20 percent. The partial regression coefficient for Z_{121} was positive and highly significant, trend (T) and Z_{251} were positive and significant and for Z_{360} was negative and significant. The equation for 29 years′ data comprised of the variables *viz.*, trend (T) and $Z_{251,}$ the results showed that that the partial regression coefficient for trend (T) was positive and significant and for Z_{251} was positive and highly significant. The fitted model explained the variation up to 57.00 percent.

The results related to 12 weeks crop period based on generated variables (Table 3) revealed that the variables entered were Z_{251} (weight of correlation coefficient to cross product of maximum temperature and morning relative humidity), Z_{121} (weight of correlation coefficient to cross product of bright sunshine and maximum temperature) and Z_{61} (weight of correlation coefficient to evening relative humidity) for 27 years model explained about62.40 percent of variation in productivity of summer pearl millet crop. The partial regression coefficients for Z_{251} and Z_{121} were positive and highly significant and for Z_{61} was positive and significant.

Table 2. Partial regression coefficients of summer pearl millet productivity on trend and different weather variables in correlation coefficients as weight (11 weeks)

Variables in the equation	Years		
	80-81 to 06-07	80-81 to 07-08	80-81 to 08-09
Constant	-527.11 (588.86)	-1018.23 (620.79)	76.131 (464.45)
Z_{121}	8.95** (2.29)	7.27** (2.50)	–
Trend	14.35** (4.70)	10.56* (4.43)	12.15* (4.79)
Z_{251}	-	0.19* (0.07)	0.29** (0.08)
Z_{360}	-	-0.09* (0.04)	
S.E.	188.30	170.72	193.38
R^2 (percent)	54.50	67.20	57.00
Adjusted R^2	50.70	61.60	53.60
RMSE	177.54	158.28	183.11
MAE	152.16	123.46	147.81

* Significant at 0.05 level of probability ** Significant at 0.01 level of probability

Table 3. Partial regression coefficients of summer pearl millet productivity on trend and different weather variables in correlation coefficients as weight (12 weeks)

Variables in the equation	Years		
	80-81 to 06-07	80-81 to 07-08	80-81 to 08-09
Constant	367.44 (435.56)	-104.79 (461.72)	271.68 (445.77)
Z_{251}	0.24** (0.07)	0.25** (0.06)	0.23** (0.08)
Z_{121}	4.81** (1.59)	4.81* (1.75)	4.76* (1.92)
Z_{61}	9.51* (3.72)	-	-
Z_{161}	-	100.36 (0.35)	–
Trend	-	-	12.07* (4.42)
S.E.	174.85	178.22	178.23
R^2 (percent)	62.40	63.00	65.00
Adjusted R^2	57.50	58.10	60.60
RMSE	161.39	165.01	165.49
MAE	122.34	127.58	142.38

* Significant at 0.05 level of probability
** Significant at 0.01 level of probability

Similarly, for 28 years data, the equation comprised of the variables *viz.*, $Z_{121,}$ Z_{251} and Z_{161} (weight of correlation coefficient to cross product of bright sunshine hours and evening relative humidity). The variation explained by these variables was 63.00 percent. The partial regression coefficient for Z_{121} and Z_{161} were positive and significant and for Z_{251} was positive and highly significant. The equation for 29 years data comprised of the variables *viz.*, trend (T), Z_{121} and $Z_{251,}$ the partial regression coefficient for trend (T) and Z_{121} were positive and significant and for Z_{251} was positive and highly significant. The fitted model explained the variation up to 65.00 percent.

Simulated forecast based on fitted model: The simulated forecast for all the models in 11thweek are presented in Table 4. The simulated forecast of summer pearl millet productivity for the fitted equation for 27 years showed deviation from observed productivity ranged from 0.86 to 19.58 percent. The simulated forecast of 28 years summer pearl millet productivity for the fitted equation showed deviation from observed productivity ranging from 2.24 to 15.77 percent. Similarly, the simulated forecast for 29 years showed 2.75 to 10.19 percent deviation from the actual data.

The simulated forecast for 12th week of summer pearl millet productivity for the fitted equation showed deviation from observed productivity ranged from 3.71 to 20.93 per

Table 4. Simulated forecast based on fitted equations

Year	Observed productivity (Kg/ha)	Simulated forecast (Kg/ha)		
		80-81 to 06-07	80-81 to 07-08	80-81 to 08-09
07-08	2425	2189 (9.74)	-	-
08-09	2475	1990 (19.58)	2085 (15.77)	-
09-10	2275	2256 (0.86)	2412 (-6.04)	2338 (-2.75)
10-11	2394	1989 (16.92)	2340 (2.24)	2528 (-5.62)
11-12	2550	2120 (16.84)	2288 (10.27)	2328 (8.71)
12-13	2536	2179 (14.06)	2383 (6.04)	2363 (6.83)
13-14	2544	2266 (10.91)	2276 (10.55)	2285 (10.19)

Table 5. Simulated forecast based on fitted equations

Year	Observed productivity (Kg/ha)	Simulated forecast (Kg/ha)		
		80–81 to 06–07	80–81 to 07–08	80–81 to 08–09
07–08	2425	2091 (13.77)	-	-
08–09	2475	1957 (20.93)	1933 (21.91)	-
09–10	2275	2190 (3.71)	2225 (2.19)	2306 (–1.37)
10–11	2394	2145 (10.40)	2264 (5.44)	2403 (–0.36)
11–12	2550	2070 (18.84)	2115 (17.07)	2260 (11.37)
12–13	2536	2161 (14.78)	2178 (14.13)	2406 (5.14)
13–14	2544	2148 (15.55)	2143 (15.77)	2411 (5.21)

cent of 27 year of data (Table 3). The simulated forecast of summer pearl millet productivity for the fitted equation showed deviation from observed productivity ranging from 2.19 to 21.91 percent of 28 years data. The simulated forecast for this model showed 0.36 to 11.34 percent deviation in 29 years data from the actual data.

CONCLUSION

The crop productivity forecasting is more relevant as climate change is one of the important challenges in recent scenario. From the present investigation the model fitted for 11 weeks of 28 years could be considered as pre harvest forecast model which can predict the pearl millet productivity at 2 weeks before harvest. It is also found that all the residuals are *i.i.d.* with normal distribution having zero mean and constant variance, which indicates the proper specification of the model .The suggested model based on the generated weather variables is**:** $Y = -1018.23 + 7.27\ Z_{121} + 10.56\ T + 0.19\ Z_{251} - 0.09\ Z_{360}$.

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Characterization of Stress Tolerant Mungbean Rhizobia as PGPR and Plant Growth Promotion under Abiotic Stress

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Abstract: Mungbean is one of the economically important *kharif* legumes of arid and hyper-arid zones of Rajasthan in India. In this study, characterization and assessment of high temperature and drought tolerance among cultivable mungbean rhizobia were performed under *in vitro*, *in vivo* and axenic conditions. A total of 96 mungbean rhizobial isolates were retrieved from 40 nodule samples collected from four districts of Rajasthan, India. Only 26 isolates showed combined high drought tolerance of 40 per cent concentration of polyethylene glycol 6000 and high temperature tolerance at 45°C. Most of the stress tolerantisolates possessed multiple PGPR traits i.e. phosphate solubilization, ACC deaminase activity and bacteriocin production. Four efficient stress tolerant isolates along with reference strain were tested for nodulation efficiency and plant growth promotion in mungbean under axenic condition using Leonard jar assemblies for high temperature tolerance and in pot house experiment for drought tolerance at different soil moisture levels (100, 50 and 25% field capacity). Among four stress tolerant rhizobial isolates, the isolate MuJs10A showed better nodulation efficiency which resulted in the maximum increase (394.73%) of plant biomass yield as compared to non-bacterized control. Hence, the isolate MuJs10A showed the enormous potential as bioinoculant for arid and hyper-arid zone of India.

Keywords: Mungbean, High temperature tolerance, Drought tolerance, Hyper-arid zone, Rhizobia

Mungbean (*Vigna radiata* L.) is one of the major *kharif* legumes grown in arid and hyper-arid zones of India. Abiotic stresses like high temperature and drought affect *Rhizobium*–legume symbiosis and severely reduce legume production. Hence, the mungbean production in these zones is drastically declining due to prevailing high abiotic stress. Currently, hyper-arid zone of India is spread across four districts of Rajasthan state mainly Churu, Bikaner, Jaisalmer and Barmer (Hussain, 2015). According to recent estimates, Rajasthan possesses the first position in both area (30.81%) and production (34.67%) in mungbean in India. The highest productivity in mungbean 787 kg/ha also comes from this state. But due to harsh climatic effects the productivity of mungbean of this arid and hyper-arid zone is very low 462 Kg/ha (RACP, 2012). Hence, the overall mungbean production of country currently faces severe reduction. Currently, the subject of *Rhizobium* is of great practical importance because the luxurious use of nitrogenous fertilizers has resulted inunacceptable levels of nitrate pollution, the eutrophication of water bodies along with toxic metal pollution by use of sewage sludge as N source and the enhanced deterioration of soil health. To prevent these, the use of *Rhizobium* as PGPR has become one of the attractive strategies for developing sustainable agricultural systems through improving agricultural production, soil, and plant health in many parts of the world due to their eco-friendliness, low production cost, reduced consumption of non-renewable resources. According to previous report, inoculation of high stress tolerant strains of rhizobia improves the nitrogen fixation as well as biomass yield of legumes under stress conditions (Ahmad *et al.,* 2011).Therefore, the prevalent use of an efficient rhizobial inoculant to harness plant production is a fascinating cost effective approach to help sustainable development in these zones.

Hence, the present study was carried out to characterize high temperature and drought tolerance of the cultivable mungbean rhizobia of hyper-arid zone of Rajasthan, India and assessment of their multiple PGPR traits i.e. phosphate solubilization, ACC deaminase activity and bacteriocin production under *in vitro* condition.

MATERIAL AND METHODS

Sample collection: A total of 40 rhizospheric soil and nodule samples from hyper-arid zone of Rajasthan (India) were collected every 8 km covering the four districts of Churu (28°14'N, 74°52'E), Bikaner (27°47'N, 72°48'E), Jaisalmer (26°50'N, 70°58'E) and Barmer (25°44'N, 71°22'E) on September, 2013. The pooled sample from each field represented one rhizospheric soil sample. The top layer of the soil was removed before collecting samples, as the microorganisms present around the rhizosphere and rhizoplane would be effective in crop improvement. The samples were transported to the laboratory in the sterile plastic bags and kept at 4°C for further analyses.

Soil physico-chemical properties and isolation of mungbean rhizobia: The soil samples were analyzed for the physico-chemical properties, i.e. pH, EC and available N (Table 1.). Soil available N was determined by the Kjeldahl method (Bremner, 1996). Isolation of rhizobia from nodules of mungbean plants were accomplished as described by Vincent (1970). The isolates were purified on YEMA (Yeast Extract Mannitol Agar) Congo red plates and maintained on YEMA slants at 4˚C (Vincent, 1970). Gram staining of the rhizobial isolates was performed as described by Beveridge (2001). Nomenclature of the isolates was done according to our own convenience.

***In vitro* temperature and drought tolerance and combined stress tolerance of rhizobial isolates:** Freshly grown cultures of rhizobial isolates were spotted on YEMA plates and incubated at different temperatures of 30, 35, 40 and 45ºC to screen for temperature tolerance. After 3 days of incubation, rhizobial growth was observed and compared to control at 30ºC (Mangla *et al.,* 2014). Drought tolerance of the isolates were accomplished by inoculating YEMA broth with rhizobial isolates using different concentration of polyethylene glycol 6000 (PEG 6000) i.e. 20, 30 and 40 per cent (Mangla, 2013). For assessment of combined stress tolerance the broth was incubated at 40°C and 45°C depending upon the highest PEG concentration and temperature tolerance of the individual isolate during single stress.

Acetylene Reduction Assay (ARA) and PGPR traits: Nitrogenase activity was measured by acetylene reduction assay (Boddey, 1987). The acetylene reduction assay (ARA) was expressed as nmol ethylene mg^{-1} protein h^{-1}. Phosphate solubilization ability of rhizobial isolates assessed through Pikovskaya medium supplemented with tricalcium phosphate and bacteriocin production was accomplished by standard method (Kumar *et al.,* 2014). The minimal medium plates (Dworkin and Foster, 1958) supplemented with 3 mM ACC as sole nitrogen source were used to determine ACC deaminase enzyme activity.

Preparation of rhizobialinocula: Inocula were prepared by using YEM medium as broth. Each broth was inoculated with respective rhizobial isolates and incubated at 28±2°C for 72 h under shaking (150 rpm/min) conditions.

Evaluation of temperature tolerance and plant growth promoting traits of selected rhizobial isolates under axenic condition: The effect of four stress tolerant rhizobial isolates on the growth of mungbean was screened for their temperature tolerance under axenic condition by using Leonard jar assemblies (Somasegaran and Hoben, 1985). The seeds of mungbean (cultivar MH-421) were surface-sterilized by in 0.2 % mercuric chloride solution for 3 min. The rhizobialinocula (as mentioned before)were applied to each assembly on the sown seed @ 1 mL/seed. The soil temperature was recorded by soil thermometer at regular interval from July 7 to September 6, 2015. Treatments including four rhizobial isolates MuJs10A, MuJs15A, MuJs23B and MuBk20B along with one commercial reference rhizobialstrain (703) were evaluated with uninoculated control in this study. The assemblies were arranged in completely randomized design using three replicates. The plant growth parameters were observed as nodule number, nodule fresh weight at 45 days after sowing (DAS) and shoot and root dry matter and total dry matter after 60 DAS.

Evaluation of drought tolerance and plant growth promoting traits of selected rhizobial isolates: The effect of four stress tolerant rhizobial isolates on the growth of mungbean (variety same) was appraised for their drought tolerance using pot house condition. The soil was used in this experiment a non-sterile soil from CCS Haryana Agricultural University, Hisar fields (29˚10′N, 75˚46′E). The seeds were surface-sterilized as mentioned earlier. After that soil humidity was kept constant at 100 per cent field capacity (FC) for one set of experiment i.e. without moisture stress condition. For other two sets of experiment soil moisture content was left to fall to mimic drought conditions up to 50 and 25 per cent FC and same conditions were maintained until the experiment was finished (Keneni *et al.,* 2010). The experiment was set up in a completely randomized design with three replicates. All the pots were supplemented with recommended dose of fertilizers (RDF) 20, 40 NP kg^{-1} ha^{-1} before sowing. The rhizobialinocula (as mentioned before)were applied to each pot as mentioned earlier. Treatments were kept same as axenic culture for all moisture stress regime. The plant growth parameters were studied as nodule number, nodule fresh weight at 45 DAS and total dry matter after 60 DAS.

Statistical analysis: Analysis of variance (ANOVA) techniques were applied to analyze the data by SPSS version 22. The treatment means were compared using Duncans Multiple Range Tests at the *p*=0.05.

RESULTS AND DISCUSSION

Isolation of rhizobia and physico-chemical properties of soils: A total of 96 mungbean rhizobial isolates were obtained from 40 different samples collected from four different districts namely Churu, Bikaner, Jaisalmer and Barmer of Rajasthan, India (Table 2.). The physico-chemical properties (pH, EC, available soil N) of 40 rhizospheric soil samples are shown in Table 1. The number and occurrence of rhizobial isolates in legume root nodules showed quite

Table 1. Physico‒chemical properties of soils of four districts of Hyper‒arid zone of Rajasthan, India (Mean±SEM)

Districts	pH	EC (dSm^{-1})	Available N (Kg/ha)
Churu	8.1±0.03	0.26±0.03	200.2±7.13
Bikaner	8.7±0.04	0.19±0.01	171.6±5.01
Jaisalmer	8.9±0.06	0.12±0.01	151.5±3.02
Barmer	7.9±0.02	0.33±0.03	224.4±7.05

reduced value from the plant roots exposed without abiotic stress as observed in previous study (Zahran, 1999).

High abiotic stress tolerant rhizobia: Among all isolates, 26 isolates were able to grow under high drought condition at 40 per cent of PEG 6000 concentration and 42 isolates were showed vividly growth at 45°C (Table 2). In combined stress tolerance, there were only 26 rhizobial isolates accomplished steady growths under high abiotic stress (combined) condition. And is lucidly visible that higher abiotic stress tolerant rhizobia frequently encounter in rhizospheric region of this legume grown under exposure of higher abiotic stress‒prone situation in soils of Jaisalmer and Bikaner as compared to other two districts i.e. Churu and Barmer where harshness of the climate is considerably reduced. This observation is in line with previously documented report mentioning high salinity tolerant rhizobia mainly prevail in soils with high salt content (Keneni *et al.,* 2010).

ARA and PGPR traits of rhizobia: ARA of the isolates deciphered that there was a significant variation in *in vitro* dinitrogenase activity among the 26 stress tolerant isolates and all of the isolates showed the ability to fix atmospheric dinitrogen under *in vitro* condition (Figure 1). Out of 26 stress tolerant isolates, around 46% of isolates showed very low (<1 nmol ethylene mg^{-1} protein h^{-1}) and only 11 per cent isolates acquired high ARA of >20.0 nmol ethylene mg^{-1} protein h^{-1}. This also reflects the significant diversity on the capacity to fix atmospheric dinitrogen might be because of their genetically and biochemically differences as reported in previous study (Kumar *et al.,* 2014). Most of the stress tolerant isolates possess multiple PGPR traits and around 51 per cent isolates

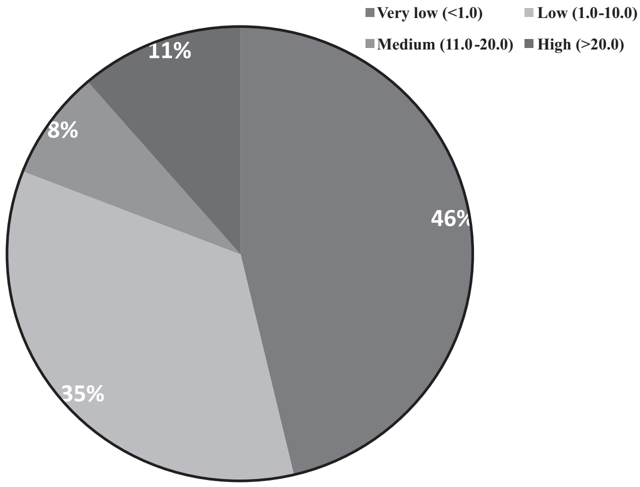

Fig. 1. Mungbean rhizobia with diversified efficiency of *in vitro* dinitrogenase activity expressed as ARA (nmol ethylene mg^{-1} protein h^{-1})

attributed the possessionof P‒solubilization ability, 38 per cent with ACC deaminase activity and bacteriocin production observed in only 11 per cent of rhizobial isolates (Figure 2). Hence, our result showed that there was a significant diversity in possession ofdifferent PGPR traits of rhizobial isolates as reported in earlier study (Kumar *et al.,* 2014).

Evaluation of high temperature tolerance and PGP abilities of isolates under axenic condition: The rhizobial isolates showed lucidly positive responses on mungbean plants among all the growth parameters measured as compared with nonbacterized control under high temperature condition. The soil temperature in Leonard jars was reached in its peak up to 47.5°C whereas outer atmospheric temperature reached up to 42.3°C. The data on plant growth parameters showed the uninoculated control plants acquired minimum plant biomass. However, rhizobia inoculated plants significantly reduced the high abiotic stress resulted from increased temperature and enhanced the plant growth but with different degrees of efficacy. The significant variation was observed on the effect of rhizobial inoculation on mungbean plant growth promotion. The MuJs10

Table 2. Agro‒climatic features of study sites and stress tolerant of rhizobial isolates

Districts	Avg. temperature (°C)	Avg. rainfall per annum (mm)	No of nodule and soil samples	No of isolates	Stress tolerance at 40% PEG	Stress tolerance at 45°C	Stress tolerance (40% PEG & 40°C)	Stress tolerance (40% PEG & 45°C)
Churu	46.0	319.5	8	23	5	5	3	−
Bikaner	46.5	248.5	13	31	9	12	10	3
Jaisalmer	47.1	182.8*	11	27	11	18	11	5
Barmer	46.0	320.3	8	15	1	7	2	−

*Minimum recorded rainfall per annum 79.6 mm (source: RACP, 2012)

Table 3. Effect of abiotic stress tolerant rhizobia on nodulation efficiencyat 45 DAS and plant growth promotion at 60 DAS in mungbean under high temperature stress in Leonard jars

Treatment	Nodule no./plant	Nodule fresh wt./plant	RDM	SDM	TDM	Per cent increase
Control	–	–	0.029[a]	0.106[b]	0.133[a]	–
703	6.5[a]	0.031[a]	0.032[a]	0.123[b]	0.165[b]	24.06
MuJs10A	41.0[bc]	0.229[d]	0.238[ab]	0.440[cd]	0.658[ab]	394.73
MuJs15A	17.0[b]	0.065[b]	0.051[b]	0.239[c]	0.226[c]	69.92
MuJs23B	28.0[c]	0.126[c]	0.199[bc]	0.341[cd]	0.572[d]	330.07
MuBk20B	18.0[b]	0.123[c]	0.078[b]	0.321[bc]	0.348[cd]	161.65

Note: RDM−Root dry matter, SDM−Shoot dry matter, TDM−Total dry matter;
Values followed by the same letter are not significantly different at *p*= 0.05 (n=3).

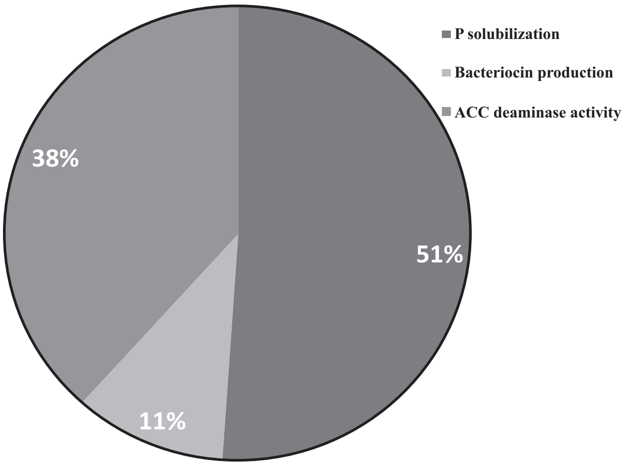

Fig. 2. Different PGPR traits of mungbean rhizobia

Arhizobial isolate inoculated plants registered the highest root length, shoot length with maximum per centage of total dry matter increase (394.73%) than control (Table 3). This observation is in line with previous study where rhizobial isolates significantly reduced the abiotic stress on mungbean (Ahmad *et al.,* 2012). The isolate MuJs10A also significantly enhanced nodulation in mungbean than other isolates with the highest nodule number and nodule fresh weight (0.229 g/plant) (Table 3). This observation is in conformity with previous study (Ahmad *et al.,* 2011). There is also strong correlation observed between ARA of isolate and nodule no, nodule fresh mass, between nodule fresh mass and total dry matter (R^2= 0.9298) in all inoculated plants.

Assessment of high drought tolerance and PGP abilities of isolates under pot- house condition: There was a significant variation observed with different degrees of efficacy on the effect of rhizobial inoculation on nodulation, plant growth promotion and nutrient content parameters under different levels of soil moisture regimes. It was obviously visible that there was an increase of nodulation, root and shoot length, dry matter yield and nutrient content with the consecutive reduction of soil moisture levels in both control and rhizobia inoculated plants (Table 4). The data on growth parameters including nodulation efficiency clearly showed that there was a significant reduction of plant growth in all treatments at 25 per cent FC as compared to 50 per cent FC. This observation shows contrast from previous study where nodulation and plant growth in legume reduced significantly from 90 per cent FC to 30 per cent FC and also under high abiotic stress condition (Mnasri *et al.,* 2007; Ahmad *et al.,* 2012). But the cultivar was drought sensitive in earlier study whereas we used drought tolerant cultivar.

Table 4. Effect of abiotic stress tolerant rhizobia on nodulation efficiency at 45 DAS and total dry matter yield at 60 DAS in mungbean with different soil moisture levels in pots

Treatment	Nodule no. plant^{-1}	Nodule fresh wt. plant^{-1}	TDM (g plant^{-1})
	100% Field capacity (FC)		
Control	7.1[a]	0.074[a]	0.342[a]
703	8.7[b]	0.094[b]	0.401[b]
MuJs10A	11.0[c]	0.171[c]	0.679[c]
MuJs15A	8.6[b]	0.121[bc]	0.558[bc]
MuJs23B	10.2[c]	0.141[d]	0.661[c]
MuBk20B	9.1[ab]	0.133[d]	0.625[c]
	50% Field capacity (FC)		
Control	6.6[a]	0.054[b]	0.524[a]
703	7.6[b]	0.104[a]	0.608[b]
MuJs10A	19.6[d]	0.144[d]	0.781[d]
MuJs15A	9.0[bc]	0.107[a]	0.647[c]
MuJs23B	14.0[c]	0.126[c]	0.735[d]
MuBk20B	12.3[cd]	0.105[a]	0.657[c]
	25% Field capacity (FC)		
Control	4.0[a]	0.047[a]	0.500[a]
703	4.3[a]	0.072[b]	0.595[b]
MuJs10A	11.6[b]	0.108[c]	0.725[c]
MuJs15A	7.0[c]	0.073[b]	0.566[b]
MuJs23B	9.2[d]	0.094[c]	0.689[d]
MuBk20B	7.6[c]	0.087[c]	0.633[d]

Values followed by the same letter are not significantly different at *p*= 0.05 (n=3).

Isolate MuJs10A inoculated plant showed the highest nodulation, nodule fresh weight and total dry matter yield as compared to other isolates in all three soil moisture levels. Two isolates MuJs10A and MuJs23B boosted maximum total dry matter yield with 0.725 and 0.689 g/plant from uninoculated control under high drought stress at 25 per cent FC (Table 4.). Stress tolerant rhizobia inoculated plants showed enhanced nodulation efficiency which resulted increased plant biomass yield under high drought stress. Apart from nitrogen fixation, there might be other reasons like extra nutrients acquisition through P solubilisation, enhanced nodulation for bacteriocin production and ACC deaminase activity (Ahmad *et al.,* 2011). High ACC deaminase activity in rhizobia also prevents the plant roots from the injurious effect of plant stress hormone ethylene in rhizospheric region due to high abiotic stress as observed earlier (Ogutcu *et al.,* 2010; Ahmad *et al.,* 2011). There is also strong correlation observed between ARA of isolate and nodule no, nodule fresh mass, between nodule fresh mass and total dry matter (R^2= 0.9184)in all inoculated plants.

From the present study, it is evident that mungbean rhizobial isolate MuJs10A showed the highest nodulation efficiency as well as plant growth promotion under both high temperature and drought stress than other rhizobial isolates. Hence, the isolate MuJs10A might be a potential bioinoculant in near future after further testing in field trials.

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Inheritance Pattern of Salt Tolerance in Rice (*Oryza sativa* L.) at Seedling Stage

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***Abstract*: S**alinity is the second major abiotic stress next to drought which hampers the sustainable production of rice. The present study was undertaken by screening 1156 F_2 individuals derived from cross between *ADT 45* and *Nona Bokra* in the Yoshida nutrient solution in glass house. The donor parent *Nona Bokra* performed similarly with that of *pokkali* (tolerant check). The salinity score was normally distributed in green house indicating that the trait is polygenic in nature. The moderate tolerance of the F_1s indicates that the trait is governed by the additive gene action. Selection differential of 4.11 and selection response of 1.05, observed in this study, resulted in the low realized heritability (h^2_R) of 0.26. The correlation among the physiological traits was highly significant because the individuals taken for analysis are the extremes. So for improving quantitative traits like salinity tolerance one can opt for conventional breeding combined with molecular breeding approaches to hasten the selection process.

Keywords: Salinity, Rice, Selection differential, Heritability

Rice (*Oryza sativa* L.) is the most salt‑sensitive cereal (Munns and Tester, 2008) and in Asia alone, 21.5 million ha of land area is thought to be salt affected (of which 12 million ha are saline and the remaining 9.5 million ha is due to alkaline/sodic conditions). In India an area of 8.6 million ha is salt‑affected area and this includes 3.4 million ha of sodic soils (Sahi *et al*., 2006). Salinity adversely affects quantity and quality of the crop produce (Blumwald and Grover, 2006). Moreover, the salt affected areas are increasing at a rate of 10 per cent annually; low precipitation, high surface evaporation, weathering of native rocks, irrigation with saline water, and poor cultural practices are among the major contributors to the increasing soil salinity. To feed the increasing global population, a 26 per cent−increase in rice yield is predicted to meet global demands in the next 25 years (IRRI, 2013). Hence, serious attention is to be drawn towards the salinity stress to increase rice productivity on salinized lands. The pace of progress in breeding salt tolerant rice is slow owing to varied factors including poor understanding of the mechanisms underlying tolerance, complexity of the trait, need of efficient selection criteria, and absence of reliable, repeatable screening methodology and variation of tolerance with ontogeny. However, evaluating field performance under salt stress is very difficult due to variation of salinity within fields and the enormous potential for interactions with other environmental factors (Flowers, 2004). Consequently, prediction of field performance is commonly carried out in trial plots, or using a solution‑based method where the salinity of the medium that can readily be adjusted to required values. The solution culture technique is used in two ways: first, for screening up to seedling stage; second, for screening up to maturity.

For improving any trait first the breeder has to know its inheritance pattern and this has been demonstrated conclusively, in a variety of experiments, that salt tolerance is multigenic and quantitative in nature. Additive and non−additive gene action for almost all characters associated with salt tolerance has been reported (Thirumeni *et al*., 2003). In diallel analysis the effects of salinity on the seedling stage and on sterility suggested both additive and dominance effects, some with high heritability. The research on the physiology of salt tolerance suggests that the overall trait is determined by a number of sub‑traits any of which might, in turn, be determined by any number of genes (Flowers, 2004). Furthermore, because several traits and mechanisms are usually involved in salt tolerance, pyramiding traits of interest via MAS may be an effective approach to substantial improvement in plant salt tolerance. So the present investigation was carried out with the objective to study inheritance pattern of salt tolerance at seedling stage, correlation among component physiological traits and utilize them in breeding program.

MATERIAL AND METHODS

The present investigation was carried out at Pandit

Jawarharlal Nehru College of Agriculture and Research Institute, Karaikal, 2012−2014. *ADT 45* a popular rice variety of Tamil Nadu as female parent and Nona *Bokra* a salt tolerant land race of West Bengal as male parent were used to develop mapping population. In the first season 2012‒13 the crossing was made to obtain the F_1 hybrid and selfed to produce the F_2 mapping population. F_1, F_2 and F_3 progenies generated from the above cross, *Pokkali* (tolerant check) and *IR29* (susceptible check) formed the materials of the study. Pre‒germinated seeds were sown in holes on Styrofoam floats with a net bottom suspended on trays filled with Yoshida nutrient solution (Yoshida *et al.,* 1976). The pH of the solution was adjusted to 5.0 to 5.1 daily and solution was replaced every week. Fourteen day old seedlings were subjected to salinity stress by adding the NaCl to nutrient solution and electrical conductivity was maintained at 12 dSm^{-1} and weather conditions prevailed during the entire screening were recorded.

Individual scoring was done based on visual symptoms using IRRI SES protocol (Standard Evaluation System; IRRI, 2013) for rice (Table 1).Data on salinity evaluation score and four physiological traits namely chlorophyll content, shoot Na^+ content, shoot K^+ content and shoot Na^+ /shoot K^+ ratio content were recorded in the highly tolerant and susceptible individuals. The tolerant individuals and susceptible F_2 individuals were forwarded to F_3 generation and phenotyped for salt tolerance same as in F_2 generation. Total leaf chlorophyll content in the leaf was calculated (Arnon, 1949) which although derived for ice cold acetone was hold good for ethanol too (Yeo and Flowers, 1983). The sodium and potassium content in shoot were recorded as per procedure followed by the Thomson *et al*., 2010.Descriptive statistics was calculated using STAR (Statistical Tool for Agricultural Research) version 1.10 software developed by Biometrics and Breeding Informatics Group of IRRI (http://bbi.irri.org/products) and distributional normality of salinity score was analysed using Shapiro− wilk test. Realized heritability for salinity score was calculated (Falconer 1989) as

$$h^2_R = R / D$$

Where,

R is the selection response as measured as the difference between the average salinity score of the selected F_3 progeny families and that of the parental F_2 population before selection (N=1156)

D is the selection differential as measured as the difference between the average salinity score of the selected F_2 plants (N=1156) and that of the F_2 population before selection.

RESULTS AND DISCUSSION

Phenotypic screening for salinity tolerance: The F_2 progenies salinity score was not normally distributed in all the eight days for salinity score (Table 2). The salinity score was normally distributed on 9^{th} and15^{th} day of salinization. However salinity score recorded highly platykurtic (flatter peakedness of ‒1.09) and regards to skewness it is slightly rightward skewed (0.12) on 15^{th} day of salinization. Transgressive segregants were noticed towards susceptibility during initial days of salinization (up to 8^{th}−11^{th} DAS) but it shifted towards tolerance during final days of salinization (12^{th} – 15^{th} DAS). There are hardly many inheritance studies for salt tolerance based on frequency distribution of salinity score of individual plants of parents and their segregating progenies screened in hydroponics system in green house. The normal distribution of salinity score in F_2 (Table 2), in this experiment was suggestive of polygenic nature of the trait and thus confirmed to the findings of Mishra *et al.* (1998).

The parental means indicated tolerant parent, *Nona Bokra* and susceptible parent *ADT45* differed by salinity score of 2 (during initial days of salinization) to 6 (final days of salinization). *Pokkali,* tolerant check used in the experiment performed similar to tolerant parent *Nona Bokra* as indicated by the same salinity scores in the entire scoring intervals. The tolerant parent *Nona Bokra* exhibited significantly higher tolerance (SES = 2.66) than the mega rice variety *ADT45* (SES = 9.00) indicating greater salt tolerance and consistent with earlier reports (Mishra *et al*., 1998). However, *ADT45* the susceptible parent, differed with *IR29* the susceptible check, in salt tolerance response as indicated by late onset of salt stress symptoms. Mean score of 6.8 and 9 on 11 and 13 DAS were recorded in *ADT45* while 7 and 8.9 score was recorded in *IR29* on 9 and 11 DAS. Therefore *ADT45* is not as

Table 1. Modified standard evaluation system (SES) of visual salt injury at seedling stage (IRRI, 2013)

Score	Observation	Tolerance
1	Normal growth, no leaf symptoms	Highly tolerant
3	Nearly normal growth, but leaf tips or few leaves whitish and rolled	Tolerant
5	Growth severely retarded, most leaves rolled, only few are elongating.	Moderately tolerant
7	Complete cessation of growth, most leaves dry, some plants dying	Susceptible
9	Almost all plants dead or dying	Highly susceptible

susceptible as *IR29* and tolerates salt stress slightly better. The mean score of F_1 plants varied between 1 and 4.69 on eighth and fifteen day of salinization respectively. The level of tolerance of F_1 is moderate compared to tolerant parent and check variety (2.66).The moderate tolerance of F1s (mean score of 4.69) compared to highly tolerant *Nona Bokra* (mean score of 2.66) is the reflection of additive gene action, suggesting that salt tolerance of *Nona Bokra* was inherited in additive fashion.

Realized heritability: This report was similar with the findings of Mishra *et al*., 1998**.** Selection differential (D) of 4.11 (Table 3) and selection response (R) of 1.05, observed in this study, resulted in the low realized heritability (h^2_R) of 0.26. Similar trend was earlier reported for salt tolerance in tomato (Foolad *et al.,* 2001)**.** This estimate may be considered with caution as parent (F_2) and progeny (F_3) were phenotyped, through hydroponics system at same EC of 12 dSm^{-1}, at different times (November–December, 2013 and March – April, 2014). This low to moderate estimate of heritability (h^2) for seedling stage salt tolerance indicated that this trait can be improved by traditional phenotypic selection and breeding, though selection progress might be slow (Foolad *et al.,* 2001). For traits with low to moderate heritability (h^2), MAS may be more efficient than phenotypic selection for crop improvement (Collard and Mackill, 2008).

Correlation of physiological traits: The correlation coefficients between chlorophyll content, shoot Na^+, K^+ contents and Na: K ratio of tolerant extremes (131 F_2 plants) and susceptible extremes (48 F_2 plants) along with parents subjected to analysis are presented in Table 4.Salt tolerance in monocots is generally associated with the ability of plants to exclude Na^+ from the shoot tissue (Tester and Davenport, 2003). Salinity score regarded as measure of overall survival or vigour of the plant and therefore, good indicators of performance of the plant under salt stress (Gregorio *et al*., 1997). It is, in turn, the reflection of the cumulative effects of various physiological traits including Na^+ and K^+ contents in shoot and root Na: K ratio, chlorophyll content. In this study

Table 3. Salinity score of parents, checks, F_1, F_2 and F_3 generations

Genotype	No. of individuals	Mean SES ± SD	SES range
P_1 (*ADT45*)	24	9.00 ± 0.00	9
P_2 (*Nona Bokra*)	24	2.66 ± 0.81	1 −3
IR29 (Susceptible check)	24	9.00 ± 0.00	9
Pokkali (Tolerant check)	24	2.33 ± 1.01	1 −3
F_1 (*ADT45* X *Nona Bokra*)	24	4.69 ± 1.89	3 −9
F_2 Population	1156	5.11 ± 2.57	1−9
F_2 (Tolerant class)	36	1.00 ± 0.00	1
F_2 (Susceptible class)	24	8.76 ± 0.01	7 −9
F_3 (Tolerant class)	36	4.06 ± 0.88	1 – 5.3
F_3 (Susceptible class)	24	8.07 ± 0.41	3 −9

Selection response (R) = 1.05
Selection differential (D) = 4.11
h^2_R = 0.26

Table 2. Salinity score means and other statistical parameters relative to F_2 population

Frequency of scoring (DAS)	Mean	Range	Standard deviation	Variance	Shapiro–Wilk value	Pr(<W)	Skewness	Kurtosis
8	1.64	1 −9	1.74	3.04	0.6774	0.0042	3.33	10.79
9	2.27	1 −9	1.83	3.37	0.7879	0.0644	2.20	5.49
10	3.08	1 −9	1.71	2.94	0.7126	0.0129	1.98	4.99
11	3.33	1 −9	1.79	3.22	0.6561	0.0031	1.93	4.10
12	3.52	1 −9	1.90	3.62	0.6661	0.0041	1.64	2.69
13	3.77	1 −9	2.06	4.28	0.7304	0.0194	1.29	1.21
14	4.22	1 −9	2.27	5.17	0.7369	0.0224	0.76	−0.24
15	5.11	1 −9	2.57	6.61	0.9607	0.8128	0.12	−1.09

DAS = Days after Salinization

Table 4. Correlation coefficient between salinity score and physiological traits in F_2 extremes

Characters	Salinity score	Leaf chlorophyll content	Shoot Na^+	Shoot K^+	Shoot Na:K ratio
Salinity score	1				
Leaf chlorophyll content	−0.763**	1			
Shoot Na^+	0.603**	−0.500**	1		
Shoot K^+	−0.275**	0.349**	0.411**	1	
Shoot Na:K ratio	0.767**	−0.878**	0.575**	−0.373**	1

** = Significant at 1 per cent level

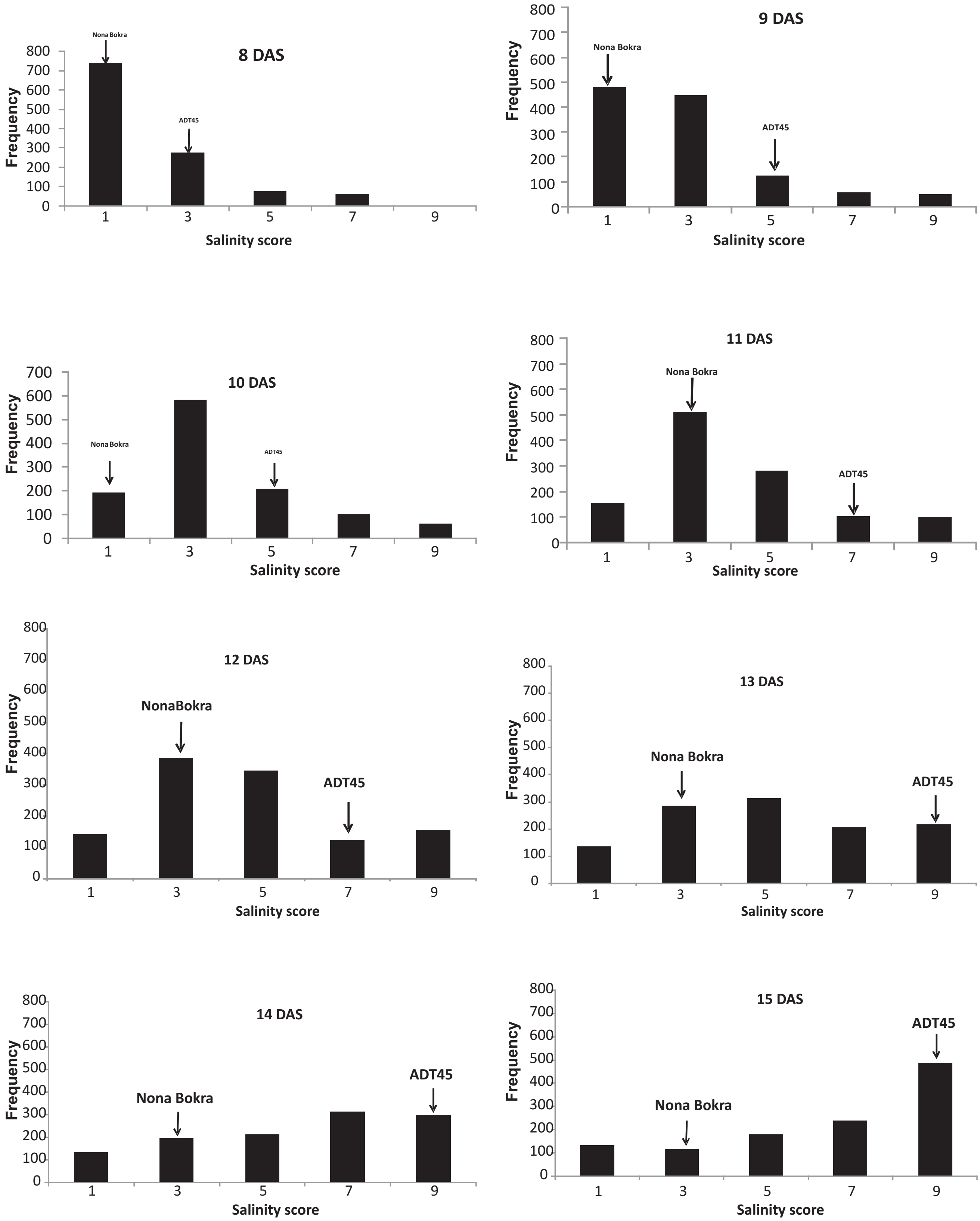

Fig. 1. Graphical representation of frequency distribution of salinity score in F2 generation

salinity score was significantly and negatively correlated with chlorophyll content (−0.763) and shoot K^+ content (−0.275) while it was positively correlated with shoot Na^+ content (0.603) and shoot Na: K ratio (0.767). Further strength of correlation is very high (r > 0.5) for six pair wise comparison while moderate (between 0.27 and 0.50) other four traits. This trend may be due to the experimental materials chosen in the study that are extremes for salt stress (highly tolerant and susceptible). Hence it is inferred from this study that salt tolerance is governed by polygenes with low heritability. So improving salt tolerance through conventional breeding is a difficult task for a breeder. So, improving the quantitative traits like salt tolerance only through conventional breeding is difficult task for a breeder. This can be overcome by combining coventional breeding with Marker assisted selection to hasten the process of selection and yield fruitful results.

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Farmers Adaptations to Climate Variability under Nagarjuna Sagar Right Canal of Andhra Pradesh

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***Abstract*:** Climate change is essentially a long term phenomenon and is supposed to be gradual in its impact for most part. The vulnerability of different regions to climatic change was assessed and quantified using the long term data. The present study was carried out to assess the vulnerability index under Krishna river basin, farmer's perceptions and adaptability to climate variability in NSRC of Andhra Pradesh. To assess the Vulnerability index, Iyengar and Sudhershan methodology was adopted. Out of the 9 districts in Krishna river basin, Anantapur district occupies rank first in term of vulnerability under all the three components and also overall vulnerability. 59.17 percent of farmers adapted strategies to climate change of which 49 percent of farmers adapted to water saving methods followed by crop diversification with 23 percent, followed by shift to livestock by 15 percent and off farm activities by 13 percent.

***Keywords*:** Climate variability, Vulnerability Index, Nagarjuna Sagar Right canal, Andhra Pradesh

Climate change (CC) will have multi-dimensional effect on mankind in terms of several socio-economic parameters. Among the different sectors, agriculture is the most important sector which will be severely affected by CC. Any scientific study on CC should take into account vulnerabilities of the different regions and then proceed to study its impacts on several sectors. IPCC (2007) defines vulnerability as 'the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity'. Krishna river basin cover major part of the combined state of Andhra Pradesh irrigation of 10 districts within the river basin namely, Anatapur, Kurnool, Prakasam, Guntur, Krishna, Khammam, Nalgonda, Warangal, Mahboobnagar and Rangareddy. Moreover the area is also influenced due to frequent droughts and floods under the command area The present research is focused on the objectives to assess the vulnerability indices under Krishna river basin, to study the farmers perceptions on climate variability and to analyse the farmers adaptability to climate variability.

MATERIAL AND METHODS

Krishna river basin cover major part of the Andhra Pradesh irrigation needs which extends about 76,252 Km^2. Guntur district was selected purposively as it has the highest command area covering 39 mandals in the district under Nagarjuna Sagar Right Canal (NSRC). The area is also influenced due to frequent droughts and floods under the command area in the district. Iyengar and Sudarshan (1982) methodology was employed for the development of composite index of vulnerability to CC from multivariate data and it was used to rank the districts in terms of their economic performance. The farmers perceptions and adaptation strategies followed is analyzed by simple tabular analysis.

Vulnerability Index: Vulnerability index is a composite one constructed on the basis of several factors, which are prone to be affected by climatic change. In the present study the following indicators were employed for the construction of vulnerability index. The vulnerability indices for all the 10 districts were constructed as per the methodology described later. Based on the indices, the districts were ranked and the rankings are given in Table 2. For this Beta probability distribution was fitted to the observed indices and the per centile values at 20, 40, 60, and 80 were taken as cut-off points for the five groups.

a) Demographic vulnerability: There are data on three components involved in this index to explain the demographic patterns of the people living in the respective district was collected. density of population (persons per square kilometre) ; literacy rate (per centage) and infant mortality rate (deaths per '000 infants)

b) Climatic vulnerability: It combines six separate indices which are the variances of annual rainfall (mm), south west and north east monsoon (mm) , maximum and minimum temperature (°C) and diurnal temperature variation (°C).

c) Agricultural vulnerability: This includes the six variables to predict the vulnerability related to agricultural activities–production of food grains (tonnes / hectare) , productivity of major crops (tonnes/ hectare), cropping intensity (per centage), irrigation intensity (per centage) , livestock population (number per hectare of net sown area) and forest area(per centage geographic area)

d) Occupational vulnerability: Six indicators were taken to calculate the vulnerability related to occupational characteristics of people and all these variables are converted into per hectare of net sown area–number of cultivators, total main workers, agricultural labourers , marginal , industrial and non workers

e) Geographic vulnerability: This includes the coastal length (kilometer) and geographical area (hectare)

Vulnerability of districts under Krishna river basin: The functional relationship of different variables with vulnerability were shown in the Table 1.

Iyengar and Sudarshan (1982) methodology was employed for the development of composite index of vulnerability to CC from multivariate data and it was used to rank the districts in terms of their economic performance. A brief discussion of the methodology for the development of composite index of vulnerability assumed that there are *M* regions/districts, K components for vulnerability and C_k is the number of variables in component *k* so that *kic X* is the value of the variable c_k of the k^{th} component for the i^{th} region(). First, these values of vulnerability indicators which may be in different units of measurement are standardized. When the observed values are related positively to the vulnerability, the standardization is achieved by employing the formula

Table 1. Functional relationship of different variables with vulnerability

Component		Indicator	Functional Relationship with Vulnerability**
Exposure	1	Percentage change in the annual rainfall* (V1)	↑
	2	Percentage change in maximum temperature* (V2)	↑
	3	Percentage change in minimum temperature* (V3)	↑
	4	Number of severe drought weeks for the past 10 years (V4)	
	5	Percentage of irrigated land (V5)	↓
Sensitivity	1	Land degradation Index (V6)	
	2	Rural population density (V7)	
	3	Crop diversification index*** (V8)	↓
	4	Percentage of small and marginal farmers (V9)	↑
Adaptive capacity	1	Rural literacy rate (V10)	
	2	Average farm size (V11)	
	3	Agricultural output index (V12)	↓
	4	Infrastructure index*** (V13)	
	5	Farm Infrastructure index*** (V14)	↓
	6	Percentage of HYV area (V15)	
	7	Milk animals (V16)	
	8	Poultry (V17)	

*Absolute value

**The symbols ↑indicates that vulnerability of the region increases (decreases) with the increase (decrease) in the value of the indicator. The symbols ↓indicates that vulnerability of the region increases (decreases) with the decrease (increase) in the value of the indicator.

*** provides the variables included and the methodology of construction.

$$y_{id} = (X_{id} - Min\ X_{id})/(Max\ X_{id} - Min\ X_{id})$$

When the values of X^{id} are negatively related to the vulnerability, the standardized values would be computed by

$$y_{id} = (Max\ X_{id} - X_{id})/(Max\ X_{id} - Min\ X_{id})$$

Where Min X_{id} and Max X^{id} are the minimum and maximum of (X_{i1}, X_{i2}….X_{in}) respectively. Obviously these standardized indices lie between 0 and 1. The level or stage of development of d[th] zone is assumed to be a linear sum of y_{id} as

$$\overline{y_d} = \sum_{i=1}^{m} w_i y_{id}$$

Where w's $(0 < w < 1\ and\ \sum_{i=1}^{n} w_i = 1)$ are the weights determined by

$$W_i = \frac{k}{\sqrt{\text{var}(y_i)}}$$

$$k = \left[\sum_{i=1}^{n} \frac{1}{\sqrt{Var(y_i)}} \right]^{-1}$$

The choice of the weights in this manner would ensure that large variation in any one of the indicators would not unduly dominate the contribution of the rest of the indicators and distort inter zone comparisons.

For classificatory purposes, a simple ranking of the zone indices viz., y_d would be enough. However for a meaningful characterization of the different stages of vulnerability, suitable fractile classification from an assumed distribution is needed. Probability distribution which is widely used is the Beta distribution. This distribution is defined by

$$f(z) = x^{a-1}(1-x)^{b-1}(a,b), 0 ς x ς 1 and a, b > 0$$

This distribution has two parameters *a* and *b*. They can be estimated by using the method given by Iyengar and Sudharshan (1982). The vulnerability indices for all the 10 districts were constructed as per the methodology described earlier. Based on the indices, the districts were ranked and the rankings are given in Table 2. For this Beta probability distribution was fitted to the observed indices and the per centile values at 20, 40, 60, and 80 were taken as cut-off points for the five groups. The Beta distribution is skewed. Let (0, z_1), (z_1, z_2), (z_2, z_2), (z_3, z_4) and (z_4, 1) be the linear intervals and each interval has the same probability weight of 20 per cent. These fractile intervals can be used to characterize the various stages of vulnerability.

1.	Less vulnerable	If	$0 < y_d < z_1$
2.	Moderately Vulnerable	If	$z_1 < y_d < z_2$
3.	Vulnerable	If	$z_2 < y_d < z_3$
4.	Highly vulnerable	If	$z_3 < y_d < z_4$
5.	Very highly vulnerable	If	$z_4 < y_d < 1$

RESULTS AND DISCUSSION

Vulnerability index under Krishna river basin: Out of the 9 districts, Anantapur district occupies first rank in terms of vulnerability under all the three components and also overall vulnerability (Table 2). The second rank was occupied by Ranga Reddy in terms of vulnerability. Warangal district was the least vulnerable among the districts of Krishna basin with a vulnerability index of 0.37.

Table 2. Vulnerability Index and ranks for districts under Krishna river basin

Districts	Vulnerability index	Rank
Anantapur	0.614	1
Guntur	0.437	6
Hyderabad(Ranga Reddy)	0.510	2
Khammam	0.412	7
Krishna	0.465	4
Kurnool	0.439	5
Mahabubnagar	0.481	3
Nalgonda	0.393	8
Warangal	0.370	9

Perception on climate variability: Farmers were questioned to elicit their observation on changes in climate in the last 5 years. The significant changes in climate during the last 5 years was observed by 51.7 per cent farmers while 48.3 per cent of the farmers opined that there was no significant change in climate (Table 3).

Adaptation to climate variability: The adaptation measures taken up by the farmers indicate that the farmers have perceived the changes in the climate and made use of the technical guidance and finally have gone for adaptations against changing climate. A total

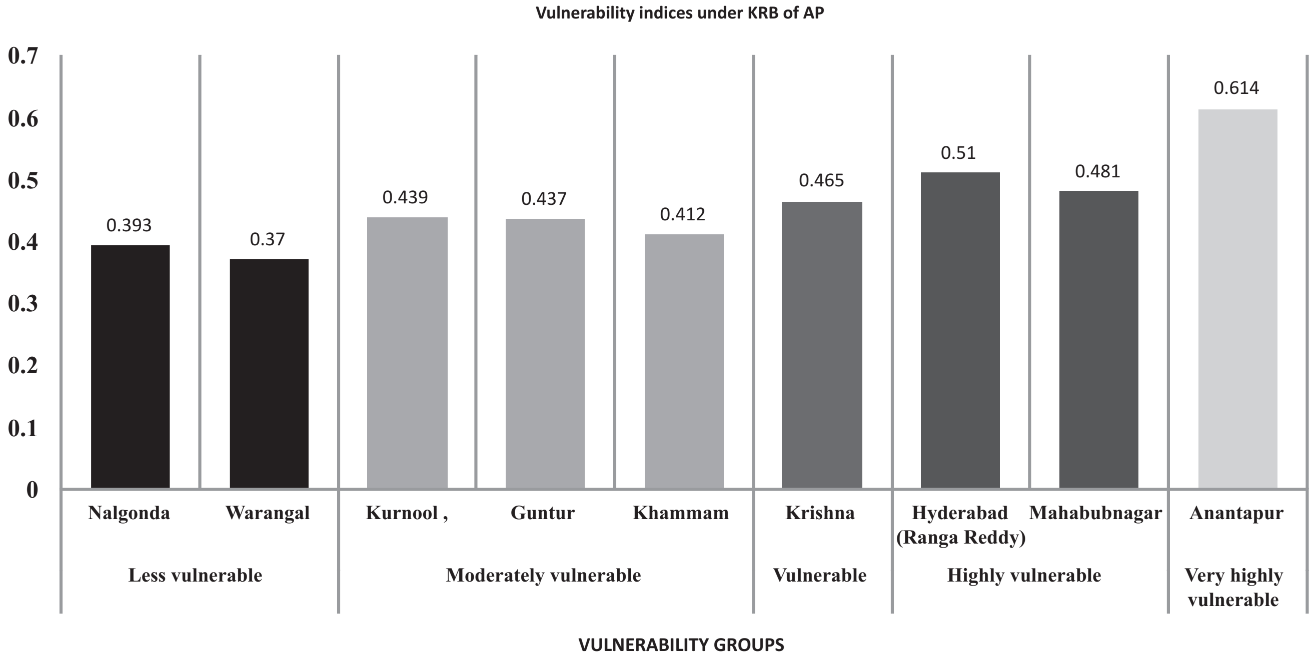

Fig.1. Classification of districts under different vulnerability groups

Table 3. Frequency of climate variability-observation by farmers in the study area

Region	Farmers Perception on climate variability for the past 5 years	
	Not Significant	Significant
Canal Head (n = 80)	35	45
Canal middle (n = 80)	54	26
Canal tail (n = 80)	27	53
Total (N = 240)	116	124
Percentage to the total	48.33	51.67

Table 4. Various adaptation measures in the study area

Region	Crop diversification	Water saving methods	Off farm activities	Change to livestock
Canal Head (n = 46)	14(30.43	16(34.78)	4(8.70)	12(26.09)
Canal middle (n = 49)	14(28.58	24(48.98)	5(10.20)	6(12.25)
Canal tail (n = 47)	4(8.51)	30(63.83)	9(19.15)	4(8.51)
Total (N = 142)	32(22.54	70(49.30)	18(12.67)	22(15.49)

Figures in parentheses indicate percentages to total

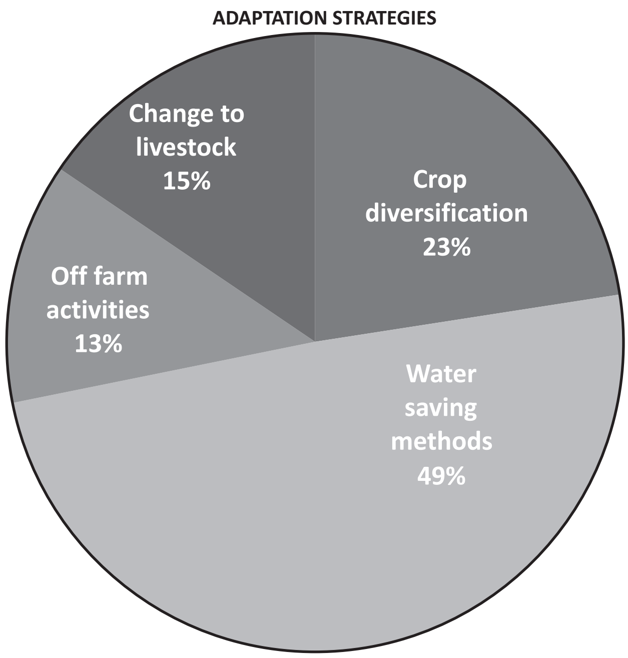

Fig. 2. Farmers adapting to climate variability

of 142 farmers adapted to climate change. In tail end region 63.83 per cent farmers adapt water saving methods followed by off farm activities with 19.15 per cent. Whereas in head and middle regions most of the farmers adapt crop diversification followed by water saving methods.

The use of water saving technologies was the most commonly used method which contributes to 49 per cent of the total adaptation followed by crop diversification to extent of 23per cent, change to livestock up to 15 per cent and off farm activities to an extent of 13 per cent, where off-farm activities was the least adaptation practiced among the major adaptation methods identified in the Krishna river basin.

Table 5. Constraints to Climate adaptation of non adapted farmers in the study area

Region	Lack of information	Lack of money	Shortage of labour	Shortage of land	Poor potential for irrigation
Canal Head (n = 34)	17(50.00)	7(20.59)	10(29.41)	0(0)	0(0)
Canal middle (n = 31)	11(35.48)	5(16.13)	10(32.26)	5(16.13)	0(0)
Canal tail (n = 33)	16(42.43)	6(18.18)	4(12.12)	1(3.03)	8(24.24)
Total (N = 98)	42(42.86)	18(18.37)	24(24.49)	6(6.12)	8(8.16)

Figures in parentheses indicate percentages to total

Barriers of adaptation: The analysis of barriers to adaptation to climate variability of non adapted farmers in the study area indicates that there were five major constraints to adaptation. These were lack of information, lack of money, shortage of labour, shortage of land and poor potential for irrigation (Table 5). Lack of information to adaptation options could be attributed to the fact that research on climate change and adaptation options have not been strengthened in the country and thus, information was lacking in this area. Lack of money hinders farmers from getting the necessary resources and technologies.

Adaptation to climate change was costly, and this cost could be revealed through the need for intensive labour use. Thus, if farmers do not have sufficient family labour or the financial means to higher labour, they cannot adapt. Poor irrigation potential can most probably be associated with the inability of farmers to use the already existing water due to technological incapability. The lack of information was the major constraint contributing to about 43per cent, followed by shortage of labour with 25 per cent, lack of money with 18 per cent, poor potential of irrigation with 8per cent and shortage of land contributing to 6per cent.

CONCLUSIONS

In terms of vulnerability, Anantapur district was classified under very highly vulnerable group whereas Warangal and Nalgonda district falls under less vulnerable group in Krishna river basin of Andhra Pradesh. Majority of the farmers adapted to climate variability. Among all the strategies, majority of the famers adapted to water saving methods followed by crop diversification, change to livestock and off farm activities respectively. Lack of information was the major constraint followed by shortage of labour and lack of money for farmers who haven't gone for any adaptation. Hence, there is need of government intervention for the farmers to overcome the barriers of adapting to climate variability. The measures like proper and timely extension services, sufficient and timely availability of institutional credit and alternative activities like livestock may be materialised by the government to the farmers to overcome the climate variability.

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Adaptation Behaviour of Farmers with respect to Climate Change in Ranchi, Jharkhand

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***Abstract**:* This study was conducted with the objective to explore reasons that are effecting farmer's development through adaptation against climate change in two blocks (Ormanjhi and Angara) of Ranchi district of Jharkhand state in India during 2016 with sample size of 105. Majority of respondents were in the age group of 29-48 years with average educational qualification. Eighty percent of them were small and marginal farmers having estimated annual average income between 16.98 −66.81 thousands rupees and 9 to 24 years average farming experience. Agricultural university, KVKs, mobile massaging and mass media were major sources of information for them. According to farmers adaptation is the best strategy taken against effects of climate change than mitigation. Farmers are adopting many adaptation strategies out of which agroforestry, crop diversification and exchange of crop seed were most commonly practiced adaptation strategies. However, lower interest in adaptation strategies like afforestation, use of crop shed or greenhouses, processing of crop to minimise post harvest losses was observed. Even after adopting various adaptation strategies they are lacking at various places due to various reasons like poor knowledge, skill and resources. So, an integrated, well planned and area specific strategies should be developed to help the farming community.

***Keywords**:* Farmers, Climate Change, Adaptation

In India, agriculture plays a very significant role, as about 54.6 per cent of its population depends on agriculture directly and indirectly. In per cent Gross Value Added (GVA) of India, agricultural sector contributed 17.4, 18.8 , 18.2 and 18.3 in 2014-15,2011-12,2012-13 and 2013-14 (Annual report, 2015-16). These data show a continuous decline in share of agriculture sector in GVA. This may be due to various reasons like increased growth of other sectors; decrease in agriculture production, etc. Climate change is one of those reasons, as it is a direct input in crop growth. Consequently, it had created difficulties for farmers, especially of developing countries, who belong to the weaker section of society and are more vulnerable to vagaries of climate change due to poor adaptation capacity. "The anticipating the adverse effects of climate change and taking appropriate action to prevent or minimise the damage they can cause, or taking advantage of opportunities that may arise may help in reducing and managing the risks of climate change in the 21st century and beyond, increase prospects for effective adaptation, reduce the cost and challenges of mitigation in the long term and contribute to climate resilient pathways for sustainable development. Adaptation can reduce the risks of climate change impacts, but there are limits to its effectiveness, especially with greater magnitudes and rates of climate change. Taking a longer term perspective, in the context of sustainable development, increases the likelihood that more immediate adaptation action will also enhance future option and preparedness" (IPCC, 2014). Adaptive capability of farmers was measured by Asante *et al*. (2009) and Nakuja *et al*. (2012) through five attributes like knowledge, use, availability, accessibility and consultation.

Farmers of various places have adopted different adaptation strategies under different situation. Bryan *et al*. (2013) have revealed that in "Kenya adaptation to climate change at the farm level includes many possible responses, such as changes in crop management practices (e.g., planting dates or crop varieties), land use and land management (e.g., fallowing, irrigation and water harvesting, soil and water conservation measures or tillage practices) and livelihood strategies (e.g., a mix of crops or livestock produced, combination of agricultural and non-farm activities or temporary or permanent migration)". "Farmers of both irrigated and non-irrigated villages are adopting a variety of adaptation strategies such as agronomic management, water harvesting, water resources exploitation, crop intensification, alternative enterprises, other income generating activities and others such as selling of live stock, migration and borrowing money from relatives & neighbour, etc. out of these agronomic practices are most popular" (Habiba *et al.,* 2012). Jianjun *et al.* (2015) reported in his experiment that, "the most common adaptation practices were adopting new drought-resistant crop varieties and increasing investments in irrigation infrastructure". Rao and Venkateswarlu (2013) suggested several adaptation measures, "with respect to incidence of insect pests like changing planting dates, planting different varieties, development and promotion of alternative crops and higher adoption of crop diversification or intercropping". Above studies describes numbers of adaptation strategies being adopted by farmers in different situation at various location. But, still the problem of environment degradation had not improved much. This may be due to poor implementation of adaptation programmes at bottom level. Studies of Parry *et al*. (2007); Olesen *et al*. (2011); Below *et al*. (2012) and Rao *et al*. (2011), revealed that the current awareness of farmers in terms of climate change and need for adaptation might still be low and incomplete. According to Tol (2002) various former studies often assumed "limited capacities of farmers to adapt to changing circumstances". This gaps in implementation of adaptation programme and climate improvement is due to top to down approach. There is a need to understand the culture, socio-economic condition, resources availability and existing adaptation behaviour of community for a successful adaptation programme planning. In order to understand the socio−economic status of farmers, what major climatic contingencies they are facingΩ How much capable they are in adapting in current situationΩAnd what adaptation strategies they have currently adoptedΩ Keeping these problems in mind study was designed and conducted with Objectives: To study socio economic profile and adaptation behaviour of farmers.

MATERIAL AND METHODS

Locale of study: The study was performed at two CD blocks (Ormanjhi and Angara) in Ranchi district of Jharkhand state of India. The main reason for selection of these two blocks was due to its association with Climate Change Knowledge Network in Indian Agriculture (CCKN-IA) programme. CCKN−IA programme is an initiative of government of India with technical support from Deutsche Gesellschafts fur International Zuammenarbit (GIN) with an aim to improve the agriculture extension service delivery to contribute towards sustainable agricultural development under the context of climate change adaptation. Jharkhand is located at Chhota Nagpur Plateau in north eastern part of India. Ranchi is capital of this state and is spread over 18.73 lakh acre and homes 29,14,253 peoples. It has a humid subtropical type of climate with temperature range from 42^{o}C to 20^{o}C during summer and 25^{o}C to 0^{o}C during winter. The average annual rainfall is about 1430mm. Subarnrekha river and its tributaries enhance the beauty and fulfils the water demand of this state. However, due to its undulating topography most of water losses occurs, 20% of annual precipitation is lost in the atmosphere, 50% flow as surface runoff and 30% soacks into the ground as soil moisture and ground water (Gupta, 2013). The higher elevation and forest cover makes its climate pleasant and provides favourable condition for orchards, pulses, millet and vegetable cultivation in up hills and paddy cultivation in middle and lower areas as rainfed crop. Only 8.30 per cent of cultivated area has irrigation facilities. Major sources of irrigation are well and canal. These conditions make the district more prone to drought and mainly affect the farming community of this area. Ormanjhi and Angara blocks are spread in 22,796.86ha and 39,856ha and homes 94,137 and 112,759 peoples respectively. CCKN-IA programme is operational in 12 out of 87 villages and 14 out of 82 villages of Ormanjhi and Angara block respectively. 4 respondents were selected randomly from all 24 villages and 5 respondents from one of the village. Thus, total 105 respondents were interviewed. In most cases head of the family were interviewed who could response to asked questions, perform most farm work and takes decision. In case if head of family was unable to response and involved in off farm work, family member who was responsible for most of farm work were interviewed.

Research design: The research design adopted for this study was exploratory research design. Under this study it had been tried to explore the socioeconomic status of farmers, major climatic contingencies faced by them, their capacity to adapt in changing climatic conditions and adaptation strategies adopted by them in current situation.

Data collection: Data were collected through interview schedule consisting of structured open as well as close ended questions. Questions were prepared keeping in view the objective of the study after consulting relevant literature and experts on the subject under study. The interview schedule was pre tested with 15 respondents on a non sampled respondents in order to find out the weakness of the interview schedule. The schedule was suitably modified on the basis of the pre-test analysis. The collected data were analysed and classified through use of some statistical tools like calculation of frequencies, percentage, mean, standard deviation and mean score.

RESULTS AND DISCUSSION

Socio economic status of farmers: Majority of respondents were in the age group 29-48 years , educated upto middle school with small land holdings .This is due to increased population density; undulating topography and the reason being respondents were of labour class. This result matches with the data of Jharkhand government that "83 percent of the agricultural land in the state belongs to small and marginal farmers and only 1 percent of holdings are above 10 hectares" (Government of Jharkhand, 2013). Annual income of any population affects their expenditure characteristic and simultaneously influences their view about nature and natural resources. Majority of the respondents have estimated annual income range between 13.98-66.81

thousand. This result matched with the Singh (2013) Baseline survey report of the project area for developing farming system models for pritorised micro watersheds in rainfed areas of Jharkhand that the average total household annual income was Rs.24465. However, a slight higher result in present study may be due to the effect of CCKN-IA programme in the study area. Majority of population have medium farming experience of 9.23 – 27.95 years. This was due to the presence of majority of respondents being in medium age group. Most of them gather information from agricultural university and KVK due to its close proximity with these institutions. However, mobile messaging and mass media (T.V., Radio and news paper) were the major information source regarding climate change. Due to effect of CCKN-IA programme many of them were using internet for seeking information. Drought was the most important climatic contingency faced by farmers of study area followed by pest and disease outbreak. About 84 per cent of them believe adaptation strategies are best action to reduce climate change impact. This may be due to poor knowledge regarding mitigation strategy.

Capacity to Adapt: The majority of the respondents (67.62%) feels that they have low capacity to adapt followed by medium capacity (20.95%) and no capacity (11.43%) to adapt to cope with the potential impact of climate change. The capacity to adapt has been studied as per their perception.

Adaptation strategies adopted by farmers: There are abundance of varieties for a single crop having different qualities, suitable for specific location and climatic situation. So, there is need to replace old seeds with new varieties as per changing situations. With 82.86% of farmer's choice exchange of seed ranked at 1st position. Market and rural fair were sources for buying different seed varieties. "Agroforestry has real potential to contribute to food security, climate change mitigation and adaptation" (Mbow *et al*. 2014). Since most of the farmers were from tribal community and have more attachment with forest and trees as well as due to influence of CCKN-IA programme. About 72.38% farmers have adopted agroforestry as second best option against climate change. More diverse agro-ecosystem with a broader range of traits and functions will be better able to perform under changing environmental conditions (Altieri 1999; Lin, 2011). So, 69.52% respondents ranked crop diversification as 3rd most preferred adaptation habit. They were diversifying their farm through growing wheat, oilseeds, pulses and vegetables. Sinha (2015) have also reported crop diversification in Bihar and Jharkhand as one of adaptation habit against climate change. About 10% of total cultivated area in Jharkhand is under organic cultivation and it is growing steadily (http://timesofindia.indiatimes.com /city/ranchi/Jkhand-makes-slow-but-steady-switch-to-organic-farming/articleshow/50844401.cms). Even afterthis, 68.57% farmers believe organic farming as a better option against climate change. However, they also accept it would reduce their yield initially. Crop insurance is playing a very important role in adaptation against climate change among farming community all around the world. Jianjun *et al*. (2015) in their study at Yogqiao, China also reported that "crop insurance was preferred by 53% farmer as adaptation strategies against climate change". Similarly, in the present study 67.62% respondent preferred crop insurance and ranked it as 5th most preferred adaptation strategy. About 65.71% respondents believe that only crop cultivation could not help them to survive in this changing scenario and adopted various other income generating activities along with crop cultivation. Again 65.71% respondents have reduced use of chemical fertilizer and adopted judicious way of fertilizer application in order to reduce the harmful effect on environment. Change of crop varieties was one of the common adaptation methods among farmers as 64.76% uses disease tolerant varieties, 60% uses disease resistant varieties and 57.14% uses drought resistant varieties. About 63.81% respondents adopted short duration crops and varieties like millets. Since, irrigation water is one of the major issue in the study area about 63.81% respondents believe that taking soil and water conservation method would be good adaptation strategies while 62.68% believe construction and rejuvenation of farm ponds would more effective. Proper management of agriculture wastes like crop residues and animal dung was considered as 10th best adaptation strategies by 61.90% respondents, as it help address climate change through reducing green house gas emission and energy saving. Since, climate change caused shift in rainfall pattern 60.95% respondent believe, that delay sowing of few crops would help them in matching the sowing time with rainfall and provide better yield. About 59.05% respondents believe that more investment in inputs and labours provided better adaption options while 54.29% leaved crops involving high cost of cultivation and poor return. Study area is geographically situated at higher altitude due to which water table of the location is much deeper than normal as well as decrease during summer too. For population of study area it's very difficult to have underground water for irrigation due to this 54.29% believe in judicious use underground water as an important adaptation method. Most of them have shifted from paddy to vegetable cultivation. Excess use of chemical insecticide and pesticide leave its residual effect on environment thus leads to environmental degradation. About 53.33% respondent

Table 2. Distribution of respondents according to their adaptation strategies they generally apply in farm against climate change

(N = 105)

Adaptation Strategies	Frequencies	Percentage	Rank
Fill or replant	51	48.57	18th
Delay sowing time	64	60.95	11th
Fallowing	33	31.43	25th
Exchange crop seed	87	82.86	1st
Use short growth period crop	67	63.81	8th
Use disease resistant variety crop	63	60.00	12th
Use disease tolerant variety of crop	68	64.76	7th
Use drought tolerant variety	60	57.14	14th
Crop diversification	73	69.52	3rd
Introduction of modern machineries and technology	48	45.71	20th
Purchasing crop insurance	71	67.62	5th
Organic farming	72	68.57	4th
Agro forestry	76	72.38	2nd
Irrigation water management	50	47.62	19th
Use of renewable energy instead of conventional energy	47	44.76	21th
Proper application of fertilizers	69	65.71	6th
Judicious use of insecticides and pesticide	56	53.33	16th
Proper dumping of agriculture wastes	65	61.90	10th
More investment	62	59.05	13th
Giving up crop involving more cost of production	57	54.29	15th
Taking alternate enterprise like horticultural crop with main crop	54	51.43	17th
Other income generating activities like fisheries, cottage industries, etc.	69	65.71	6th
Processing of crops to minimise post harvest losses	43	40.95	22nd
Use of wind break and shelter belt	34	32.38	24th
Use of crop shed or growing crops in greenhouse	37	35.24	23rd
Growing forest in waste land (Afforestation)	43	40.95	22nd
Judicious use of underground water	57	54.29	15th
Construction and rejuvenation of farm ponds	66	62.86	9th
Taking soil and water conservation measures	67	63.81	8th

started using it in judicious way to protect the environment. "Agriculture diversification is an important mechanism for economic growth" (http://www.fao.org/ docrep /005/ ac484e/ac484e06.htm). About 51.43% farmers were taking other enterprises like horticulture, animal husbandry, pisiculture, mushroom production, etc. along with crop cultivation. Due to bad effect of climate change few patches on field destroy and remain unfilled in whole season. About 48.57% respondents use to fill those losses though replanting in crops like paddy and vegetables. Irrigation had become major issue due to non availability of upland water and decreased level of underground water. Various farmers of study area consider irregularity of rainfall as main cause for this problem as they are performing rainfed farming. However, 47.62% of them have started irrigation water management though adopting rainwater harvesting, drip and sprinkler irrigation, straw and plastic mulching etc. Most of the population felt that they have medium compatibility with modern technologies, while about 26% of them have low compatibility with technologies and machineries due to which only 45.71% gives importance to introduction of modern machineries and technologies and 40.95% performs processing of crop to minimise post harvest losses. This may be due to their poor educational back ground and low annual income. This shows that they were in developing stage in term of technological development. With above, only 44.76% used have adopted renewable sources of energy instead of conventional sources. Most of population are tribal and they

Table 3. Classification of adaptation strategies (N =105)

Categories	Frequency range	Adaptation strategies
Less common $(\bar{x}-\sigma)$	33-45	Growing forest in waste land (Afforestation), use of crop shed or growing crops in greenhouse, processing of crops to minimise post harvest losses, use of wind break and shelterbelt and Fallowing.
Common $(\bar{x}-\sigma)$	46-72	Taking soil and water conservation measures, construction and rejuvenation of farm ponds, judicious use of underground water, other income generating activities like fisheries, cottage industries, etc., alternate enterprise like horticultural crop with main crop, giving up crop involving more cost of production, more investment, proper dumping of agriculture wastes, judicious use of insecticides and pesticide, proper application of fertilizers, use of renewable energy instead of conventional energy, irrigation water management, organic farming, purchasing crop insurance, introduction of modern machineries and technology, use drought tolerant variety, introduction of modern machineries and technology, use disease tolerant variety of crop, use disease resistant variety crop, use short growth period crop, delay sowing time and fill or replant.
Most common $(\bar{x}-\sigma)$	73-87	Agro forestry, crop diversification and exchange crop seed.

$\bar{x}$=58.93 σ=13.20

use to worship forest and believe in its protection, even after that only 40.95% adopted forest development in waste lands. Growing crops in shed and green houses is being adopted by 35.24% respondents and this is in growing trend as more people are adopting this adaptation strategy due to its observable result in higher yield. Windbreak is use in areas having problem of higher wind velocity as well as it reduces soil erosion and enriches crop microclimate. Fewer farmers (32.38%) of the study area give preferences to windbreak (shelterbelts) as they faces lower problem regarding wind speed and are not aware about the other benefits of windbreak. A shifting cultivation landscape will have a higher probability of being a 'carbon sink' compared to mature forest landscapes(http://agrobiodiversityplatform.org/climatechange/2010/11/10/rotational-farming-shifting-cultivation-and-climate-change/). However, successive interventions or repeated agriculture-fallow cycles can affect species composition, reduce carbon storage capacity, and act as a precursor to the establishment of more permanent non-forest land cover (Eaton and Lawrence, 2009; Peres *et al*., 2006). Only 31.43% of population practices or believe it as an adaptation option.

Agroforestry, crop diversification and exchange crop seed' were most common adaptation strategies (Table 2). Soil and water conservation measures, construction and rejuvenation of farm ponds, judicious use of underground water, use of wind break and shelter belt, other income generating activities like fisheries, cottage industries, etc., practice of alternate enterprise like horticultural crop with main crop, leaving crop involved more cost of production, more investment, proper dumping of agriculture wastes, judicious use of insecticides and pesticide, proper application of fertilizers, use of renewable energy instead of conventional energy, irrigation water management, organic farming, purchasing crop insurance, introduction of modern machineries and technology, use of drought tolerant variety, use of disease tolerant variety of crop, use of disease resistant variety crop, use of short growth period crop, delay sowing time and fill or replant method' were common adaptation strategies. Growing forest in waste land (Afforestation), use of crop shed or growing crops in greenhouse, processing of crops to minimise post harvest losses, use of wind break and shelterbelt and fallowing were least practiced strategies.

CONCLUSION

From the above study it can be concluded that even after having lower adaptation confidence farmers are adopting various adaption strategies. Out of various adaption strategies crop management practices like exchange of crop seed, selection of suitable varieties and crops, sowing time, etc. were most common among them. Good consequence of government intervention could be judge through popularity of crop insurance among farmers. Input management practices like fertilizer, water and pesticides application are fairly adopted among them. But due to lack of technical knowledge they are performing skeptical in adopting new technologies. So, there is need to provide technical guidance though training or other means and low cost technologies should be intervened in the market. Since they are having lower confidence regarding their adaptation capacity most probably due to poor resource availability so there is need to build strong resource base. Due to effect of CCKN-IA programs farmer of study area are getting timely information and are satisfied with it so this should be expended in broader area. Over all there is need of integrated, well planned and area specific strategies to help the farming community in coping with climate change.

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Genetic Variability of Chickpea Genotypes under Heat Stress Condition: Character Association and Path Coefficient Based Analysis

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Abstract: Genetic variability, correlation and path analysis for seed yield and its component characters in twenty nine chickpea genotypes sown under heat stress environment was analysed. The sowing of these genotypes was carried out on15th December 2015 (late sown) at Pulse Research farm, Bhitti, Bihar Agricultural University Sabour. In field condition, in case of late sowing, chickpea plants met to high environment temperature (≥35˚C) during its reproductive stage which creates an unfavorable heat stress condition and affects its seed yield. The analysis of variance revealed the significant differences among the genotypes for all the traits indicating presence of sufficient variability among the genotypes for various traits. The high GCV and PCV were observed for disease reaction to wilt, number of pods per plant, 100-seed weight and grain yield. High heritability with high genetic advance as percentage of mean was noticed for number of pods per plant, 100-seed weight and disease reaction to wilt. Seed yield per plant was positively and significantly correlated with plant stand at harvest and number of pods per plant while highly significantly and negatively correlated with disease reaction to wilt indicating that these three traits were main yield attributing traits. The path analysis revealed that the plant stand at harvest and number of pods per plant had maximum direct effect on seed yield. On the basis of seed yield, Phule G-13110 (2080kg/ha), RKG 11-155 (2038kg/ha), PBC 501(1920kg/ha) and CSJ (1907kg/ha) were identified as promising heat tolerant genotypes. The potential for indirect selection for heat stress tolerance using these associated characters may be useful to the breeder to formulate appropriate breeding plans for selection of the genotype which tolerate high temperature conditions.

Keywords: Chickpea, Correlation, Heat Tolerance, Path Coefficient

Chickpea (*Cicer arietinum* L.) is the third most important pulse crop globally, with a production of 7.33 m t from an area of 8.25 m ha (Project Coordinator's Report 2015-16). It is even more important for India as the country's production accounts for 67% of the global chickpea production and chickpea constitutes about 40% of India's total pulse production. In spite of India being the largest chickpea producing country, a deficit exists in domestic production and demand which is met through imports. In India, the total area under chickpea is 8.25 M ha with 7.33 million tonnes production with productivity 889 kg/ha and the total area in Bihar reached 60.0 thousand ha with 57.50 thousand tonnes of production with productivity of 958 kg/ha (2014-15: Agricultural Statistics Division, Directorate of Economics & Statistics, Dept. of Agriculture & Cooperation). Chickpea is a cool season food legume and incurs heavy yield losses when exposed to high temperatures (≥35˚C) at reproductive stage. Heat stress is increasingly becoming a major constraint to chickpea production in India because, increase in area under late sown conditions due to increasing cropping intensity or late maturity of rainy season crop, and expected increase in overall temperatures due to climate change. (Gaur *et al.,* 2008 and Gowda *et al.,* 2009). Reproductive stages (flowering and podding) in chickpea are susceptible to changes in external environment and heat stress (Krishnamurthy *et al.,* 2011). Frequent reductions in chickpea seed yields were observed when plants at flowering and pod development stages were exposed to high (>35^{0}C) temperatures (Wang *et al.,* 2006). It is estimated that about 11.7 million ha of rice area in India, currently remains fallow after late harvest of rice during the winter season in the central and north-eastern India (Subbarao *et al*. 2001). These lands potentially offer expansion in chickpea cultivation provided genotypes capable of standing heat stress are made available. Finally, heat stress is expected to be an increasingly important constraint in near future due to climate change and global warming. By 2050, a rise in temperature by at least 2^{0}C, particularly the night temperatures, is being predicted with higher levels of warming in northern parts of India. Predicted climate change, particularly high temperature will reduce grain yield in chickpea. For example, the yields of chickpea declined by up to 301 kg/ha per 1˚C increase in mean seasonal temperature in India (Karla *et al*. 2010). So, there is an urgent need to search the gene bank for diverse sources of heat tolerance. Heat tolerance is greatly needed in chickpea cultivars for realizing higher yields in all growing conditions that expose chickpea to high temperature, particularly at the reproductive stage. So, heat tolerant varieties are needed for improving chickpea yields in late sown conditions. The genetic variability presents in the base population for desired characters play an important role in development of desirable plant type. Less information is present in the cultivated chickpea lines grown under heat stress conditions. Therefore, the identification of heat tolerant genotypes is essential for development of high yielding chickpea variety under heat stress condition, considering this, the present investigation was carried out to assess the genetic variability, association of different traits towards yield and selection of high yielding genotypes with better architecture under heat stress conditions.

MATERIAL AND METHODS

The experimental material consisted of twenty nine chickpea genotypes (procured from ICRISAT) were sown on15th December 2015 to coincide heat stress with pollination time and grain filling period at Pulses Research farm, Bhitti, Bihar Agricultural University, Sabour (Bhagalpur). Atmospheric temperature varied from 4.0˚C minimum in January to 45.0˚C maximum in May. The experiment was laid out in a randomized complete block design with three replications. The plot size was 4.0 x 1.2 m, with 1 row of 4 m length. Inter row spacing and plant to plant spacing was 30 x 10 cm. The recommended packages of practices were followed to raise a healthy crop. Data were recorded on eight quantitative traits viz. days to 50% flowering, days to maturity, plant height (cm), number of pods per plant, disease reaction to wilt (%), plant stand at harvest (%), 100 seed weight (g), grain yield per plot (g).The days to 50% flowering, days to maturity, disease reaction to wilt (%), plant stand at harvest (%) and grain yield per plot were recorded on a plot basis and plant height and number of pods per plant and 100-seed weight were recorded from a random sample of five plants in each plot. Data were subjected to statistical analysis to work out genotypic (GCV) and phenotypic (PCV) coefficients of variation, heritability and genetic advance as per cent of mean as per standard methods. Standard statistical procedure were used for the analysis of variance, genotypic and phenotypic coefficients of variation (Burton, 1952), heritability (Hanson *et al*., 1956) and genetic advance (Johnson *et al*., 1955). The genotypic and phenotypic correlation coefficients were computed using genotypic and phenotypic variances and co-variances (Al Jibouri *et al.,* 1958). The path coefficient analysis was done according to the method by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The analysis of variance showed significant differences among genotypes (Table 1) for all the characters studied which provides an opportunity for selecting suitable genotypes with better performance for the traits. The estimates of phenotypic coefficient of variation (PCV) in general, were higher than the estimates of genotypic coefficient of variation (GCV) for all the characters, which suggested that the apparent variation is not only due to the genotypes but also due to the influence of environment (Table 2). The characters viz. disease reaction to wilt, number of pods per plant and 100-seed weight showed high GCV estimates. This is an indicative of less amenability of these traits to environmental fluctuations and hence, greater emphasis should be given to these characters, while breeding cultivars from the present material. High GCV for number of pods per plant and 100-seed weight were also earlier reported by Jeena *et al*. (2005), Younis *et al.* (2008) , Alwani *et al.* (2010) and Babbar *et al.*(2012). The high PCV were recorded by number of pods per plant, 100-seed weight and grain yield per plot. The magnitude of PCV ranged from 4.19 for days to maturity to 40.02 for number disease reaction to wilt. The characters with high phenotypic coefficient of variation indicated more influence of environmental factors. Therefore, caution has to be exercised during the selection program because the environmental variations are unpredictable in nature and may mislead the results. The heritability for most of the characters ranged from 7.77 (plant stand at harvest) to 0.984 (100-seed weight). The heritability estimates were recorded high for 100-seed weight, number of pods per plant, plant height, days to maturity and disease reaction to wilt which suggested that the characters are least

Table 1. Analysis of variance for eight quantitative characters of chickpea genotypes under late sown condition

Characters	Mean Sum of Squares Replication (d. f.=2)	Treatment (d .f.=28)	Error (d. f.=56)
Days to 50% flowering	0.32	22.37**	7.24
Days to maturity	21.97	46.82**	7.44
Plant height (cm)	7.94	151.32**	12.73
No. of pods plant^{-1}	29.21	329.02**	10.08
Disease reaction to Wilt (%)	6.11	14.75**	7.67
Plant stand at harvest (%)	35.36	21.91	17.49
100-seed weight(g)	1.24	100.23**	1.18
Grain yield plot^{-1} (q ha^{-1})	23.25	29.69**	11.83

* , ** Significant at 5% and 1% levels of significance, respectively

influenced by the environmental factors and also indicates the dependency of phenotypic expression which reflects the genotypic ability of cultivars to transmit the genes to their off–springs. Similar results were also reported by Bicer and Sarkar (2008) and Younis *et al.* (2008). High heritability does not mean a high genetic advance for a particular quantitative character. The expected genetic advance was high for grain yield per plot while number of pods per showed moderate heritability. High heritability coupled with high genetic advance over mean was observed for number of pods per plant, 100–seed weight and disease reaction to wilt which suggested that these characters can be considered as favorable attributes for the improvement through selection and this may be due to additive gene action and thus, could be improved upon by adapting selection without progeny testing. Similar results have also been reported by Yadav *et al.* (2003). The study of inter–relationship among various characters in the form of correlation is, in fact, one of very important aspects in selection programme for the breeder to make an effective selection based on the correlated and uncorrelated response. Knowledge of nature and magnitude of associations among different characters are important on three counts. Indirect selection is important when desirable characters have low heritability measure in one sex only. The efficiency of indirect selection is measured as a correlated response (Falconer, 1960). Knowledge of correlation is required when selection is to be made on several characters at a time through some simultaneous selection model. Even if, the objective is to make selection on a single trait, the knowledge of correlation is essential to avoid the undesirable correlated changes in other characters. In general, magnitude of genotypic correlation was higher than their corresponding phenotypic correlation coefficients in most of the characters suggesting that a strong inherent association exists for the traits studied and phenotypic selection may be rewarding. Similar results were also reported by Pathak *et al.* (1986). Higher magnitude of genotypic correlation helps in selection for genetically controlled characters and give a better response for seed yield improvement than that would be expected on the basis of` phenotypic association alone (Robinson *et al*., 1951). Grain yield per plot was found significantly correlated with plant stand at harvest and number of pods per plant while highly significantly and negatively correlated with disease reaction to wilt (Table 3). Kuldeep *et al.* (2014) suggested that yield could be raised by selecting for more number of pods per plant and plant stand, which is evident in the present study. Similar findings were reported by Telebi *et al.* (2007), Hahid *et al*. (2010) and Ali *et al*. (2011). Amongst the other characters, days to 50% flowering, showed positive and significant correlation with 100–seed weight and days to maturity. Similarly plant height also exhibited significant positive association with 100–seed weight and significant negative association with number of pods per plant.

Path coefficient analysis (Table 4) for grain yield per plot revealed that the plant stand at harvest and number of pods per plant showed highest positive direct effect towards seed yield. These results are agreement with the earlier reports of Priti *et al.* (2003). It means a slight increase in any one of the above traits may directly contribute towards seed yield. Positive direct effect of number of pods plant and indirect positive effect via 100–seed weight and plant height were the main reason for strong positive correlation of this character with seed yield (0.1189). Similar results were reported by Talebi *et al.* (2007) and Babbar *et al.* (2012). The indirect contribution of plant stand at harvest was number of pods per plant and 100–seed weight. For days to 50% flowering, the direct effect was positive while, its association with seed yield was observed to be negative, indicating the importance of restricted selection model for exploitation of the direct effect noticed. On the basis of seed yield and its attributing traits (Table 5) Phule G–13110 (2080kg/ha), RKG 11–155

Table 2. Estimates of genetic parameters for eight quantitative characters under late sown condition

Characters	GV	PV	GCV	PCV	H (%)	GA	GA as of % of mean
Days to 50% flowering	5.04	12.28	3.07	4.78	41.04	2.97	4.05
Days to maturity	13.12	20.57	3.35	4.19	63.82	5.96	5.51
Plant height (cm)	46.19	58.92	14.01	15.82	78.40	12.39	25.55
No. of pods plant^{-1}	106.31	116.38	29.81	31.19	91.34	20.30	58.69
Disease reaction to wilt (%)	12.35	20.03	31.44	40.02	61.69	5.68	50.86
Plant stand at harvest (%)	1.47	18.96	1.34	4.81	7.77	0.69	0.77
100–seed weight (g)	33.01	34.19	29.41	29.93	96.54	11.63	69.54
Grain yield plot^{-1} (g)	5952.95	17784.40	9.68	16.74	33.47	91.95	11.14

Table 3. Phenotypic and genotypic correlation coefficients between yield and its component characters in chickpea genotypes under late sown condition

Characters	Days to maturity	Plant height (cm)	No. of Pods per Plant	Disease reaction to Wilt (%)	Plant stand at harvest (%)	100-seed weight (g)	Grain yield plot^{-1} (g)
Days to 50% flowering	0.6210 ** 1.0650	0.2008 0.4210	0.0614 0.0286	0.1485 0.1786	-0.0984 0.3697	0.2338* 0.3665	-0.1525 -0.2287
Days to maturity		0.1582 0.1912	0.0052 0.0147	0.2000 0.2176	-0.0104 0.6772	0.1685 0.2133	-0.2278* -0.1902
Plant height (cm)			-0.2587* 0.3179	0.1579 0.2207	-0.2017 -0.3264	0.3903** 0.4558	-0.1860 -0.2565
No. of pods plant^{-1}				-0.1082 -0.1247	0.0424 0.3952	-0.1593 -0.1734	0.1189* -0.1073
Disease reaction to wilt (%)					0.0152 0.8204	0.1584 0.1645	-0.5324** -0.9470
Plant stand at harvest (%)						0.0099 0.0820	0.2198* -1.5602
100-seed weight (g)							-0.1103 -0.2333

* , ** Significant at 5% and 1% levels of significance, respectively

Table 4. Direct and indirect phenotypic effect of different characters towards seed yield in chickpea

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of pods plant^{-1}	Disease reaction to wilt (%)	Plant stand at harvest (%)	100-seed weight (g)	Correlation with seed yield plot^{-1}
Days to 50% flowering	0.0772	0.0479	0.0155	0.0047	0.0115	-0.0078	0.0180	-0.1525
Days to maturity	-0.0925	-0.1490	-0.0236	-0.0008	-0.0298	0.0015	-0.0251	-0.22788*
Plant height(cm)	-0.0200	-0.0157	-0.0995	0.0257	-0.0157	0.0201	-0.0388	-0.1860
No. of Pods per Plant	-0.0134	-0.0011	0.0563	0.2176	0.0235	-0.0092	0.0347	0.1189*
Disease reaction to Wilt (%)	-0.0775	-0.1045	-0.0825	0.0565	-0.5223	-0.0080	-0.0827	-0.5324**
Plant stand at harvest (%)	-0.0220	-0.0023	-0.0450	0.0095	0.0034	0.2232	0.0022	0.2198*
100-seed weight(g)	-0.0043	-0.0031	-0.0072	0.0030	-0.0029	-0.0002	-0.0186	-0.1103

Residual effect = 0.777; *, **= Significant at 5 and 1% levels of significance, respectively

(2038kg/ha), PBC 501(1920kg/ha) and CSJ (1907kg/ha) were identified as promising heat tolerant genotypes.

CONCLUSION

The above findings revealed that under heat stress high plant stand at harvest and number of pods per plant had showed the maximum contribution towards seed yield. On the basis of seed yield and its attributing traits Phule G-13110, RKG 11-155, PBC 501 and CSJ () were identified as promising heat tolerant genotypes. The identified promising heat tolerant genotypes may be used as donor in chickpea hybridization programme. Breeding strategies for improvement of yield potential in chickpea genotypes under heat stress would aim on selection of plants having higher number of effective pods, high plant stand at harvest and 100-seed weight and using these associated characters may be useful to the breeder to formulate appropriate breeding plans for selection of the genotype which tolerate high temperature conditions.

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Table 5. Mean performance of genotypes for quantitative characters in chickpea genotypes under heat stress condition

Genotypes	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of pods plant^{-1}	Disease reaction to Wilt (%)	Plant stand at harvest (%)	Plant type	100 seed weight (g)	Seed yield plot^{-1} (g)	Yield (kg ha^{-1})
CSJ-887	73	105	47	24	6.33	84.00	SE	14.31	917	1907
NBeG 507	74	106	62	23	10.67	81.67	SE	32.84	0800	1664
BG3067	71	104	53	25	14.00	90.67	E	25.75	0760	1581
RKG 13-155	76	110	42	37	4.00	90.00	SE	19.16	0980	2038
PG 158	75	114	58	27	19.00	93.00	SE	21.27	0637	1324
KPG59 (NC)	74	109	43	58	7.67	93.00	SE	20.68	0647	1345
H 12-62	72	105	62	41	11.67	88.67	SE	15.83	0770	1602
PBC 501	70	108	37	33	6.00	93.00	SE	17.74	0923	1920
JG24	77	113	59	22	12.66	93.67	SE	30.72	0750	1560
IPC 2012-49	79	114	56	43	12.66	91.67	E	21.45	0830	1726
PhuleG-13110	74	110	47	38	5.33	91.67	SE	27.63	1000	2080
GL 12003	73	108	54	32	15.00	90.33	SE	14.45	0783	1629
RKG 13-180	70	104	50	40	12.67	92.33	SE	24.22	0767	1595
PG186 (NC)	72	107	49	30	7.67	88.67	SE	18.27	0720	1498
JG 74315-14	71	105	44	26	12.00	89.67	SE	16.13	0850	1768
CSJ-884	69	102	37	31	14.00	92.33	SE	15.29	0827	1719
NDG 14-24	73	106	46	28	9.00	92.67	SE	22.65	0880	1830
H 12-55	72	105	35	52	13.00	88.00	SE	15.63	0833	1733
GNG 2304	70	104	43	32	10.33	91.67	SE	11.86	0753	1567
PhuleG0719-10	75	109	45	50	18.67	91.67	SE	24.98	0543	1130
GJG 1319	76	107	55	28	13.33	91.33	E	26.64	0737	1532
BG 3068	71	105	44	42	13.33	93.67	SE	13.19	0797	1657
BG372 (NC)	74	111	47	60	6.00	89.00	SE	12.91	0860	1789
NBeG 511	73	113	44	27	15.33	91.33	SE	22.70	0697	1449
GNG 2299	70	103	53	35	8.33	87.66	SE	13.03	0810	1685
RVSSG 38	74	112	45	28	12.33	89.33	SE	15.01	0840	1747
IPC 2012-98	71	105	54	26	6.67	91.67	E	17.02	0887	1844
GL 29098	80	116	47	23	13.67	90.33	SE	11.97	0727	1511
PBG 510	78	114	49	41	13.00	90.00	SE	23.32	0773	1609
Mean	73	108	49	35	11.18	90.44		19.53	0796	1656
CD(p=0.05)	4.4	4.5	5.8	5.20	4.53	–		1.78	177	37070
C.V.%	3.67	2.52	7.36	9.18	24.77	4.62		5.57	13.66	13.65

Plant type: S = spreading, SE = semi-erect and E = erect

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Spatial Distribution of Lead in Soils of Different Agro-climatic Zones of Jharkhand

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Abstract: Surface and profile samples were collected from different locations and topo-sequences covering three agro-climatic zones of Jharkhand viz. zone-IV (Baliapur, Jharia and Dhanbad), zone-V (Bagru, Pakharpat, Kisko and Lohardaga) and zone-VI (Moshabani, Jadugonda and Chandil). Total number of surface soil samples were 225 were examined. All the soil samples were analyzed by using standard procedure and prediction maps were prepared by ArcGIS 10.3 version. DTPA (Diethylene triamine penta acetic acid) extractable lead in zone-IV was 0.02-4.3 mg kg^{-1}; in zone-V 0.62-2.22 mg kg^{-1} whereas in zone-VI 0.48-2.7 mg kg^{-1} respectively. Total content of lead in zone-IV were 229-547 mg kg^{-1}; in zone-V 177-711 mg kg^{-1} whereas in zone-VI 173-662 mg kg^{-1} respectively. Higher amount of DTPA-extractable and total content of cobalt, nickel and lead was observed in lowland against the different topo-sequences. *S*tep wise multiple regression equations showed more impact of soil pH and organic carbon on extractable Pb than other soil parameters whereas in case of total Pb content, organic matter was important determining factor.

Keywords*:* Agro-climatic zone, Jharkhand, Lead, Soil

Heavy metals are natural components of the Earth's crust and cannot be degraded or destroyed. To a small extent they enter our bodies via food, drinking water and air. As trace elements, some heavy metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of the human body,. however, at higher concentrations they can lead to poisoning. Due to accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition, concentration of heavy metals rises to such a level that it becomes phytotoxic (Khan *et al*., 2008; Zhang *et al*., 2009). Soils are the major sink for heavy metals released into the environment by aforementioned anthropogenic activities (Kirpichtchikova *et al*., 2006).

A high metal concentration in one soil may not result in an adverse effect, whereas a lower concentration in another soil may result in a greater effect. So, the determinants of metal bioavailability must be understood if one is to predict the effect of a metal. Soil quality criteria must consider the bioavailability of metals (Peijnenburg *et al*., 1997). Such criteria can then be used to establish maximum tolerable levels of metals that can be accommodated in soil and as remediation standards.

It is a naturally occurring, bluish gray metal usually found as a mineral combined with other elements, such as sulphur (i.e., PbS, PbSO4), or oxygen (PbCO3), and ranges from 10 to 30mg kg^{-1} in the earth's crust (USDHHS, 1999). Lead(II) compounds are predominantly ionic (e.g., Pb2+, SO42−), whereas Pb(IV) compounds tend to be covalent (e.g., tetraethyl lead, Pb(C2H5)4).Ionic lead, Pb(II), lead oxides and hydroxides, and lead metal oxyanion complexes are the general forms of Pb that are released into the soil, groundwater, and surface waters. The most stable forms of lead are Pb(II) and lead-hydroxy complexes. Lead(II) is the most common and reactive form of Pb, forming mononuclear and polynuclear oxides and hydroxides (GWRTAC, 1997).Toxicity of lead occurred through the displacement of essential metals from their native binding sites or through ligand interactions. To have a physiological or toxic effect, most metal ions had to enter into the microbial cell. Many divalent metal cations (e.g. $Mn^{2+,}$ Fe^{2+}, Co^{2+}, Ni^{2+}, Cu^{2+} and Zn^{2+}) were structurally very similar and substitute each other and create disorder. (Nies, 1999; Bruins *et al*., 2000). Changes in their chemical forms (speciation) and bioavailability are, however, possible. The presence of toxic metals in soil can severely inhibit the biodegradation of organic contaminants (Maslin and Maier, 2000).

Jharkhand is comprising of three agro-climatic zones viz. Central and north-eastern plateau, Western plateau and South eastern plateau. Soils have been classified under the major soil orders of Entisol, Inceptisol and Alfisol. The state is popularly known for industries and metalliferous ores. Out of the several sources, industrial effluents, sewage and mines are major sources of heavy metals. Soil characterization would provide an insight into heavy metal speciation and bioavailability, attempt at remediation of heavy metal contaminated soils would entail knowledge of the source of contamination, basic chemistry, and environmental and associated health effects (risks) of these heavy metals. In the rapid pace of development, risk assessment is an effective scientific tool which enables decision makers to manage contaminated sites in a cost-effective manner while preserving public and ecosystem health (Zhao and Kaluarachchi, 2002). Keeping these views in mind, the present investigation was started to know spatial distribution of lead in different agro-climatic zones of Jharkhand.

MATERIAL AND METHODS

Geology, soils, agriculture, land use and climate of study area: The state having three agro-climatic zones viz. Central and north-eastern plateau i.e zone-IV (Baliapur, Jharia and Dhanbad), Western plateau i.e zone-V (Bagru, Pakharpat, Kisko and Lohardaga) and South eastern plateau i.e zone-VI (Moshabani, Jadugonda and Chandil), is popularly known for its coal mines, industries and metalliferous ores. Out of the several sources, industrial effluents, sewage and mines are major sources of heavy metals. Dhanbad, Jharia and Baliapur (zone-IV) were geologically comprised with Archean granites and gneisses. Three soil orders namely Entisols, Inceptisols and Alfisols were observed in these areas. Important trees were *Shorea robusta, Dalbergia sissoo, Gmelina arborea, Diospyros melanoxylon, Madhuca longifolia, Semecarpus anacardium,* and *Thunder Mountain* etc. The major cereal crops of the area were paddy, maize and wheat. The district is in the east of the state and nearer to Bay of Bengal and also have less elevation. The area provides climatic conditions slightly different from the higher plateau area of the state. During winter season temperature ranges from 8.4 to 34˚C and during summer season temperature ranges from 13.3 to 45.5˚C. During rainy season the temperature ranges from 15 to 36˚C. Average annual rainfall is 1270 mm.

Bagru, Kisko, Pakharpat and Lohardaga (zone-V) were geologically comprised with Archean granites and gneisses. In the uplands considerable thickness of laterite of Pleistocene age was found in the granite in the Granite and Gneisses tracts. Alluvium of the recent to sub-recent age was found in the river valley. Three soil orders namely Entisols, Inceptisoils and Alfisols were observed in these areas. The most important mineral was bauxite. Other minerals were feldspar, fire clay and china clay and had less economic importance. The main crops were rice followed by millets (marua, gondli and maize), pulses, wheat, oilseed (sarguja and groundnut) and vegetables. Forest areas covered majority of *Shorea robusta, Madhuca longifolia, Syzygium cumini* and *Azadirachta indica* vegetation. The district enjoy healthy, pleasant climate throughout the year. The annual average temperature is 23˚C, the highest temperature goes to 36˚C in summer and lowest of 10˚C in winter. The district receives annual rainfall of 1000 to 1600 mm and it increases from west to east.

Mosabani, Jandugonda and Chandil (zone-VI) were geologically comprised with granites gneiss and schist. Formation of igneous, sedimentary and metamorphic rocks of Dharwarian period was found at places. Three soil orders namely Entisols, Inceptisoils and Alfisols were observed in these areas. Due to varied landscape, the coverage of forest was found in different proportion in different areas. The sal trees were dominant in this area. Other trees were *Gmelina arborea, Mangifera indica, Syzygium cumini, Artocarpus heterophyllus, Millettia pinnata*, Bastard Teak etc. Plain areas were quite productive for agriculture and farmers were cultivated vegetables and seasonal fruits apart from paddy. The district receives an annual rainfall of 1500 mm. and most of it occurs during the rainy season. Mean annual temperature is above 26˚C. The temperature ranges from 16˚C in winter month to 44˚C in summer months.

Soil analysis: With a view to achieve the objective of the research (characterization of lead in soil), all together 225 surface (0-20cm depth) soil samples were collected from different places and topo-sequence i.e. upland, midland and lowland from three agro-climatic zones namely (i) Central and north-eastern plateau i.e zone-IV (Jharia), (ii) Western plateau i.e. zone-V (Bagru) and (iii) South eastern plateau i.e. zone-VI (Moshabani) of Jharkhand. Jharia (zone-IV) was coal mines areas. Bagru, (zone-V) was bauxite mines areas. Moshabani (zone-VI) area was dominated with copper and uranium mines. The soil samples were analysed for various physico-chemical properties, viz. organic carbon, pH, EC (1:2.5:: soil: water), CEC, CaCO3, clay and silt content, by using standard laboratory procedures. The available content of Ni in soil samples were extracted with a solution of 0.005 M DTPA -0.01 M CaCl2 -0.1 M tri-ethanol amine (adjusted to pH 7.3) as outlined by Lindsay and Norvell (1978). Total content was determined after digestion of soil with perchloric-hydrofluoric acids (Hesse, 1994). The concentrations of nickel were measured with the help of atomic absorption spectrophotometer. Multiple linear regression equations were computed between different forms (available and total) of metals and soil properties. Step-wise multiple regression analysis was computed by adopting standard statistical procedures (Panse and Sukhatme, 1961).

Predictability of available and total content of Pb:

Multiple regression equations were estimated through step wise method to analyse the relative impacts of different factors responsible for determining the content of different heavy metals in the soils. In the process of regression analysis, the dependent variables were categorised as Available Pb, and Total Pb. The independent variables or the explanatory variables were recognized as X_1 (pH), X_2 (EC), X_3 (Organic carbon), X_4 ($CaCO_3$), X_5 (Silt), X_6 (Clay) and X_7 (CEC). The predicting equations of the heavy metals were denoted as:

$Y= a + b_1X_1 + b_2X_2 + b_3X_3$ ....

Where

Y= Dependent variables.

X_1, X_2, X_3, X_4 .... independent variables and a, b_1, b_2, b_3, b_4, b_5, b_6 and b_7 are regression coefficients to be estimated from the predicted models.

Many equations in different soil profiles had higher coefficients of multiple determinations (R^2) with insignificant coefficients selected through the step wise methods. However considering the facts that presence of insignificant coefficients in an equation, suppress the size and level of significance of statistically significant coefficients, it was held that even at the cost of marginal reduction in the value of R^2, only those equation which had significant coefficients in the right hand side of an equation are being selected for discussion. Using this statistically supported process of selection of predicting equations, the following regression equations were selected at 5% level of significance for different soil profiles for different heavy metals in the soils analysed.

RESULTS AND DISCUSSIONS

Distribution of available and total content of lead in soils: Systematic survey for delineation of soil lead (Pb) was initiated by few workers. The analyses of 225 collected surface soil samples of different topo-sequence i.e. upland, midland and lowland from Baliapur, Jharia and Dhanbad (Central and north-eastern plateau i.e zone-IV), Bagru, Pakharpat, Kisko and Lohardaga (Western plateau i.e. zone-V) and Moshabani, Jadugonda and Chandil (South eastern plateau i.e. zone-VI) of Jharkhand were completed. This soil samples belonging to soil order Entisols, Inceptisols and Alfisols. DTPA-extractable lead in upland soils of areas under zone IV, V and VI with a mean of 0.64^{1}, 1.25 and 1.13 mg kg^{-1} respectively (Table 1). In midland soils of areas under zone IV, V and VI, with a mean of 1.66 , 1.08 and 1.25 mg kg^{-1} respectively whereas in lowland soils, with mean of 1.92 mg kg^{-1}, 1.64 mg kg^{-1} and 1.69 mg kg^{-1} respectively. Overall DTPA-extractable lead under areas of zone IV, V and VI varied from 0.02-4.3, 0.62-2.22 and 0.48-2.7 mg kg^{-1} respectively. Critical study revealed that mean value of DTPA-extractable lead in lowland soils were higher than midland followed by upland except zone-V. Higher amount was observed due to topography of the areas which was related with slope, drainage and deposition of clay particles (Mitsimbonas *et al*., 1998). In midland of zone-V, DTPA-extractable lead decreased in compare to upland due to antagonistic effect of organic carbon value and soil pH value (Mitsimbonas *et al*., 1998).

Total content of lead in upland soils of areas under zone IV, V and VI with a mean of 300.28, 326.24 and 388.8 mg kg^{-1}, respectively (Table 1). In midland soils of areas under zone IV, V and VI mean lead value of 408.76 , 388.16 and 410.96 mg kg^{-1}, respectively whereas in lowland soils, mean of 431.76 , 409.52 and 511.44 mg kg^{-1} respectively. Total lead under areas of zone IV, V and VI varied from 229-547, 117-711 and 173-662 mg kg^{-1}, respectively. The observation revealed that mean value of total content of lead in lowland soils were higher than midland followed by upland, it might be due to land slope and organic matter content which had a major influence on their content. Similar results were also observed by (Mitsimbonas *et al*., 1998).

The 3D representation and contour plots of available Pb and total Pb in IV evidently identify, categorize and quantify the specific areas where the enrichment of Pb is higher. The available Pb was observed low in the centre as 3.0 mg kg^{-1} (Fig. 1a). Similarly the total Pb concentration was observed very low in those regions. Similarly in the zone V it was observed that soils have low of available Pb in majority of area whereas the total Pb has slightly less values as compared to Zone IV. In the agro-climatic zones VI the total

Table 1. Total and DTPA-extractable Pb contents (mg kg^{-1}) in soils of different topo-sequences (agro-climatic zones) of Jharkhand

Zone	Total Pb		Available Pb	
	Range	Mean	Range	Mean
		Upland		
iv	229-412	300.28	0.02-1.64	0.64
v	177-560	326.24	0.7-2.22	1.25
vi	173-650	388.80	0.84-1.56	1.13
		Medium land		
iv	302-503	408.76	0.7-3.66	1.66
v	203-621	388.16	0.62-1.90	1.08
vi	278-653	410.96	0.86-1.64	1.25
		Lowland		
iv	308-547	431.76	0.74-4.3	1.92
v	221-711	409.52	1.06-2.1	1.64
vi	346-662	516.48	0.48-2.7	1.69

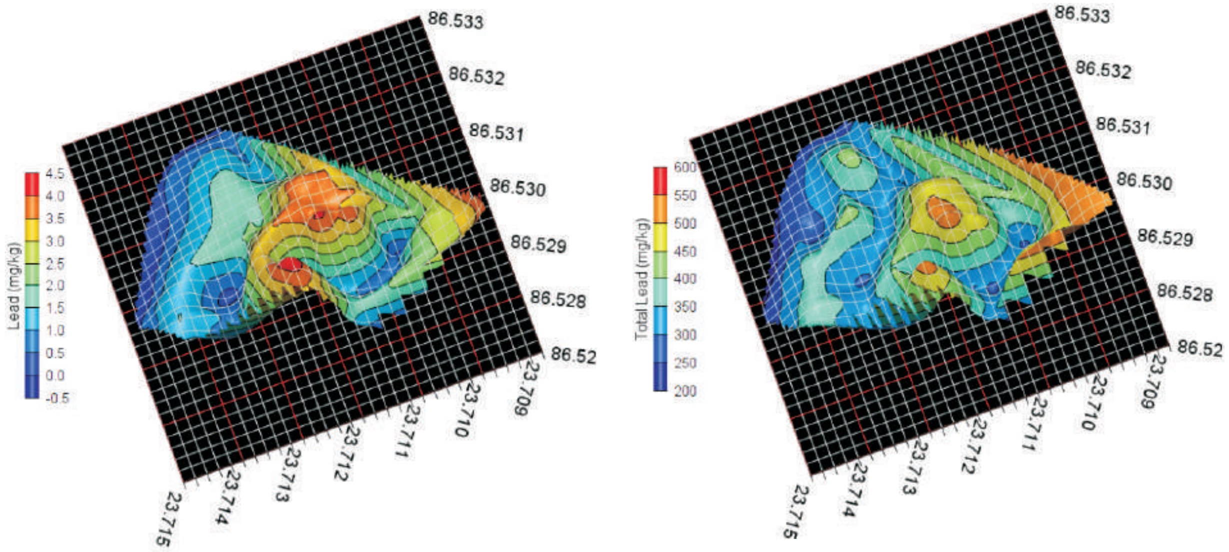

Fig. 1a. 3D representation of available and total Pb content in Agro-climatic zones IV

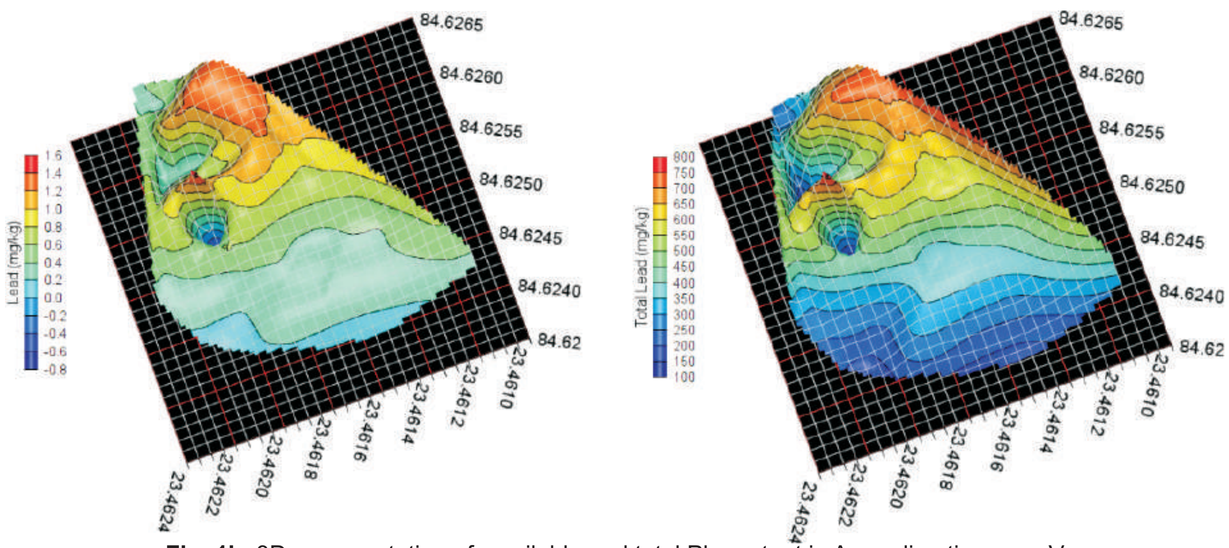

Fig. 1b. 3D representation of available and total Pb content in Agro-climatic zones V

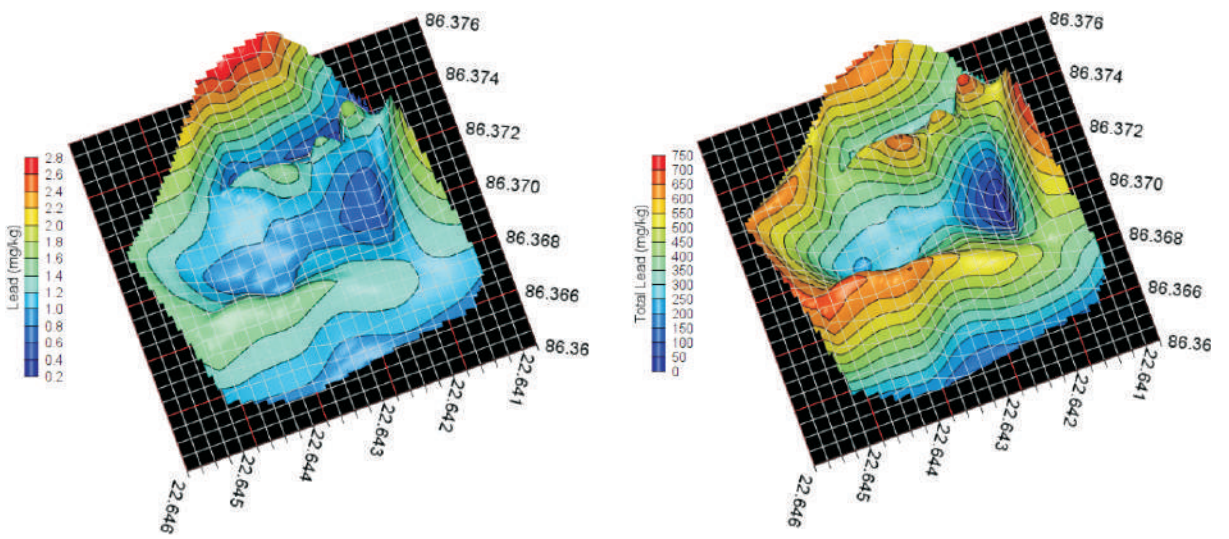

Fig. 1c. 3D representation of available and total Pb content in agro-climatic zones VI

and available Pb content is illustrated in Fig 1c which shows similar patterns as Zone V.

Relationship between soil characteristics and lead content*:* High significant and negative correlations were observed (Table 2) with available lead vs pH and available lead Vs $CaCO_3$. Available lead was significantly and positively with organic carbon and clay . It did not show any significant relationship with EC, silt , sand and CEC . These results consent with the work of Garg and Totawat (2005), and Singh and Singh (1994). Soil pH of the soils had significant negative correlation with total content of lead . While relationship between total lead vs organic carbon was highly positive and significant whereas clay, EC, silt and CEC had positive non-significant correlation. Correlation coefficient (r) values of $CaCO_3$ and sand were non-significant and negative. The results agree with the findings of Kumar *et al.* (2010). Soil pH was highly significant and negatively correlated with DTPA-extractable and total content of heavy metals, which suggest that increase in soil pH within soil profiles decrease the amount of available Pb. Different forms of heavy metals (available and total) were correlated with organic carbon and found highly significant positive correlation. Such findings in the present study suggest the dependence of available and total content of Pb largely on the organic matter content.

Table 2. Correlation coefficient (r) between soil properties and lead in soil samples

Soil Parameters	DTPA−extractable Pb	Total Pb
pH	-0.486**	-0.363*
EC	0.030	0.035
OC	0.641**	0.555**
$CaCO_3$	-0.504**	-0.242
Silt	0.076	0.146
Clay	0.327*	0.114
Sand	-0.192	-0.142
CEC	-0.155	0.007

* and ** significant at and 1 percent level of significance

Effect of soil characteristics on predictability of available and total content of Pb: The size of the co−efficient of the multiple determinations (R^2) indicated that 48.09 percent of available lead was determined by pH and organic carbon (Table 3). In case of total content of lead, they were determined by organic carbon up to 30.85%. As far as the prediction of available lead was concerned, it had been observed that it was determined by X_1 (pH) and X_3 (organic carbon) components of soils. Whereas organic carbon had a positive association with available lead, the pH component had negative impact on available lead of soils. One unit increase in organic carbon could brought about 0.15 unit increase in available lead. On the other hand, one unit change in pH component reduced available lead by about 0.168 units. The prediction equation for total content of cobalt, nickel and lead had indicated that they were determined by a solidityory factor i.e. organic carbon which has positive impact on the total content of lead. Again in a quantitative way it could be inferred that one unit increase in organic carbon increased the total lead by a greater proportion of 62.58 units.

Table 3. Predictability of available and total content of Pb with relation to soil characteristics

	Stepwise multiple regression equation	R^2 X 100
Available Pb	$Y = 1.617 – 0.168X_1$** + $0.1505X_3$** (0.0651) (0.031)	48.09
Total Pb	$Y = 208.995 + 62.58X_3$** (13.11)	30.85

Figure in parenthesis indicates S. E. of coefficient
* and ** Significant at 5 and 1 percent level of significance,
X_1, X_2, X_3, X_4, X_5, X_6 and X_7 indicate pH, EC, Organic carbon, $CaCO_3$, silt, clay and CEC, respectively

CONCLUSIONS

DTPA −extractable lead in zone-IV was 0.02-4.3 mg kg^{-1}; in zone-V 0.62-2.22 mg kg^{-1} whereas in zone-VI 0.48-2.7 mg kg^{-1} respectively. The magnitude of DTPA-extractable nickel in lowland soils was higher than midland followed by upland due to soil drainage and clay content which affect their status. Total content of lead in zone-IV were 229-547 mg kg^{-1}; in zone-V 177-711 mg kg^{-1} whereas in zone-VI 173-662 mg kg^{-1} respectively. However, higher amount of total content of Pb was noted in lowland topo-sequence with a mean value of 431.76 in zone-IV; 409.52 mg kg^{-1} in zone-V and 516.48 mg kg^{-1} in zone-VI respectively. The study of step wise multiple regression equations showed more impact of soil pH and OC on available content of lead than other soil parameters whereas in case of total content, organic matter was important determining factor.

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Estimation of Crop Water Requirement Using CROPWAT 8.0 Model For Bina Command, Madhya Pradesh

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Abstract: Understanding of crop water requirement (CWR) is essential for better irrigation practices, irrigation scheduling and efficient use of water. In the present study reference evapotranspiration (ET_0), crop water and net irrigation requirements for *rabi* crops were estimated for Bina command situated in Sagar district of Madhya Pradesh, India. The average daily reference evapotranspiration estimated by the Penman−Monteith method in Bina command is 4.62 mm/day. By using crop coefficient approach *the* crop water requirements of wheat, gram−pulses and mustard were determined as 349.8, 304.1 and 316.9 mm respectively. It was estimated that the total crop water and net irrigation demands in Bina command were 232.45 MCM and 212.27 MCM respectively. The present study is useful for effectively planning and management of irrigation water in Bina command area.

Keywords: CROPWAT 8.0; Crop water requirements; Net irrigation ; Penman−Monteith method; Crop evapotranspiration

Water is becoming precious and scarce due to its increasing demand in agriculture and other sectors. Increased water demand brought about by rapid population growth has created the necessity to increase food production through the expansion of irrigation and industrial production to meet basic human needs. Agriculture is the largest (81%) consumer of water in India and hence the most efficient use of water in agriculture needs to be a top most priority (Surendran *et al.,* 2013). A better understanding of the intricate interactions between climate, water and crop growth needs to be a priority area in India. Water is an essential input for crop production so accurate planning and delivery of this precious resource is necessary. For effective planning of this resource, accurate information of evapotranspiration, crop water requirement and net irrigation requirement is needed. The water requirement of crop varies widely from crop to crop and also during the entire crop growth period of an individual crop. The scientific information on crop water requirement is essential for efficient irrigation scheduling, water balance, canal design capacities, regional drainage, water resources planning, and reservoir operation and to assess the potential for crop production. Kamel *et al*. (2012) revealed that optimal irrigation scheduling requires accurate estimates of crop evapotranspiration (ET_c). The net irrigation requirement needs to be determined for proper design of the irrigation system and for the establishment of the irrigation schedules. The objective of this study is to compute the crop water (agricultural water demand) and net irrigation requirements of major Rabi crops in Bina command using long term climatic data by Penman−Monteith method (FAO, 1998) using CROPWAT 8.0 model.

MATERIAL AND METHODS

Description of study area: The Bina command area selected for the study is located at the longitude of 78° 02′ to 78°25′ E and latitude of 23°47′ to 24°27′ N at the altitude of 481 m above mean sea level in Sagar district of the Madhya Pradesh. The Bina command comes under Survey of India (SOI) toposheet NO. 54L3, 54L4, 54L7, 54L8 & 55I5 with 1:50,000 scale. Proposed Chakarpur dam will be the major source in this command which is situated on Bina river. The area experiences sub−humid sub−tropical monsoon type of climate, characterized by hot summers (41 ºC) and mild winters (12 ºC). The command area receives an average annual rainfall of 1156.5 mm, out of which more than 80 percent rainfall contributes during monsoon season (June–October).The direction of the prevailing wind is generally south−west during the period of April to July, while it is north −west during September to November. The general topography of command area is plain having gentle slopes. Soils of the Bina command area fall under the broad group of deep and medium black soils. The area having different sub command like as Bina main canal, Khurai branch canal, Dhikua−Hardua sub branch canal, Khurai and Kanjia sub branch canal (Fig. 1., Table 1).

Land use/land cover: Land use/land cover was developed by supervised classification technique with maximum likelihood algorithm for the classification of digital data of IRS−P6 (LISS III) satellite in which an area of a group of pixels that belongs to one or more categories of specific land use and

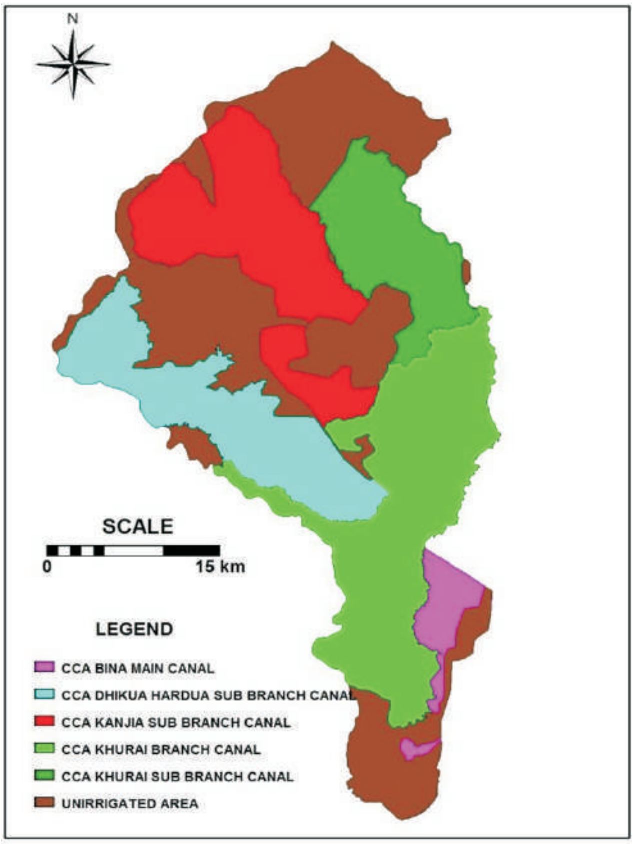

Fig. 1. Culturable command area of different canal/branch in Bina command area

Table 1. Distribution of CCA of different canals in the command area

Canal command	GCA (ha)	CCA (ha)	CCA coverage (ha)
Bina Main canal	3351.48	3016.34	2859
Khurai Branch canal	23270.54	20943.49	20544
Dhikua-Hardua Sub Branch canal	18368.19	16531.37	16548
Khurai Sub Branch canal	12894.62	11605.16	11475
Kanjia Sub Branch canal	20649.72	18584.75	18616
Total	78534.55	70681.11	70042

land cover was classified. Verified land use map gave broadly seven classes; namely, agriculture1, agriculture2, current fallow, barren land, dense forest, open forest and water body (Fig 2). The agriculture1 is the most dominant land use. Wheat is taken as the major crop in agriculture1 (37600 ha) in Bina command out of which 29116 ha area is under irrigation. The agriculture2 is the second most dominant land use covering an area of 37523 ha out of which 28429 ha area is under irrigation. Gram –pulses, wheat and mustard are taken as major crops in agriculture2, which are 73, 20 and 7 percent respectively. The area covered by the fallow land is 31309 ha.

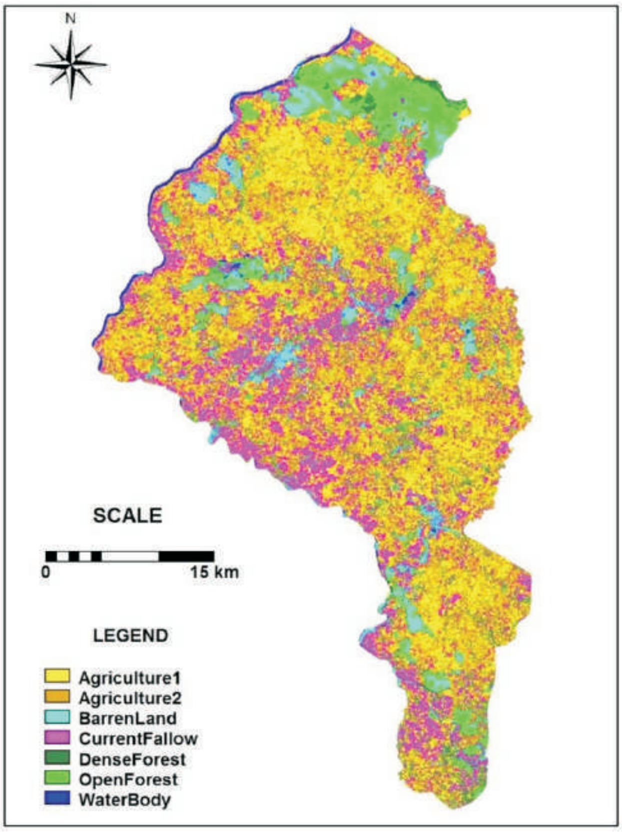

Fig. 2. Land use/land cover map of Bina command

Wheat, gram –pulses and mustard are taken as major crops in current fallow, which are 56, 38 and 6 percent respectively.

Crop distribution: The maximum area 41799 ha covered under wheat crop and under mustard crop it was minimum (2739 ha), whereas 25501 ha area is covered by gram–pulses crops. The Khurai branch canal covered the maximum area of wheat, gram-pulses and mustard, which is 32.52, 32.63 and 32.65 per cent, respectively, whereas the Bina main canal covered the minimum area of these crops, which is 4.48, 5.05 and 4.80 percent respectively (Table 2).

Reference evapotranspiration: The reference evapotranspiration ET_0 was estimated by FAO Penman – Monteith method (equation 1), using decision support software CROPWAT 8.0 model developed by FAO.

$$ET_0 = \frac{0.408\,\Delta(R_n - G) + y\,\dfrac{900}{T+273}U_2(e_a - e_d)}{\Delta + y(1 + 0.34U_2)}$$

Where,

ET_0: reference crop evapotranspiration, mm/d; R_n: net radiation at the crop surface, MJ/(m^2·d); G: soil heat flux, MJ/(m^2·d); T: average air temperature, ºC; U_2 : wind speed measured at 2 m height, m/s; (e_a–e_d): vapor pressure deficit, kPa; Δ: slope of the vapor pressure curve, kPa/ºC; γ:

psychrometric constant, kPa/ ºC. The FAO CROPWAT model incorporates procedures for reference crop evapotranspiration and crop water requirements. In this study a long term recorded (1972 –2007) meteorological data used for calculation of ET_0 were latitude, longitude and altitude of the station, maximum and minimum temperature (°C), maximum and minimum relative humidity (%), wind speed (km/day) and sunshine hours. ET_0 was calculated for every ten days (defined as "decade" by FAO) and then cumulated to monthly data.

Crop data: The major cultivated *rabi* crops in the study area are wheat, gram-pulses and mustard. The salient details of crops like crop coefficient, the length of growth stages, yield response factor, crop height and other related information were considered for the study area as per guide for estimating irrigation water requirements, Ministry of Irrigation, Govt. of India (1984) and FAO – Irrigation and Drainage paper -24 & 56.

Effective rainfall: Rainfall data was collected from Bina meteorological station. In order to estimate the effective rainfall, USDA Soil Conservation Service formula (equation 2 and 3) has been used.

$$P_{eff} = \frac{P_{tot} \times (125 - 0.6 P_{tot})}{125} \quad \text{for } P_{tot} <= (\frac{250}{3}) \text{ mm} \quad \text{…. (2)}$$

$$P_{eff} = \frac{125}{3} + 0.1 \times P_{tot} \quad \text{for } P_{tot} > (\frac{250}{3}) \text{ mm} \quad \text{…. (3)}$$

Where,

P_{eff} = Effective rainfall (mm); P_{tot} = Total rainfall (mm)

Crop eEvapotranspiration (ET_c): The crop evapotranspiration was calculated from FAO Penman-Monteith approach in CROPWAT 8.0 model. The crop evapotranspiration has was for different crop growth stages namely, initial stage, development stage, growth stage and the final stage on the basis of ten-daily. The total crop evapotranspiration is arrived at by summing up the ten-daily crop evapotranspiration over the entire crop period.

$ET_C = K_C \ ETC_0$ …. (4)

Where,

ET_c is crop evapotranspiration; K_c is crop coefficient; ET_0 is reference evapotranspiration.

Net Irrigation Requirement: CROPWAT 8.0 model.

$IR_n = ET_c - (P_e + G_e + W_b) + LR$ …. (5)

Where,

IR_n = Net irrigation requirement (mm), ET_c = Crop evapotranspiration (mm), P_e = Effective dependable rainfall (mm), G_e = Groundwater contribution from water table (mm), W_b = Water stored in the soil at the beginning of each period (mm), LR = Leaching requirement (mm).

Table 2. Canal command wise crop distribution in Bina command

Canal command	Wheat (ha)	Gram-pulses (ha)	Mustard (ha)
Bina main canal	1873.243	1287.220	131.642
Khurai branch canal	13594.913	8321.975	894.666
Dhikua-Hardua sub branch canal	8194.732	5724.293	633.974
Khurai sub branch canal	6822.581	3959.846	415.493
Kanjia sub branch canal	11314.283	6208.547	664.020
Total	41799.75	25501.88	2739.80

RESULTS AND DISCUSSION

Reference evapotranspiration: The reference evapotranspiration (ET_0) varied from 2.6 mm/day to 7.79 mm/day with an average value of 4.62 mm/day (Fig 3). The lowest ET_0 was in December while highest during May. The low value of ET_0 during the winter season implies that the rate of ET_0 is directly proportional to the solar radiation. This is because for evapotranspiration to take place, energy is required to change the state of the molecules of water from liquid to vapour. This energy is provided by solar radiation incident on the Earth's Surface. It could be observed that among the climatic factors affecting ET_0, solar radiation and temperature are the most important factors (Rim, 2004).

Effective rainfall: The total average effective rainfall is 610.3 mm which is 52.77 per cent of the average annual rainfall (1156.5 mm).The average effective rainfall was maximum in August (166.4 mm) and in April it was minimum (0 mm) (Fig. 4).

Crop water and net irrigation requirement: CROPWAT 8.0 model is used in order to estimate the water requirements for each crop using evapotranspiration, crop coefficient, effective rainfall and crop's data (Table 3). Similar trend was found for water requirement of wheat and gram during initial to mid-growth stage. However, for the mustard crop, the peak water requirement was observed in between mid and late season stage. Crop evapotranspiration (ET_c) and the crop water requirement for wheat varied from 0.90 – 4.27 mm/day and 5.70 –43.0 mm/dec respectively. In case of gram-pulses it was varied from 1.22 –4.27 mm/day and 7.90 to 43.0 mm/dec and for mustard varied from 0.74 – 3.85 mm/day and 4.10 – 42.40 mm/dec respectively. From the results, it reveals that the net irrigation requirement was maximum for wheat (319.90 mm) followed by mustard (285.20 mm). Whereas in gram –pulses it was minimum (277.40 mm). In decade (10 daily) wise the net irrigation requirement for wheat varied from 4.50 – 41.10 mm/dec, gram 6.70 –41.10 mm/dec. and for mustard varies from 3.8 – 40.5 mm/dec. The higher value of this requirement shows that the availability of effective rainfall is low.

Table 3. Crop water and net irrigation requirements of wheat, gram–pulses and mustard

Months	Decade (10–Daily)	Stages			Crop Coefficient (K_c)			ET_c(mm/day)			ET_c(mm/dec)			Effective rainfall (mm/dec)			Irrigation Requirement (mm/dec)		
		Wheat	Gram–pulses	Mustard	Wheat	Gram–pulses	Mustard	Wheat	Gram–pulses	Mustard	Wheat	Gram–pulses	Mustard	Wheat	Gram–pulses	Mustard	Wheat	Gram–pulses	Mustard
October	2			Init			0.21			0.83			4.10			0.40			3.80
	3			Init			0.21			0.78			8.60			1.40			7.20
November	1			Dev			0.21			0.74			7.40			3.50			3.90
	2	Init	Init	Dev	0.29	0.4	0.38	0.95	1.31	1.26	5.70	7.90	12.60	1.40	1.40	2.40	4.50	6.70	10.20
	3	Dev	Init	Dev	0.29	0.4	0.65	0.9	1.22	1.99	9.00	12.20	19.90	2.20	2.20	2.20	6.70	10.0	17.70
December	1	Dev	Dev	Dev	0.51	0.45	0.92	1.42	1.25	2.55	14.20	12.50	25.50	2.20	2.20	2.20	12.00	10.30	23.20
	2	Dev	Dev	Mid	0.86	0.69	1.13	2.15	1.72	2.84	21.50	17.20	28.40	2.00	2.00	2.00	19.50	15.20	26.40
	3	Mid	Dev	Mid	1.13	0.95	1.15	3.05	2.57	3.11	33.60	28.20	34.20	1.80	1.80	1.80	31.80	26.40	32.40
January	1	Mid	Mid	Mid	1.15	1.14	1.15	3.37	3.35	3.37	33.70	33.50	33.70	1.30	1.30	1.30	32.40	32.20	32.40
	2	Mid	Mid	Mid	1.15	1.15	1.15	3.55	3.55	3.55	35.50	35.50	35.50	1.00	1.00	1.00	34.60	34.60	34.60
	3	Mid	Mid	Late	1.15	1.15	1.13	3.91	3.91	3.85	43.0	43.0	42.40	1.90	1.90	1.90	41.10	41.10	40.50
February	1	Mid	Mid	Late	1.15	1.15	0.88	4.27	4.27	3.27	42.70	42.70	32.70	3.40	3.40	3.40	39.30	39.30	29.30
	2	Late	Late	Late	1.06	1.01	0.56	4.27	4.05	2.27	42.70	40.5	22.70	4.40	4.40	4.40	38.20	36.10	18.30
	3	Late	Late	Late	0.84	0.65	0.29	3.70	2.87	1.30	29.60	23.00	9.10	3.80	3.80	3.30	25.80	19.20	5.30
March	1	Late	Late		0.61	0.41		2.95	1.97		29.50	7.90		3.20	1.30		26.30	6.30	
	2	Late			0.44			2.28			9.10			1.10			7.70		
							Total				349.80	304.10	316.80	29.70	26.70	31.20	319.90	277.40	285.20

Table 4. Different canal command-wise crop water and net irrigation demands of Bina command

Canal Command	CWR (MCM)				NIR (MCM)			
	Wheat	Gram -pulses	Mustard	Total	Wheat	Gram–pulses	Mustard	Total
Bina main canal	6.55	3.91	0.412	10.88	5.99	3.57	0.38	9.94
Khurai branch canal	47.56	25.31	2.83	75.70	43.49	23.09	2.55	69.13
Dhikua-Hardua sub branch canal	28.67	17.41	2.01	48.08	26.21	15.88	1.81	43.90
Khurai sub branch canal	23.87	12.04	1.32	37.22	21.83	10.98	1.18	34.00
Kanjia sub branch canal	39.58	18.88	2.10	60.56	36.19	17.22	1.89	55.31
		Grand Total		232.45				212.27

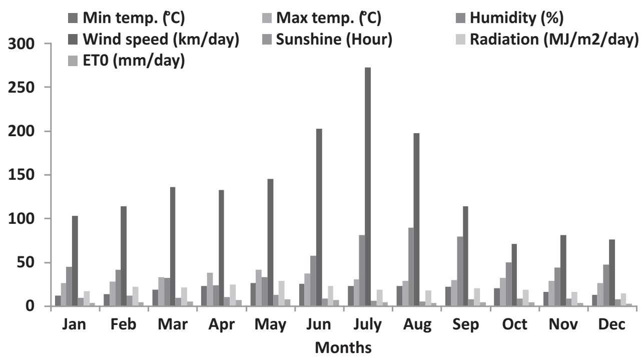

Fig. 3. Climate and reference evapotranspiration (ET_0) at Bina

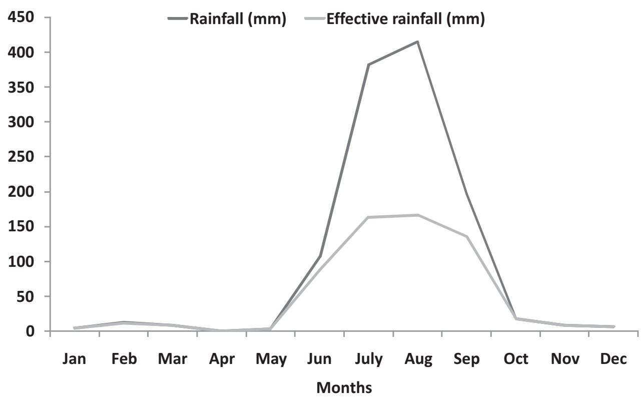

Fig. 4. Monthly average effective rainfall of Bina command

Canal command-wise crop water and net irrigation demands: The total crop water and net irrigation demands in Rabi for the Bina command which was 232.45 MCM and 212.27 MCM respectively (Table 4). The Khurai branch canal has maximum crop water requirement (75.70 MCM) and net irrigation requirement (69.13 MCM) in the Bina command because it covers the larger area. While the minimum crop water and net irrigation demands were found to be 10.88 and 9.94 MCM respectively in Bina sub command.

CONCLUSION

Understanding of crop water requirement (CWR) is essential for better irrigation practices, irrigation scheduling and efficient use of water. In the present study crop water and net irrigation requirements for *rabi* crops were estimated by using FAO – CROPWAT 8.0 model for Bina command area situated in Sagar district of Madhya Pradesh, India. The information generated can be used to supply an appropriate amount of irrigation water at different canal command of the study area as per the actual crop water demand.

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Chlorophyll Stability: A Better Trait for Grain Yield in Rice under Drought

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Abstract: The present work aimed at elucidating some of the drought sustaining characters that gives direct impact on grain yield. In the study, 8 genotypes were induced to drought stress conditions. The genotypes were evaluated in terms of chlorophyll contents (Chl a, Chl b and Total Chl), Chl a/b ratio, Chl stability, expression of antioxidant enzymes, generation of reactive oxygen species and grain yield. Significant variation for the chlorophyll a/b ratio was observed revealing variation in the activity of chlorophyll synthesizing mechanism among genotypes when exposed to drought stress. Among the genotypes studied, significant differences in chlorophyll stability index (CSI) were observed between control and drought stressed plants. BRR-0028 showed the highest CSI with higher yield irrespective of less chlorophyll content. Increased activities of antioxidant enzymes like peroxidise (POD), catalase (CAT) and superoxide dismutase (SOD) scavenging reactive oxygen species i.e. hydrogen peroxide and superoxide anion in the genotypes with higher CSI was observed. Therefore, CSI is an indicative of the maintenance of photosynthetic pigments under drought and is more dependent parameter for drought tolerance than chlorophyll content. The CSI showed significant (r = 0.804**) positive correlation with the grain yield. Therefore, chlorophyll stability index has paved a way to an advantageous parameter for screening tolerant rice genotypes to obtain better yield under drought condition.

Key Words: Chlorophyll stability, Drought, Rice, Antioxidant enzyme, Yield

Plants are continually under the threat due to adverse environmental conditions. Among them, drought has been identified as the single most critical threat to the world food security (Farooq *et al*., 2009), and one of major factors inhibiting photosynthesis, decreasing growth and crop loss, reducing average yields for most major crop plants by more than 50% (Bray *et al*., 2000; Wang *et al*., 2003). In Asia, around 130 million ha of paddy are annually affected by drought, thus limiting rice production worldwide (Rajiv *et al*., 2010; Rahimi *et al*., 2013). Global climate change affects a variety of factors associated with drought and extreme drought land area is likely to increase from 1-30 % by 2100 (Lijuan Miao *et al*., 2015). Therefore, to facilitate the selection or development of rice genotypes that not only adapt to the drought conditions but also obtain better yield, a thorough understanding of the various traits that govern the yield of rice under water stress condition is a prerequisite. A recent review considered that yield improvement in last few decades is due to increasing harvest index by modifying canopy structure. Further, it is suggested that future increases in yield would come from photosynthetic efficiency. Several components of photosynthesis were examined for crop yield. Amongst all, leaf chlorophyll is one significant indicator in determining yield (John *et al*., 2014). Chlorophyll being the most important photosynthetic pigment plays vital role in regulating crops yield. However, chlorophyll is quite delicate, not very stable and easily affected by abiotic stresses. Both chlorophyll a and b are very much prone to soil drying anddrought stress variously altered chlorophyll contents. These alterations in amount of chlorophylls depend on edaphic and climatic factors. In addition plant species and position of leave affect the amount of chlorophyll (Gond *et al*., 2012). There have been many studies that reported on positive correlation between chlorophyll contents, photosynthetic rate and grain yield in different crops like wheat (Kabanova and Chaika, 2001), cotton (Karademir *et al*., 2009). But in maize chlorophyll had little direct effect on grain yield (Wang *et al*., 1999). In support to this, differential correlation between reduction in chlorophyll concentration and grain yield are reported in other crops. Semiha and Huseyin(2007) revealed the lowest leaf cholorophyll content as not a sign of poor yield in dry bean (*Phaseolus vulgaris* L.). The study on traditional rice (*Oryza sativa* L.) genotypes of Assam by Chutia and Borah, 2012, reported that water stress effects on leaf growth and chlorophyll content but not the grain yield.

The reduction in chlorophyll content may occur due to stress-induced impairment in pigment biosynthetic pathways or in pigment degradation, loss of the chloroplast membrane, and increased lipid peroxidation thus resulting in generation of reactive oxygen species (ROS) (O_2, H_2O_2, OH), which are potentially dangerous under drought stress conditions (Reddy *et al*., 2004). However, plants have its own defence mechanism that ROS detoxification can be evolved at enzymatic and non enzymatic defence systems. Some antioxidant enzymes are POD, CAT, SOD that scavenges ROS. The degrees to which the activities of antioxidants enzymes and the amount of antioxidants are elevated under drought stress varies among several plant species and even differ between two cultivars of the same species as reported by many under different stress conditions. The CSI is another important index for screening of genotypes for abiotic stresses. Significant variation and higher value for CSI indicating rice tolerance for salt stress had been reported (Madhan Mohan *et al*., 2000). In addition, the positive and significant association between grain yield and CSI was further suggested by Raja Babu *et al*., 2005. The parameters viz., total chlorophyll content, chlorophyll stability Index, relative water content, proline accumulation, and protein synthesis are sufficient enough to provide reliable laboratory screening indictors to screen for drought tolerance in rice breeding programmes (Deivanai *et al*., 2010). Yield is a complex quantitative trait, considerably affected by environment. Therefore, selection of genotypes based on yield is not effective. Selection has to be made for the components of yield. In regard to this the study was shaped to evaluate the response of within and between rice genotypes variation in chlorophyll content and chlorophyll stability with its impact on grain yield to water deficit that might provide basis for selecting the most tolerant variety to water deficit in order to stabilize yield and solve food crisis. The present study was also aimed at exaggerating some of the drought tolerant characters that has direct impact on grain yield, which breeders are still looking up higher for more accurate traits that could be considered in their screening for suitable rice genotypes for drought conditions.

MATERIAL AND METHODS

The present study was conducted using eight rice genotypes (IR-83381-B-B-18-3, BRR-0026, Sabour Ardhjal, IR-87759-5-2-1-3, BRR-0028, Sabour Surbhit, MAS-946, R Bhagwati) in direct seeded condition. Randomized block design was followed with three replications, under two situations, one in the open field as control and second under the rain out shelter for drought stress induction. All the data were collected at 60 days of growth. Drought stress was imposed by withholding irrigation and bringing the soil moisture content (SMC) upto 25%. Overall yield data was expressed in terms of kg/h.

Total chlorophyll content: The rate of Chlorophyll (a, b and total) content was determined in a fully expanded leaf from the the main tiller and estimated as per the method of Arnon (1949) with little modification. 200 mg of leaf tissue was homogenized at 80% acetone and supernatant was used for determination of photosynthetic pigments. The respective chlorophyll contents were calculated as per the formula given below:

Total chlorophyll content (μg g^{-1} FW) = $17.3\,A_{646} + 7.18\,A_{663}$

Chlorophyll a (μg g^{-1} FW) = $12.21\,A_{663} - 2.81\,A_{646}$

Chlorophyll b (μg g^{-1} FW) = $20.13\,A_{646} - 5.03\,A_{663}$

Chlorophyll stability index (CSI): CSI was estimated using the method of Koleyoreas (1958). 200mg of fresh leaf sample of uniform sizes were used for the study. Leaves were put into the ready test tubes maintaining two sets: One set was left as control under room temperature and other set was kept in water bath at 80ºC for 30 minutes. Then, spectral absorbance of the water is recorded at 652 nm for each tube.

$$\text{CSI (\%)} = \frac{\text{Total chlorophyll content (heated)}}{\text{Total chlorophyll content (control)}} \times 100$$

Peroxidase enzyme (POD): Peroxidase (POD) activity assay was performed spectrophotometrically according to the method of Egley *et al*., 1983. POD was extracted by homogenizing about 200 mg of root and shoot samples in 5 ml of 60 mM phosphate buffer (pH 6.0) using a chilled mortar and pestle at 4ºC. The homogenates were centrifuged at 22,000g for 10 min and supernatant were used for enzyme assay. Assay mixture in a final volume of 2 ml contained 50 μl enzyme, 200μl guaiacol and 50 μl H_2O_2 in 1.7 ml of buffer. The increase in absorbance was measured at 470 nm.

Catalase (CAT) activity: Catalase (CAT) was assayed as given by Beers and Sizers, 1952. The enzyme was extracted from 200 mg fresh root and shoot samples by homogenization in 5 ml of 50 mM Tris-NaOH buffer (pH 8.0) containing 0.5 mM EDTA, 2% (w/v) PVP and 0.5% (v/v) Triton X-100 using a chilled mortar and pestle. The homogenate was centrifuged at 22,000g for 10 min at 4ºC and after dialysis supernatant was used for enzyme assay. Assay mixture in a total volume of 1.5 ml contained 1 ml of 100 mM potassium-phosphate buffer H_2O_2 decomposition was monitored at 240 nm.

Superoxide dismutase (SOD) activity: The superoxide dismutase (SOD) was assayed according to the method of Mishra and Fridovich, 1972. For extraction of the enzyme, about 200 mg fresh root and shoot samples were homogenized in 5 ml of 100 mM potassium-phosphate buffer (pH 7.5), containing 1.0 mM EDTA, 0.1% (v/v) Triton X-100 and 2% (w/v) of soluble polyvinyl pyrrolidone (PVP) using prechilled mortar and pestle. After centrifugation at 22,000g for 10 min at 4ºC, the supernatant was dialyzed in cellophane membrane tubings against the cold extraction buffer for 4 h with 3-4 changes of the buffer. After dialysis the SOD activity was assayed in the supernatant. The assay mixture contained 50 mM sodium carbonate-bicarbonate buffer (pH 9.8), containing 0.1 mM EDTA, 0.6 mM epinephrine and 0.1

ml enzyme in a total volume of 3 ml. Epinephrine was the last component to be added. The adrenochrome formation during the next 4 min was recorded at 470 nm.

Measurement of H_2O_2: The H_2O_2 level was determined according to the method of Jana and Chaudhuri, 1981. Extraction was done by homogenizing 150 mg root tissues with 5 ml of phosphate buffer 50 mM (pH 6.5). The 3 ml of the supernatant was mixed with 1 ml of 0.1% titanium sulphate in 20 % (v/v) sulphuric acid. After centrifugation at 6000 x g for 15 min the yellow color intensity was measured at 410 nm.

Measurement of superoxide anion (O_2^-): The rate of superoxide production was measured following the method of Chaitanya and Naithani, 1994. 200 mg fresh plant samples were homogenised in prechilled mortar pastel in 100 mM sodium–phosphate buffer containing 1 mM diethyl dithiocarbamate to inhibit SOD activity. After centrifugation at 22,000× g for 20 min, superoxide anion (O_2–) was measured in the supernatant, by its capacity to reduce nitroblue tetrazolium (NBT). The absorbance of the end product was measured at 540 nm.

RESULTS AND DISCUSSION

Chlorophyll contents: The variation pattern in chlorophyll–a (Chl a), chlorophyll–b (Chl b) and total Chlorophyll (Total Chl) contents showed the similar trend in all the genotypes. Reduction in chlorophyll contents were observed in the genotypes exposed to drought. This reduction could be a typical symptom of oxidative stress may be the result of pigment photo–oxidation and chlorophyll degradation. The results are agreement with Nyachiro *et al*., 2001, who described a significant decrease of chlorophyll a and b caused by water deficit in six *Triticum aestivum* cultivars. A decrease of total chlorophyll with drought stress implies a lowered capacity for light harvesting. Since the production of reactive oxygen species is mainly driven by excess energy absorption in the photosynthetic apparatus, this might be avoided by degrading the absorbing pigments (Herbinger *et al*., 2002). The previous findings reported that the chlorophyll content would either increase or decrease or even remain unchanged during drought stress depending on the duration and severity of the drought condition (Anjum *et al*., 2011). In present study increased in chlorophyll a and b content in genotype Sabour Ardhjal under drought situation whereby genotypes IR–87759–5–2–1–3 and BRR–0028 showed increased in Chl a as compared to control. This increased in chlorophyll content marked the adaptability potential of the genotypes under and when exposed to drought conditions. The results can be referred to as one of the most tolerant genotypes in terms of destruction of its chloroplast during stress condition. The result has similar discussion with the report by Raja Babu *et al*. (2005), in rice crops under salt tolerance. In other crops like maize (Khayatnezhad *et al*., 2012), chickpea (Mafakheri *et al*., 2010) also reported on the increased in chlorophyll content under drought stress.

Chlorophyll a/b ratio has often been considered as a measure of the activity of chlorophyll synthesising mechanism in plants under stress condition. In the present study, significant variation for the chlorophyll a/b ratio was noticed among the genotypes (Table 1) revealing variation in the activity of chlorophyll synthesizing mechanism among genotypes when exposed to drought stress. Genotypes IR–87759–5–2–1–3, Sabour surbhit and BRR–0026 were observed with highest chlorophyll a/b ratio as 1.55, 1.52 and 1.46 respectively under drought stress (Table 1). Increased in chlorophyll a/b ratio and the variation amongst the genotypes were also reported and well discussed in other crops (Guo *et al*., 2016; Singh and Jain 1982 and Raja Babu *et al*., 2005).

Chlorophyll stability: Significant differences in chlorophyll stability index were observed between control and drought stressed plants. BRR–0028 showed the highest CSI with higher yield irrespective of less chlorophyll content (Table 1 and 2). The CSI showed significant (r = 0.804**) positive correlation with the grain yield. The enhanced activities of antioxidant enzymes like peroxidise (POD), catalase (CAT) and superoxide dismutase (SOD) scavenging reactive oxygen species i.e. hydrogen peroxide and superoxide anion in the genotypes BRR–0028, Sabour Adrhjal with higher chlorophyll stability index. This finding may be referred as one of the most tolerance potential of genotypes from destruction of chloroplast under stress conditions thus scavenging the production of ROS.

Reactive oxygen species: The increased superoxide anion (O_2^-) production and hydrogen peroxide (H_2O_2) content in all the genotypes under drought stress as compared to the control. Due to imposition of drought stress, a significant increase in superoxide anion production was observed in genotypes BRR–0026, BRR–0028 and R Bhagwati. Similarly, maximum increased in the concentration of H_2O_2 under drought stress has been observed in genotypes Sabour Ardhjal, BRR–0028, MAS 946 and R. Bhagwati. The findings are in support that drought stress induces increases in levels of oxidative stress factors which may be caused by aggravation of membrane leakage and cellular damage (Pinto *et al*., 2003; Sharma and Dubey 2005; Sharma *et al*., 2012).

Antioxidant Enzyme: In order to cope with continuous ROS production plants have a battery of enzymatic and non–enzymatic antioxidants, which function as an extremely efficient cooperative system. The major scavenging mechanisms include SOD, POD and CAT (Maria, 2008). The activity of POD increased significantly in all the genotypes except in Sabour surbhit. Response of genotypes on scavenging the ROS by antioxidant enzyme activities varied at different levels. Our results indicated a declined in POD for genotype Sabour Surbhit, a non significant increase in CAT, SOD activity for the genotypes and BRR-0026, Sabour Ardhjal may not to be an effective scavenger of H_2O_2 and O_2^- in our case. Findings indicated CAT and SOD might have relatively poor affinity for H_2O_2 and O_2^- under drought for these genotypes. Similar to our results, a decline in antioxidant enzyme activities has been observed under many stressful conditions (Nahakpam and Shah, 2011; Sharma and Dubey, 2005; Radotic *et al*., 2000). The result is also a strong indicative that increased in the activities of antioxidant enzymes has a vital role in attributing chlorophyll stability as discussed above under the result of chlorophyll stability.

Correlation between Chlorophyll Contents, Chlorophyll Stability and Yield

Correlation analyses reveal that yield was positively and significantly correlated with chlorophyll stability in both the control and drought conditions with 0.719 and 0.804 at p<0.05 and p<0.01 level respectively. Chlorophyll 'a' has strong positive correlation with yield at drought condition whereby total chlorophyll correlate with yield under control condition. The chlorophyll 'b' has non-significant positive correlation with yield. Amongst the chlorophyll contents, there are significant positive correlations in both the stress and control situation which directly or indirectly play a role in contributing to yield. The study reveals a differential contribution of chlorophyll contents into the yield which might be highly genotypic and environmental specific (Sikuku *et al*., 2012; John *et al*., 2014). Chlorophyll stability has always been mentioned as one of the most important indicators for stress tolerance. The results indicate close reliability and direct contribution of chlorophyll stability towards yield irrespective of chlorophyll contents as observed in genotypes, BRR-0028, BRR-0026, Sabour Surbhit, IR 83381-B-B-18-3. Similar report with a cross talk about low chlorophyll contents as not a sign for poor yield in different

Table 1. Effect of drought on various parameters (Chlorophyll content (μg g^{-1} FW), chlorophyll a/b ratio, chlorophyll stability index (%), levels of H_2O_2 (μmol g^{-1} DW), superoxide anion (Δ_{540} mg^{-1} FW), activities of POD (μmol H_2O_2 reduced min^{-1} mg^{-1} protein), CAT (μmol H_2O_2 reduced min^{-1} mg^{-1} protein) and SOD (units mg^{-1} protein) and yield

Genotypes	% decreased (↓) and increased (↑)			Chlorophyll a/b ratio	Chlorophyll Stability (%)	Expression of Antioxidant enzyme activity			Generation of reactive oxygen species		Yield (Kg/ha)
	Chl a	Chl b	Total Chl			POD	CAT	SOD	H_2O_2	Superoxide anion	
IR 83381-B-B-18-3	↓20.59	↓7.03	↓4.47	1.25^b	78	300.71	199.63	199.1^d	227.25	136.28^c	2706
BRR-0026	↓4.37	↓21.59	↓12.6	1.46^{cd}	87	246.29	258.33	100.8^a	219.11	109.45^a	3827
Sabour Ardhjal	↑1.91	↑1.73	↓5.61	1.28^b	91	300.08	149.82	121.6^b	286.4^d	115.55^b	4124
IR-87759-5-2-1-3	↑0.694	↓18.31	↓6.65	1.55^d	87	349.52	230.02	100.1^a	231.74	108.09^a	3769
BRR-0028	↑6.69	↓7.99	↓11.07	1.26^b	92	394.02	240.08	198.4^d	258.12	204.3^d	4436
Sabour Surbhit	↓0.462	↓17.83	↓10.97	1.52^d	84	289.54	251.61	146.2^{bc}	200.28	130.11^c	3480
MAS-946	↓11.5	↓6.99	↓26.48	1.34^c	90	353.02	178.68	109.4^b	248.73	137.16^c	3733
R Bhagwati	↓19.6	↓12.64	↓4.11	1.05^a	78	269^a	209.89	168.1^c	294.19	91.1^a	3662

Values with different alphabets are significantly different at P ≤0.05

Table 2. Correlation matrix between the chlorophyll contents, chlorophyll stability and yield under control and drought stress

Parameters		Chl. a	Chl. b	Total Chl	Chl stability	Yield
Chl. a	Control		0.932**	0.866**	0.692	0.553
	Stress		0.907**	0.726*	0.647	0.769*
Chl. b	Control			0.888**	0.576	0.532
	Stress			0.921**	0.241	0.557
Total Chl	Control				0.740*	0.749*
	Stress				0.039	0.462
Chl stability	Control					0.719*
	Stress					0.804**

*Significant (p<0.05); ** Significant (p<0.01) crops have been discussed earlier (Guler and Qzeclik, 2007; Chutia and Borah, 2012).

By reviewing the above results, it can be concluded that most effective criteria among the chlorophyll base traits in identifying high yield genotypes under drought is to use of chlorophyll stability. It is an efficient screening method able to screen large amounts of plant material in the shortest time possible with minimum traits and select the most efficient genotypes. Aamong the genotypes studied BRR-0028 performed well with higher chlorophyll stability correlating with higher yield even at a low total chlorophyll contents. This genotype can be used in future rice improvement program for higher yield under drought situation.

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Study on Willingness to Adoption of Mitigation Measures of Greenhouse Gases Emission in Dairy Farming

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Abstract: Present issues like climate change, food and nutritional security made the agriculture vulnerable. At the same time Agriculture being a sufferer of climate change is itself a vital source of greenhouse gases (GHGs). Moreover, dairy farming has become recognized source of GHGs emission. Nevertheless, to be optimistic there are mitigation measures available to mitigate the emission of GHGs. In this perspective, a study was conducted to assess the willingness to adopt of different mitigation measures by the dairy farmers. This study was conducted in three districts of Haryana. The result says that 100 percent farm owners were willing to adopt the practices best farm management plan, feeding practices for dairy animals, increase forage quality to reduce the methane (CH_4) emission, while 86.66 percent of farm owners were unwilling to adopt silage preservative and digestion of manure. Some practices which were simple and less cost involved (as frequent removal of manure, minimization of grazing period etc.) were easily acceptable to the farmers whereas some were difficult (use of silage preservative, anaerobic digester etc.) to attract the farmers. In this context, need to identify location specific, resource oriented and less cost involved practices so that all categories of farmers including small and marginal farmers can use and make dairy farming eco-friendly.

Keywords: Dairy farming, Greenhouse gases, Mitigation measures

Indian agriculture comprises agriculture and allied sectors, where livestock farming plays an important role in farmers′ economy. India became the milk oyster; accounting 18.5 percent of the total world′s milk production (Economic Survey of India, 2015-16). However, livestock as well as dairy animals are the sufferer of present day′s threat that is climate change; directly–indirectly it is going to affect our Indian livestock and their productivity. Agriculture, which is backbone of Indian economy, contributes about 13.5 percent of global emission (IPCC, 2007); whereas in India, this sector contributes 18 percent of the total GHG emission (INCCA, 2010). Mainly emissions from agriculture are primarily due to methane emission from enteric fermentation in ruminants (63 %) and rice fields (21 %), nitrous oxide from application of nitrogen through manure and fertilizer to agricultural soil (13 %) and manure management and burning of crop residue (2.7 %). Well, dairy farming is one of the anthropogenic causes of greenhouse gases emission where methane (CH_4), carbon di –oxide (CO_2) and nitrous oxide (N_2O) are three main GHGs used to emit. Globally, milk production generates 2.7 percent of GHG emissions, with a further 1.3 percent caused by meat produced from the dairy herd (Gerber *et al*., 2010). Recent studies suggest that annual global GHG emissions will have to be cut up to 80 percent (relative to 1990 levels) before 2050 to prevent the worst effects of climate change (Fisher *et al*., 2007). However, demand for milk products is projected to be double between 2000 and 2050 (Gerber *et al*., 2010). Thus, reducing GHG emissions per unit of milk is becoming a necessity for sustainable development. In recent years, there has been an increasing focus on evaluating the environmental effects of milk production systems, particularly in relation to greenhouse gas (GHG) emissions (Thomassen *et al*., 2008; Flysjö *et al*., 2011b). The major source of CH_4 emission is due to enteric fermentation of animals (Hospido, 2005). Nitrous oxide (N_2O) emission is due to production and use of fertilizer, manure storage and Carbon dioxide (CO_2) emission occurs due to use of energy at farm level as well as processing level (Thomasen *et al*., 2008). Several studies concluded that agricultural phase of milk production was the most critical; mainly due to enteric fermentation, manure management, fertilizers use, diesel consumption and airborne emissions. Even, if methane (CH_4) emissions grow in direct proportion to projected increases in livestock numbers, then global methane (CH_4) emissions from livestock production are expected to increase 60 percent by 2030 (FAO,2003).So, reducing the increase of GHG emissions from agriculture, especially livestock production should therefore be a top priority, because it could curb warming fairly rapidly (Sejian *et al.,* 2011). Nevertheless, to be optimistic there are many mitigation measures available to adopt and follow to mitigate the emission of greenhouse gases from dairy farming. An integrated management of dairy animals including improved feeding practices, altered breeding management or other management practices etc. can helps to mitigate or reduce GHGs emission. So, knowing the willingness to adoption of different mitigation measures is essential before formulation of any particular strategy, in this perspective this study was conducted to assess the willingness to adoption of different mitigation measures available at the farm level.

MATERIAL AND METHODS

Any technology is successful when it is able to penetrate as much as in the field condition by the farmers. In this context, it was very genuine to know the willingness of farmers to adopt or not to adopt different mitigation measures to sustain the dairy farming eco-friendly in long run condition. So this paper tried to analyses the willingness of adoption of dairy farms owner at commercial level in two possible ways i.e. YES or NO. There are so many factors responsible for farmers′ decision, as Tripp and Woolley, 1989 stated that compatibility with the farming system, possibility of testing new technology and availability of institutional support are some of ease that influences farmers to adopt a technology. This study was conducted in three districts of Haryana namely Karnal, Yamunanagar and Hisar; here those commercial dairy farms were taken in to consideration where since last 5 years farmers were associated with dairy farming commercially and have good hard size (>30 animals). From each districts 10 farms were considered and total 30 dairy farms were interviewed personally with structured, pretested, reliable interview schedule.

RESULTS AND DISCUSSION

Majority of the farm owners were belonged to middle age group, educated up to higher secondary to graduate level. On an average all the farm owners were having 25-30 years experience in dairy farming; majority of the farm owners were having medium level of social participation and extension contact (Table 1). In most of the cases farmers didn′t receive any training; very few have received only one training. While interacting with the farm owners it has found that they were having low to medium level interest in seeking information, very few farm owners have good social network in the locality. In case of farm′s characteristics herd size was good (60-100 animals), moderate to well fascinated farm condition, good milk yield etc.

The results show that 100 per cent commercial dairy farms owner were willing to adopt some practices like best farm management plan, feeding practices and increase forage quality for dairy animals (Table 2). Even 93.33 per cent of respondents were ready to minimize the grazing period of the dairy animals while in the other hand, 86.66 per cent of respondents were unwilling to use of silage preservative and digestion of manure. At the same time 100 per cent farms owner were not willing to adopt anaerobic digesters for manure management. 70 per cent peoples were unwilling to adopt feed additives for their dairy animals. Further, result says that 50 per cent respondents agreed to follow covered manure storage structures and rest 50 per cent expressed not to adopt, even 56.66 per cent respondents expressed their unwillingness to change housing systems after years of interval.

Table 1. Farmers′ and Farm′s characteristics of the study area

Farmers′ Characteristics	
Age	Middle age (35-50 years)
Education	Higher secondary to Graduate
Family Type	Nuclear
Family Size	8 to 10 members
Experience in dairy farming	25-30 years
Social participation	Medium level
Extension Contact	Medium level
Training received	0 to 1 (number)
Interest in seeking information	Low to medium
Farm Characteristics	
Herd Size	60-100
Farm infrastructure	Moderate to well fascinated
Land holding	12-15 ha
Milk yield of the farm	500-700 kg/day

As because some practices are affordable and complex in nature; more over trialability and observeability of the practices or technology also sometimes helpful for the adopters, which were not possible, might be the only reason that farmers′ were not ready to admit or willing to adopt those mitigation measures. At the same time some practices were fairly acceptable to most of the farmers such as minimization of grazing time for dairy animals, removal of manure from floor regularly, etc. Different authors have identified different farm and farmer characteristics which are responsible as determinants of adoption of any technology. Some determinants like land holding, annual income of the farmer, milk yield, herd size etc. is always important to influence the farm owners/farmers′ decision at every level.

CONCLUSION

It was very precious to me to assess the willingness to adopt of different mitigation measures by the dairy farmers to sustain the eco-friendly dairy farming in long run condition. The study shows that farmers were very willing to adopt some of the practices easily but in other hand some practices were not at all acceptable to them. It has been found that the mitigation practices which were simple and easy to

Table 2. Willingness to adoption of different mitigation measures in dairy farming

Mitigation Practices	Willingness to adoption			
	YES		NO	
	Frequency	Percentage	Frequency	Percentage
Best farm management plan	30	100.00	0	0.00
Improve the feeding practices	30	100.00	0	0.00
Use feed additives	9	30.00	21	70.00
Increase the forage quality	30	100.00	0	0.00
Proper management practices	26	86.66	4	13.33
Anaerobic digesters that can improve energy efficiency from manure	0	0.00	30	100.00
Willing to manage indoor storage of manure	20	66.67	10	33.33
Improving soil management practices	8	26.66	22	73.33
Digestion of manure	4	13.33	26	86.66
Avoid excess nitrogen in the diet for animals	21	70.00	8	26.66
Increasing the manure storage time	17	56.66	13	43.33
Follow covered manure storage structures	15	50.00	15	50.00
Ready to minimize the grazing period for your dairy animals	28	93.33	2	6.66
Follow more frequent removal of manure from housing floors of the farm	27	90.00	3	10.00
Willing to change housing systems after years of interval	13	43.33	17	56.66
Willing to increase the level of concentrate in diet for your animals	14	46.66	16	53.33
Use silage preservatives	4	13.33	26	86.66
Harvesting the forage at early stage	13	43.33	17	56.66

understand were acceptable to farmers rather than the practices which were somewhat complex and some sort of cost was involved. There is need to identify more location specific mitigation strategies which are resource oriented, less cost involved, so that small and marginal farm owners also can use and make dairy farming eco-friendly.

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Analysis of Morpho-Physiological Traits for Rice Improvement Under Submergence Condition

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Abstract: Genetic variability among 184 rice land races including four checks were worked out under submergence condition. The analysis of variance showed significant differences among treatments for the yield and yield attributing traits. The extent of phenotypic coefficient of variation (PCV) was slightly higher than the corresponding genotypic coefficient of variation (GCV) for all the characters studied. The traits like plant height, tillers per hill, survival per cent, total shoot elongation, relative shoot elongation, tolerance score and grain yield per hill showed high genotypic and phenotypic coefficient of variation and high heritability coupled with high GAM indicating their direct selection for improvement of rice under submergence. Besides the yield parameters, the stress parameters viz., TSE was found predominant and might be used in breeding programme as selection criteria for screening of submergence tolerance in rice genotypes.

Keywords: Genetic advance, Heritability, Rice land races, Survival, Submergence, Variability

In India 32.4 percent of total rice area is under rainfed lowlands and which constitute highly fragile ecosystems, always prone to flash-floods (submergence). Among the 42 biotic and abiotic stresses affecting rice production, submergence has been identified as the third most important constraint for higher rice productivity (Sarkar *et al.,* 2006). Scientists have estimated that 4 million tonnes of rice is being lost every year because of flooding (IRRI, 2008). According to an estimate of National Bureau of Soil Survey and Land Use Planning nearly 3.3 M ha of land is affected by flood of varying degree. Germplasm survey revealed the existence of limited amount of genetic variation for submergence tolerance. Rice plants that exhibit only limited elongation during submergence often show tolerance to flash flooding. Landraces are very poor in yield (not >2 t ha^{-1})but possess one or more adaptive traits required for this ecosystem, which range from temporary submergence of one to two weeks, long periods of stagnant water, or daily tidal fluctuations that may sometimes cause complete submergence as in coastal areas. Plant breeders are trying to increase production in the low laying areas by introducing submergence tolerance traits to high yielding varieties. Yield and submergence tolerance, both are quantitative and very complex in nature. Selection for submergence tolerance based on yield only can be misleading sometimes. It is therefore essential that together with grain yield, some essential yield components should be evaluated and their relationship should be assessed for effective selection. Besides, relationship between yield, yield components and stress parameters, it may be helpful to submergence rice breeding programs because correlation analysis provides the information on correlated response of important plant characters and therefore, leads to directional model for yield. Determining and processing effective components and their relationships may help in selecting the significant components for yield increase under submergence with better results.

Keeping the above facts under consideration, the present investigation was designed to assess the genetic variation and association among yield, yield components and stress parameters for improvement of rice for submergence tolerance.

MATERIAL AND METHODS

The present investigation was conducted with 184 land races of rice collected from different countries including four checks *i.e.* Swarna sub-1, Rajendra Mahsuri Sub-1, FR-13A and FR-13B to access the variability parameters based on 10 quantitative traits including grain yield and stress indices. The experiment was conducted at Crop Research Farm of RAU, Pusa, Samastipur. A Field experiment was performed in Augmented Design (AD-II) during two years i.e. *kharif* 2013 and *kharif* 2014. Each genotype was sown in four rows in plot of 5 m length with 20 cm inter-row and 15 cm intra-row (inter-plant) spacing in water tank for submergence screening. Recommended fertilizer was applied during the crop growth period. Five random plants were tagged from each plot to record the data for the yield and its related traits except days to 50 per cent flowering. Days to 50 per cent flowering was recorded on plot basis. Stress indices were calculated by following the procedures (Toojinda *et al*., 2003).

$$\text{Percent plant survival (PPS)} = \frac{\text{Total no. of surviving seedlings}}{\text{Total no. of seedlings counted before submergence}} \times 100$$

Total shoot elongation (TSE) = Height of shoot after de-submergence – Height of shoot before de-submergence.

$$\text{Relative shoot elongation (RSE)} = \frac{\text{Elongation growth under submergence} \times 100}{\text{Elongation growth under non-submerged conditions}}$$

Tolerance score (TS) = Scored on the basis of percent plant survival (PPS).

For calculation of percent plant survival the number of hills before submergence and after de-submergence were counted and calculated as follows:

PPS= Number of hills after de-submergence / number of hills before submergence × 100

The data on yield, its other related traits and tolerance indices were subjected to pooled analysis of variance, variability parameters estimation and association analysis by using statistical package WINDOSTAT version 9.2 (INDOSTAT Service Hyderabad).

RESULTS AND DISCUSSION

The analysis of variance showed significant differences (P < 0.01) among the entries for the yield and yield attributing traits, indicating the presence of exploitable extent of variability in population. The coefficient of variation studies indicated that the magnitude of phenotypic coefficient of variation (PCV) were slightly higher than the corresponding genotypic coefficient of variation (GCV) for all the characters, indicated the influence of environmental factor on these traits (Table 3). The high estimates of GCV and PCV (>20%) was exhibited by plant height, number of tillers per hill, survival percentage, total shoot elongation, relative shoot elongation, tolerance score and grain yield per hill, whereas rest traits showed moderate values except number of productive tillers per hill. Number of productive tillers per hill showed moderate estimates of GCV and high estimates of PCV. Heritability and genetic advance are important selection parameters.

High heritability (>70%) was recorded for all the traits *viz.*, number of tillers per hill and panicle length. High estimates of heritability coupled with high genetic advance as per cent of mean (>20%) was observed for days to 50 per cent flowering, plant height, number of productive tillers per hill, survival percentage, total shoot elongation, relative shoot elongation, tolerance score and grain yield per hill, indicated the involvement of additive gene action for these traits. (Prajapati *et al*., 2011, Devi *et al*., 2013). Number of tillers per hill exhibited moderate heritability estimates coupled with high GAM, whereas panicle length showed low estimates coupled with low GAM, indicated the involvement of both additive and non-additive gene action in expression of these traits. Similar finding for panicle length has earlier been reported by Singh *et al*. (2011). The consideration of variance components, heritability estimates and genetic advance together gives better chance for selection of appropriate parents. (Yimram *et al*., 2009, Singh *et al*., 2014). The traits PH, NPTH, SP, TSE, RSE, TS and GYP showed high GCV, PCV, heritability coupled with high GAM values may be directly selected for rice crop improvement with reverence to submergence tolerance. Rest of the traits may be utilized for recombination breeding programmes.

Trait Association : The degree and direction of correlation among traits depend upon the genetic linkage or pleiotropic effect of genes. The effect of genotypic correlation was higher than the effect of phenotypic correlation coefficient. This difference was moderate and sometimes more for some of the characters, suggesting the traits were little influenced by environmental effects. The trait GYP exhibited positive association with days to 50 percent flowering, plant height and plant survival percentage but these were non-significant.

Table 1. Genetic parameters on various yield components and stress indices in rice (Pooled for two years)

GP/ Trait	Days to 50 per cent flowering	Plant height (cm)	Tillers per hill	Fertile tillers per hill	Panicle length (cm)	Survival (%)	Total shoot elongation (cm)	Relative shoot elongation (cm)	Tolerance score	Grain yield per plot (g)
Range	56.90-177	31.12-226	0.21-17.10	0.20-17.08	-2.35-16.90	34.94-102.94	0.90 -57.30	16.82-1730.71	1-10	35.95-621.08
Mean	128	144.5	8.20	7.81	24.20	79.98	20.60	152.53	1.00	239.89
GCV (%)	16.74	21.12	31.26	26.68	10.76	20.03	49.50	69.40	60.44	38.52
PCV (%)	17.06	21.86	35.27	30.53	12.89	20.90	54.36	71.48	61.45	45.32
h^2bs (%)	96.20	93.40	22.26	76.4	14.35	91.90	82.90	81.80	89.98	72.20
GAM (0.05)	33.82	42.05	16.74	48.04	31.81	39.54	92.87	92.76	93.10	67.43

GP= Genetic parameters, VG= Genotypic variance, VP= Phenotypic variance, GCV= Genetic coefficient of variation, PCV= Phenotypic coefficient of variation, h^2bs= Heritability in broad sense, GAM= Genetic advance as % of mean

Table 2. Correlation coefficient among various yield components and stress indices in rice (Pooled of two years)

Character	Days to 50 % Flowering	Plant Height cm	Panicle Length cm	Tillers/ Plant	Fertile Tillers/ Plant	Survival %	Total Shoot Elongation	Relative Shoot Elongation	Tolerance Score	Grain Yield/ Plant
Days to 50 % Flowering	1.000	0.559**	0.331**	0.076	-0.048	0.066	0.008	0.032	-0.102	0.066
Plant Height cm		1.000	0.340**	0.102	-0.020	0.047	-0.062	-0.123	-0.070	0.083
Panicle Length cm			1.000	0.711**	0.438**	0.120	-0.132	-0.047	-0.159*	-0.059
Tillers/ Plant				1.000	0.698**	0.193**	-0.040	0.010	-0.210**	-0.067
Fertile Tillers/ Plant					1.000	0.179*	-0.127	-0.024	-0.193**	-0.043
Survival %						1.000	-0.161*	0.041	-0.949**	0.029
Total Shoot Elongation							1.000	0.419**	0.173*	-0.011
Relative Shoot Elongation								1.000	-0.055	-0.059
Tolerance Score									1.000	-0.030
Grain Yield/ Plant										1.000

*= ($P<0.01$), **= ($P<0.05$) significant at probability level

Table 3. Path coefficient analysis of ten morphological traits on grain yield /plant of Rice (Pooled of two years)

Character	Days to 50	Plant Height cm	Panicle Length cm	Tillers/ Plant	Fertile Tillers/ Plant	Survival %	Total Shoot Elongation	Relative Shoot Elongation	Tolerance Score
Days to 50 % Flowering	0.056	0.031	0.018	0.004	-0.003	0.004	0.000	0.002	-0.006
Plant Height cm	0.044	0.079	0.027	0.008	-0.002	0.004	-0.005	-0.010	-0.006
Panicle Length cm	-0.033	-0.034	-0.100	-0.071	-0.044	-0.012	0.013	0.005	0.016
Tillers/ Plant	-0.002	-0.003	-0.019	-0.027	-0.019	-0.005	0.001	0.000	0.006
Fertile Tillers/ Plant	-0.001	0.000	0.007	0.012	0.017	0.003	-0.002	0.000	-0.003
Survival %	0.000	0.000	0.000	0.001	0.001	0.003	0.000	0.000	-0.003
Total Shoot Elongation	0.000	-0.001	-0.002	-0.001	-0.002	-0.002	0.015	0.006	0.003
Relative Shoot Elongation	-0.002	0.008	0.003	-0.001	0.002	-0.003	-0.027	-0.064	0.004
Tolerance Score	0.004	0.003	0.006	0.008	0.008	0.038	-0.007	0.002	-0.040
Grain Yield/ Plant	0.066	0.083	-0.059	-0.067	-0.043	0.029	-0.011	-0.059	-0.030

R^2 Value = 0.0222

(Paul *et al*., 2011 and Singh *et al*., 2013). The negative association was observed for panicle length, tillers and fertile tillers per hill, total shoot elongation, relative shoot elongation and tolerance score, indicating the low yielding nature of local land races used in present study. Days to 50 per cent flowering exhibited positive and significant association with plant height and panicle length and plant height exhibited positive significant correlation with panicle length. Survival percent showed positive significant association with tillers and fertile tillers per hill, whereas negative significant correlation with total shoot elongation and tolerance score. The positive significant relationship of total shoot elongation was found with relative shoot elongation and tolerance score, indicating the rapid growth of shoot elongation may enhance the tolerance capacity of the plant. So in the submergence related parameters viz., TSE was found predominant and may used in breeding programme for screening of submergence tolerance genotypes.

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Exploring Genetic Diversity for Heat Tolerance among Lentil (*Lens culinaris* Medik.) Genotypes

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Abstract: Genetic diversity is crucial for genetic improvement of lentil crop. The information on genetic diversity in this important legume crop is not utilized enough; the genetic diversity study would be very useful and essential for developing new/improved varieties in lentil for major abiotic stresses; particularly for heat stress condition. The inclusion of diverse parents in the hybridization program serves the purpose of combining desirable genes in new recombination. The present investigation was carried out to assess the genetic diversity among forty nine genotypes of Lentil (*Lens culinaris* Medik.). Wide genetic diversity was observed among the genotypes which were grouped into eight clusters by Tocher's method and Ward minimum variance method. In Ward minimum variance method, the cluster IV containing the maximum of 10 genotypes followed by 9 genotypes in cluster VI, 8 genotypes each in cluster II and V, 6 genotypes each in cluster I, 4 genotypes in cluster III and 2 genotypes each in cluster VII and VIII while, in Trocher method all the forty nine genotypes were also grouped into eight clusters, with cluster V containing the maximum 12 genotypes followed by 9 genotypes in cluster VIII, 8 genotypes in cluster VII, 7 genotypes in cluster VI, 4 genotypes in cluster IV and 3 genotypes each in cluster I, II and III. The intra-cluster distances were lower in all cases reflecting homogeneity in genotypes within the clusters. The highest intra-cluster distance was exhibited by cluster VIII followed by cluster I and V. The intra cluster distance was maximum in cluster VIII followed by cluster I indicate hybridization involving genotypes within the same clusters may result in good cross combinations. The highest inter cluster distance was observed between cluster IV and VIII followed by cluster IV and VII and cluster III and VIII. These lines may be utilized in further breeding programme for the exploitation of hybrid vigour. In Tocher's method the highest inter cluster distance was observed between cluster V and VI followed by cluster IV and VI and cluster I and VI suggesting wide diversity between them and genotypes in these clusters could be used as parents in hybridization programme to develop heat tolerant lines. The promising genotypes for grain yield per plant, number of branches per plant and days to harvest, biological yield and number of pods per plant, plot yield and number of seeds per pod were identified from cluster VII , VI and V on the basis of mean values which could be utilized for hybridization programme for the development of high yielding genotypes. The major contributing character towards genetic divergence was found to be maximum for plot yield (56.38%) followed by plant stand at harvest (30.10%) and number of pods per plant (11.48%). Therefore, these characters may be given importance during hybridization programme.

Key words: Lentil (*Lens culinaris* Medik.), Genetic diversity, D^2 statistics & Seed yield

The lentil (*Lens culinaris* Medik) is next to chickpea and is being grown in 1.47M ha area with production 1.03M t and productivity 705 kg/ha . Bihar covers 1.96 Lakh ha area with production 1.94 Lakh tones and productivity 989 kg/ha {Project Coordinator's report (Rabi Crops 2015-16, AICRP on MULLaRP)}. In rabi pulse crops, severity of the damage caused by heat stress depends on timing. Pulse crops including lentil are particularly sensitive to the effects of heat stress at the reproductive stages of development when plants are in full bloom. Even a few days of high temperature (30 -35°C) limits many processes including photosynthesis, metabolic pathways, electron flow and respiration rates (Redden *et al.,* 2014), causing flower and pod abortion, resulting in yield losses by reducing seed set, seed weight and accelerating senescence (Gaur *et al*., 2015). Heat waves (temperatures > 35°C) during flowering and pod-filling of lentil can result in significant reductions in seed yield, quality and profitability. Adaptation of lentil to heat waves may be managed through avoidance and involves selecting early maturing genotypes or alternatively genetic solutions through identifying and breeding additional tolerance into commercial lines. Heat tolerant lentil genotypes exist and allow flexibility in sowing dates and enhance opportunities for improving grain yield and expanding areas of pulses to new cropping systems (Gaur *et al.*, 2014). However, this genetic potential has not been fully explored in lentil to heat stress and this can be achieved by enhancing the production of lentil by developing improved varieties through heterosis breeding among parents having high genetic divergent. Developing high yield varieties of lentil with desirable traits require a thorough knowledge about the existing genetic variability. The selection of the divergent parents is the most important aspect for this purpose, as greater the genetic divergence among the parents for the character (s) under consideration, better are the chances for release of variability and vice-versa. The more genetic diverse parents, the greater chances of obtaining higher heterotic expression in F_1's and broad spectrum of variability in segregating population. Cluster analysis helps to understand the genetic relation among the genotypes and also to facilitate the selection of genetically diverse parents in hybridization programme resulting in considerable amount of heterosis and wide range of segregation. Several genetic diversity studies have been conducted in lentil crop based on quantitative and qualitative traits in order to select genetically distant parents for hybridization (Solanki *et al.,* 2000 , Sultana *et al.*, 2005; Sirohi *et al.,* 2007; and Tyagi and Khan, 2010). In views of these facts, the current research was undertaken to assess the magnitude of genetic diversity and characters contributing to genetic diversity among late sown lentil genotypes.

MATERIAL AND METHODS

The experiment was conducted during, *rabi*, 2015-16 at the Pulse Research farm, Bhitti, of Bihar Agricultural University, Sabour, (Bhagalpur), India in lattice design with two replications. The investigation was carried out to assess the genetic diversity among the important fifteen characters in relation to seed yield in forty nine genotypes of lentil including four checks viz., HUL57, Arun, Noori and KLS 218 including advance breeding lines procured from ICARDA, Lebanon, IIPR, Kanpur, G.B.P.U.A.T., Pantnagar, Uttarakhand, NBPGR, New Delhi and local races of Lakhisarai, Bihar. All the genotypes were grown in 4 rows of 4 m length with distance of 30 cm between rows and 10 cm between plants. Five competitive plants were taken at random from each row to record data on the following characters viz. plant stand at harvest, plant height (cm), number of primary branches per plant, number of seeds per pod, number of pods per plant, 1000 seed weight (g), grain yield per plant (g), biological yield per plant and harvest index (%). Days to first flowering, days to 50% flowering, days to maturity, days to harvest plot yield (g) and wilt incidence (%) were recorded on plot basis. Genetic divergence was estimated by using D^2 statistics of Mahalanobis (1936) and clustering of genotypes was done according to Tocher's method as described by Rao (1952) and Ward minimum variance method. The per cent contribution of characters towards genetic divergence was calculated according to Singh and Chaudhary (1985).

RESULTS AND DISCUSSION

All the genotypes were grouped into eight clusters in Ward minimum variance method, with cluster IV containing the maximum of 10 genotypes followed by 9 genotypes in cluster VI, 8 genotypes each in cluster II and V (Table 1). In Trocher method all the forty nine genotypes were also grouped into eight clusters (Table 2), with cluster V containing the maximum 12 genotypes followed by 9 genotypes in cluster VIII, 8 genotypes in cluster VII, 7 genotypes in cluster VI (Table 2). It means the overall genetic similarity was found in the germplasms were presented within the cluster and the pattern of distribution of genotypes in different clusters exhibited that geographical diversity was not related to genetic diversity as genotypes of same geographical region were grouped into different cluster and vice-versa, as supported by earlier finding of Tyagi and Khan, 2011, Kumar *et al*., 2013 and Singh *et al.,* 2014. The possible reason for grouping of genotypes of different places into one cluster could be free exchange of germplasm among the breeder of different region or unidirectional selection practiced by breeder in tailoring the promising cultivar for selection of different region. The intra-cluster D^2 value ranged from 10.70 to 23.88 while, inter-cluster D^2 value ranged from 18.79 to 62.34 (Table 3) in Ward minimum variance method. The highest intra-cluster distance was exhibited by cluster VIII (23.88) followed by cluster I (23.80) and V (20.07). The intra cluster distance was maximum in cluster VIII followed by cluster I which indicate hybridization involving genotypes within the same clusters may result in cross combination. The highest inter cluster distance was observed between cluster

Table 1. Distribution of forty nine lentil genotypes in various clusters (Ward minimum variance)

Cluster	No. of Genotypes	Name of Genotypes
I	06	X2011S-208, X2011S-193, GP3221, X2011S-111, GP3771, FLIP86L.
II	08	GP3955, PL230, IC208326, GP2717, GP2802, NDL316, KLS218, LKH-3.
III	04	PL029, Noori, FLIP2011-57L, GP3113,
IV	10	GP3140, GP4201, GP2506, GP4182, GP4318, GP2699, GP2595, FLIP2011-32L, GP2657, GP3643
V	08	DPL58, FLIP2011-42L, GP4079, HUL57, GP3262, FLIP2011-17L, X2011S-103, GP3227
VI	09	GP3734, GP3256, GP3290, K75, BARI Masoor, BL138, PLK234, Arun, GP2961
VII	02	LKH-1, LKH-2
VIII	02	GP4073, LKH-4

IV and VIII (62.34) followed by cluster IV and VII (62.24) and cluster III and VIII (59.13). These lines may be utilized in further breeding programme for the exploitation of hybrid vigour. In Tocher's method the intra-cluster D^2 value varies from 2877 to 18493 while, inter-cluster D^2 value ranged from 9038 to 123439 (Table 4). The highest intra-cluster distance was recorded by cluster VI (18493) followed by cluster IV (9004) and III (5532). The highest inter cluster distance was observed between cluster V and VI (123439) followed by cluster IV and VI (94293) and cluster I and VI (86461) suggesting wide diversity between them and genotypes in these clusters could be used as parents in hybridization programme to develop desirable type because crosses between genetically divergent lines will generate heterotic segregants. As heterosis can be best exploited and chances of getting transgressive segregants are maximum when generating diverse lines are crossed (Tyagi and Khan, 2011). Therefore, crosses between the members of clusters separated by inter-cluster distances are likely seemed to be beneficial for further improvement. Significant differences among the genotypes for different characters indicated variations among the genotypes favorable for their use in the breeding programs. Crosses between parents with maximum divergence would be more responsive to improvement since they are likely to produce higher heterosis and desirable genetic recombination (Roy *et al.*,

Table 2. Distribution of forty nine lentil genotypes in various clusters (Tocher' method)

Cluster	No. of Genotypes	Name of Genotypes
I	06	PL234, Arun, LKH-2
II	08	DPL-58, FLIP2011-42L, FLIP2011-17L
III	04	NDL316, LKH-1, LKH-3
IV	10	GP3955, IC208326, KLS218,GP2717
V	08	HUL57, GP3221, GP2802, FLIP2011-57L, GP4079, X2011S-111, GP3140, Noori, FLIP2011-32L, GP2595, GP3227, GP3113
VI	09	X20115-193, BARI Masoor, PL230, BL138, GP3643, GP4073, LKH-4
VII	02	FLIP-86L, PL-029, GP4182, GP4201, GP4318, GP2657, GP2506.GP2699
VIII	02	X20115-208, GP3734, GP2961, GP3290, GP3256, X20115-103, K75, GP3771, GP3262

Table 3. Average intra and inter cluster distance values among eight clusters for forty nine genotypes of lentil (Ward minimum variance method)

Cluster	I	II	III	IV	V	VI	VII	VIII
I	23.801	26.842	30.913	28.111	31.503	29.287	50.934	54.306
II		12.01	18.793	22.147	26.536	24.167	31.531	41.009
III			10.701	19.007	25.207	24.681	49.927	58.129
IV				11.136	24.306	30.241	62.247	62.343
V					20.079	24.185	53.199	42.738
VI						15.279	34.559	50.975
VII							18.603	43.817
VIII								23.888

Table 4. Average intra and inter cluster distance values among eight cluster for forty nine genotypes of lentil (Tocher's method)

Cluster	I	II	III	IV	V	VI	VII	VIII
I	2877	9467	23555	9038	11601	86461	31545	33393
II		4300	16624	23612	9612	73890	29365	40130
III			5532	33063	40744	31837	16246	16484
IV				9004	27108	94293	40062	31713
V					0	123439	56744	71639
VI						18493	31560	28142
VII							0	10461
VIII								0

Table 5. Mean values of clusters of different characters towards genetic divergence in forty nine lentil genotypes under heat stress condition

Clusters	Days to 1st Flowering	Days to 50% Flowering	Days to Maturity	Plant Stand At harvest	Days to harvest	Plant Height (cm)	Branches/ Plant	Seeds/ Pod	Pods/ Plant	1000–seed Weight (g)	Grain Yield/ Plant (g)	Biological Yield/ Plant (g)	Plot Yield (g)	Wilt Incidence%
I	61.680	66.284	113.755	178.858	136.796	34.511	2.274	1.700	82.780	25.173	2.931	35.995	113.401	1.868
II	71.049	75.902	119.223	249.324	133.696	33.607	2.169	1.738	64.338	23.383	2.276	28.601	137.568	1.609
III	68.987	73.707	119.293	227.321	134.778	35.560	2.137	1.906	77.924	24.778	2.631	32.719	244.412	2.014
IV	67.847	72.493	118.694	122.273	138.975	33.641	2.384	2.005	89.165	27.843	3.151	52.556	122.195	1.843
V	76.500	80.849	125.644	246.733	133.470	42.662	2.477	2.000	47.804	25.941	2.736	24.189	52.970	2.355
VI	61.271	65.617	110.263	237.617	131.143	36.826	2.111	2.031	134.076	23.310	3.144	33.261	381.828	1.357
VII	57.393	61.030	98.162	231.967	127.262	34.835	1.989	2.000	188.610	20.571	4.220	56.572	237.377	1.582
VIII	61.521	65.681	110.176	145.567	142.778	38.442	2.443	2.025	153.173	23.051	5.020	54.635	273.338	1.307

2013 and Bhartiya *et al*., 2015).

The genotypes of cluster VII showed the highest mean values (Table 5) for grain yield per plant, number of branches per plant and days to harvest while; cluster VII had highest mean value for biological yield and number of pods per plant. The cluster VI recorded highest mean value for plot yield and number of seeds per pod and cluster V had highest mean value for days to 1st flowering and days to 50% flowering days to maturity and plant height. The cluster IV showed high mean value for 1000–grain weight while, cluster II noticed high mean value for plant stand at harvest. The promising genotypes for grain yield, number of pods per plant, 100–seed weight, harvest index and early maturity were identified from cluster VII, VIII and IV on the basis of mean values which could be utilized for hybridization programme for the development of high yielding genotypes. Among the fifteen traits studied, maximum contribution was made by plot yield (56.38%) (Table 6) followed by plant stand at harvest (30.10%) and number of pods per plant (11.48%). Therefore, these characters may be given importance during hybridization programme.

CONCLUSION

Genetic variability in response of 49 lentil genotypes to imposed heat stress during the reproductive stage has been demonstrated. Four genotypes have been identified GP–2961, PL–234 and LKH–2 to have improved tolerance to high temperature and absolute yield equivalent to current commercial cultivars. The high inter cluster distance was observed between clusters, suggesting wide diversity between them and genotypes in these clusters could be used as parents in hybridization programme to develop heat tolerant lines because crosses between genetically divergent lines will generate heterotic sergeants. Among the fifteen traits studied, maximum contribution was made by plot yield followed by plant stand at harvest and number of pods per plant. Therefore, these characters may be given importance during hybridization programme and offers provides the opportunity for breeding programs to improve the tolerance of lentil to heat stress, leading to better yield stability and profitability for growers. Further controlled studies are required to validate these early findings, refine screening methods and investigate mechanisms inferring tolerance.

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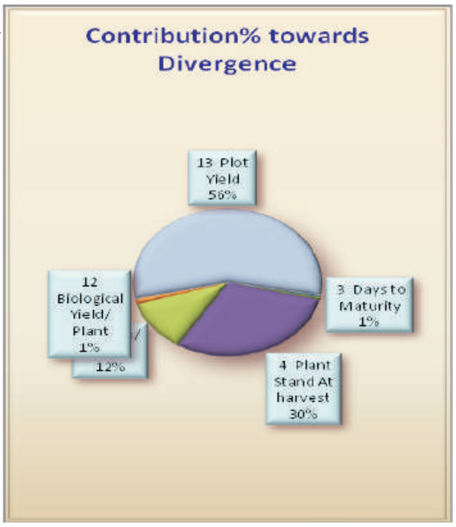
Table 6. Contribution of different characters towards genetic divergence of forty nine lentil genotypes (Ward minimum variance method)

Source	Times Ranked 1st	Contribution (%)
Days to 1st flowering	4	0.34
Days to 50% flowering	0	0.00
Days to maturity	7	0.60
Plant stand at harvest	354	30.10
Days to harvest	0	0.00
Plant height (cm)	0	0.00
Branches/ Plant	0	0.00
Seeds/ pod	0	0.00
Pods/ plant	135	11.48
1000-seed weight(gm)	0	0.00
Grain yield/ plant (gm)	0	0.00
Biological yield/ Plant(gm)	13	1.11
Plot yield (gm)	663	56.38
Wilt incidence%	0	0.00



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Effect of Light Intensity on Yield of Wheat under *Eucalyptus tereticornis* based Agri-silvi-horticultural System

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Abstract: The study was carried out during *rabi* season 2015-16 in the research farm of Department of Forestry, CCS Haryana Agricultural University, Hisar. A pre-established five year old plantation of Kinnow alone and Kinnow + Eucalypts was used as the basic agroforestry model in the study. The data on light intensity was recorded at 0700 ,0900 , 1100 , 1300 , 1500 and 1700 hours. The Kinnow + Eucalypts had more adverse effect on test crop as compared to Kinnow alone due to evergreen nature of both Kinnow and Eucalypts. The maximum light intensity (802.0 LUX) was recorded under Kinnow + Wheat while the minimum intensity was under Kinnow + Eucalypts + Wheat (27.5 LUX) at 1.00 pm and 7.00 am respectively. The results revealed that the average grain yield reduction under Kinnow + Eucalypts and Kinnow alone was 68.9 and 40 per cent, respectively may due to competition for light.

Keywords: Agroforestry, Wheat, Luxmeter, and Shade

Adversities of climatic factors in arid and semi-arid regions accelerate soil moisture deficit and chance of crop failure throughout the world (Lawless *et al*., 2008; Cai *et al*., 2009). Increasing human population is placing unprecedented demand for food and natural resources. It has been estimated that an increasing population and changing dietary intake will lead to about 80–120% increase in global food requirement by 2050 (Tilman *et al*., 2001; FAO 2006; Foley *et al*., 2012). This large amount of food production and the increasing pressure of industries cannot be achieved by the agricultural sector only, rather through a combination of technological improvements and involvement of other natural ecosystems (Licker *et al*. 2010). In order to meet the ever-increasing demand of tree products viz. fuelwood, fodder, timber, fruits etc. there is a need to increase number of trees on aerable/non-areable farmlands because their voluntary regeneration is decreasing. On drylands, plantation of trees apart from improving the ecosystem the ecosystem, will sustain agricultural productivity, raise the farmer's income and provide multiple yield products (Kaushik *et al*., 2000). Agroforestry is one of the best options to increase the tree cover outside the forest. The need of agroforestry has been necessitated in many parts of the country, which face several agricultural and ecological problems, predominant of which are soil degradation, large scale deforestation, increasing population pressure of human beings and livestock, and decreasing land : man ratio.

Agroforestry is a popular tool to modify the microclimatic under field conditions. Trees mainly modify radiations, relative humidity, carbon dioxide concentration, wind velocity and soil environment to crop (Dhillon *et al*., 2016). Tree crop integration results into many types of interactions for solar radiations, soil moisture and plant nutrients, there by changing microclimate, which affect the productivity of component crop. The large crown of trees produces a striking shade effect. Because of the plant height ratio of tree-crop intercropping is far greater than in pure crops, an entirely new pattern for light utilization is formed (Whiting, 2011). The farmers adopt only those agroforestry systems, which do not adversely affect their agricultural crops for food security. However, accommodation of trees on hectare basis in the farm land without unduly affecting crops under reduced light condition of the agroforestry system still remains to be inconclusive. The better understanding of tree crop interaction would be a strong scientific basis for improving as well as evolving new systems. Keeping in view the importance of light intensity in productivity of agroforestry systems into consideration, there is need to investigate effect of light intensity on yield of wheat under *Eucalyptus tereticornis* based agri-silvi-horticultural system. The major objective was to undersatnd tree growth and effect of canopy shade on yield of wheat under agri-silvi-horticultural system.

MATERIAL AND METHODS

The present study was conducted during 2015-16 during winter season at CCS Haryana Agricultural University, Hisar (29°09′N latitude and 75°43′E longitude at an elevation of 215 m above sea level), situated in semi-arid region of North-Western India. The climate is subtropical-monsoonic with an average rainfall of 350-400 mm, 70-80 per cent of which occurs during July to September. The summer months are very hot with maximum temperature ranging from 40 to 45°C in May and June whereas, December and January are the coldest months (lowest January temperature as low as 0°C). The texture class of the soil is 'sandy loam' and the soil of the experiment site is medium in organic carbon, available N, P and K.

A pre-established five year old plantation of Kinnow alone and Kinnow plus Eucalypts was used as the basic agroforestry model in the study. The experiment was laid out in split plot design with three replications. Wheat variety HD-2967 representing early sown variety of north-western India were selected to test its performance under agri-silvi-horticultural system in comparison to control (devoid of trees). Four fertilizer levels i.e. recommended dose of fertilizer [RDF: 150 kg N + 60 kg P_2O_5 + 30 kg K_2O + 25 Kg $ZnSO_4$ per hactare), RDF + 10 additional 20% and 30% additional dose of N were applied. Sowing of variety was done in the start of the second fortnight of November following all the package and practices. Observations for yield and yield attributing parameters such as plant height, number of tillers per plant, ear length, number of grains per ear, 1000-grain weight etc were recorded to assess the influence of shade caused by tree canopy under both the systems in comparison to control. The light intensity was measured by "Luxmeter" (electronic digital Luxmeter) at crop surface at monthly interval under agroforestry system and in control (devoid of trees) . The data were recorded at 0700, 9000, 1100, 1300, 1500 and 1700hours.

RESULTS AND DISCUSSION

The average initial tree height and basal diameter of *Eucalyptus tereticornis* under agri-silvi-horticultural system was 17.9 m and 17.1 cm respectively, while, the height and basal diameter of Kinnow was 2.70 m and 6.97 cm respectively in combination with Eucalypts whereas it showed 2.80 m height and 7.60 cm basal diameter in absence of trees (Table 1). The annual increment in tree height and basal diameter was 1.5 m and 6.1 cm respectively. The annual increment in Kinnow was 0.11 m and 0.5 cm respectively with Eucalypts and while 0.29 m and 1.02 cm in absence of Eucalypts. The results shows a significant variation among the growth patterns of kinnow and Eucalypts which proves that when a crop is grown in association with trees, there is a competition for light, moisture, nutrients and a positive or negative interaction might be expected to develop between them.

The average light intensity across the months was maximum (876.9 LUX) under sole cropping at 1300 hrs and the minimum (99.3 LUX) at 0700 hrs (Table 2). Similar pattern was discernible for shade conditions under both agroforestry systems with maximum 682.9 LUX at 1300 hrs and minimum of 61.3 LUX at 0700hrs under agri-horticultural system while maximum 560.2 LUX at 1300 hrs and minimum 34.8 LUX at 0700 hrs under agri-silvi-horticultural system. The light intensity in sole cropping exceeded the light intensity under agroforestry system. The results obtained are in conformity with results obtained by Jha and Gupta (2003) and Rana *et al.* (2011) also revealed that the open area receives higher light intensity as compared to the agroforestry system because there are no trees in the field.

The significant variation in plant population was recorded among different agroforestry systems and control (Fig. 1). However, variation for plant population/m^2 was non-

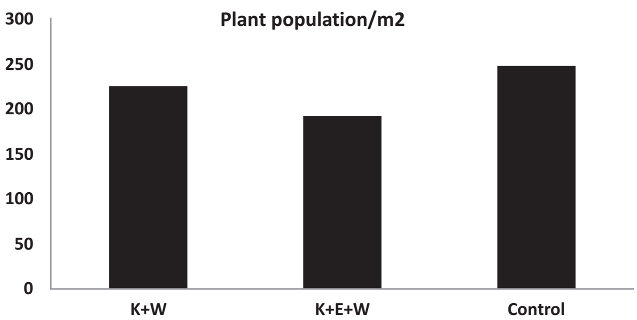

Fig. 1. Effect light intensity on Plant population (per m^2) under agroforestry system as compared to sole cropping

Table 1. Growth performance of eucalypts and kinnow under silvi -agri-horti system

Treatment	Tree growth of Eucalyptus tereticornis						Annual growth increment		
	Initial			At Harvest			Height (m yr^{-1})	Basal diameter (cm yr^{-1})	DBH (cm yr^{-1})
	Height (m)	Basal diameter (cm)	DBH (cm)	Height (m)	Basal diameter (cm)	DBH (cm)			
Eucalyptus	17.9	21.5	17.1	19.4	27.6	21.6	1.5	6.1	4.5
Kinnow (Eucalyps + Kinnow + Agril. crops)	2.70	6.94	-	2.81	7.44	-	0.11	0.5	-
Kinnow (Kinnow+ Agril. crops)	2.80	7.60	-	3.09	8.62	-	0.29	1.02	-
CD (p=0.05)	3.521	6.112	NS	4.341	3.212	NS	0.21	0.45	NS

Table 2. Measurement of light intensities (LUX) under control and *E. tereticornis* based agri-silvi-horticultural system.

Months	Light Intensity (LUX)																	
	7 am			9am			11am			1pm			3pm			5pm		
	Open	K alone	K+E	Open	K alone	K+E	Open	K alone	K+E	Open	K alone	K+E	Open	K alone	K+E	Open	K alone	K+E
December	74.1	46.4	27.5	276.8	193.5	60.3	525.6	412.1	255.9	652.7	530.3	434.3	472.0	356.4	245.0	155.3	64.9	43.1
January	88.0	56.9	32.1	333.4	231.7	73.4	633.5	493.5	309.2	782.2	635.7	521.1	567.1	426.7	295.3	187.3	77.4	52.7
February	105.2	69.1	38.9	401.9	279.0	87.9	761.2	595.5	373.3	941.1	763.8	627.1	700.2	513.1	357.0	223.9	95.6	64.4
March	130	72.6	40.8	484	293.0	92.3	918.4	625.3	392.0	1131.9	802.0	658.5	821.5	538.8	374.9	271.5	100.4	67.6
Average	99.3	61.3	34.8	374.0	249.3	78.4	709.7	531.6	332.6	876.9	682.9	560.2	640.2	458.7	310.6	209.5	338.3	56.9
CD (p=0.05)	9.05	7.23	7.04	9.72	8.10	7.37	15.21	12.11	9.76	17.41	14.04	12.02	14.34	13.86	13.08	12.83	12.09	14.7

significant between agri-horti (kinnow+ wheat) and agri-silvi-horti (kinnow+ eucalypts + wheat) systems. The highest numbers of plants per square meter (248) were in control (non agroforestry) followed by kinnow (225) based agroforestry system while the minimum population ($192/m^2$) of wheat was observed in Kinnow + eucalypts based agroforestry system. Kiran *et al.* (2002) also revealed that plant population of wheat crop reduced upto 34 to 54 percent respectively, under *Eucalyptus tereicornis and Dalbergia sissoo* based agroforestry system. Similarly, plant height at 30, 60, 90 and 120 days after sowing (DAS) of wheat showed significant variation with varying levels of fertilizer under different agroforestry systems (Table 3). Significantly higher plant height was in agri-horti (kinnow + wheat) system as compared to agri-silvi-horti (kinnow + eucalypts + wheat) system. In agri-horti (kinnow + wheat) and agri-silvi-horti (kinnow + eucalypts + wheat) system, RDF + additional dose of N (10, 20 and 30%) significantly increased the plant height over recommended dose of fertilizer at different time intervals of growth in wheat. Prasad *et al.* (2010) predicted a loss of 45 percent for various yield attributing characters of cowpea under *Eucalyptus tereticornis* based agroforestry system as compared to sole cropping in southern India. However, the differences between RDF + 10% additional dose of N, RDF + 20% additional dose of N and RDF + 30% additional dose of N were non-significant. It was observed that the due to competition for moisture, light and nutrients among the annual crops, trees and fruit plants, the observed values for different yield attributing parameters were lesser than the sole crop with recommended doses of fertilizer. The number of tillers (m^{-2}) under both the agroforestry system (265.2 m^{-2}, 242.3 m^{-2}) were much less as compared to the sole crop (324.5m^{-2}). Similar results were also obtained for other yield attributing parameters (Table 4). Recommended dose of fertilizer + additional dose of N (10, 20 and 30%) significantly increased the yield attributing parameters over recommended dose of fertilizer in both agri-horti (kinnow + wheat) and agri-silvi-horti (kinnow + eucalypts + wheat) system. However, the differences between RDF + 10% additional dose of N, RDF + 20% additional dose of N and RDF + 30% additional dose of N were found to be non-significant. Similarly, Lott *et al.* (2009) recorded a poor growth maize crop under *Grevillea robusta* based agroforestry system in semi-arid Kenya. A net reduction of 25 percent in different parameters of maize was observed under the agroforestry system as compared to the sole crop due to 30-35% reduction in light intensity under agroforestry system as compared to the sole cropping.

The significantly higher grain and straw yield of wheat

(2.79 and 4.15 t/ha respectively,) was observed in agri-horti (kinnow + wheat) system as compared to agri-silvi-horti system (1.46 t/ha and 2.26 t/ha respectively) (Table 5). An increase of 83.6 and 91.0 per cent in straw and grain yield, respectively of wheat was recorded under kinnow plus wheat system as compared to kinnow plus eucalypts based agroforestry system. However, the grain yield of wheat under agroforestry was less as compared to sole crop with recommended doses of fertilizer. However, recommended dose of fertilizer + additional dose of N (10, 20 and 30%) significantly increased the grain yield over recommended dose of fertilizer under both the agroforestry systems while varying fertilizer levels did not influence straw yield of wheat under both the agroforestry systems. The average grain yield reduction under Kinnow + Eucalypts and Kinnow alone was 68.9 and 40 per cent, respectively as compared to sole crop may due to competition of light among the annuals and perennials. Similarly, Rana *et al*. (2007) and Verma and Rana (2014) also witnessed a yield reduction in paddy and wheat (14.9 and 29.7 percent respectively) under agroforestry system as compared to the sole cropping. The experimental results conclude that the light intensity has a strong impact on

Table 3. Effect light intensity on Plant height (cm) under agroforestry system as compared to sole cropping

Treatment		Plant height (cm)			
		30 DAS	60 DAS	90 DAS	120 DAS
Kinnow+Wheat	RDF	25.0	44.9	84.5	87.2
	RDF +10% additional dose of N	27.4	47.8	88.6	91.2
	RDF +20% additional dose of N	28.1	48.6	90.1	92.2
	RDF +30% additional dose of N	28.6	49.3	90.8	92.6
	Mean	27.3	47.7	88.5	90.8
Kinnow+	RDF	22.4	42.5	81.7	83.1
Eucalypts+Wheat	RDF +10% additional dose of N	24.2	45.3	84.8	86.2
	RDF +20% additional dose of N	25.0	46.4	85.4	87.0
	RDF +30% additional dose of N	25.3	47.0	86.2	88.1
	Mean	24.2	45.3	84.5	86.1
Control	RDF	29.9	52.2	91.3	93.3
CD (p=0.05)	AFS	1.2	1.5	2.4	2.1
	Fertilizer levels	1.4	1.8	2.7	2.8
	AFS x FLS	NS	NS	NS	NS

Table 4. Effect of light intensity on yield attributing parameters of wheat in different agroforestry systems

Treatment		Yield attributes			
		Tillers/m^2	Ear heads/ m^2	Grains/ear head	Test weight (g)
Kinnow+Wheat	RDF	238.0	235.3	44.2	43.8
	RDF +10% additional dose of N	266.0	261.1	48.0	46.7
	RDF +20% additional dose of N	278.7	272.2	48.6	47.0
	RDF +30% additional dose of N	278.0	271.2	48.8	46.9
	Mean	265.2	259.9	47.4	46.1
Kinnow+	RDF	228.0	223.0	40.7	39.8
Eucalypts+Wheat	RDF +10% additional dose of N	244.0	239.0	43.6	43.0
	RDF +20% additional dose of N	248.0	242.0	43.9	43.3
	RDF +30% additional dose of N	249.0	244.0	43.8	43.2
	Mean	242.3	237.0	43.0	42.3
Control	RDF	324.5	319.0	49.8	47.2
CD (p=0.05)	AFS		10.4	1.9	1.8
	Fertilizer levels	2.8	14.7	2.7	2.6
	AFS x FLS	NS	NS	NS	NS

Table 5. Effect of light intensity on yield of wheat in different agroforestry systems

Treatment		Yield (t/ha)	
		Grain	Straw
Kinnow+ Wheat	RDF	2.50	3.88
	RDF +10% additional dose of N	2.80	4.15
	RDF +20% additional dose of N	2.94	4.31
	RDF +30% additional dose of N	2.90	4.25
	Mean	2.79	4.15
Kinnow+	RDF	1.31	2.09
Eucalypts+ Wheat	RDF +10% additional dose of N	1.47	2.29
	RDF +20% additional dose of N	1.54	2.33
	RDF +30% additional dose of N	1.53	2.32
	Mean	1.46	2.26
Control	RDF	4.70	6.80
CD (p=0.05)	AFS		0.16
	Fertilizer levels	0.15	NS
	AFS x FLS	NS	NS

the growth and yield of wheat crop and even a change in the fertilizer dose can overcome the loss in grain and straw yield of wheat crop.

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Exogenous Applied Salicylic Acid Alleviates Adverse Effects of High Temperature on Photosynthesis in Late Sown Wheat *(Triticum aestivum)*

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Abstract: A pot culture experiment was conducted to study the role of exogenously applied salicylic acid (SA) in imparting thermal tolerance to wheat (*Triticum aestivum* L.) crop during reproductive stage. Exogenous application of SA (0.1mM) on leaves of four wheat genotypes HD3086, HD2985, HD3043 and HD3076 genotypes were done at reproductive stage of normal and very late sown plants (high temperature induced by staggered sowing of wheat). SA application increased the activities of superoxide dismutase (SOD) and ascorbate peroxidase (APOX) while catalase (CAT) activity were decreased in comparison to unsprayed plants. The beneficial effect of SA application which caused by increase in antioxidant enzymes activity, while measured 2 and 10 DAFS was reflected in terms of increase in SPAD value, membrane stability index (MSI), and net photosynthesis (Pn) over unsprayed plants. Genotypic variation response to SA was also observed in antioxidant enzymes and physiological traits. Activities of SOD and APOX were highest in HD 2985 and minimum in HD 3076 However, the activity of antioxidant enzymes and physiological traits were decreased when recorded 10 DAFS, but it was higher than unsprayed plant in all genotypes.

Keywords: Wheat, Photosynthesis, Enzyme, Salicylic acid, SPAD, antioxidant

Wheat is one of the most important staple food crops of the world including India in terms of the harvested area, human nutrition and grown primarily for its grain. Most of the wheat growing areas of the world experience many environmental stresses including drought (water stress) and high temperature (heat stress) that adversely affect yield (Lott *et al*., 2011). The excess active oxygen species (AOS) generated during high temperature stress leads to oxidative stress in plant system (Hasanuzzaman *et al*., 2012). Yield reduction in wheat under high temperature (HT) stress is caused by hastened phasic development, decrease in photosynthesis, fast senescence. Exogenous treatments with SA have been evidenced to impart defence alongside several kinds of stresses. The function of salicylic acid in imparting tolerance to a several biotic stresses has been exhaustively deliberated; in addition, fresh reports have also confirmed that salicylic acid provide tolerance to several abiotic stresses like salt, drought, chilling, heat, ultraviolet radiation, and heavy metals (Miura and Tada, 2014). However, outcome of exogenous SA depends on various factors for instance the species and developmental stage of the plant, the mode of application, and the concentration of SA and its endogenous level in the specified plant (Horvath *et al*., 2007). Based on background knowledge and prior scientific facts, it is apparent that the effects of salicylic acid (SA) were studied only at seedling stage and controlled conditions (short duration of heat stress) in wheat. On the other hand, late sown wheat crop encounters prolonged heat stress throughout reproductive phase. Therefore, this study was accomplished to elucidate the role of SA in imparting thermal tolerance to wheat crop during reproductive stage.

MATERIAL AND METHODS

A pot culture experiment was conducted in completely randomized design with three replications using with four wheat genotypes (HD3086, HD2985, HD3043, and HD3076). The experiments were performed at pot culture facility of Division of Plant Physiology, IARI, in two *rabi* seasons during 2013–14 and 2014–15, during 20th November (normal sowing) and 9th January (very late sowing) both the year, following the recommended cultural practices. The staggered sowing strategy was used for terminal heat stress treatment. When anthesis started, foliar application of salicylic acid (SA) (0.1mM) was done and distilled water was sprayed on control plant. Flag leaves were collected from control and SA treated wheat genotypes at 2 and 10 days after foliar spray (DAFS) of SA for biochemical estimations. Physiological parameters were also measured in flag leaf at 2 and 10 DAFS of SA. Membrane stability index (MSI) was estimated according to the procedure illustrated by Premachandra *et al*. (1990). Soil and plant analyser development (SPAD) values were determined in the centre of flag leaves by means of portable Minolta SPAD–502 chlorophyll meter (Minolta camera Co. Ltd., Osaka, Japan).

Net photosynthesis (Pn) was estimated by means of Infrared Gas Analyser (IRGA), LI-6400XT Model (Li-COR Ltd., Lincoln, Nebraska, USA). The superoxide dismutase (SOD) activity was estimated based on formation of blue coloured formazone, adhering to the method given by (Dhindsa *et al*., 1981). The catalase (CAT) activity was estimated, adhering to the method given by Aebi *et al*., (1984). The total Ascorbate peroxidase (APOX) activity was determined following the procedure described by Nakano and Asada, (1981).

RESULTS AND DISCUSSION

The photosynthesis rate (Pn) decreased significantly in all genotypes grown under late sown condition as compared to normal sown condition, with maximum decrease evinced in HD3043 (28%) followed by HD3076 (27%) and HD 3086 (27%) and minimum in HD2985 (17%). 2 DAFS of SA, the Pn enhanced significantly in late sown crop, with maximum increase observed in HD 2985 (13%) which was satisfactorily at par with normal sown, however, 10 days after foliar spray under late sown conditions Pn decreased, even though it was still higher than their respective control (Table 1). Foliar spray of SA maintained significantly higher SPAD value in late sown condition and maximum value recorded in HD2985 (9%) than respective control (Table 2). Foliar spray of SA maintained

Table 1. Effect of SA on the photosynthesis rate (μmolCO_2 m^{-2} s^{-1}) in wheat genotypes under normal and high temperature stress (induced by late sowing) conditions during reproductive stage

Days after foliar application (DAFS)	Genotypes	Photosynthesis rate (μmolCO_2 m^{-2} s^{-1})							
		Normal sown				Late sown			
		C	C+SA	Mean	%change	HT	HT+SA	Mean	Percent change
2	HD2985	22.6	23	22.8	1.77	18.6	21.1	19.85	13.44
	HD3086	23.9	24.1	24	0.84	17.5	19.7	18.6	12.57
	HD3076	19.3	19.5	19.4	1.04	14.1	15.3	14.7	8.51
	HD3043	21.4	21.4	21.4	0.00	15.3	17	16.15	11.11
10	HD2985	22	22.1	22.05	0.45	17.1	18.9	18	10.53
	HD3086	24.5	24.6	24.55	0.41	14.3	15.9	15.1	11.19
	HD3076	20	20.1	20.05	0.50	9.1	9.6	9.35	5.49
	HD3043	21.4	21.1	21.25	−1.40	10.9	11.8	11.35	8.26

	Factors	Sowing (S)	Treatment (T)	S×T	Variety (V)	S×V	T×V	S×T×V
2 DAFS	CD (p=0.05)	0.614	0.614	0.868	0.868	1.227		
10 DAFS	CD (p=0.05)	0.691			0.977	1.381		

C = Control; C+SA = Control + salicylic acid; HT = High Temperature; HT+SA = High temperature + salicylic acid

Table 2. Effect of SA on SPAD value in wheat genotypes under normal and high temperature stress (induced by late sowing) conditions during reproductive stage

Days after foliar application (DAFS)	Genotypes	SPAD value							
		Normal sown				Late sown			
		C	C+SA	Mean	% change	HT	HT+SA	Mean	Percent change
2	HD2985	49.2	49.3	49.3	0.20	41.1	44.8	43.0	9.00
	HD3086	46.7	46.9	46.8	0.43	38.2	41.2	39.7	7.85
	HD3076	46.0	46.2	46.1	0.43	35.2	38.0	36.6	8.11
	HD3043	46.4	47.0	46.7	1.40	38.1	41.1	39.6	7.87
10	HD2985	50.2	50.2	50.2	0.00	39.5	43.8	41.7	10.89
	HD3086	46.1	46.5	46.3	0.98	36.5	39.7	38.1	8.77
	HD3076	44.4	44.5	44.5	0.23	32.2	34.1	33.1	6.07
	HD3043	46.4	46.7	46.6	0.65	34.4	37.5	36.0	9.01

	Factors	Sowing (S)	Treatment (T)	S×T	Variety (V)	S×V	T×V	S×T×V
2 DAFS	CD (p=0.05)	1.498	1.498		2.119			
10 DAFS	CD (p=0.05)	1.399	1.399		1.978			

See Table1 for treatment detail

significantly higher MSI in late sown condition. 2 DAFS of SA, the MSI enhanced significantly in the late sown crop, with maximum increase evinced equally by HD 2985 (15%) and HD3086 (15%) and minimum by HD3076 (7%) (Table 3). Foliar spray of SA reduced the CAT activity significantly in normal sown as well in late sown crops. Under late sown condition, 2 DAFS of SA, a significant drop in the CAT activity in all genotypes was measured with most of the decrease substantiated in HD3076 (18%) and least but significant decrease in HD2985 (15%), however, 10 days after foliar spray the catalase activity enhanced, even though it was reasonably lower (10–11%) than its respective control (Table 4). Foliar spray of SA further enhanced the SOD in all genotypes with the maximum increase evinced in HD2985 (26%) (Table.5). In comparison to normal sown condition, APOX activity increased significantly under late sown (high temperature stress) condition in all the genotypes with highest increase quantified in HD2985 (49%). Besides, the foliar spray of SA enhanced the APOX activity considerably in the normal sown crop with maximum increase determined in HD2985 (7%) (Table 6).

The reactive oxygen species generated during high

Table 3. Effect of SA on the membrane stability index (%) in wheat genotypes under normal and high temperature stress (induced by late sowing) conditions during reproductive stage

Days after foliar application (DAFS)	Genotypes	Membrane stability index (%)							
		Normal sown				Late sown			
		C	C+SA	Mean	Percent change	HT	HT+SA	Mean	Percent change
2	HD2985	84.64	85.29	84.965	0.77	70.12	80.23	75.175	14.42
	HD3086	82.27	82.78	82.525	0.62	66.38	73.61	69.995	10.89
	HD3076	83.15	82.3	82.725	−1.02	62.28	68.35	65.315	9.75
	HD3043	83.98	84.12	84.05	0.17	65.32	72	68.66	10.23
10	HD2985	85.31	86.2	85.755	1.04	71.2	76.9	74.05	8.01
	HD3086	81.41	82	81.705	0.72	69	74.1	71.55	7.39
	HD3076	82.3	80	81.15	−2.79	64.28	67.12	65.7	4.42
	HD3043	84.95	85.3	85.125	0.41	68.31	74.3	71.305	8.77

	Factors	Sowing (S)	Treatment (T)	S×T	Variety (V)	S×V	T×V	S×T×V
2DAFS	CD (p=0.05)	0.297	0.297	0.421	0.421	0.595	0.595	0.841
10DAFS	CD (p=0.05)	0.255	0.255	0.361	0.361	0.51	0.51	0.722

See Table1 for treatment detail

Table 4. Effect of SA on the catalase activity (µmol H_2O_2 reduced mg^{-1} protein min^{-1}) in wheat genotypes under normal and high temperature stress (induced by late sowing) conditions during reproductive stage

Days after foliar application (DAFS)	Genotypes	Catalase activity (µmol H_2O_2 reduced mg^{-1} protein min^{-1})							
		Normal sown				Late sown			
		C	C+SA	Mean	%change	HT	HT+SA	Mean	Percent change
2	HD2985	5.48	5.00	5.24	−8.76	6.12	5.22	5.67	−14.71
	HD3086	4.98	4.61	4.80	−7.43	5.59	4.70	5.15	−15.92
	HD3076	3.51	3.31	3.41	−5.70	3.89	3.21	3.55	−17.48
	HD3043	4.98	4.51	4.75	−9.44	5.38	4.55	4.97	−15.43
10	HD2985	5.98	5.77	5.88	−3.51	6.43	5.75	6.09	−10.58
	HD3086	5.58	5.28	5.43	−5.38	6.11	5.50	5.81	−9.98
	HD3076	4.09	3.89	3.99	−4.89	3.98	3.51	3.75	−11.81
	HD3043	5.41	5.11	5.26	−5.55	5.69	5.31	5.50	−6.68

	Factors	Sowing (S)	Treatment (T)	S×T	Variety (V)	S×V	T×V	S×T×V
2 DAFS	CD (p=0.05)	0.211	0.211	0.298	0.298			
10 DAFS	CD (p=0.05)		0.216		0.306			

See Table1 for treatment details

Table 5. Effect of SA on the superoxide dismutase activity (units mg^{-1} protein min^{-1}) in wheat genotypes) under normal and high temperature stress (induced by late sowing) conditions during reproductive stage

Days after foliar application (DAFS)	Genotypes	Superoxide dismutase activity (units mg^{-1} protein min^{-1})							
		Normal sown				Late sown			
		C	C+SA	Mean	%change	HT	HT+SA	Mean	Percent change
2	HD2985	4.96	5.31	5.14	7.06	6.28	7.48	6.88	19.11
	HD3086	4.48	4.59	4.54	2.46	5.23	6.11	5.67	16.83
	HD3076	3.17	3.25	3.21	2.52	3.58	3.89	3.74	8.66
	HD3043	4.61	4.91	4.76	6.51	5.25	5.87	5.56	11.81
10	HD2985	5.03	5.17	5.10	2.78	5.85	6.51	6.18	11.28
	HD3086	4.39	4.41	4.40	0.46	5.07	5.59	5.33	10.26
	HD3076	3.44	3.49	3.47	1.45	3.84	4.08	3.96	6.25
	HD3043	4.62	4.67	4.65	1.08	5.10	5.58	5.34	9.41

	Factors	Sowing (S)	Treatment (T)	S×T	Variety (V)	S×V	T×V	S×T×V
2DAFS	CD (p=0.05)	0.286	0.286	N/A	0.404	0.571	N/A	N/A
10DAFS	CD (p=0.05)	0.266	0.266	N/A	0.376	N/A	N/A	N/A

See Table1 for treatment details

Table 6. Effect of SA on the ascorbate peroxidase activity (μmol H_2O_2 reduced mg^{-1} protein min^{-1}) in different wheat genotypes under normal and high temperature stress (induced by late sowing) conditions during reproductive stage

Days after foliar application (DAFS)	Genotypes	Ascorbate peroxidase activity (μmol H_2O_2 reduced mg^{-1} protein min^{-1})							
		Normal sown				Late sown			
		C	C+SA	Mean	%change	HT	HT+SA	Mean	Percent change
2	HD2985	6.11	6.57	6.34	7.53	9.12	11.35	10.24	24.45
	HD3086	5.80	6.25	6.03	7.76	8.15	10.21	9.18	25.28
	HD3076	5.10	5.25	5.18	2.94	7.32	8.65	7.99	18.17
	HD3043	6.10	6.40	6.25	4.92	7.81	9.51	8.66	21.77
10	HD2985	6.51	6.71	6.61	3.07	9.00	10.00	9.50	11.11
	HD3086	5.81	5.95	5.88	2.41	6.51	7.31	6.91	12.29
	HD3076	4.81	4.86	4.84	1.04	5.00	5.32	5.16	6.40
	HD3043	6.13	6.25	6.19	1.96	6.21	6.82	6.52	9.82

	Factors	Sowing (S)	Treatment (T)	S×T	Variety (V)	S×V	T×V	S×T×V
2 DAFS	CD (p=0.05)	0.302	0.302	0.427	0.427	0.604	N/A	N/A
10 DAFS	CD (p=0.05)	0.214	0.214	0.303	0.303	0.428	N/A	N/A

See Table1 for treatment details

temperature stress damage the photosynthetic machinery especially D1 and D2 protein of photosystem II. Exogenous application of signaling compounds play an important role in minimising the negative effects of high temperature stress mainly by reducing damage caused by oxidative stress (Larkindale, 2004). Induced thermotolerance has been reported when plants were pre-treated with salicylic acid (Larkindale and Knight, 2002). Dat *et al*. (1998b) have also reported that pre-treatment with SA and mild accumulation of hydrogen peroxide in plants may carry out a signaling function during high temperature stress. In present experiments, antioxidant enzyme activity after foliar application of SA on reproductive stage of wheat plants enhanced the activities of SOD and APOX not only in late sown crop (high temperature stress conditions), but also improved their activities in normal sown crops in all genotypes. Increased in activity of antioxidant machinery might be helped to keep the reactive oxygen species level at optimum level which helped in protection of photosynthetic machinery and ultimately net photosynthesis in late sown condition of wheat genotypes. The results are similar with Wang *et al*. (2006) who have also observed in grape, that SA application (0.1mM) promptly increased SOD and peroxidase (POD) activities in grape leaves. Contrast to our finding Wang *et al*. (2014) have also reported that only slight enhancement of SOD activity in response of 0.3mM SA application in wheat plant under short term heat stress. The SPAD values were maintained significantly higher in treated plant compared to respective control in all genotypes. Similar to our results, Khan *et al*. (2013) also reported that SA application ameliorated the adverse effect of heat stress on SPAD value in wheat seedling. Findings of present study are in agreement with that of Wang *et al*. (2010) who reported that, SA did not significantly affect the net photosynthesis rate (Pn) of grape leaves prior to heat stress, but, SA pretreatment alleviated the reduction in Pn under heat stress, by keeping a higher Rubisco activation state and greater PSII efficiency and may also increase PSII revival. On the other hand, Khan *et al*. (2013) explained that SA application elevated photosynthesis even during no stress condition, and lessened the harmful outcome of heat stress in wheat.

CONCLUSIONS

The exogenous application of SA (0.1mM) positively modulated the antioxidant defense system and protected the photosynthetic apparatus from reactive oxygen species when analyzed two days after foliar application, however, the enzyme activity shown decreasing trends when analyzed ten days after foliar spray. Genotypic difference in fortification of antioxidant machinery was also reported in this study to exogenous application of SA.

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Productivity and Economics of Wheat in Pearlmillet-Wheat Cropping System

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Abstract: A field experiment was conducted during the year 2013–14 at CCS Haryana Agricultural University, Hisar to observe the effect of various nutrient source on productivity and economics of wheat in pearlmillet-wheat cropping system. Grain, straw and biological yield of pearlmillet and wheat was significantly higher in 50% recommended dose of nitrogen and phosphorus through fertilizers + 50% nitrogen through farmyard manure in pearlmillet and 100% NP through fertilizer in wheat than other treatments but was at par with 100% N and P through fertilizers in pearlmillet and wheat in pearlmillet-wheat cropping system. This might be due to easy availability of plant nutrients, high photosynthetic rate as compared to under dose fertilized treatments and probably came through favourable influence on vegetative growth in terms of dry matter accumulation. Higher availability of plant nutrients increased the biological yield and economics of wheat under pearlmillet–wheat cropping system.

***Key words*:** Productivity, Economics, Wheat, Pearlmillet, Cropping system

Pearlmillet-wheat cropping system is a popular double cropping system in sandy loam soils of arid and semi-arid areas. This cropping system is followed in an estimated area of 2.26 million ha area in India and contribution of this cropping system in total food grain production is considerably large. Integrated use of organic and inorganic sources of nutrients plays an important role for sustaining the productivity of soil and crops in an intensive cropping system in north-western India. The nature of both the crops poses a great challenge for sustainable productivity of these crops. Since pearl millet and wheat are exhaustive crops for soil nutrients, replenishment of nutrients on regular basis becomes important aspect of management for sustainability. Research in India has indicated the need for integrated use of organic and inorganic manures for sustaining the productivity of soil and crop in an intensive cropping system (Hegde and Babu, 2004). This approach restores and sustains soil health and productivity in the long run besides meeting the nutritional deficiencies. Limited information is available on productivity and economics aspects in wheat under system base research. It is being realized that pearlmillet-wheat cropping system research in sandy loam soils on nutrient application is need of the hour for optimizing the use of different sources of plant nutrients. Present study was, therefore, undertaken to assess the effect of integrated nutrient management system on crop productivity and economics of wheat in pearlmillet-wheat cropping system in sandy loam soil conditions of Haryana.

MATERIAL AND METHODS

The field experiments were carried out in permanent laid out research plots in Agronomy Research Area at CCS Haryana Agricultural University, Hisar during the year 2013–14. The soil of the experimental site was sandy loam in texture, having pH 7.87, poor in available nitrogen (191.53 kg ha^{-1}), low in phosphorus (17.25 kg ha^{-1}) and rich in potassium (288 kg ha^{-1}). The experiment was laid out in randomized block design with 12 treatment combinations replicated thrice (Table 1). The recommended levels of nitrogen and phosphorus were 125 and 62.5 kg ha^{-1} for pearl millet and 150 and 60 kg ha^{-1} for wheat. The pearl millet variety used was HHB 197 with 5 kg seed ha^{-1}, keeping row spacing of 45 cm. In wheat, variety WH 711 was sown with 125 kg seed ha^{-1} keeping row spacing of 20 cm. The nitrogen content in different organic materials was determined each year and the amount of these materials required for substituting a specified amount of nitrogen as per the treatment was calculated. The organic sources of nutrients viz., FYM, green manure of *sesbania* and wheat straw were incorporated in soil at 30, 36 and 30 days, respectively, before sowing of pearl millet crop. The recommended nitrogen and phosphorus were applied through urea and diammonium phosphate (DAP), respectively. One post sowing irrigation was applied during both the years to pearl millet. Similarly, in wheat five irrigations were applied each year. Recommended package of practices were followed in both the crops for agronomic operations (CCS, HAU, Hisar, 2012–13). Grain yield of pearlmillet from each plot was recorded by threshing two kg ear-heads from total ear-heads and then converted into kg/ha and biological yield was calculated after harvesting net plot area, the bundles of pearlmillet crop were sun dried and their weight recorded and converted into kg/ha. Plants of wheat crop were cut from 25 cm row length from two places in the third row on either side in each plot. Dry weight was recorded after drying first in the sun and then in oven at 60±5^{0}C to the constant weight and after this dry matter of plants (per running meter) was worked out. Ten representative spikes of wheat crop were taken from each plot and spike length (cm) was measured from the base of the lower spikelet to the tip of the top spikelet of the spike. Awns length was not considered. From the spikes selected for measuring spike length, the grains were separated from spikelet, the total number of grains was counted and the number of grains per spike was recorded. After harvesting the net area from each plot, the crop was threshed separately. Grain yield of wheat crop from each plot was recorded and computed as grain yield kg/ha and straw yield from each plot was worked out by subtracting the grain yield from total biological yield of individual net plot area and computed as kg/ha. Harvest index calculated by this formula:−

$$\text{Harvest index (\%)} = \frac{\text{Economic (grain) yield}}{\text{Biological yield}} \times 100$$

RESULTS AND DISCUSSION

Pearlmillet

Yield studies: The significantly higher grain yield of pearlmillet was obtained in T_6 (3012 kg/ha) and at par with T_5 (2935 kg/ha) and 209 percent higher over control (Table 1) and significantly better over rest of the treatments. Similar observation was reported by Singh *et al*. (1999) in pearlmillet‒wheat cropping sequence. The higher grain yield of pearlmillet obtained with 100% RD‒NP and 50% RD‒NP + 50% N through FYM in pearlmillet could be ascribed to their favourable effects on yield. Biological yield of pearmillet was found higher n T_6 (10843 kg/ha) than control. These two parameters also increased with higher dose of inorganic fertilizers. This might be due to easy availability of plant nutrients and higher photosynthetic activities as compared to under dose fertilized treatments. Replacement of 50% N through FYM also results into higher grain and biological yield of pearlmillet. This increase in biological yield probably came through favourable influence on vegetative growth (Dahiya *et al*. 2008) and also reported that in total production of the system only FYM could replace 50% nitrogen need of pearlmillet without much adverse effect on its production. The increased availability of P increased the growth and yield attributing characters which reflected in higher yield of pearlmillet. Grain and biological yield of pearlmillet were found better in treatments where N was supplied through FYM and green manure, as to that of wheat straw. This may be due to higher C:N in wheat straw at initial growth period of the crop. The results are similar to the findings of Jat and Shaktawat (2003).

Table 1. Effect of different treatments on biological and grain yield (kg/ha) of pearlmillet

Treatments	Seasons		Grain yield	Biological yield
	Kharif	Rabi		
T_1	Control (no fertilizer)	Control (no fertilizer)	976	3220
T_2	50% N and P through fertilizers	50% N and P through fertilizers	1814	6076
T_3	50% N and P through fertilizers	100% N and P through fertilizers	1932	6607
T_4	75% N and P through fertilizers	75% N and P through fertilizers	2412	8273
T_5	100% N and P through fertilizers	100%. N and P through fertilizers	2935	10272
T_6	50% N and P through fertilizers + 50% N through FYM	100%. N and P through fertilizers	3012	10843
T_7	75% N and P through fertilizers + 25% N through FYM	75% N and P through fertilizers	2704	9355
T_8	50% N and P through fertilizers + 50% N through wheat straw	100% N and P through fertilizers	2824	9827
T_9	75% N and P through fertilizers + 25% N through wheat straw	75% N and P through fertilizers	2472	8503
T_{10}	50% N and P through fertilizers + 50% N through green manure	100% N and P through fertilizers	2841	9915
T_{11}	75% N and P through fertilizers + 25% N through green manure	75%. N and P through fertilizers	2575	8883
T_{12}	Farmers′ practice = (N, P = 49.125, 15.175kg/ha) FYM = 37.8q/ha.	Farmers' practice = (N, P,K = 156.25, 58.575, 3.7kg/ha)	2768	9604
CD (p=0.05)			86	725

Wheat

Growth characters: In general, the growth characters in wheat were superior due to favourable weather conditions. The 50% RD-NP + 50% N through FYM in pearl millet and 100% RD-NP in wheat recorded maximum dry matter accumulation (145 g/mrl) at maturity (Table 2). Besides its role in chlorophyll synthesis, nitrogen plays an important role in cell division and cell enlargement. Nitrogen inside the plant control the synthesis of body building materials, obviously the deposition of protoplasmic constituents in the cells and higher hydration ratio affected by nitrogen nutrition might have increased the turgidity of the elongated cells (Lal *et al*. 1995). This could have brought an increase in growth and development of plants which ultimately affected the dry matter positively. The dry matter accumulation increased with increase in the nitrogen dose. Awasthi and Bhan (1993) conforms these findings. Pronounced response obtained through the application of FYM in growth characters might be attributed primarily to the enriched supply of essential nutrients and enhanced availability of native phosphorus. The CO_2 produced during the mineralization of organic matter play important role in the solubilisation of native phosphorus. The poor performance of wheat straw in comparison to FYM and green manure might be due to the immobilization of nitrogen in the rhizosphere and thus consumption of more energy for the decomposition of cellulose, hemicelluloses and lignin parts in straw. Poor performance of wheat mainly because of immobilization in wheat straw applied plots have also been reported by Kundu *et al*. (2006).

Yield contributing characters: yield components of wheat crop *viz*., length of spike (12.2 cm) was recorded significant in T_6 over T_5 (11.5 cm) and also grains per spike (44.0) in T_6 significantly at par with T_5 (41.1), when supply 50% RD-NP + 50% N through FYM in pearl millet and 100% RD-NP in wheat. Dry matter accumulation of wheat crop in T_6 (145 g/mrl) was significantly at par with T_5 (143.7 g/mrl). Supply of most of the required macro and micro nutrients in adequate amount for a long time due to slow release of nutrients by the FYM. These findings are in close conformity with that of Gawai and Panwar (2006).

Grain and straw yield: Highest grain yield was recorded highly significant in T_6 (5582 kg/ha) over T_5 (5490 kg/ha) followed by other treatments. Yield contributing characters viz., tillers per meter row length, length of spike and 1000−grain weight were higher in T_6. The results are in close proximity with the findings of Jain and Punia (2003). Phosphorus application might have shown significant effect on the yield of the wheat. This might be attributed to its beneficial effect on yield attributes, higher availability of P that promoted growth and development, and ultimately resulting in higher yield. These findings are in confirmation of Sammuria and Yadav (2008). Fertilizer caused pronounced effect on growth parameters, on yield contributors and finally on the grain and straw yield of wheat crop. Higher straw yield were recorded in T_6 (6687 kg/ha) and statistically not at par with T_5 (6560 kg/ha). This might be attributed to the better growth of plant which in turn resulted in significant dry matter accumulation resulting into higher straw yield. Similar results have been reported by Kumar *et al*. (2008). The highest harvest index (47.17) recorded in T_4 indicated that the increase in grain yield rather than straw yield could be due to more translocation of photosynthates from source to sink.

Table 2. Effect of different treatments on the yield contributing characters and yield of wheat

Treatments	Dry matter accumulation at maturity (g/*mrl)	Spike length (cm)	Grains/spike	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
T_1	46.6	6.6	29.7	1190	1309	46.73
T_2	131.3	8.0	34.0	3610	4188	46.29
T_3	136.0	8.8	37.2	4649	5253	46.95
T_4	134.0	8.6	35.8	4640	5196	47.17
T_5	143.7	11.5	41.1	5490	6560	45.56
T_6	145.0	12.2	44.0	5582	6687	45.49
T_7	139.3	10.0	38.8	5036	5841	46.29
T_8	142.0	10.8	40.0	5127	6049	45.87
T_9	137.0	9.2	38.0	4742	5405	46.73
T_{10}	142.3	11.0	40.0	5421	6450	45.66
T_{11}	138.0	9.6	38.4	4749	5461	46.51
T_{12}	141.3	10.4	39.2	5085	5949	46.08
CD (P=0.05)	12.9	0.5	2.0	47	81	NS

*mrl= meter row length

Dahiya *et al.* (2008) also reported similar results. It was found that there was no significant difference in grain yield of wheat recorded at 100% RD-NP and the treatment where nitrogen was substituted through FYM in pearl millet followed by 100% RD-NP in wheat. This might be attributed to availability of nitrogen for entire growing season due to slow mineralization of organic nitrogen from FYM in pearl millet-wheat cropping system.

Economic: Highest gross returns/ha (Rs. 139818 and 84518)and B:C (2.52) was in T_6 with the application of 50% RD-NP + 50%N through FYM in pearl millet and 100% RD-NP in wheat than control (Table 3). The 50% RD-NP + 50% N through FYM in pearl millet and 100% RD-NP in wheat increased the soil fertility status, microbial activity in soil and provided all the essential nutrients but in small amount for a longer time. These results are in corroboration with the findings of Kumar *et al.* (2008).

Table 3. Effect of different treatments on gross returns (Rs/ha), net returns (Rs/ha) and B:C of pearlmillet-wheat cropping system

Treatments	Gross returns	Net returns	B:C
T_1	34184	-7903	0.81
T_2	87315	42259	1.93
T_3	106139	59331	2.26
T_4	113150	66685	2.43
T_5	136630	81734	2.48
T_6	139818	84518	2.52
T_7	124829	75179	2.51
T_8	128553	66287	2.06
T_9	116061	61969	2.14
T_{10}	133920	78522	2.41
T_{11}	118511	67841	2.33
T_{12}	126808	75152	2.45

Thus it can be concluded that net return was higher with the application of 50% RD-NP + 50%N through FYM in pearl millet and 100% RD-NP in wheat under pearlmillet-wheat cropping system and enhance the economic value of the farmer.

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Effect of Tillage, Nutrient Management and Mulch on Productivity and Profitability of Cropping Sequences under Vertisols in Central Plateau Zone of Maharashtra

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***Abstract**:* A field experiment was carried out to study the effect of resource conservation technologies cropping systems and nutrient management on crop productivity and profitability in Marathwada region. Grain yield and fodder yield (kg ha^{-1}) in *Kharif* and *Rabi* was maximum with the conventional tillage, maize‑wheat cropping systems, 100% RDF and with mulch 5 tonnes ha^{-1}. Soybean equivalent yield (SEY) and net profit under conventional tillage were 6.15 and 12.19% higher respectively. In pooled data, soybean – rabi sorghum (36.55 q ha^{-1}) recorded significantly SEY and higher net profit of Rs. 92, 956. Significant effect of 25 % higher fertilizer on SEY (35.3 q ha^{-1}) and net profit of Rs. 85, 847 ha^{-1} over 75% RDF was observed in individual years and in pooled result. Mulching with 5 tonnes/ha recorded significantly higher SEY (34.03 q ha^{-1}) and net returns (Rs. 80573) than the no mulch treatment.

Key-words: Cropping systems, Mulching, Minimum tillage, Nutrient management, RDF, Soybean equivalent yield

At present, global agriculture is under significant pressure to meet the demands of rising population. The finite and degraded soil and water resources used in agriculture are predicted to be further stressed by the impact of climate change. Soybean−*rabi* sorghum is one of the most dominant systems in Marathwada region. The productivity of this existing sequence in small and marginal farmer's field is low, besides having lower cropping intensity as the fields remain idle for nearly three to four months. Diversification and intensification with suitable tillage operations (Zero/Minimum) is the only answer if farmers are to make their farming profitable as well as achieving higher cropping intensity. Furthermore, cropping intensity tends to increase soil organic carbon and microbial biomass through greatest retention of crop residues (Stromberger *et al.,* 2007). Crop residues as mulch modifies the hydrothermal regime of the soil surface and have been reported to increase soil organic fertility (Bakht *et al.,* 2009).

Tillage plays an important role in the nutrient storage and release from soil organic matter, with conventional tillage soil disturbance through tillage is a major cause of reduction in the number and stability of soil aggregates and subsequently organic matter depletion (Six *et al.,* 2000). Cropping systems plays an important role in determining soil physical characteristics and in nutrient cycling mechanisms. According to Lal (2007) zero till farming in combination with residue retention are substantial in terms of erosion control, water conservation, soil fertility enhancement and carbon sequestration. Vertisols in India occupy area of the country of which constituting 8.1% of the total geographical area of the country of which 40.4% and 21.01% are in Madhya Pradesh and Maharashtra respectively (Bhattacharya *et al,*‑2009). Minimum soil disturbance with organic soil cover and diversified crop rotations gaining more attention to address the challenge of livelihood security especially of small holders (Gangwar *et al.,* 2006). So, present investigation was undertaken to assess the effects of resource conservation technologies, cropping system and crop residue on yields between different cropping systems.

MATERIAL AND METHODS

An experiment was initiated during 2012‑13 at AICRP on Integrated Farming Systems, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani to study the effect of resource conservation technologies cropping systems and nutrient management on crop productivity and profitability in Marathwada region. The area is characterized by fairly hot summer, moderately humid and warm monsoon with heavy rains. The soil of the experimental site was clayey in texture, 143.5 kg ha^{-1} available N, 11.5 kg ha^{-1} available P and 340.5 available K. the experiment was in split‑split plot design with three replications *viz.* six main treatments; T_1: Minimum tillage, T_2: Conventional tillage; C_1: Soybean‑Rabi sorghum, C_2: Soybean−Wheat, C_3: Maize‑Gram, C_4: Maize‑Wheat. The two levels of mulch as sub treatment *i.e.,* M_1: No mulch, M_2: with mulch 5 tonne /ha. and the levels of nutrients; N_1: RDF,

N_2: 75% RDF were taken as sub−treatments. The doses of fertilizers were 30:60:0, 100:75:75, 100:50: 50 and 25:50:0 NPK kg ha^{-1} for soybean, maize, wheat and gram respectively. SEY were calculated on the basis of farm gate prices for each crop. The incident of pests and diseases was low and no protection was given during the crop seasons. Available nitrogen, phosphorus and potassium were estimated by alkaline permanganate method (Sharawat and Burford, 1982), Olsen′s method as described by Sparks (1996) and Hanway and Heidel (1952), respectively. The experiment was analyzed in SAS model through NARS portal developed by TASRI, New Delhi.

RESULTS AND DISCUSSION

Effect of Tillage: The tillage had significant effect in respect of soybean equivalent yield, gross monetary returns and net monetary returns of sequences during individual years and on pooling the data. Conventional tillage recorded significantly highest SEY (108.37 q ha^{-1}) of 6.15% over minimum tillage (94.32 q ha^{-1}). Reduced mineralization of plant residues have been considered responsible for the low yields obtained with minimum tillage systems. The transition from intensive to conservative tillage systems will require the modification of N dynamics in the soil plant systems on crop productivity and on efficiency of N fertilizer use (Malecka and Blecharzyk, 2008). Same trend was observed in case of GMR and NMR. Increase in net profit of conventional tillage (Rs.2, 59, 881) over minimum tillage (Rs.2, 28, 185) to the tune of 12.15 percent (Table.1). The impact of treatments on improvement in grain yield might have helped in accruing higher profit.

Effect of Cropping Systems: The effect of cropping systems during individual years was significant among the treatments. Significantly highest soybean equivalent yield (SEY) (27.31 q ha^{-1}) was under maize−gram during the 2012−13, while in 2013−14 and 2014−15 Soybean−Rabi sorghum was significantly superior over the rest of the cropping systems. In pooled data, maize−gram (36.35 q ha^{-1}) recorded significantly higher SEY. Cropping sequence maize−wheat secured significantly lowest SEY (30.89 q ha^{-1}) over the soybean−wheat and maize−gram. The net profit, Soybean−Rabi sorghum was significantly during individual years and as well as in pooled data due to higher land use efficiency of this cropping sequence. Cropping system, maize−wheat recorded significantly lowest net profit in 2012−13, 2014−15 while in 2013−14 the lowest net profit was in maize, Desai *et al.* (2014) also reported similar findings in relation with the cropping systems.

Effect of fertilizer/ nutrient management; Soybean equivalent yield was significantly higher with additional fertilizer during all three years over 75% RDF, while in pooled results, 100% RDF recorded significantly higher SEY over 75% RDF (Table 2). Similar findings were reported by Parvez *et al.* (2009). Significant effect of 100% RDF on net profit over 75% RDF was observed during all individual years except 2012−13. Tripathi and Chauhan (2000) also reported that RDF may have supplied nutrients to crop in optimum and balanced proportion required for its better growth and development, thereby leading to higher grain yield.

Effect of Mulch: Mulch has significant effect on SEY during the years of study. The treatment with mulch application (M_2) recorded significantly highest SEY during and pooled data, also showed similar (Table 1), which may be due to gradual addition of large amount of easily decomposable mulch material. Gross and net profit was significantly affected due to use of mulch in experimentation. Mulching recorded significantly highest gross profit of Rs. 1, 13, 116 over no mulch Rs. 1, 06, 762 and net profit was Rs. 86, 573 with mulching and Rs. 77, 619 with no mulch. These results are in accordance with the findings of Jat *et al*. (2012). Crop residue application (Mulch) reduces water evaporation losses and also moderates soil temperature, which reduces fluctuations in water availability to crop (Gosai *et al.,* 2009).

Interaction effect: Interaction effect of tillage x cropping system x nutrient management on net monetary return for the year 2013−14 was significant. The minimum tillage with soybean−sorghum cropping sequence with 100 % RDF recorded the significantly highest net monetary return (Rs. 112318 ha^{-1}) over the rest of the treatment combinations. Similarly the conventional tillage with soybean−sorghum cropping sequence with 100 % RDF recorded significantly higher NMR (Rs.138836) than other treatment combinations. The lowest NMR was recorded in maize−wheat cropping sequence with 75 % RDF in both tillage combinations. Kihara *et al.* (2012) also observed significant effects of tillage and fertilizer on yields of maize and soybean crop. Interaction effect of tillage x cropping system on soybean equivalent yield for the year 2014−15 was significant. Maize−gram with the conventional tillage recorded the highest soybean equivalent yield of 45.65 q/ha followed by soybean−sorghum sequence. Gupta *at al.* (2007) also reported significant interaction effect of tillage system with fertility levels.

Interaction effect of tillage x mulch on soybean equivalent yield for the year 2014−15 was also significant. Conventional tillage with 5 tonnes ha^{-1} recorded the highest soybean equivalent yield (41.74 q ha^{-1}) which significantly superior over all treatment interaction. Interaction effect of tillage x cropping system on GMR for the year 2014−15 was significant. Maize−gram cropping sequence recorded the highest gross monetary return Rs 162067 which is significantly superior over all treatment interaction. Palliwal *et*

Table 1. Grain and fodder yield (kg ha^{-1}) of the different crop sequences

Treatment	Kharif		Rabi		Kharif		Rabi		Kharif		Rabi	
	Grain yield	Fodder yield	Grain yield	Fodder yield	Grain yield	Fodder yield	Grain yield	Fodder yield	Grain yield	Fodder yield	Grain yield	Fodder yield
	2012–13				2013–14				2014–15			
Tillage (T)												
Minimum tillage	2120	3338	1957	4303	3061	6728	2441	5215	3358	7364	1972	5234
Conventional tillage	2241	3460	2065	4539	3734	7389	2837	5652	3567	7721	2222	5808
Cropping systems												
Soybean –Rabi Sorghum	1223	1609	2329	6405	2357	3009	3074	8199	2089	3957	2518	9125
Soybean –Wheat	1213	1645	2304	4783	2322	2951	2945	5711	2060	3938	2134	5396
Maize – Gram	3106	5695	1238	1624	4364	1241	2091	2350	4862	1242	1924	2135
Maize −Wheat	3181	5330	2358	4872	4548	1127	2829	5472	4839	11266	2130	5426
Nutrient Management (N)												
100% RDF	2251	3482	2083	4535	3608	7285	2925	5801	3592	7767	2271	5756
75% RDF	2111	3317	2031	4306	3187	6832	2544	5066	3333	7318	2083	5285
Mulch (M)												
No mulch	2108	3379	1978	4357	3244	6991	2613	5146	3317	7470	2025	5413
with mulch 5 tone/h	2253	3420	2136	4485	3551	7125	2856	5721	3608	7615	2329	5629

Table 2. Effect of tillage, nutrient management and mulch on soybean equivalent yield and economics of different crop sequences

Treatment	Soybean Equivalent yield (q ha^{-1})			Gross Monetary return (Rs)			Net monetary return (Rs ha^{-1})			B:C ratio on the basis GMR			B:C ratio on the basis NMR		
	2012–13	2013–14	2014–15	2012–13	2013–14	2014–15	2012–13	2013–14	2014–15	2012–13	2013–14	2014–15	2012–13	2013–14	2014–15
Tillage															
Minimum tillage	24.06	35.22	35.04	70927	116519	124404	43428	88713	96044	2.58	4.19	4.39	1.58	3.19	3.39
Conventional tillage	25.80	43.27	39.30	76050	143139	139505	43701	110559	105621	2.35	4.39	4.12	1.35	3.39	3.12
CD (p=0.05)	0.77	0.83	0.79	2270	2741	2822	2270	2741	2822						
Cropping systems															
Soybean –Rabi Sorghum	25.94	43.15	39.96	76472	142736	141855	49315	115322	114230	2.82	5.21	5.13	1.82	4.21	4.13
Soybean –Wheat	22.91	38.74	32.81	67533	128156	116469	40377	100733	87894	2.49	4.67	4.08	1.49	3.67	3.08
Maize – Gram	27.31	33.62	35.47	69053	132919	125903	47806	78246	92139	2.11	3.37	3.73	1.11	2.37	2.73
Maize – Wheat	23.56	34.92	34.19	69451	115505	121370	36759	82542	86845	2.12	3.50	3.52	1.12	2.50	2.52
CD (p=0.05)	1.09	1.17	1.12	2321	3876	3990	2321	3876	3990	—	—	—	—	—	—
Nutrient Management															
RDF	25.46	41.83	38.61	75067	138377	137062	44315	107913	105315	2.44	4.54	4.32	1.44	3.54	3.32
75% RDF	24.39	36.66	35.73	71910	121281	126847	42813	91883	96349	2.47	4.13	4.16	1.47	3.13	3.16
CD (p=0.05)	0.52	0.56	0.77	1535	1839	2721	1535	1839	2721	—	—	—	—	—	—
Mulch (M)															
No mulch	24.11	37.65	35.22	71067	124193	125028	42393	95249	95216	2.48	4.29	4.19	1.48	3.29	3.19
with mulch 5 tone/h	25.95	38.97	37.17	71941	135465	131944	44736	97472	99511	2.31	4.10	4.07	1.31	3.10	3.07
CD (p=0.05)	0.52	0.56	0.77	1535	1839	2721	1535	1839	2721	—	—	—	—	—	—
Interaction															
TxC															
CD (p=0.05)	N.S	1.66	1.59	N.S	5482	5644	N.S	5482	5644	—	—	—	—	—	—
TxN															
CD (p=0.05)	N.S	1.00	NS	N.S	3299	NS	N.S	3299	N.S	—	—	—	—	—	—
TxM															
CD (p=0.05)	0.72	NS	1.10	2171	NS	3918	2171.68	NS	3918	—	—	—	—	—	—
CxN															
CD (p=0.05)	N.S	1.41	NS	N.S	4666	NS	N.S	4666	NS	—	—	—	—	—	—
CxM															
CD (p=0.05)	1.08	1.41	NS	3071	4666	NS	3071.22	4666	NS	—	—	—	—	—	—
NxM															
CD (p=0.05)	N.S	NS	NS	N.S	NS	NS	N.S	NS	NS	—	—	—	—	—	—
TxCxN															
CD (p=0.05)	N.S	1.99	NS	N.S	6599	NS	N.S	6599.19	NS	—	—	—	—	—	—
TxCxM															
CD (p=0.05)	N.S	NS	NS	N.S	NS	NS	N.S	NS	NS	—	—	—	—	—	—
TxNxM															
CD (p=0.05)	N.S	NS	NS	N.S	NS	NS	N.S	NS	NS	—	—	—	—	—	—
CxNxM															
CD (p=0.05)	1.46	1.80	NS	4343	5940	NS	4343	5940	4343	—	—	—	—	—	—
TxCxNxM															
CD (p=0.05)	N.S	NS	NS	N.S	NS	NS	N.S	NS	N.S	—	—	—	—	—	—

Table 3. Interaction effect of tillage x cropping system x nutrient management on net monetary return 2013–14

Tillage x cropping system x nutrient management	Minimum tillage(Rs. ha^{-1})				Mean	Conventional tillage(Rs. ha^{-1})				Mean
	Soybean–sorghum	Soybean–wheat	Maize–gram	Maize–wheat		Soybean–sorghum	Soybean–wheat	Maize–gram	Maize–wheat	
100% RDF	112318	91144	97400	81058	95480	138836	121065	121869	95420	119298
75% RDF	91526	80951	85134	70169	81945	118609	109773	95378	83521	101820
CD (p=0.05)						6599.19				
Mean	101922	86047	91267	75614	88713	128723	115419	108623	89471	110559

Table 4. Interaction effect of tillage x cropping system on Soybean equivalent yield, Rs/ha (2014–15)

Tillage x cropping system	Soybean–sorghum	Soybean–wheat	Maize–gram	Maize–wheat	Mean
Minimum tillage	38.20	31.40	37.80	32.77	35.04
Conventional tillage	41.72	34.21	45.65	35.60	39.30
CD (p=0.05)			1.59		
Mean	39.96	32.81	41.72	34.18	37.17

Table 6. Interaction effect of tillage x cropping system on GMR (2014–15)

Tillage x cropping system	Soybean–sorghum	Soybean–wheat	Maize–gram	Maize–wheat	Mean
Minimum tillage	135612	111478	134180	116345	124404
Conventional tillage	148098	121459	162067	126395	139505
CD (p=0.05)			5644.11		
Mean	141855	116468	148124	121370	131954

al. (2011) also reported the significant interaction effect of land configuration and mulching with nutrient management in case of net profit. The three years experimental findings concluded that the effect of tillage, nutrient management and mulch recorded higher SEY, GMR, NMR and B : C ratio by conventional tillage as per RDF with 5 tons FYM in soybean – *rabi* sorghum crop sequence.

Table 5. Interaction effect of tillage x mulch on soybean equivalent yield q/ ha (2014–15)

Tillage x Mulch	No mulch	Mulch with 5 tonne ha^{-1}	Mean
Minimum tillage	33.59	36.50	35.04
Conventional tillage	36.85	41.74	39.30
CD (p=0.05)		1.10	
Mean	35.22	39.12	37.17

Table 7. Prices of crops

Soybean	2948	3308	3550
Rabi Sorghum	1133	1421	1620
Wheat	1211	1549	1730
Gram	3408	3138	3428
Maize	1000	1200	1260
Soybean straw	75	87	80
Rabi Sorghum fodder	200	225	260
Wheat straw	50	55	60
Gram straw	75	50	50
Maize fodder	120	125	180

CONCLUSION

The study led to the conclusion that adoption of conventional tillage, maize–wheat cropping systems, 100% RDF and with mulch 5 tonnes /ha has better results than the follow of other practices in study.

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Influence of Pressurised Irrigation with Fertigation on Nutrient Uptake, Yield and Quality Parameters of Groundnut

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Abstract: A field investigation was carried out with groundnut variety TMV 13 in an RBD with three replications comprising of 11 treatments. The drip irrigation at 100% PE with fertigation at 100% RDF as WSF recorded significantly high nitrogen, phosphorus and potassium uptake by groundnut crop at harvest 128.19, 25.16 and 98.06 kg ha^{-1}, respectively, followed by drip irrigation at 75% PE with fertigation at 100% RDF as WSF. The higher post-harvest available soil nitrogen, phosphorus and potassium content under micro sprinkler at 75% PE with fertigation at 100% RDF as WSF were 248, 31.20 and 230 kg ha^{-1}, respectively. Drip irrigation at 100% PE with fertigation at 100% RDF as WSF resulted in significantly higher pod yield (3495 kg ha^{-1}), kernel yield (2585 kg ha^{-1}), oil content (51.80%), oil yield (1339 kg ha^{-1}) and crude protein yield (706 kg ha^{-1}) however, crude protein content (27.32%) was statistically at par with drip irrigation at 75% PE with fertigation at 100% RDF as WSF. Therefore, drip irrigation at 100% PE with fertigation at 100% RDF as WSF is very effective, that resulted in higher nutrient uptake that leads to a higher yield of groundnut followed by micro sprinkler fertigation and least under surface irrigation.

***Keywords*:** Groundnut, Pressurized irrigation, Fertigation, Nutrient uptake, Yield, Quality

Groundnut (*Arachis hypogaea* L.) occupies a predominant position in the Indian oilseed economy. It ranks first in area and production with respect to the total oilseeds production in the country having area of 5.53 m ha, annual production of 7.4 m t with an average productivity of 1338 kg ha^{-1} (Anonymous, 2016). In order to achieve sustained production under the changing climate, the most important crop management factors, irrigation and fertilization must be efficiently utilized by farmers. Development of appropriate water-management technologies to maximize the crop productivity per drop of water is the need of the hour. In India the fertilizers being used as granular, pills and amorphous forms which are applied by various methods such as band application, broadcasting and drilling, where in the fertilizers are likely to be lost by higher rains, flood irrigation *etc*. This can be avoided by applying the fertilizers through micro irrigation called as fertigation (Sameerkumar *et al*., 2016). Studies shows that fertigation of NPK by drip in tomato crop as WSF had significantly higher N, P and K uptake than the normal fertilizers used under drip and conventional method of cultivation (Hebbar *et al*., 2004), Thaman *et al*. (2001) reported that scheduling irrigation through successive increase in IW/CPE ratio from 0.40 to 1.0 significantly improved various growth parameters *viz*. plant height, branches/plant, leaf area index, nodules per plant and the crop growth rate. Sorensen and Lamb (2009) concluded that drip irrigated groundnut had greater yield and market grade compared with non-irrigated regimes. Thus, the use of pressurized irrigation comprises drip and micro sprinkler offers a great degree of control over water and fertilizer application to meet the requirement of crops (El-Habbasha *et al*., 2014). In view of the above, an investigation was undertaken to assess the influence of pressurized irrigation with fertigation on nutrient uptake, yield and quality parameters of groundnut.

MATERIAL AND METHODS

A field experiment was conducted at Pudhupalayam, Tamil Nadu Agricultural University, Coimbatore, during 2015 with groundnut variety TMV 13 in a randomized block design (RBD) with three replications comprising of 11 treatments (Table 1). The soil was sandy clay loam with slightly alkaline in pH (7.24), low organic carbon (0.23 per cent) and medium available N (305 kg ha^{-1}), available P_2O_5 (20.12 kg ha^{-1}), available K_2O (169.27 kg ha^{-1}). A total rainfall of 4.3 mm was received during the cropping period. The daily mean maximum and minimum temperatures were 32.7°C and 21.3°C, respectively with mean pan evaporation per day was 5.6 mm having the average relative humidity of 60.8 per cent during the cropping period.

The raised bed of 120 cm bed width and 30 cm furrow width for drip irrigation treatments, 360 cm bed width with 30 cm furrow for micro sprinkler treatments and check basin for control plot were formed, having row spacing of 30 x 10 cm, with bed size 28.8 m^2 (drip: 24 x 1.2 m, micro sprinkler: 8 x 3.6 m), so as to have uniform population (Figure 1) and the recommended dose of fertilizer (RDF) at 25: 50: 75 kg NPK ha^{-1}. Drip and micro sprinkler irrigation were based on daily pan evaporation (PE) and fertigation was based on nutrient uptake pattern at the different growth stage of groundnut as suggested by Loganathan and Krishnamoorthy (1977), at once in three days interval and the volume of irrigation water was calculated as:

Volume of irrigation (V) = 3 days CPE × Kp × Kc × Area (m^2) × Wp −ER

Where,CPE −Cumulative pan Evaporation for three days (mm); Kp −Pan factor (0.8); Kc −Crop coefficient; Wp −Wetted percentage (80%) for drip; 100% for micro sprinkler (As over lapping was 100%); Area −28.8 m^2; ER −Effective rainfall

The surface irrigation was given at 0.8 IW/CPE ratio with 5 cm depth of water. The required quantity of water soluble fertilizers (WSF) *viz.,* N, P_2O_5 and K_2O were applied as urea (46:0:0), all 19 (19:19:19), MAP (12:61:0) and SOP (0:0:52) were used under drip and micro sprinkler whereas, for surface application urea, MOP and SSP (0:16:0) were used. The observations on the nutrient uptake (kg ha^{-1}) of the plant at harvest stage was down by recording dry matter production of the plants, were chopped into pieces, dried in hot air oven at 65ºC ± 5ºC and ground into fine powder in a Willey mill. The powdered samples were used for the analysis of total nitrogen by Micro-Kjeldahl method (Humphries, 1956), total phosphorus through triple acid digestion method (Jackson, 1973) and total potassium by triple acid digestion method *ie*., Flame photometry (Jackson, 1973) and expressed in per cent on oven dry weight basis. The nutrient uptake was worked out by multiplying the dry matter with the respective nutrient content. Whereas, the post-harvest soil samples collected at a depth of 0–15 cm from each plot were shade dried, powdered and sieved through 2.0 mm sieve for the analysis of available nitrogen by alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus through Olsen method (Olsen *et al.,* 1954) and available potassium by neutral normal ammonium acetate method (Stanford and English, 1949). The nutrient contents were expressed in kg ha^{-1}. The pod yield (kg ha^{-1}) was obtained after stripping, cleaning and drying, the pod yield was recorded at 12% moisture and kernel yield (kg ha^{-1}) by multiplying the pod yield to the shelling percentage. Quality parameters *viz*., oil content of kernels (%) was estimated using the method described by AOAC (1975), the crude protein content (%) of kernels were analyzed for total nitrogen content by Micro-Kjeldahl method (Humphries, 1956) and the N fraction of protein was multiplied by the factor 6.25 to arrive at the protein content of kernels. Oil yield (kg ha^{-1}) on the basis of kernel oil content and kernel yield of groundnut, whereas, crude protein yield (kg ha^{-1}) were recorded on the basis of seed protein content and kernel yield of groundnut.

RESULTS AND DISCUSSION

The fertilizer application methods and form of fertilizer were made a significant impact on nitrogen, phosphorus and potassium uptake. Among different treatments nitrogen, phosphorus and potassium uptake at harvest were significantly high 128.19, 25.16 and 98.06 kg ha^{-1}, respectively under drip irrigation at 100% PE with fertigation at 100% RDF as WSF followed by drip irrigation at 75% PE with fertigation at 100% RDF as WSF with 110.37, 22.38 and 88.47 kg ha^{-1} respectively. Among the micro sprinkler fertigation system, 100% PE with fertigation at 100% RDF as WSF performed higher nitrogen (105.77 kg ha^{-1}), phosphorus (20.22 kg ha^{-1}) and potassium (82.83 kg ha^{-1}) uptake. The surface irrigation (5 cm depth) at 0.8 IW/ CPE ratio with soil application at 100% RDF as NF recorded significantly lower NPK uptake compare to all treatments (Table 1). Krishnasamy *et al.* (2012) reported that due to excess irrigation in surface irrigation methods, fertilizer nutrients might have been leached beyond the root zone. The higher uptake of NPK under the drip at 100% PE and 100% RDF as WSF was 67.15, 125.65, and 80.92% while under the micro sprinkler at 100% PE and 100% RDF as 37.92, 81.34 and 52.82%, respectively over surface irrigation. The increased uptake of plant nutrients under drip fertigation mainly due to the continuous availability of higher soil moisture content which helped to solubilize the plant nutrient near the root zone and favoured easy absorption of plant nutrients by the crop. Similarly, under micro sprinkler fertigation water and water soluble nutrients were applied directly to the foliage, maximum absorption of nitrogen and potassium take place through stomata, and remaining quantity of nitrogen, potassium and full phosphorus was taken up by plants from soil as it became moist soil condition during irrigation (Vasu and Reddy, 2013; Jayakumar *et al*., 2014). In addition, due to the production of more fibrous roots near the top soil under these systems of irrigation has increased the root contact area with soil which ultimately helped to absorb more nutrients into the plant system. This was in conformity with the findings of Hebbar *et al.* (2004).

Data pertaining post-harvest NPK status of the soil (kg ha^{-1}) is influenced by drip and micro sprinkler fertigation with different sources and levels of fertilizers (Table 1). Among the treatments, micro sprinkler at 75% PE with fertigation at 100% RDF as WSF registered highest amount of available N, P_2O_5 and K_2O in post harvest soil *viz*., 248, 31.20 and 230 kg ha^{-1}, followed by drip irrigation at 75% PE with fertigation at 100% RDF as WSF. Surface irrigation (5 cm depth) at 0.8 IW/ CPE ratio with soil application at 100% RDF as NF recorded least N, P_2O_5 and K_2O content in post harvest soil *viz*., 179, 18.50 and 162 kg ha^{-1}, respectively. The decreased plant nutrient status under high irrigation regime under drip system was mainly due to the higher uptake of nutrients as a result of increased dry matter production, which favoured depletion of soil available plant nutrients under these treatments, while under micro sprinkler system due to inadequate moisture content at the deeper layer leads to unutilized nutrients in that layer, may be the reason for higher NPK content in soil over drip (Jain and Meena, 2015). Under surface irrigation due to excess irrigation at once leads to leaching losses of nutrients, that leads to inadequate N, P_2O_5 and K_2O in the post-harvest soil sample (Srijita Paul *et al*., 2016).

Among all treatments, under drip irrigation at 100% PE with fertigation at 100% RDF as WSF was recorded significantly highest pod yield (3495 kg ha^{-1}) and kernel yield (2585 kg ha^{-1}) followed by drip irrigation at 75% PE with fertigation at 100% RDF as WSF and micro sprinkler at 100% PE with fertigation at 100% RDF as WSF. Significantly lowest pod yield (1902 kg ha^{-1}) and kernel yield (1177 kg ha^{-1}) was recorded under surface irrigation (5 cm depth) at 0.8 IW/ CPE ratio with soil application at 100% RDF as NF (Table 2). The increase in groundnut pod yield and kernel yield in fertigation at 100% PE and 100% RDF as WSF were 83.75% and 119.62% in drip system respectively, however, under micro sprinkler system 53.63% and 69.78% respectively over the

Table 1. Nutrient uptake by plant and post-harvest nutrient status of soil

Treatments		Nutrient uptake by plant (kg ha^{-1})			Post-harvest nutrient status of soil (kg ha^{-1})		
		N uptake	P uptake	K uptake	N	P_2O_5	K_2O
T_1	DI at 100% PE + fertigation at 100% RDF with WSF	128.19	25.16	98.06	212	27.14	198
T_2	DI at 75% PE + fertigation at 100% RDF with WSF	110.37	22.38	88.47	235	30.50	223
T_3	DI at 100% PE + fertigation at 75% RDF with WSF	98.63	19.08	80.11	190	22.01	170
T_4	DI at 75% PE + fertigation at 75% RDF with WSF	84.20	14.10	64.34	223	29.10	209
T_5	DI at 100% PE + fertigation at 100% RDF with NF	99.66	19.06	80.30	201	25.32	184
T_6	MS at 100% PE + fertigation at 100% RDF with WSF	105.77	20.22	82.83	213	28.10	205
T_7	MS at 75% PE + fertigation at 100% RDF with WSF	92.57	18.46	75.74	248	31.20	230
T_8	MS at 100% PE + fertigation at 75% RDF with WSF	89.39	17.73	71.31	195	24.30	179
T_9	MS at 75% PE + fertigation at 75% RDF with WSF	82.58	13.01	60.23	225	29.32	215
T_{10}	MS at 100% PE + fertigation at 100% RDF with NF	84.65	17.18	71.86	205	26.80	196
T_{11}	SI (5 cm depth) + soil application at 100% RDF with NF	76.69	11.15	54.20	179	18.50	162
CD (p=0.05)		6.91	2.03	7.51	20	2.95	22

DI -Drip Irrigation, MS-micro sprinkler, WSF-Water soluble fertilizers, NF-Normal fertilizers, SI-Surface irrigation

Table 2. Yield and quality characters as influenced by pressurized irrigation with fertigation at different levels of irrigation and fertilizers in groundnut

Treatments	Pod yield (kg ha^{-1})	kernel yield (kg ha^{-1})	Oil content (%)	Oil yield (kg ha^{-1})	Crude protein content (%)	Crude protein yield (kg ha^{-1})
T_1	3495	2585	51.80	1339	27.32	706
T_2	3183	2261	51.10	1155	26.32	595
T_3	2611	1774	49.03	870	25.14	446
T_4	2292	1449	45.52	660	22.89	332
T_5	2558	1711	47.86	819	24.85	425
T_6	2922	1996	50.02	998	25.90	517
T_7	2501	1626	46.87	762	24.34	396
T_8	2438	1581	46.48	735	23.57	373
T_9	2014	1251	43.52	545	22.13	277
T_{10}	2311	1481	45.60	675	23.11	342
T_{11}	1902	1177	42.70	503	20.61	243
CD (p=0.05)	290	242	2.56	156	2.12	83

See Table 1 for treatment details

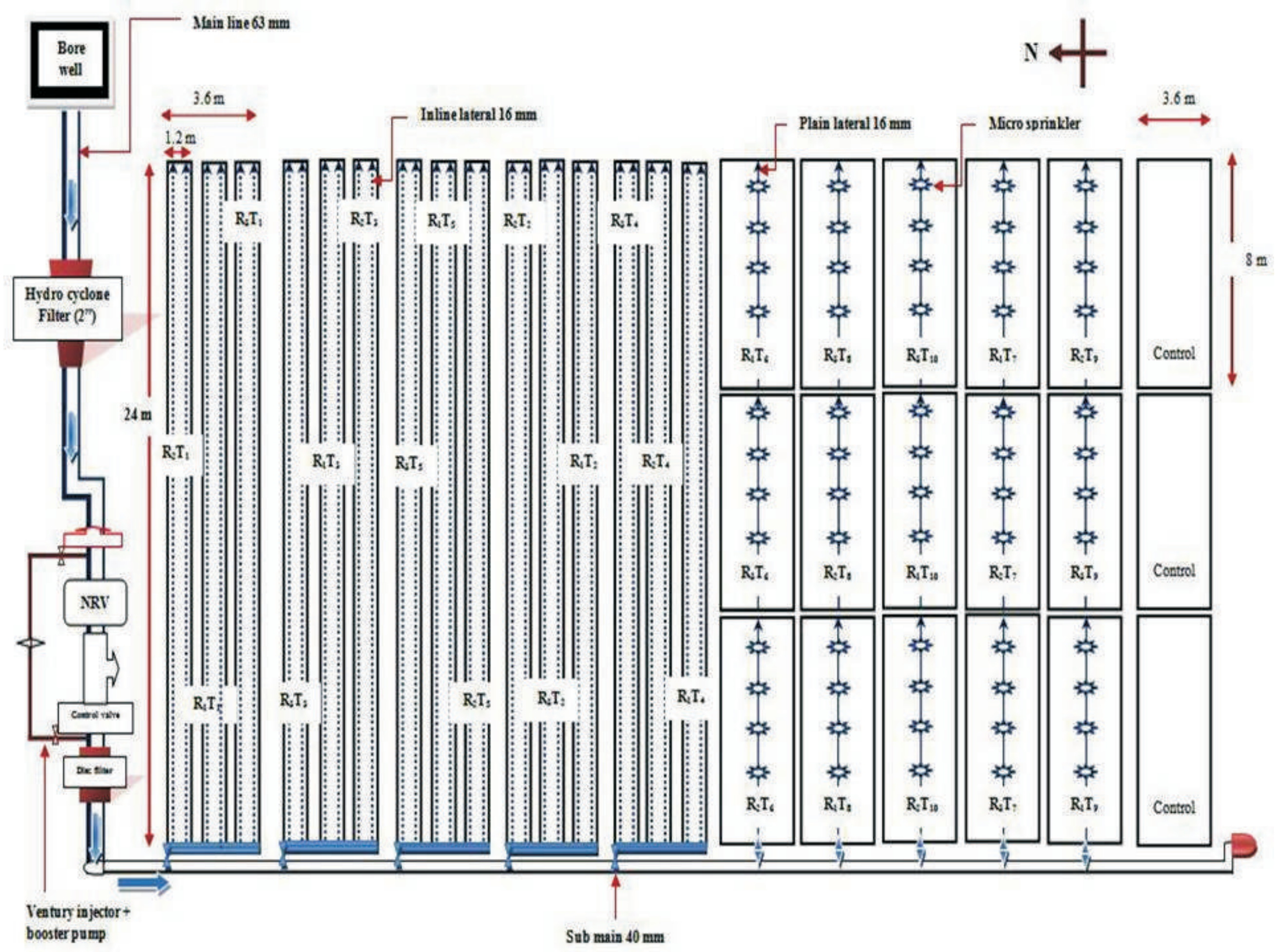

Fig. 1. Layout of pressurized irrigation with fertigation system in the experimental field

surface irrigation. This finding was in concordance with Suresh *et al.*, 2013. The reason might be due to nutrient supply through irrigation water increased solubility and availability of nutrients, as they were supplied at splits, thus minimizing the loss to a considerable extent. The higher pod yield further related to high-frequency irrigation which in turn maintained the soil moisture content in the active root zone at adequate level throughout the crop growth period (Krishnamurthi *et al.,* 2003). The drip irrigation at 100% PE with fertigation at 100% RDF as WSF resulted in higher oil content (51.80%), oil yield (1339 kg ha^{-1}) and crude protein yield (706 kg ha^{-1}) however, crude protein content (27.32%) was statistically at par with drip irrigation at 75% PE with fertigation at 100% RDF as WSF. The significantly lower quality parameters, oil content, oil yield, protein content and crude protein yield were observed in surface irrigation (5 cm depth) at 0.8 IW/ CPE ratio with soil application at 100% RDF as NF (Table 2). Bashir and Mohamed (2014) also observed that by maintaining optimum available soil moisture content in the active root zone, high-frequency irrigation enhanced carbohydrate accumulation and increased oil content in soybean and sunflower. Higher kernel yield with application of drip fertigation of 100% PE with 100% RDF as WSF and drip fertigation of 75% PE with 100% RDF as WSF, respectively results in higher oil yield (Zayton *et al*., 2014). The higher protein was due to more availability of nutrients particularly nitrogen which is an integral part of protein. Higher protein yield may be attributed to higher kernel yield with higher protein in the seed (Vijayalakshmi *et al.,* 2011) in groundnut. Therefore, it can be concluded that groundnut under drip fertigation performed best in terms of higher nutrient uptake by the plant, pod yield and quality parameters followed by micro-sprinkler fertigation and least under surface irrigation.

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Effect of Combined Organic and Inorganic Fertilizers and Weed Management for Sustained Productivity of Aromatic Rice

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Abstract: A field experiment was conducted during the rainy (*kharif*) season of 2016 to study the performance of aromatic rice (*Oryza sativa* L.) by integrated nitrogen management (INM) and integrated weed management (IWM). The 50% RDN (Recommended dose of Nitrogen) through inorganic source + 50% RDN through vermicompost recorded the lowest weed count (13.60/m^2), weed dry weight (26.12 g/m^2) and the highest Plant height (110.60cm), number of panicles/m row length (167.33), number of grains/panicle (107.33), 1000-grain weight (24.83g), grain yield (4.90 tonnes/ha), straw yield (6.91tonnes/ha) and gross returns (₹89,749 ha^{-1}) which were significantly superior over rest of the treatments except number of grains/panicle, grain yield and straw yield which were statistically at par with 75% RDN through inorganic source + 25% RDN through vermicompost. However, the highest net return (₹51,740 ha^{-1}) and B: C ratio (2.74) was recorded by 100% RDN (120 kg N-60 kg P_2O_5–40 kg K_2O ha^{-1}) through inorganic source which were significantly superior over rest of the treatments. Among the IWM, the lowest weed count (10.89/m^2), weed dry weight (20.20g/m^2) and the highest weed control efficiency (66.22 %), grain yield (4.67 tonnes/ha), gross returns (₹85524 ha^{-1}), net return (₹46933/ha) were recorded by weed free (2 HW at 20 & 40 DAT) however, the highest B: C ratio (2.44) was in Pretilachlor 1.5 kg ha^{-1} (P.E.) + bispyribac sodium 20 g/ha at 20 DAT.

Keywords: Aromatic Rice, Integrated nutrient management (INM), Integrated weed management (IWM)

Rice is cultivated as rainfed crop under transplanted ecosystem during *Kharif* season. Huge labour cost is incurred in the nursery raising, puddling and transplanting operations. Cultivation of aromatic rice is very remunerative as it fetches sufficiently higher price over the coarse varieties. However, productivity of aromatic rice varieties is low. Nitrogen and phosphorus fertilizers are major essential plant nutrients and key input for increasing crop yield (Dastan *et al*., 2012). The integration of organic sources and synthetic sources of nutrients not only supply essential nutrients but also have some positive interaction with chemical fertilizers to increase their efficiency and thereby reduce environmental hazards. Weeds also pose major problem in rice production due to the prevalence of congenial atmosphere during *kharif* season and uncontrolled weeds compete with rice and reduce yield. Therefore, an effective and economical weed control strategy needs to be implemented to meet the demand of staple food for increasing population. Herbicides are considered to be an economical alternative to manage weeds compared to hand weeding, which becomes costlier and more impractical because of the non-availability of labour during the critical period of weeding. To sustain the rice productivity at present levels, the N removed in harvested produce or lost from the system must be replaced by N fertilizers or must be obtained from organic manures. Therefore, integrated nutrient management in which both organic manures and inorganic fertilizers and integrated weed management are used simultaneously is the most effective method to maintain a healthy and sustainably productivity of rice. Thus, the present study was undertaken to find out the usefulness of organic manures along with inorganic fertilizers and weed management on growth, yield and economics of rice crop.

MATERIAL AND METHODS

Field experiment was conducted during the *kharif* season in 2016 at Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar (25.59º N, 84.40º E and 52.3 m above the mean sea level). The experiment was in split plot design, which was replicated thrice. The two factors comprised of eight treatments *i.e.* Main-plot: (Integrated nutrient management),N_0– Control N_1–50% RDN through inorganic source + 50% RDN through vermicompost, N_2–75% RDN through inorganic source + 25% RDN through vermicompost and N_3–100% RDF (120 kg N-60 kg P_2O_5–40 kg K_2O ha^{-1}) through inorganic source. Sub-plot: (Integrated weed management)-W_1 – Pretilachlor 1.5 kg ha^{-1} (P.E.) + Bispyribac sodium 20 g/ha at 20 DAT, W_2– Pretilachlor 1.5 kg ha^{-1} (P.E.) + 1 HW at 20 DAT, W_3–Weed free (2 HW at 20 & 40 DAT) and W_4– Weedy check. The gross plot size under each treatment was 16 m^2 and the net plot size was 9.6 m^2.The variety used was Rajendra Bhagwati and crop was transplanted directly in unpuddled (1 harrowing + 2 cultivator

+ 1levelling) conditions. The soil of the experimental plot was sandy loam having pH 8.3, organic carbon 0.44%, low in available nitrogen (212.2) kg/ha), phosphorus (20.5 kg p_2o_5/ha) and potassium (115.8 kg k_2o/ha). The recommended dose of fertilizers was 120-60-40 kg N– P_2O_5– K_2O/ha. However, the nitrogen was applied as per treatment. The half of nitrogen and full dose of phosphorus and potassium were applied as basal and remaining dose of nitrogen was applied in two equal splits at active tillering and panicle initiation stages respectively. The plant height of randomly selected five tagged rice plants in net plot area was measured from the base of the plant to the tip of the upper most leaf. The number of panicles per meter row length was counted from net plot size at the harvesting of crop. Number of grains per panicle calculated by counting the number of grains per panicle was average of five panicles. Test weight was calculated from each plot by weighing 1000-seed weight and expressed in percentage. Grain yield was determined from the net plot area and the straw yield was obtained by subtracting the seed yield from the biological yield. The herbicides were applied with battery-operated knapsack sprayer using spray volume of 500 liters water/ha. The weed density was worked out by counting number of weeds from randomly thrown of quadrate (1.0 m^2) at two place in each plot and average of two reading was done and after counting number of weeds, and were uprooted from the plot for dry weight recording. They are sun-dried subsequently oven drying was done at 60ºC till constant weight reached. Thereafter weighing was done and average of two reading was recorded. Weed data were subjected to square-root transformation {$\sqrt{\ }$ X+0.5}and analyzed statistically. The weed control efficiency was calculated on the basis of dry matter production of weeds at 60 DAS.

RESULTS AND DISCUSSION

The lowest weed population (13.60 /m^2) and weed dry weight (26.12 g/m^2) were in 50% RDN through inorganic source + 50% RDN through vermicompost which were significantly superior over rest of the treatments in main plots. In sub-plot the lowest weed population (10.89 /m^2), weed dry weight (20.20 g/m^2) and weed control efficiency (66.22%) were recorded in weed free treatment (2 HW at 20 & 40 DAT) which were significantly superior over rest of the treatments. The findings of the present research were enclosed confirmity with the result reported by Kumari et al., 2016. Among the different herbicide treatments, the lowest weed population (15.15 /m^2) and weed dry weight (28.33 g/m^2) were recorded in Pretilachlor 1.5 kg/ha (P.E.) + 1 HW at 20 DAT which were significantly superior over rest of the treatments in sub plots. The highest weed control efficiency (66.22 %) was recorded under the weed free (2 HW at 20 & 40 DAT) treatment which was closely followed by Pretilachlor 1.5 kg/ha (P.E.) + 1 HW at 20 DAT (52.62%). The highest plant height (110.60 cm) in 50% RDN through inorganic source + 50% RDN through vermicompost (Table 1). Plant height progressively increased with advancement of the age of crop. When organic sources of nutrients were applied and supplemented with inorganic sources of nutrients enhanced the nutrient availability and helped in increasing the plant height (Dekhane *et al*., 2015).The highest grain yield of rice (4.90 t/ha) was recorded by the treatment 50% RDN through inorganic source + 50% RDN through vermicompost which was statistically at par with 75% RDN through inorganic source + 25% RDN through vermicompost (4.70 t/ha) in main plots and the highest grain yield of rice (4.67 t/ha) was recorded by weed free treatment (2 HW at 20 & 40 DAT) which was significantly superior over rest of the treatments except Pretilachlor 1.5 kg/ha (P.E.) + 1 HW at 20 DAT treatment (4.48 t/ha) which was statistically at par with weed free treatment. Prakash et al. (2013) were reported higher grain yield under hand weeding and herbicidal treatments which was attributed to better utilization of applied nutrients by crop as compared to weedy check. The results were similar to that of the experimental findings of Kabdal *et al*. (2014). There were not any phytotoxic effects on rice crop. The yield advantage on the application of organic sources is due to their capability to supply essential nutrients in addition to N, P and K. Application of organic manure along with chemical fertilizers accelerated microbial activity, increased nutrient use efficiency and enhanced availability of the native nutrients to the plants resulting higher nutrients uptake**.** Vermicompost applied plots built-up residual soil fertility because of slow release of nutrients and reduction of nutrient losses. Application of vermicompost might help in improving soil physical condition on one hand and improving the nutrient availability in the soil on the other hand and there by improved the grain yield. The highest gross return (Rs.89,749/ha) was obtained by 50% RDN through inorganic source + 50% RDN through vermicompost which was significantly superior over rest of the treatments in main plots and the highest gross return (Rs. 85,524/ha) was obtained by weed free (2 HW at 20 & 40 DAT) treatment which was significantly superior over rest of the treatments and found statistically at par with Pretilachlor 1.5 kg/ha (P.E.) + 1 HW at 20 DAT treatment (Rs. 82,192/ha) in sub plot treatments (Table-1). However, the highest net return (Rs. 51,740/ha) was recorded by 100% RDN (120 kg N-60 kg P_20_5– 40 kg K_2O/ha) through

Table 1. Effect of combined organic and inorganic fertilizers and weed management for sustained productivity of aromatic rice

Treatments	Weed count (No./m^2) at 60 DAT	Weed dry wt. (g/m^2) at 60 DAT	WCE (%)	Plant height (cm)	No of panicles/m row length	No of grains $panicle^{-1}$	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
Main plot : Nitrogen levels												
N_1–Control	25.20	46.26	–	94.62	131.92	93.08	23.35	2.58	3.64	47,198	23,262	1.98
N_2–50% RDN through inorganic source + 50% RDN through vermicompost	13.60	26.12	–	110.60	167.33	107.33	24.83	4.90	6.91	89,749	42,339	1.89
N_3–75% RDN through inorganic source + 25% RDN through vermicompost	17.46	32.30	–	106.76	164.42	103.56	24.25	4.70	6.58	85,949	47,614	2.23
N_4–100% RDN (120 kg N-60 kg P_2O_5–40 kg K_2O ha^{-1}) through inorganic	20.68	38.48	–	104.22	162.17	101.32	23.97	4.42	6.25	81,004	51,740	2.74
CD (p=0.05)	1.06	2.04	–	2.05	2.53	4.11	NS	0.20	0.42	3,305	3,305	0.09
Sub plot: Weed management												
W_1 – Pretilachlor 1.5 kg/ha (P.E.) + bispyribac sodium 20 g ha^{-1} at 20 DAT	18.64	34.85	41.71	103.92	170.08	99.48	23.75	4.34	6.11	79,403	46,308	2.44
W_2 – Pretilachlor 1.5 kg/ha (P.E.) + 1 HW at 20 DAT	15.15	28.33	52.62	106.00	171.92	104.08	24.49	4.48	6.34	82,192	46,109	2.31
W_3– Weed free (2 HW at 20 & 40 DAT)	10.89	20.20	66.22	107.40	178.50	109.49	24.50	4.67	6.58	85,524	46,933	2.23
W_4 – Weedy check	32.26	59.79	–	98.88	105.33	92.24	23.67	3.10	4.34	56,781	25,606	1.86
CD (p=0.05)	1.31	1.29	–	2.10	2.28	2.44	NS	0.21	0.13	3,365	3,365	0.11

inorganic source which was significantly superior over rest of the treatments in main plots. The highest net return (Rs.46,933 ha^{-1}) was in weed free (2 HW at 20 & 40 DAT) treatment which was statistically at par with Pretilachlor 1.5 kg/ha (P.E.) + 1 HW at 20 DAT (₹46,109 ha^{-1}) and Pretilachlor 1.5 kg/ha (P.E.) + bispyribac sodium 20 g/ha at 20 DAT (₹46,308 ha^{-1}). The lowest net return obtained in weedy check was due to high infestation of weeds resulting in low weed control efficiency. These results are in conformity with those reported by Sanjay *et al*. (2008). The highest B: C ratio (2.74) was also recorded by the treatment 100% RDN (120 kg N-60 kg P_2O_5– 40 kg K_2O ha^{-1}) through inorganic source which was significantly superior over rest of the treatments in main plots. Similar result was also reported by Kundu et al., 2016. In sub plots, the highest B:C ratio (2.44) was recorded by Pretilachlor 1.5 kg ha^{-1} (P.E.) + bispyribac sodium 20 g/ha at 20 DAT which was significantly superior over rest of the treatments in sub plot treatments. The cost of weeding was comparatively higher with hand weeding (twice) than herbicidal treatments, that's why lowest B: C ratio recorded under weed free except weedy check (Uma et al. 2014).

CONCLUSION

The highest net return and B: C ratio was recorded by 100% RDN (120 kg N-60 kg P_2O_5– 40 kg K_2O ha^{-1}) through inorganic source which were significantly superior over rest of the treatments. Among the IWM, the lowest weed count, weed dry weight and the highest weed control efficiency, grain yield, gross returns, net return were recorded by weed free (2 HW at 20 & 40 DAT) however, the highest B: C ratio was in Pretilachlor 1.5 kg ha^{-1} (P.E.) + bispyribac sodium 20 g ha^{-1} at 20 DAT.

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Effect of Different Row Arrangements on Performance of Linseed (*Linum usitatissimum* L.) and Dwarf Field Pea (*Pisum sativum* L.) Intercropping Association

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Abstract: A field experiment was conducted during the winter season of 2013–14 at Varanasi to evaluate the effect of various row arrangements on growth and yield attributes of linseed and dwarf field pea intercropping system. Among the row arrangements, row ratio of 4:1 with 80% linseed + 20% dwarf field pea recorded maximum plant height, number of branches plant^{-1}, dry matter accumulation, seed bolls plant^{-1}, seeds boll^{-1}, grain and straw yield of linseed as compared to other treatments. However, maximum test weight and harvest index of linseed was in row ratio of 1:4 with 20% linseed + 80% dwarf field pea and row ratio of 1:3 with 25% linseed + 75% dwarf field pea. In case of dwarf field pea, row ratio of 1:4 with 20% linseed + 80% dwarf field pea ,the plant height, number of branches plant^{-1}, dry matter accumulation **plant^{-1},** pods plant^{-1}, seeds pod^{-1}, grain and straw yield was significantly higher as compared to rest of the treatments. The highest seed index and harvest index of dwarf field pea was recorded in row ratio of 4:2 with 66.67% linseed + 33.34% dwarf field pea followed by the row ratio of 3:1 with 75% linseed + 25% dwarf pea and row ratio of 4:2 with 66.67% linseed + 33.34% dwarf field pea , respectively. None of the row arrangements were superior over sole crop of either linseed or dwarf field pea .

Keywords: Growth, Yield, Intercropping, Linseed, Dwarf field pea

Among the oilseed crops grown during *rabi,* linseed is next in importance to rapeseed and mustard and is cultivated in more than 50 countries. However, in recent time, linseed oil has becoming more popular as functional food in the health food market because of their reported health benefits and disease preventive properties on coronary heart disease, some kinds of cancer, neurological and hormonal disorders (Herchi *et al.,* 2010). Intercropping is an effective approach for boosting the production and quality productivity of crop, agricultural practices are cultivating of two or more generally dissimilar crops simultaneously on the same piece of land, in distinct row arrangement is known as intercropping. It is a practice that increases diversity in the cropping system (Bahadur *et al*., 2015; Kumar *et al*., 2016). Intercropping improves soil fertility through biological nitrogen fixation with the use of legumes, increases soil conservation through greater ground cover than sole cropping, enhances crop competitiveness in weed suppression and provides better lodging resistance for crops susceptible to lodging than when grown in monoculture. One of the reasons of the linseed finding place in mixed or intercropping has been minimizing risk of moisture variation and infestation of insect pest and diseases (Sharma *et al*., 2012). Intercropping of linseed with dwarf field pea under irrigated condition gives higher seed yield, help in great amount of dry matter production by both crop. In the light of above context this crop has great production potential in irrigated conditions.

MATERIAL AND METHOD

The field experiment was conducted during the *rabi* season of 2013–14 at Banaras Hindu University, Varanasi. This is geographically located 25°18′N latitude and 83°3′E, longitude at an elevation of about 128.39 m above mean sea level in the northern Gangatic Alluvial plains. The experimental site was fairly uniform in topography and well drained. It has sub–tropical type of climate with hot summer and cold winter. The total rainfall in the study area during the crop growing season (5th November to 1st April) was recorded 133.9 mm, besides the crop was irrigated two time (pre–sowing and pre flowering). The irrigation was given 5 cm each time. Prior to the commencement of the present study, the field was under rice–intercropping (linseed + dwarf field pea with similar set of treatments). Composite soil samples were collected from the field, before experimentation from a depth of 0–20 cm. and the processed samples were subjected to appropriate mechanical, physical and chemical analysis to determine the physical and chemical properties of the soils. Soil at the experimental field was sandy clay loam in texture with neutral in reaction (pH 7.22) was worked out by using Buck man pH meter, EC (0.28 dS m^{-1}) systronics electrical conductivity meter suggested by (Jackson, 1973), bulk density (1.39 g cm^{-3}) was worked out by adopting the core sampler method suggested by (Black, 1965), low in organic carbon (0.45%) by using Walkley and Black rapid titration method (Jackson, 1973), available N (209 kg ha^{-1}) by using alkaline potassium permanganate method (Subbiah and Asija, 1956), P (19.7 kg ha^{-1}) by using Olsen′s method (Olsen *et al.*, 1954) and medium in K (215.9 kg ha^{-1}) by using flame photometric method (Jackson, 1973). The experiment was in randomized block design, with fourteen row arrangement treatment (Table 1). The gross plot size was 5.0 m × 4.0 m. The seed rate of crop was 30 kg ha^{-1} of linseed and 80 kg ha^{-1} of dwarf field pea in lines spaced as per treatment in sole cropping. In intercropping treatments row to row distance was maintained 30 cm and sowing was done by *"kera"* method in open furrow. The crop was sown on 15 November 2013 with using "Shekhar" linseed and "Prakash" dwarf field pea variety. The recommended fertilizer dose for linseed 50 kg N, 40 kg P_2O_5 and 40 kg K_2O and 20 kg N, 40 kg P_2O_5 and 40 kg K_2O for dwarf field pea were applied through urea DAP and MOP at prior to sowing only in sole crop. In intercropping combinations seed rate and fertilizers were adjusted according to number of row arrangement. The parameters relating to growth, yield attributes and yield were measured to make a critical analysis of the crop as affected by different treatments. The technique of representative sample was adopted for recording the observations on various morphological characters in linseed and dwarf field pea. At every observation, five plants from each plot were randomly selected and tagged. The observations were recorded from these tagged plants.

RESULTS AND DISCUSSION

Growth attributes: The intercropping treatments significantly influenced the plant growth parameters such as plant height, branches and dry matter accumulation of both crops linseed and dwarf field pea. Significant variation in plant height of both crops was observed due to intercropping systems (Table 1). Highest plant height was under sole cropping of both crops, intercropping association row ratio of 4:1 with 80% linseed + 20% dwarf field pea (T_8), was significantly higher over the rest of the row arrangements but were with T_3, T_9 and T_{10}. In cash of dwarf field pea row ratio of 1:4 with 20% linseed + 80% dwarf field pea (T_{11}) plant height was significantly more over rest of the row arrangements but was par growth attributes T_5, T_6 and T_{12}. This might be due to the fact that higher spacing leads to less number of plant per unit area which allows the plant to grow more as all the

Table 1. Growth of linseed and dwarf field pea as influence by intercropping association

Treatments	Linseed			Dwarf field pea		
	Plant height (cm)	Branches $plant^{-1}$	Dry matter accumulation $plant^{-1}$ (g)	Plant height (cm)	Branches $plant^{-1}$	Dry matter accumulation $plant^{-1}$ (g)
T_1 (Sole linseed)	74.50	39.80	13.50	–	–	—
T_2 (Sole dwarf field pea)	–	–	–	55.23	12.2	12.05
T_3 (3:1)	73.53	36.89	11.79	47.25	8.33	9.97
T_4 (3:2)	72.70	36.03	11.36	47.64	8.53	10.05
T_5 (1:3)	70.17	32.30	9.18	53.19	11.60	11.40
T_6 (2:3)	71.33	32.43	9.29	52.29	11.47	11.31
T_7 (3:3)	71.90	32.87	9.46	51.81	11.03	11.09
T_8 (4:1)	74.03	38.30	12.70	47.95	8.30	9.95
T_9 (4:2)	73.30	36.73	11.71	48.54	8.45	10.02
T_{10} (4:3)	73.23	36.60	11.57	48.90	8.89	10.21
T_{11} (1:4)	70.07	31.10	9.08	53.76	11.76	11.53
T_{12} (2:4)	71.23	31.83	9.33	52.57	11.50	11.19
T_{13} (3:4)	72.43	32.57	9.67	52.10	11.12	11.02
T_{14} (4:4)	72.92	33.03	10.03	51.85	10.97	11.01
CD (p=0.05)	0.98	1.71	1.17	1.54	0.63	0.42

Note: Sole linseed (T_1), sole dwarf field pea (T_2), row ratio of 3:1 with 75% linseed + 25% dwarf pea (T_3), row ratio of 3:2 with 60% linseed + 40 dwarf field pea (T_4), row ratio of 1:3 with 25% linseed + 75% dwarf field pea (T_5), row ratio of 2:3 with 40% linseed + 60% dwarf field pea (T_6), row ratio of 3:3 with 50% linseed + 50% dwarf field pea (T_7), row ratio of 4:1 with 80% linseed + 20% dwarf field pea (T_8), row ratio of 4:2 with 66.67% linseed + 33.34% dwarf field pea (T_9), row ratio of 4:3 with 57.15% linseed + 42.86% dwarf field pea (T_{10}), row ratio of 1:4 with 20% linseed + 80% dwarf field pea (T_{11}), row ratio of 2:4 with 33.34% linseed + 66.67% dwarf field pea (T_{12}), row ratio of 3:4 with 42.86% linseed + 57.15% dwarf field pea (T_{13}) and row ratio of 4:4 with 50% linseed + 50% dwarf field pea (T_{14}).

inputs are easily available with lesser competition among plants and because of production of more number of branches and leaves plant^{-1}. Similar results were reported by Mishra *et al.* (2001) under chickpea and mustered intercropping and Singh *et al*. (2001) under the study of different row spacing of field pea.

***Yi*eld attributes:** The yield attributes of both crops significantly influenced by different row ratios except test weight (linseed) and seed index (dwarf field pea) (Table 2). The highest yield attributes of both crops was marked under sole planting. Among the intercropping association row ratio of 4:1 with 80% linseed + 20% dwarf field pea (T_8) was significantly higher over the rest of the row arrangements but were with row ratio of 3:1 with 75% linseed + 25% dwarf pea (T_3) and row ratio of 4:2 with 66.67% linseed + 33.34% dwarf field pea (T_9) in linseed. In cash of dwarf field pea row ratio of 1:4 with 20% linseed + 80% dwarf field pea (T_{11}) was recorded significantly highest over rest of the row arrangements but were with row ratio of 1:3 with 25% linseed + 75% dwarf field pea (T_5) and row ratio of 2:4 with 33.34% linseed + 66.67% dwarf field pea (T_{12}). This might be due to the fact that higher availability of natural resources which allows the plant to grow more as all the inputs are easily available with lesser competition among plants this finding closely corroborated with Baishya *et al*. (2014).

Yield and harvest index: Intercropping treatments significantly influenced the yield of both crops linseed and dwarf field pea, highest seed and straw yield was recorded under sole planting. Significant variation in seed and straw yield of both crops was observed due to intercropping systems. Among the intercropping association highest seed and straw yield was in linseed and dwarf field pea under row ratio of 4:1 with 80% linseed + 20% dwarf field pea (T_8) and row ratio of 1:4 with 20% linseed + 80% dwarf field pea (T_{11}) respectively (Table 2). The highest reduction in grain yield with decreasing row ratio in above intercropping system could be attributed to poor development of plants and shedding effect on an each other which resulted poor utilization of resources such as moisture, space, nutrients and solar radiation. Increasing the row ratio show positive effect on grain yield of each other crop this theory supported by Ansari *et al*. (2015). Dry biomass production was higher in sole planting; this is also responsible for higher yield. Similar finding were reported by (Tuti, 2012) and Chaudhary *et al.* (2014). Highest harvest index of linseed was recorded in T_{11} followed by T_5 .In case of dwarf field pea in T_8 followed by T_3.

CONCLUSION

Based on present investigation, it was concluded that sole planting of linseed and dwarf field pea performed best among treatments in respect to growth, yield attributes and yield, closely followed by 4:1 row ratio with 80 % linseed + 20 % dwarf field pea.

Table 2. Yield attributes and yield of linseed and dwarf field pea as influence by intercropping association

Treatments	Linseed						Dwarf field pea					
	Seed ball plant^{-1}	Seed ball^{-1}	Test weight (g)	Grain yield (kg)	Straw yield (kg)	Harvest index (%)	Pod plant^{-1}	Seed pod^{-1}	Seed index (g)	Grain yield (kg)	Straw yield (kg)	Harvest index (%)
T_1 (Sole linseed)	77.40	7.71	7.23	1640	3630	31.12	–	–	–	–	–	–
T_2 (sole dwarf field pea)	–	–	–	–	–	–	18.68	5.37	23.10	1775	2769	39.08
T_3 (3:1)	75.83	7.35	7.25	1301	2770	31.97	16.69	3.70	23.43	440	629	41.10
T_4 (3:2)	73.90	7.01	7.04	1118	2321	32.51	16.87	3.81	23.41	565	822	40.70
T_5 (1:3)	70.08	6.43	7.53	583	1120	34.25	17.74	5.17	23.16	1294	2001	39.30
T_6 (2:3)	70.55	6.67	7.17	740	1541	32.44	17.17	5.01	23.23	1025	1577	39.42
T_7 (3:3)	71.62	6.86	7.23	841	1760	32.34	17.03	4.95	23.27	995	1494	40.01
T_8 (4:1)	76.24	7.40	7.27	1438	3070	31.90	16.60	3.58	23.52	397	562	41.49
T_9 (4:2)	74.60	7.13	7.22	1152	2450	31.99	17.06	3.66	23.48	661	952	40.98
T_{10} (4:3)	73.30	7.02	7.16	916	1930	32.19	17.13	3.79	23.41	791	1161	40.51
T_{11} (1:4)	69.26	6.35	7.53	341	650	34.40	17.86	5.30	23.15	1426	2214	39.18
T_{12} (2:4)	70.80	6.56	7.45	510	1025	33.25	17.37	5.10	23.23	1167	1792	39.45
T_{13} (3:4)	71.02	6.72	7.40	695	1370	33.66	17.05	5.00	23.29	1029	1560	39.75
T_{14} (4:4)	72.82	6.95	7.35	934	1880	33.23	16.94	4.93	23.33	679	1005	40.41
CD (p=0.05)	1.68	0.37	NS	65.41	78.00	1.74	0.68	0.26	NS	27	94.8	1.22

See Table 1 for treatment details

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Impact of Tillage Practices on Growth, Yield and Economics of Lathyrus under Rainfed Rice Based Cropping System of Chhattisgarh

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Abstract: Field experiment was conducted at Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) to observe the effect of tillage practices on growth and productivity of lathyrus. The significantly highest plant stand (115 plant m^{-2}), plant height (52.74 cm), branches (7.65 $plant^{-1}$) dry biomass (4.25 g $plant^{-1}$), pods $plant^{-1}$ (17.89), seed and stover yield (12.16 and 18.73 q ha^{-1}, respectively) was under zero tillage direct drilling of seeds and fertilizers at 2nd day after harvest (DAH) of rice. The pod length, number of seed pod^{-1} and seed index did not vary significantly by tillage practices. The gross return (Rs 26193 ha^{-1}), net return (Rs 16256 ha^{-1}) and B:C (2.64) ratio was also higher in treatment zero tillage direct drilling of seeds and fertilizers at 2nd DAH of rice. In conclusion, zero tillage direct drilling of seeds and fertilizers at 2nd DAH of rice was the best tillage practice for cultivation of lathyrus grown under midland situation in rainfed conditions of Chhattisgarh, India.

Keywords: Tillage practices, rainfed, cropping system, economics

Lathyrus (*Lathyrus sativus* L.) or grass pea is a very hardy pulse crop capable of growing in extreme moisture stress condition. Grasspea has been cultivated in South Asia and Ethiopia for over 2500 years and is used as food and feed. It is a popular drought tolerant crop grown in drought-prone areas of Africa and Asia. Its ability to provide economic yield under adverse conditions has made it a popular crop in subsistence farming in many developing countries and it offers great potential for use in marginal low rainfall areas. Despite its tolerance to drought, grasspea is not affected by excessive rainfall and can be grown on land subject to flooding. It is a *rabi* season crop, mostly grown in October−November and harvested in late February or early March. It grows abundantly in dark loamy or sandy−loam soils. Poor soil physical condition caused by puddling is the major limiting factor for successful cropping in rice-fallows. The interaction of harvesting time of winter rice, field water situation and temperature after rice harvest determines the time of sowing as well as the success of winter crop (Kalita *et al.*, 2005). Tillage has various physical, chemical and biological effects on the soil both beneficial and degrading, depending on the appropriateness or otherwise of the methods used (FAO, 2014). Repeated ploughing enhance moisture loss or one /no ploughing lead to poor germination ultimately affecting the yield. Tillage systems have changed as new technologies have become available and the costs of fuel and labor increased. Benefits of conservation tillage, especially zero tillage (ZT) systems that leave crop residues on the soil surface are the stabilization of soil moisture and temperature, an improvement of aggregate stability and an increase in soil organic matter (Hajabbasi and Hemmat, 2000; Chauhan *et al*., 2002), higher water infiltration rates (Tullberg, 2010) and negatively weed population in some studies (Malik *et al*., 2004; Franke *et al*., 2007; Erenstein and Laxmi, 2008). Tillage methods affect the sustainable resources through its influence on soil properties, crop growth and the use of excessive and un-necessary tillage operations is often harmful to soil. Soil moisture and soil temperature conditions in the seedbed zone (top 5 cm) can promote or delay seed germination and plant emergence (Kaspar *et al*., 1990). The present investigation deals with impact of different tillage practices to alleviate the vagaries of drought on growth, productivity and economics of lathyrus.

MATERIAL AND METHODS

The field experiment was carried out with lathyrus under rainfed condition in medium winter rice land at research cum instructional farm Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattishgarh during winter season of 2014-15. The experiment was laid out randomized block design with three replications. The treatment consisted of four tillage practices *viz.* T_1−Zero tillage direct drilling of seeds and fertilizers at 2nd days after harvesting of rice, T_2 -Minimum tillage and line sowing of seeds at 3rd days after harvesting of rice, T_3−Minimum tillage at 6th days after harvesting of rice, T_4-Farmer practice broadcasting seeds and fertilizer at 12th days after harvesting of rice. The sowing of crop in T_1, T_2, T_3 and T_4 was done on 31 October, 1st, 4th and 10th November 2014, respectively and harvesting on 28 February 2015. All recommended package of practices of crop were adopted during study period. The soil of the experimental field was sandy loam in texture (*Inceptisols*), bulk density 1.48 g m^3 (0−15 cm), particle density 2.57 g m^3 and porosity 41%. Neutral in soil reaction (6.6 pH) and had medium organic carbon (0.72%), low available nitrogen (219 kg ha^{-1}), medium available phosphorus (16.70 kg ha^{-1}) and medium exchangeable potassium (322.2 kg ha^{-1}) with normal electrical conductivity. During crop growth period, the maximum temperature varied between 25^0 to 37.3^{0}C. The minimum temperature ranged between 8^0 to 21.5^{0}C. The maximum and minimum relative humidity during the crop period was 94 and 22 percent, respectively. A total of 11.7 mm rainfall was received during the crop period. The five random points in each plot were selected for recording the plant population and plant population was recorded with the help of 1 square meter quadrate. The five plants in each plot were randomly selected and tagged for recording and plant height and number of branches plant^{-1} at 30, 60 and 90 day after sowing (DAS) and harvest. However, plant population was observed 25 DAS and at harvest. The data recorded for different characters under investigation were analyzed by Windows-based SPSS program (Version 16.0, SPSS, 2007).

RESULTS AND DISCUSSION

Growth and development: Plant population at 25 DAS and at harvest was significantly higher (118 plants m^{-2} at 25 DAS and 115 plants m^{-2} at harvest) in T_1 except in T_2.The significantly lowest plant population inT_4. The highest plant population T_1 might be due to proper placement of seeds and better availability of moisture for germination of seeds due to better seed soil contact. Similarly, lowest plant population observed in T_4 might be due to late sowing and broadcasting of seed because at that time the moisture content was lower which markedly affected the germination of seeds. Rathore *et al*. (1998) also noted similar result in chickpea and mustard crops.

Likewise different tillage practices resulted in significant difference in plant height. The maximum height plant (15.11, 39.53, 50.54 and 51.74 cm) was recorded at 30, 60, 90 DAS and at harvest, respectively in T_1 and was significantly higher than in other treatment (Table 1). However, at 30 DAS, it was *at par* with T_2 and at 60, 90 DAS and at harvest was *at par* with treatments T_2 and T_3. The dwarfest plant was in T_4. The more plant height in T_1 and T_2 might be due to better moisture availability during crop growth period. Kumar *et al.* (2006) noted significantly higher plant height of chickpea in compact tillage than normal tillage. The maximum number of branches

Table 1. Effect of tillage practices on plant population and growth parameters of lathyrus

Treatment	Plant population (m^{-2})		Plant height (cm)				Branches plant^{-1}				Dry biomass plant^{-1} (g)			
	25 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_1	118.00^{a}	115.00^{a}	15.11^{a}	39.53^{a}	50.54^{a}	52.74^{a}	4.71^{a}	7.60^{a}	7.65^{a}	7.65^{a}	0.18^{a}	1.43^{a}	3.10^{a}	4.25^{a}
T_2	112.52^{ab}	109.00^{ab}	14.43^{ab}	39.25^{a}	49.53^{a}	50.12^{ab}	4.21^{ab}	6.97^{a}	7.32^{a}	7.32^{a}	0.17^{ab}	1.32^{a}	2.85^{b}	3.55^{b}
T_3	109.35^{b}	104.00^{b}	13.63^{b}	37.07^{b}	47.47^{ab}	48.05^{b}	4.07^{b}	6.20^{b}	7.00^{b}	7.00^{b}	0.17^{ab}	1.17^{b}	2.54^{c}	3.18^{c}
T_4	106.35^{b}	103.43^{b}	13.42^{b}	34.32^{b}	42.91^{b}	43.04^{c}	3.61^{b}	5.97^{b}	6.32^{b}	6.32^{b}	0.16^{b}	1.05^{c}	2.24^{d}	2.28^{d}

T_1 – Zero tillage direct drilling of seeds at 2nd DAH of rice; T_2 – Minimum tillage and line sowing of seeds at 3rd DAH of rice
T_3 – Minimum tillage and line sowing of seeds at 6th DAH of rice; T_4 – Farmer's practice seeds and fertilizers broadcasting at 12th DAH of rice

plant^{-1} was in T_1 (Zero tillage direct drilling of seeds at 2nd DAH of rice) at 30 DAS (4.71 branches plant^{-1}), 60 DAS (7.60 branches plant^{-1}), 90 DAS (7.65 branches plant^{-1}) and at harvest (7.65 branches plant^{-1}). However, it was *at par* with treatment T_2 at 30 and 60 DAS (Table 1). But at 90 DAS and at harvest it was also *at par* with T_2 and T_3. The minimum number of branches plant^{-1} throughout the crop growth period under T_4. More number of branches plant^{-1} may probably be due to more availability of moisture and nutrient during growth period of the crop.

As regard to dry biomass of plant, no significant impact of tillage practices was at 30 DAS (Table 1) Significantly highest dry biomass of plant was in T_1 at 60 DAS (1.43 g plant^{-1}), 90 DAS (3.10 g plant^{-1}) and at harvest (4.25 g plant^{-1}) but was *at par* with T_2 60 and 90 DAS. Dry biomass plant^{-1} was higher under treatment T_1 which might be due to higher number of branches plant^{-1} and tallest plants observed in this treatment.

Number and dry weight of root nodules plant^{-1}: At 30 DAS, significantly highest number of root nodules (4.52 plant^{-1}) was observed in T_2 but, was *at par* with treatment T_3. However, at 45 and 60 DAS, significantly higher of root nodules plant^{-1} (5.19 and 6.81 plant^{-1}, respectively) was observed in T_2, but was *at par* with T_1 at 45 DAS, but at 60 DAS *at par* with both treatments T_1 and T_3. At 75 and 90 DAS, significantly higher number of root nodules plant^{-1} was in T_2 as compared to rest of the treatments. Higher number of nodules plant^{-1} may probably be due to good root growth of the plant mainly because of better seed bed preparation. Significantly higher dry weight of root nodules (mg plant^{-1}) at all dates of observations was in T_2 as compared to other tillage practices, but at 30 DAS it was *at par* with treatment T_1. Maximum weight of dry nodules plant^{-1} is due to more number and greater size of nodules plant^{-1} was produced in T_2 and T_1.

Yield attributes: Significantly maximum number of pods plant^{-1} (17.89) was under treatment T_1 (Table 3) but it was *at par* with T_2. The highest number of pods plant^{-1} recorded in treatment T_1 might be due to higher number of branching in comparison to other treatments. Similarly the different tillage practices did not give significant impact on number of seeds pod^{-1}, pod length (cm) and seed index. The higher number of seeds pod^{-1} in different treatments was observed in following sequence $T_1 > T_2 > T_3 > T_4$. The highest pod length (2.26 cm) was in T_3. The highest (8.78 g) seed index was observed in treatment T_1.

Yield: Different tillage practices brought significant difference in seed yield (Table 3). Significantly highest seed yield (12.16 q ha^{-1}) was obtained in T_1. However, this was *at par* to treatment T_2. The higher plant population, higher number of branches plant^{-1}, higher yield attributing characters resulted in the highest seed yield under zero tillage. These characters was higher might be owing to higher moisture and nutrient availability. Highest seed yield recorded in zero tillage in present experiment is more or less similar to those of the reports of Das and Das (1998) who mentioned that the no-tillage sowing gave double yield than after 2 or 4 ploughing. Rathore *et al.* (1998) also observed similar chickpea yield in zero and minimum tillage. Similarly significantly highest stover yield (18.73 q ha^{-1}) was under T_1. However, it was *at par* with treatment T_2. This result was might be due to higher plant population and higher dry biomass of plants. Harvest index was not significantly influenced by different tillage practices.

Economics: Cost of cultivation, gross return, net return and B: C ratio varied due to tillage practices (Table 4) The highest gross return (Rs. 26193 ha^{-1}), net return (Rs. 16256 ha^{-1}) and

Table 2. Numbers of root nodule plant^{-1} and dry weight (mg) of root nodules plant^{-1} as influenced by tillage practices

Treatment	No. of root nodules plant^{-1}					Dry weight (mg) of root nodules plant^{-1}				
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
T_1	3.85^{ab}	4.80^{ab}	6.53^{ab}	2.67^{b}	1.40^{b}	5.36^{ab}	7.68^{b}	15.35^{d}	3.91^{c}	0.43^{c}
T_2	4.52^{a}	5.19^{a}	6.81^{a}	3.60^{a}	1.62^{a}	5.67^{a}	8.75^{a}	23.26^{a}	5.17^{a}	1.18^{a}
T_3	4.21^{a}	4.48^{b}	5.40^{bc}	3.00^{c}	1.28^{bc}	5.03^{b}	7.32^{b}	20.35^{b}	4.59^{b}	0.72^{b}
T_4	3.27^{c}	3.58^{c}	5.21^{c}	2.35^{c}	1.20^{c}	4.36^{c}	6.90^{c}	17.80^{c}	4.42^{bc}	0.47^{c}

Table 3. Yield attributes and yields of lathyrus as influenced by tillage practices

Treatment	Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)	Pod length (cm)	Seed index (g)	Seed yield (q ha^{-1})	Stover yield (q ha^{-1})	HI (%)
T_1	17.89^{a}	2.42	2.25	8.78	12.16^{a}	18.73^{a}	39.36
T_2	17.40^{a}	2.40	2.23	8.74	11.66^{a}	17.45^{ab}	40.05
T_3	14.35^{b}	2.40	2.26	8.73	10.15^{b}	16.95^{b}	37.63
T_4	11.34^{c}	2.33	2.21	8.71	7.25^{c}	11.79^{c}	37.63

Table 4. Different tillage practices influence on economics of lathyrus

Treatment	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio
T_1	26193[a]	16256[a]	2.64[a]
T_2	24648[a]	13510[b]	2.21[b]
T_3	21788[b]	10651[c]	1.96[c]
T_4	15679[c]	2842[c]	1.22[d]

B: C ratio (2.64) were highest in T_1 followed by T_2 and T_3 due to reduction in cost of cultivation in conservation tillage. Dhar *et*

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Yield Improvement of Wheat (*Triticum aestivum* L.) through Foliar Supplement of Potassium Nitrate under Low Photothermal Quotient during Anthesis

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Abstract: Lower photothermal exposure, measured by photothermal quotient (PTQ) reduce grain yield in wheat by lowering grains m^{-2} and kernel weight. The purpose of this study was to assess different PTQ exposures around anthesis, mostly associated with yield variation in wheat and to test the extent of yield restorative capacity of potassium nitrate on wheat facing low PTQ exposure during a specific period around anthesis due to elevated ambient temperature. The field experiment in wheat (variety PBW 621) was conducted with four different sowing dates for exposing wheat to different PTQs and 5 subplots having combinations of recommended dose of fertilizers in different splits without or with foliar supplement of 1.0% KNO_3 either at heading or anthesis or both at these stages. There was strong association between grain yield and cumulative PTQ during 20 days before to 10 days after anthesis (R^2=0.648) through higher grains m^{-2} and heavier kernel weight. November 15 sowing resulted in maximum cumulative PTQ during 20 days before to 10 days after anthesis. Under lowest PTQ exposure, as in 5 December sowing, grain yield reduced significantly (44.21 qha^{-1}) as compared to 15 November sowing (63.88 qha^{-1}) and can be improved by foliar supplements of 1% KNO_3, just prior to anthesis or at anthesis. An enhancement of 13percent in grain yield of wheat was recorded due to single foliar supplement of 1.0percent KNO_3 either at heading stage (46.25 qha^{-1}) and it was further increased to around 20percent due to single foliar supplement of 1.0percent KNO_3 at anthesis (47.22 qha^{-1}) or two foliar supplements of 1.0percent KNO_3 both at heading and anthesis stage (48.98 qha^{-1}) along with the application of recommended dose of fertilizers (RDF) in three splits as compared to sole application of RDF without any foliar supplement of KNO_3 under lowest PTQ exposure during 20 days before to 10 days after anthesis as occurred due to 5 December sowing.

Keywords: Wheat, Yield, Photothermal quotient, Potassium nitrate

Yield of wheat is largely controlled by radiation and temperature under optimum plant stand and adequate supplies of water and nutrients (Ortiz-Monasterio *et al.,* 1994).The combined effect of radiation and temperature on yield can be better explained by a photothermal quotient (PTQ) (Nix, 1976). PTQ is regarded as an index of growth per unit development time (Nix, 1976) and is expressed as the ratio of total solar radiation (MJ $m^{-2}day^{-1}$) to the mean daily temperature (ºC) minus a base temperature (4.5 ºC for wheat). IPCC (2013) projected that the global mean temperature may increase to the tune of 1.0-3.7˚C by the end of 2100. Therefore, it will obviously reduce the values of PTQ throughout the crop growing period in general and during anthesis in particular. High temperature stress during anthesis and grain filling period have negative impact on yield of wheat (Rane *et al*., 2007; Joshi *et al*., 2007). Reduction in grain yield of wheat was recorded to an extent of 3-10percent with 1.8˚C rise in temperature (You *et al*., 2009). Ortiz-Monasterio *et al.* (1994) concluded that the optimum yield of irrigated spring wheat cultivars at Ludhiana, Punjab, India was recorded when the crop was exposed to maximum PTQ during the period 20 days before to 10 days after heading. They have also substantiated that grain yield reduction associated with low PTQ exposure around anthesis might be attributed to reduced grains m^{-2} (GM2) and lower individual kernel weight (KW). Grain yield of wheat is directly proportional to PTQ during anthesis (Ahmed *et al*., 2011) and lower PTQ exposure during this period can significantly reduce grain yield. The overall aim of nutrient supplemental strategy in wheat under low PTQ during anthesis is to keep the source organs, especially flag leaf, actively photosynthesizing till grain filling period as grain growth has been shown to be mostly dependent upon current supply of photosynthates during post anthesis period (Austin *et al*., 1977; Inoue *et al*., 2004). It was postulated that under the low PTQ exposure during anthesis, due to elevated atmospheric temperature, foliar supplement of nitrogen and potassium may ward-off decline in yield of wheat by virtue of their respective roles in maintaining normal photosynthetic activities in flag leaves through reduced chlorophyll degradation by nitrogen (Brevedan and Hodges, 1973) and securing export and utilization of photosynthates in plants by potassium (Zhao *et al*., 2001). Foliar supplement of 1.0 per cent potassium nitrate during anthesis has been reported to have beneficial effect on yield of wheat facing high temperature stress (Singh *et al.,* 2011). Therefore, an attempt was made to assess different PTQ exposures around anthesis, mostly associated with yield variation in wheat and to test the extent of yield restorative capacity of potassium nitrate on wheat facing low PTQ exposure during a specific period around anthesis due to elevated ambient temperature.

MATERIAL AND METHODS

Experimental site: The field experiment was conducted at Punjab Agricultural University, Ludhiana (30˚56′ N, 75˚52′ E; 247 m above sea level) during *rabi* 2011–12. The soil of the experimental site was deep alluvial loamy sand, Typic Ustochrept, low in available nitrogen, medium in phosphorous and potassium with normal soil reaction.

Experimental details: The experiment was laid out in split–plot design with four replications. Main plots comprise of four different dates of sowing (D_1: November 5; D_2: November 15; D_3: November 25 and D_4: December 5) for exposing wheat to four different PTQs during anthesis. The sub–plots include: N_1: Recommended dose of fertilizers (RDF, i.e., 155: 62.5: 30 kg N: $P2O_5$:K_2O ha^{-1}) applied in two splits (50% as basal and 50% at 30DAS); N_2 : RDF applied in three splits (50% as basal, 25 % at 30 DAS and 25% at 60 DAS); N_3: RDF applied in three splits as N_2 with a single foliar supplement of 1.0% KNO_3 only at heading; N_4 : RDF applied in three splits as N_2 with a single foliar supplement of 1.0% KNO_3 only at anthesis and N_5: RDF applied in three splits as N_2 with two foliar supplements of 1.0% KNO_3 both at heading and anthesis stages.

Crop cultivar: Wheat variety PBW 621 was used under this experiment. The variety was developed by Punjab Agricultural University, Ludhiana, Punjab, India and having a maturity period of about 158 days.

Calculation of PTQ: Calculation of PTQ was done based on meteorological observations like bright sunshine hours, maximum and minimum temperatures collected from Meteorological observatory of PAU Ludhiana. The solar radiation was calculated from sunshine hours with the Angstrom formula (Angstrom, 1964). The photothermal quotient was calculated on a daily basis for each date of sowing with the following formulas:

If $T > 10$

PTQ day^{-1} = Solar radiation / (T–4.5)

If $T < 4.5$

PTQ day^{-1} = 0; and

If $4.5 < T < 10$

PTQ day^{-1} = Solar radiation x [(T – 4.5) /5.5] /5.5

Where, T is the daily mean temperature [(max + min) / 2] and PTQ is expressed as MJ m^{-2} day^{-1} ˚C^{-1} (Ortiz–Monasterio*et al.,* 1994). The figure 4.5˚C is close to the mean basal temperature as reported by Fischer (1985) for studying pre–anthesis stage used with the PTQ. Cumulated PTQ was calculated for three periods (i) from 45 days before anthesis to anthesis (PTQ1), (ii) from 30 days before anthesis to anthesis (PTQ2) and (iii) from 20 days before anthesis to 10 days after anthesis (PTQ3).

Data recording: Field data for yield attributes (earhead m^{-2}, grains $earhead^{-1}$ and 1000 grain weight) and grain yield were recorded from the net plot at harvest.

RESULTS AND DISCUSSION

Effect of dates of sowing on PTQ exposures during anthesis: Estimation of cumulated PTQ for all the three periods, i.e., PTQ1, PTQ2 and PTQ3 showed that the wheat could get maximum PTQ exposures during each of these time intervals when the crop was sown during November 15–25 (Fig. 1). Lower PTQs is generally associated with higher rate of increase in mean daily temperature as compared to rate of increase in solar radiation during each of these periods during anthesis. In case of PTQ1, the PTQ of 45 days prior to anthesis were cumulated, whereas in case of PTQ2, it was the summation of 30 days PTQs prior to anthesis. The values of PTQ1 for all the dates of sowing were high as compared to PTQ2. But, in case of PTQ3, just 30 days PTQs were cumulated just like the case of PTQ2. Therefore, it can be said that the time interval for both PTQ2 and PTQ are same i.e., 30 days, but the only difference is that in case of PTQ2, 30 days before anthesis were taken for cumulating whereas it was 20 days before to 10 days after anthesis for PTQ3. The figure also depicts that there is minute difference between PTQ2 and PTQ3 for each of the sowing dates with a

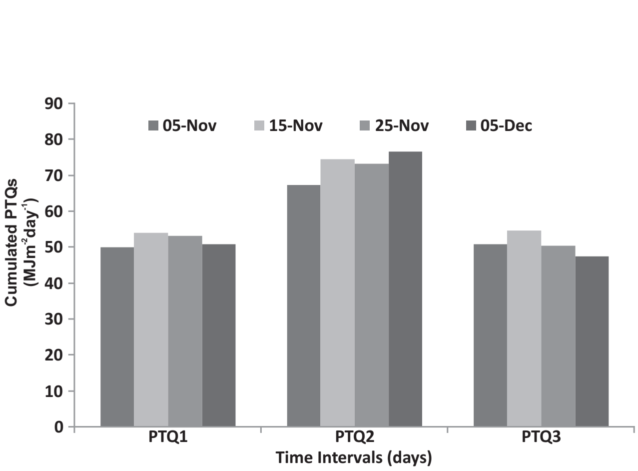
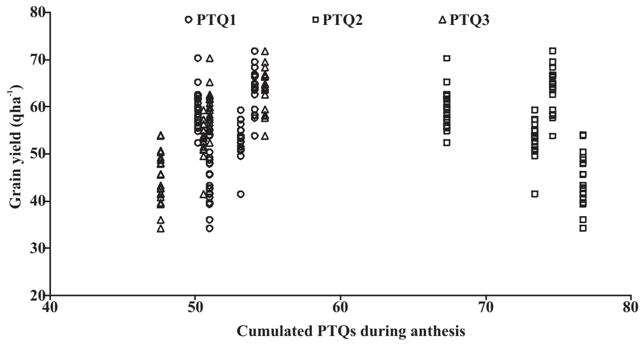


Fig. 1. Cumulated photothermal quotients (PTQs) during anthesis at different dates of sowing

marginal increase in PTQ3 associated with 15 November sowing.

Effect of PTQ exposures during anthesis on grain yield of wheat: Yield of wheat is governed by mainly two components, namely, grains m^{-2} (GM2), and kernel weight (KW). Maximum grain yield of wheat was in 15 November sowing which was significantly superior over rest of the dates of sowing. The variation in grain yield is highly associated with PTQ3 which is evident from highest R^2 value of 0.648 (Fig. 2). Therefore, about 65% variations in grain yield can be explained by the PTQ3. Therefore, not only maximum PTQ exposure, but also the time span during which the crop is getting exposed to maximum PTQ is also equally important for realizing maximum yield from a particular genotype of wheat. Higher degree of association of grain yield with PTQ3 is attributed to maximum grains m^{-2} (GM2) by large PTQ exposure during pre-anthesis coupled with heavier kernel weight (KW) by low temperature, linked with high PTQ value, during post-anthesis period (Ortiz-Monasterio *et al.,* 1994). Under the current experiment, highest association between GM2 and PTQ3 (R^2=0.611) is also in agreement with the above findings (Fig. 3). It is also evident that, maximum GM2 was obtained under 15 November sowing which was significantly superior over the GM2 obtained under 25 November or 5 December sowing, but at par with that of 5 November sowing. With respect to KW, heavier KW was recorded under 5 November followed by 15 November sowing (Table 1). Due to combined role of higher GM2 and KW under 15 November sowing grain yield reached to its maximum level under this date. It was due to maximum value of PTQ3 with which the wheat could get exposed when the crop was sown on 15 November.



R^2_{PTQ1}=0.118, R^2_{PTQ2}=0.195, R^2_{PTQ3}=0.648

Fig. 2. Relationship between PTQs during anthesis and grain yield of wheat

Effect of potassium nitrate (KNO_3) on grain yield of wheat under low PTQ exposures during anthesis: Grain yield of wheat significantly declined when it was exposed to lower values of PTQ3 due to sowing the crop other than the date of 15 November (Table 2). Under 15 November sowing maximum grain yield of wheat (65.19 qha^{-1}) was recorded when the crop was fertilized with N_2 and was at par with the grain yield obtained under the treatments N_3 (64.82 qha^{-1}); N_4 (64.88 qha^{-1}) and N_5 (65.02 qha^{-1}). Therefore, under 15 November sowing when the crop could get exposed to maximum PTQ during 20 days before to 10 days after anthesis, there was no extra benefit of foliar supplement of KNO_3. Almost similar trend was noticed under 5 November sowing.

Foliar supplement of KNO_3 showed its effect in increasing grain yield of wheat when the crop was sown on November 25, though no significant increment in grain yield was recorded. In the contrary, when the crop was sown on

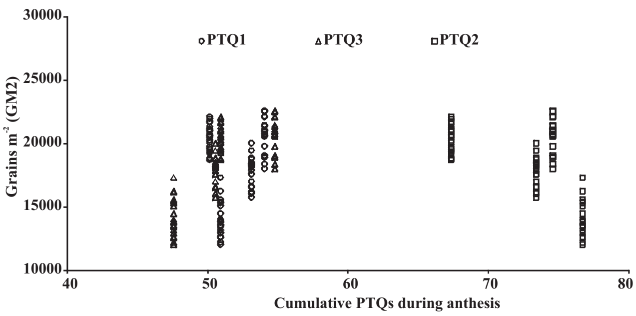
Table 1. Effect of different photothermal exposures and nutrient management on grain m^{-2} and Test weight (g) of wheat

Sowing dates	Grain Numbers m^{-2}	Test weight (g)
D_1: 5th Nov	20392	46.90
D_2:15th Nov	20577	44.08
D_3:25th Nov	17806	40.98
D_4:5th Dec	14103	37.81
CD (p=0.05)	938	2.48
Nutrient management		
N_1: RDF (155: 62.5: 30 kg N:P_2O_5:K_2O/ha)−50% as basal & 50% at 30DAS	17816	42.40
N_2: RDF−50% as basal , 25% at 30DAS & 25% at 60 DAS	18165	42.80
N_3: N_2 + Foliar supplement of 1.0% KNO_3 at heading stage	18010	42.38
N_4: N_2 + Foliar supplement of 1.0% KNO_3 at anthesis stage	18626	42.39
N_5: N_2 + Foliar supplement of 1.0% KNO_3 both at heading and anthesis stage	18481	42.24
CD (p=0.05)	NS	NS
Interaction (DxN)		
.D (p=0.05)	1581	NS

Table 2. Effect of different photothermal exposures and nutrient managements on grain yield (qha^{-1}) of wheat

N Management	D_1 (5^{th} Nov)	D_2 (15^{th} Nov)	D_3 (25^{th} Nov)	D_4 (5^{th} Dec)	Mean
Grain yield (qha^{-1})					
N_1	59.34	59.51	49.83	37.88	51.64
N_2	63.18	65.19	52.77	40.71	55.46
N_3	57.33	64.82	52.94	46.25	55.33
N_4	58.57	64.88	55.08	47.22	56.44
N_5	60.25	65.02	55.03	48.98	57.32
Mean	59.73	63.88	53.13	44.21	
CD (p=0.05) : Sowing Date (D): 2.89; N Dose (N): 2.53; D×N:5.06					

For treatment detail see Table1



R^2_{PTQ1}=0.068, R^2_{PTQ2}=0.353, R^2_{PTQ3}=0.611

Fig. 3. Relationship between PTQs during anthesis and grains m^{-2} (GM2) of wheat

December 5, it could get exposed to the lowest PTQ during 20 days before to 10 days after anthesis. In this case, grain yield was significantly increased and maximized (48.98 qha^{-1}) with N_5 as compared to the treatments without any foliar supplements of KNO_3 (N_1 and N_2). However, experimental data shows that under 5 December sowing, there was no significant difference in grain yield among the treatments N_3, N_4 and N_5 . This result clearly indicates the beneficial role of KNO_3 supplements under low PTQ exposure during anthesis in improving grain yield of wheat to the tune of around 13–20%. Lower values of PTQ during 20 days before to 10 days after anthesis results from increase in mean temperature from March 1^{st} week onwards when the crop arrives at anthesis stage and is associated with either delayed sowing in the Indo-Gangetic plains of India (Dwivedi *et al*., 2015) or terminal heat stress in the region (Ortiz *et al*., 2008). Lower grain yield under elevated mean ambient temperature is attributed to shortening of grain filling duration (Dias and Lidon 2009) leading to lower KW (Streck, 2005). Though solar radiation may also get increased during the same time period but more likely the increase will be in a slower rate as compared to the rate of increase in mean ambient temperature. Moreover, the crop may not take the advantage of this enhanced solar radiation due to attainment of partial saturation of canopy photosynthesis at higher levels of radiation during post anthesis. Therefore, other alternate way to sustain the grain yield under low PTQ is to maintain the canopy photosynthesis, especially in the flag leaf which is the chief photosynthesizing organ during post-anthesis stage in wheat supplying photosynthates to the developing grain (Borrill *et al*., 2015). Foliar supplements of KNO_3 supplies both K^+ and NO_3^- in flag leaf of wheat facing high temperature, or otherwise low PTQ during anthesis. The roles of K^+ under this condition are maintaining stomatal conductance, decreasing mesophyll resistance, increasing RUBP carboxylase activity (Zhao *et al.,* 2001), detoxification of reactive oxygen species (Cakmak 2005), export and assimilate photosynthates (Cakmak 1994). Therefore, the above study indicates that delayed sowing of wheat results in lower photothermal quotient exposure during anthesis which causes decrease in grain yield, mainly due to increase in mean temperature. Yield of wheat under lower photothermal quotient exposure can be improved by foliar supplement of 1.0 % KNO_3. It is a potential strategy to sustain yield of late sown wheat commonly found under rice-wheat cropping system under Indo-Gangetic Plains of India.

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Standardization of Date of Planting and Variety of Sprouting Broccoli (*Brassica oleracea* L.var *italica* Plenk)

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Abstract: The present experiment was investigated at Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal during the year (2015-2016). Four best performing varieties namely Early You, Princess, Fiesta and Nok Guk were evaluated with four different date of planting viz. 21st September, 15th October, 7th November and 30th November to find out the best performing variety and suitable sowing/planting dates. The experiment was laid down in Factorial Randomized Block Design and replicated thrice. It has been observed that planting date should not be very early and neither too late. In case of different planting dates 7th November was found most effective in yield and yield attributing characters. There was decreasing trend in head yield and yield attributing characters when the plants were transplanted too early and after 7th November. The highest head yield of 126.26 q/ha was observed with the planting date on 7th November. The highest head yield of 120.35 q/ha was noticed from the variety Early You and it has shown a promising performance in quality characters also. Thus early you might be suggested for commercial cultivation and to find out the potential growth, yield and quality, plant must be transplanted on 7th November.

Keywords: Broccoli, Growth, Planting Date, Quality, Variety, Yield

Broccoli (*Brassica oleracea* L.var *italica* Plenk) is an important winter season exotic vegetable from Brassicaceae family (Thakur, 2015). The consumption as well as cultivation of broccoli has been increased for the last couple of years due to its increasing awareness regarding nutritional superiority (Singhal *et al*., 2009; Yoldas and Esiyok, 2004). But for commercial cultivation it is still on infancy stage and need to be exploited fully at different vegetable growing belts. Realizing the tremendous potential of sprouting broccoli in domestic and foreign market, the cauliflowers growers of terai zone of West Bengal are gradually adopting the broccoli cultivation (Saha *et.al,* 2006). But its cultivation could not be promoted in the area due to non-availability of particular agro-techniques of this crop and suitable cultivars. Appropriate planting time is one of the important factors for boosting up the production of broccoli. Yields of cruciferous crops are often adversely affected by fluctuating temperatures; hence, planting dates significantly affect the marketable yield. Very early and very late planting adversely affect the vegetative growth also. So to get the maximum yield of the crop two factors, suitable variety and timely sowing/transplanting is very important as every variety requires specific temperature for head initiation and development (Karistsapola *et al*., 2013). Keeping this view in perspectives, the following experiment was undertaken to standardize the date of planting as well as variety of sprouting broccoli for better growth and yield.

MATERIAL AND METHODS

The present experiment was investigated at Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal during the year (2015-2016). Four best performing varieties namely Early You, Princess, Fiesta and Nok Guk were evaluated with four different date of planting *viz*. 21st September, 15th October, 7th November and 30th November to find out the best performing variety and suitable sowing/planting dates. It was laid down in Factorial Randomized Block Design and replicated thrice. The location of the experimental site is 23.5^{0}N latitude and 80^{0}E Longitude with average altitude of 9.75m above the mean sea levels. The experimental site was on a high land with assured irrigation facilities as well as good drainage facilities and is under subtropical humid region. The investigation was done during the winter season. The range of average temperature was between 25^0 and 36.5^0 during summer months and 25^0 and 12^0 during winter months with an annual rainfall of about 1500mm.

RESULTS AND DISCUSSION

Growth attributing characters

Plant height was highly significant with planting date (Table 1). The maximum plant height of 44.17cm was obtained when the plants were transplanted on 7th November and this is statistically different from all the other planting dates. But plant heights *i.e.* 38.02cm and 36.92cm obtained from 30th November and 15th October, respectively are statistically similar. From the Table 1, it is very much clear that the plant height was markedly decreased in the first two planting date of 21st September and 15th October, whereas there is a sudden increase of plant height when the plants were transplanted on 7th of November. The plant transplanted after 7th of November showed the decreasing trend on plant height. Singh *et al*., 1999 reported that effect of sowing date on plant height was significant and the maximum plant height was recorded when planting was done on 3rd November. This result was also confirmed with the findings of Emam, 2005 in broccoli. Varieties also produced significant effect on plant height at 5% level of critical difference. The maximum plant height of 41.58 cm was obtained with variety Early You which was statistically *at par* with variety Princes (39.21 cm). On the other hand the lowest plant height 35.56 cm, recorded in variety Fiesta, was statistically similar with plant height of Nok Guk *i.e.* 36.46cm. The differences in plant height among the variety may be due to the genetic variability within the variety itself or may be due to the environmental effect (Thapa and Rai, 2012). A significant (at 5% level of critical difference) variation was found among all the planting dates in number of leaves per plant. The maximum number of leaves (22.29) was observed when the plants were transplanted on 7th November and it is statistically different from all the other planting dates. From the Table 1, it has been closely observed that the number of leaves was markedly decreased in the first two planting date. The maximum number of leaves (23.17) was obtained with variety Fiesta whereas the lowest number of leaves 16.08 was recorded in variety Princes. According to Table 1, the maximum plant spread of 5763.33 cm^2 was obtained when the plants were transplanted on 7th November and this is statistically different from all the other planting dates. The minimum plant spread of 4994.49 cm^2 has been observed in 21st September planting followed by 5485.78 cm^2 (15th October) and 5593.51 cm^2 (30th November). All these planting dates are statistically different from each other. The differences of plant spread among different planting dates might be due to the reason that plant sown very early and very late does not get suitable condition, specially the temperature, for better vegetative growth of the plant. In case of varieties a significant effect on plant spread has been observed. The result revealed that plant spread varied from 4945.06 cm^2 to 6214.78 cm^2. The maximum plant spread of 6214.78 cm^2 was obtained with variety Nok Guk which was followed by Fiesta (5391.43 cm^2), Early You (5285.84 cm^2), Princes (4945.06 cm^2) and all these varieties are significantly different with each other. The maximum stem length of 31.67 cm and 28.97 cm were obtained when the plants were transplanted on 7th November and from the variety Early You, respectively. Regarding date of planting, a significant difference has been found among all the stem lengths but in case of varieties it has not been found. Stem lengths of Early You (28.97 cm) and Princess (27.44 cm) are statistically *at par* whereas stem lengths of Fiesta (24.23 cm) and Nok Guk (24.21 cm) are statistically similar. According to Table 1, the maximum stem diameter was obtained when the plants were transplanted on 7th November (3.58 cm) which is statistically different from all the other planting dates. But stem diameters obtained from 15th October and 30th November are statistically *at par*. Maximum stem diameter of Nok Guk (3.58 cm) is statistically similar with stem diameter of Early You (3.54 cm) but different from rest two varieties. On the other hand Early You is statistically similar with Princes but different with Fiesta. The present findings are not corroborated with the findings of Emam, 2005.

Yield and yield attributing characters

The maximum days for head initiation was 68.58 days

Table 1. Effect of planting date, variety on growth characters of sprouting broccoli

Treatments	Plant Height (cm)	Number of leaves/ plant	Plant spread (cm^2)	Stem length (cm)	Stem diameter (cm)
D_1	33.69	17.40	4994.49	22.26	3.42
D_2	36.92	18.85	5485.78	24.23	3.48
D_3	44.17	22.29	5763.33	31.67	3.58
D_4	38.02	20.10	5593.51	26.70	3.49
CD (p=0.05)	1.28	1.06	35.25	1.49	0.03
V_1	41.58	20.45	5285.84	28.97	3.54
V_2	39.21	16.08	4945.06	27.44	3.52
V_3	35.56	23.17	5391.43	24.23	3.34
V_4	36.46	18.93	6214.78	24.21	3.58
CD (p=0.05)	1.00	1.04	33.21	1.54	0.04

V_1–Early You, V_2–Princes, V_3–Fiesta and V_4–NokGuk

D_1–21st September, D_2–15th October, D_3–7th November and D_4–30th November and observed in the 21st September transplanted plant followed by 15th October transplanted plant (Table 2). The minimum days of 61.21 days was required for head initiation when the plants were transplanted on 7th November. All these planting dates are statistically different with each other. It indicates that earlier transplanted plant required more days to head initiation. The differences between the days required for head initiation with different date of planting might be due to the temperature avail at the time of head initiation. It means that earlier transplanted plants might get the higher temperature which is not suitable for head initiation. Broccoli being a cole crops required specific temperature for head initiation and development. In this experiment it was found that 7th November planted plants required minimum days for head initiation. The plants transplanted on 30th November again showed more days requirement for head initiation, which might be due to the suddenly fall of temperature, therefore the plant does not get proper temperature for head initiation. This finding gets support from Butt *et al.*, 1998; they reported that early and late transplanted plant required maximum days for appearance of 50 percent of head in cauliflower. Regarding varieties, the maximum days required to head initiation was obtained with variety Princess followed by variety Fiesta *i.e.* 67.75 days and 65.31 days, respectively. A perusal of result in Table 2 revealed that days to head maturity was also significantly influenced by planting date. Days to head maturity were found to be highest (76.89 days) with early planting *i.e.* from 21st September planted plant followed by 30th November planted plant, however, there was no significant differences between the plants which were transplanted on 15th October and 30th November. The minimum 70.07 days are observed for head maturity when the plants were transplanted 7th November. The different varieties resulted in significant variation on days to head maturity. Among the four varieties of the present investigation, the minimum days required for head initiation was 63.18 days which was found in Early You which is statistically different with other varieties. But Princes, Fiesta as well as Fiesta and Nok Guk are statistically *at par* (Table 2). Among the various planting dates the maximum head diameter of 21.84 cm was resulted when the planting was done on 7th November and this value has significant differences from the observation of the other three planting. The present results are similar with the findings of Ahmad and Wajid, 2004. Nok Guk produced the highest head diameter of 21.85 cm and significantly different with other varieties. Head weight was observed to be highly significant with planting date. According to the data on head weight the maximum head weight of 355.38 gm was obtained when the plants were transplanted on 7th November. The head weight was decreased in the first two planting date of 21st September, and 15th October, whereas there is a sudden increase of head weight when the plants were transplanted on 7th of November. The plant transplanted after 7th of November, was also showed the decreasing trend on head weight. Similar trends on head weight due to transplanting date were reported by several workers (Sari *et al*., 2000; Rozek, 2000). Varieties also produced significant effect on head weight. The maximum head weight (376.09 gm) was obtained with variety Early You whereas the minimum head weight of 267.27 gm was recorded in variety Princes. Head weight of Fiesta and Nok Guk are statistically similar with each other. Regarding head yield, the highest head yield of 109.45 q/ha was noticed when the plants were transplanted on 7th November. The lowest head yield of 88.51 q/ha was recorded from 21st September transplanted plant. The probable reason to get (88.01 q/ha) lowered yield from 21st September transplanted plant might be due to higher temperature during the growing

Table 2. Effect of planting date and variety on yield and yield attributing characters of sprouting broccoli

Treatments	Days to head initiation	Days to head maturity	Head diameter (cm)	Head weight (gm)	Head yield (q/ha)	No. of sprouts per plant	Sprout weight (gm	Sprout yield (gm/ plant)
D_1	68.66	76.89	18.64	268.62	88.51	2.58	35.62	70
D_2	65.63	74.11	20.28	300.53	96.17	3.41	43.94	120
D_3	61.04	70.07	22.01	355.38	109.45	3.93	47.16	140
D_4	64.76	74.37	20.35	302.25	96.72	3.01	39.86	100
CD (p=0.05)	1.63	2.00	0.54	10.89	3.49	0.14	1.51	7.11
V_1	63.18	70.52	20.79	376.09	120.35	3.94	35.46	110
V_2	67.75	76.28	18.92	267.27	85.53	3.17	30.03	80
V_3	65.31	74.59	19.74	292.89	93.69	1.90	54.80	85
V_4	63.85	73.86	21.84	290.54	88.73	3.92	46.30	150
(p=0.05)	1.61	1.88	0.35	7.17	2.54	0.10	1.00	6.41

See Table 1 for treatment detail

period which restrict the proper development of head and vegetative growth. This result is in conformity with the findings of Singh (2004). The decrease in yield with the delay in sowing was also reported by Yoldas and Esiyok, 2004; Wlazo and Kunicki, 2003. Like planting date the variety also produce the significant effect on head yield. In this experiment the maximum head yield of 120.35 q/ha was obtained with variety Early You and minimum of 85.53 q/ha was recorded in variety Princes and these two are statistically different with each other. But Princes and Nok Guk are statistically *at par* in head yield. Among the four sequential transplanting date of plants, plants from 7th November transplanting exhibited the maximum of 3.93 number of sprouts and the highest sprout weight of 47.16 gm compared to the minimum of 2.58 number of sprouts and 35.62 gm of sprout from 21st September transplanted plants. Very early and late transplanting resulted decrease is number of sprouts. This might be due to early maturity and early bolting and flowering in earlier and late transplanted plants, respectively. Their differences in number of sprouts is due to the different date of planting might also be due to the reason that earlier and very late sown crop does not get favourable environmental condition, specially the temperature for better growth of the plant. This result supported the earlier finding reported by Hamd and Esmail, 2005. The maximum number of sprout (3.94) was obtained with variety Early You whereas the highest weighed sprout was noticed in the variety Fiesta (54.80 gm). Sprout yield differed significantly with different date of planting. The highest sprout yield (140 gm/plant) was obtained from the 7th November transplanted plant. From the results it is evident that date of planting has significant role for the growth and development of plants and the result is with conformation of Dev, 2012. It was observed that the highest sprout yield was obtained from variety Nok Guk *i.e.* 150 gm/plant which is statistically different from all the other varieties.

Quality characters

Total chlorophyll content was found significant by different date of planting (Table 3). The total chlorophyll content ranges from 4.74 mg/100gm to 5.94 mg/100gm. Maximum (5.94 mg/100gm) of total chlorophyll was obtained from 7th November planting date which is statistically different from other three planting dates. Among the varieties, highest amount of total chlorophyll content was recorded from Early You *i.e.* 6.19 mg/100 gm. The effects of planting dates on reducing sugar, non-reducing sugar and total sugar were observed significantly. The maximum reducing sugar, non-reducing sugar and total sugar *i.e.*1.20%, 0.31% and 1.51%, respectively were observed from the plants which were transplanted on 30th November. Regarding varieties, Fiesta performed best regarding all the above said quality characters. 1.26% of reducing sugar, 0.35% of non-reducing sugar and 1.61% of total sugar were observed from the variety Fiesta. The highest ascorbic acid of 89.11 mg/100gm recorded at 7th November transplanted compared to 21st September, 15th October and 30th November transplanting date. Ascorbic acid content of 21st September and 30th November planted plants are statistically similar. It was clear that too early/late planting resulted in decreased ascorbic acid content. Among the cultivars, Early You variety contents maximum ascorbic acid of 107.49 mg/100gm followed by variety Fiesta (103.85 mg/100gm) and they are statistically different with each other. Total soluble solids (TSS) content in broccoli plant is well documented under different date of planting and variety. TSS content was influenced

Table 3. Effect of planting date and variety on quality characters of sprouting broccoli

Treatments	Total chlorophyll (mg/100gm)	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)	Ascorbic acid (mg/100gm)	Total soluble solids (^{0}Brix)	Carotene content (mg/100gm)
D_1	4.74	1.15	0.28	1.43	86.31	8.59	7.82
D_2	5.66	1.18	0.29	1.47	87.86	9.01	8.42
D_3	5.94	1.19	0.31	1.49	89.11	10.07	8.98
D_4	5.27	1.20	0.31	1.51	86.80	8.92	8.66
CD (p=0.05)	0.09	0.01	0.01	0.01	0.83	0.09	0.05
V_1	6.19	1.16	0.29	1.45	107.49	10.60	8.75
V_2	5.78	1.15	0.29	1.44	59.38	4.41	8.39
V_3	4.46	1.26	0.35	1.61	103.85	9.86	8.46
V_4	5.17	1.14	0.27	1.42	79.36	7.72	8.28
CD (p=0.05)	0.08	0.01	0.02	0.01	0.93	0.10	0.02

See Table 1 for treatment detail

significantly due to different date of planting and different varieties. The maximum TSS content of 10.07 ^{0}Brix was obtained when the plants were transplanted on 7th November and 10.60 ^{0}Brix from the variety Early You. Carotene content ranges between 7.82–8.98 mg/100gm. The maximum of 8.98 mg/100gm of carotene content was obtained when the plant were transplanted in 7th November and among the varieties Early You produced higher carotene content of 8.75 mg/100 gm followed by variety Fiesta. Regarding this parameter, a significant and statistical difference has been observed among all the planting dates as well as among varieties.

CONCLUSION

From the present investigation, it has been observed that planting date should not be very early and neither too late. Therefore, assumption have been made that for better growth and development ideal date of planting should be on 7th of November and best performance has been shown by variety Early You.

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Effect of Fertility Levels and Biofertilizers on Macro Nutrient Content and Uptake by Black Gram (*Vigna Mungo* L.)

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Abstract: A field experiment was conducted at institutional farm, rajasthan college of agriculture, Udaipur, (Rajasthan) during *kharif,* 2014 on clay loam soil. The experiment comprised four fertility levels of control, 50% RDF (10 kg N and 15 kg P_2O_5 ha^{-1}), 75% RDF (15 kg N and 22.5 kg P_2O_5 ha^{-1}) and 100 % RDF (20 kg N and 30 kg P_2O_5 ha^{-1}) and four biofertiliizers levels (control, PSB, Rhizobium and Rhizobium + PSB) applied to the black gram. The interaction effect of fertility levels and biofertilizers increased the growth of the plants and increased nitrogen, phosphorus, but potassium content was non significantly affected in black gram. But combination effect of fertility levels and biofertilizers increased nitrogen, phosphorus and potassium uptake in blackgram. Highest significantly biological yield (3262.54 kg ha^{-1}) was obtained under treatment combination F_3B_3 and minimum biological yield (1339.67 kg ha^{-1}) under combination F_0B_0. The interaction effect of fertility levels and biofertilizers highest significantly nitrogen (64.52 kg ha^{-1}), phosphorus (6.48 kg ha^{-1}) and potassium (20.47 kg ha^{-1}) uptake by seed was obtained combination of 20 kg N and 30 kg P_2O_5 ha^{-1} (F_3) and Rhizobium + PSB (B_3.).

Keyword: Black gram, Fertility, Biofertilizers, PSB , Rhizobium

Black gram (*Vigna Mungo* L.) is a legume, enriches soil nitrogen content and it has comparatively short (90–120 days) time period of maturity. In India, black gram is grown on 3.07 m ha area with a production of 1.60 million metric ton (Anonymous, 2012). Black gram can obtain nitrogen (N) by atmospheric fixation in their root nodules in symbiosis with soil rhizobium and thus has a potential to yield well in nitrogen deficit soils. Most of the applied P gets fixed and only 10–18 percent is utilized by the current crop. So PSB brings out more amount of fixed or unavailable native phosphorus into soluble and available form to the plants (Singh *et al*., 2008). Mineral nutrition plays a key role in exploiting the genetic potential of pulses crops. Phosphours is an important mineral element for grain legumes as it helps in root development, participates in synthesis of phosphate and proteins and takes part in energy fixing and releasing process in plants. Significant response of legumes to phosphate nutrition has been reported by several workers. There is evidence of stagnation or low productivity of black gram and other *kharif* pulses even with the application of recommended doses of NPK fertilizers (Athokpam *et al.*, 2009). So different fertility levels and biofertilizers levels application through increased the macro nutrient content and uptake by seed and straw in black gram. Therefore, an experiment was conducted to increase the production of blackgram and reduce the malnutrition in peoples. Currently, a real challenge is to stop the use of expensive agrochemicals/chemical fertilizers. Adoption of integrated nutrient management involving Inorganic fertilizers and biofertilizers application improved the soil health. The objective of this paper is to investigate the effect of fertility levels and biofertilizers on macro nutrient content and uptake by black gram.

MATERIAL AND METHODS

The experiment was conducted at college of agriculture, Udaipur, which is situated at South–Eastern part of Rajasthan at an altitude of 582.17 metre above mean sea level and at 24º 35 N latitude and 73º 42 E longitude. The region falls under Agro–climatic Zone IV a (Sub– humid Southern Plain and Aravalli Hills) of Rajasthan. The soil of experimental site was clay loam in texture, slightly alkaline in reaction. The soil was medium in available nitrogen and phosphorus while high in potassium, and sufficient in DTPA extractable micronutrients. The experiment comprised four fertility levels of control, 50% recommended dose of fertilizer (10 kg N and 15 kg P_2O_5 ha^{-1}), 75% recommended dose of fertilizer (15 kg N and 22.5 kg P_2O_5 ha^{-1}) and 100 % recommended dose of fertilizer (20 kg N and 30 kg P_2O_5 ha^{-1}) and four biofertiliizers levels (control, PSB, Rhizobium and Rhizobium + PSB) were applied to the black gram var.T–9 The experiment was laid out according to factorial randomized block design with three replications. 30 kg ha^{-1} Phosphorus was applied through DAP and nitrogen @ 20 kgha^{-1} was applied through urea after adjusting N supplied through DAP.

Seed and straw sample of black gram were taken at the time of threshing for estimation of nitrogen, phosphorus and potassium. Each dried straw sample was ground to a fine powder in Wiley Mill to be used in estimating nutrient content in straw likewise each seed sample was ground in electric grinder. Nutrient content in seed and straw were estimated by using standard methods (table.1). Uptake of macro nutrient (N,P,K) at harvest were computed from the data of N,P,K content and grain and straw yield using the following formulae:

$$\text{Macro nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content in plant material (\%) x Yield (kg ha}^{-1}\text{)}}{100}$$

RESULTS AND DISCUSSION

The biological yield (3262.54 kg ha^{-1}) of black gram was significantly highest under combination of (100 per cent RDF) 20 kg N and 30 kg P_2O_5 ha^{-1} (F_3) and Rhizobium + PSB (B_3) comparison with other treatment.

Macro Nutrient Content

Effect of fertility levels: The application of 50, 75 and 100 percent RDF (N 20 and P 30 kg ha^{-1}) increased the nitrogen content by 4.76, 20.63 and 22.22 per cent and phosphorus content by 21.87, 37.52 and 40.62 per cent in seed, respectively. Similarly trend was observed in increase of the nitrogen content (8.96, 30.60 and 34.34 per cent) and phosphorus content (5.09, 23.61 and 26.39 per cent) in straw, respectively overcontrol. The increase in nitrogen content and phosphorus content in seed and straw with 100 % RDF treatment was at par with 75 % RDF treatment. Potassium content was not significantly affected by different levels of fertility levels.

Effect of biofertilizers: The increase in nitrogen content and phosphorus content in seed and straw with inoculation of Rhizobium was at par with PSB. The increase in nitrogen content was 26.55, 27.24, and 32.07 per cent and phosphorus content 40.62, 18.75 and 43.75 per cent in seeds of black gram with PSB, Rhizobium and Rhizobium + PSB inoculations, respectively over control. Similarly trend was observed in increase in the nitrogen content (20.15, 23.13 and 30.60 per cent) and phosphorus content (25.85, 22.93 and 30.73 percent) in straw, respectively over control (0.32). Potassium content was not significantly affected by different levels of biofertilizers levels.

Macro Nutrient Uptake

Effect of fertility levels: The application of 50, 75 and 100 % RDF treatments increased the nitrogen uptake by seed to the extent of 22.84,75.05 and 86.90 per cent whereas increased by straw was to the extent of 21.23, 60.51 and 74.55 per cent, respectively over control uptake (23.29 kg ha^{-1}). Similarly, increased the phosphorus uptake by seed and straw to the extent of 41.25, 97.5 and 112.08 per cent and 16.24, 51.28 and 63.68 per cent, respectively over control (3.83 kg ha^{-1}). The application of 50, 75 and 100 % RDF treatments increased the potassium uptake by seed significantly difference $CD_{(P= 0.05)}$ at 1.13 and straw significantly difference $CD_{(P=0.05)}$ at 2.44, respectively over control .

Effect of biofertilizers: The nitrogen uptake by seed and straw with inoculation of Rhizobium was also to be at par with that of PSB. The increase in nitrogen, phosphorus and potassium uptake by seeds of black gram with PSB, Rhizobium and Rhizobium + PSB inoculations, respectively over control. In straw the uptake in 50, 75 and 100 per cent RDF was 53.18, 59.69 and 82.10 per cent in nitrogen ($CD_{(P= 0.05)}$ at 2.03), 60.19, 60.19 and 83.01 per cent in phosphorus ($CD_{(P= 0.05)}$ at 0.30) and 29.27, 30.15 and 40.26 per cent in potassium ($CD_{(P=0.05)}$ at 2.44), respectively over control.

Interaction effect of fertility levels and biofertilizers on N, P and K uptake: The application of fertility levels and biofertilizers through N (64.52 kg ha^{-1}), P (6.48 kg ha^{-1}) and K

Table 2. Interaction effect of fertility levels and biofertilizers on biological yield (kg ha^{-1}) of black gram

Treatments	F_0	F_1	F_2	F_3	Mean
B_0	1339.67	1646.81	1857.28	1941.43	1696.29
B_1	1931.76	2096.30	2296.61	2334.22	2164.72
B_2	1947.35	2195.71	2442.45	2448.88	2258.59
B_3	1956.22	2225.63	3043.64	3262.54	2622.00
Mean	1793.73	2041.11	2409.99	2496.76	8741.60
CD (p= 0.05)	367.47				

Table 1. Methods adopted for plant analysis

Determinations	Methods	Reference
Digestion of plant sample	Wet digestion of plant samples with H_2SO_4 and H_2O_2 will be carried out for determination of nitrogen content	Jackson (1973)
Nitrogen content	Colorimetric method using spectrophotometer after development of colour with Nesseler's reagent	Snell and Snell (1949)
Digestion of plant sample	Digestion with di-acid mixture HNO_3 ,$HClO_4$ (3:1)	Johnson and Ulrich (1959)
Phosphorus content	Vando-molybdo phosphoric acid yellow colour method	Jackson (1973)
Potassium content	Analysis of suitable aliquot of acid digested plant material by Flame photometer	Metson (1956)

(20.47kg ha^{-1}) uptake by seed were significantly higher in combination of 20 kg N and 30 kg P_2O_5 ha^{-1} (F_3) + Rhizobium + PSB (B_3). However, the increase in N, P and K uptake by seed and straw with F_3B_3 treatment was at par with F_2B_3 treatment.

It can be concluded that the application of 100% RDF (nitrogen @ 20 kg ha^{-1} and phosphorus @ 30 kg ha^{-1}) significantly improved N and P content in seed and straw. But the application of 100% RDF recorded not significantly difference of potassium content in seed and straw. The maximum uptake of nutrients (N, P and K) at 100% fertility level may be as a result of increased grain and straw yields as well as per cent nutrient contents in grain and straw. An improved metabolism to greater translocation of these nutrient to reproductive organs of the crop and ultimately increased the content in seed and straw. These results are in close conformity with those of Sharma *et al*., (2006), Kumhar *et al.,* (2013) and Nyoki and Ndakidemi (2014).

The increase in these values due to inoculation of seed with Rhizobium was probably due to more nitrogen fixation resulting in to better utilization of nutrients by plants, ultimately macro nutrient content (N, P) and uptake (N, P and K) increased in seed and straw, but the application of Rhizobium indicated not significantly difference potassium content in seed and straw. PSB enhanced the availability of phosphorus to plants, which might have utilized by the crop in greater root development and nodulation that in turn resulted in higher nitrogen fixation in the soil by root nodules (Vikram and Hamzehzarghani, 2008). The combined inoculation of seed with Rhizobium + PSB was more beneficial in enhancing all the above parameters due to increased solubility of phosphorus and higher nitrogen fixation in nodules, leading to increased availability of

Table 3. Effect of fertility levels and biofertilizers on macro nutrient content (%) in seed and straw of black gram

Treatments	Seed			Straw		
	Nitrogen	Phosphorous	Potassium	Nitrogen	Phosphorous	Potassium
Fertility Levels						
F_0 : Control	3.15	0.32	1.22	1.34	0.216	2.14
F_1 : 50 % RDF	3.30	0.39	1.23	1.46	0.227	2.15
F_2 : 75 % RDF	3.80	0.44	1.30	1.75	0.267	2.15
F_3 : 100 % RDF	3.85	0.45	1.30	1.80	0.273	2.21
CD (p= 0.05)	0.14	0.011	NS	0.09	0.007	NS
Biofertlizers						
B_0: Control	2.90	0.32	1.23	1.34	0.205	2.16
B_1 : PSB	3.67	0.45	1.25	1.61	0.258	2.16
B_2 : Rhizobium	3.69	0.38	1.27	1.65	0.252	2.17
B_3:PSB+Rhizobium	3.83	0.46	1.30	1.75	0.268	2.20
CD (p= 0.05)	0.14	0.011	NS	1.46	0.007	NS

Table 4. Effect of fertility levels and biofertilizers on macro nutrient uptake (kg ha^{-1}) by seed and straw of black gram

Treatments	Seed			Straw		
	Nitrogen	Phosphorous	Potassium	Nitrogen	Phosphorous	Potassium
Fertility Levels						
F_0 : Control	23.29	2.40	8.69	14.46	2.34	23.28
F_1 : 50 % RDF	28.61	3.39	10.58	17.53	2.72	25.94
F_2 : 75 % RDF	40.77	4.74	13.63	23.21	3.54	28.05
F_3 : 100 % RDF	43.53	5.09	14.49	25.24	3.83	30.46
CD (p= 0.05)	4.27	0.49	1.13	2.03	0.30	2.44
Biofertlizers						
B_0: Control	20.05	2.20	8.19	13.52	2.06	21.56
B_1 : PSB	35.68	4.41	12.02	20.71	3.30	27.87
B_2 : Rhizobium	37.29	3.86	12.77	21.59	3.30	28.06
B_3:PSB+Rhizobium	43.20	4.89	14.41	24.62	3.77	30.24
CD (p= 0.05)	4.27	0.49	1.13	2.03	0.30	2.44

Table 5. Interaction effect of fertility levels and biofertilizers on the N, P and K uptake by seed of black gram

Treatments	F_0	F_1	F_2	F_3	Mean
Nitrogen uptake					
B_0	11.25	16.86	25.29	28.79	20.54
B_1	26.95	31.15	37.48	38.13	33.42
B_2	27.44	33.03	41.70	42.69	36.21
B_3	27.54	33.41	58.63	64.52	46.02
Mean	23.29	28.61	40.78	43.53	136.19
CD (p=0.05)	8.55				
Phosphorus uptake					
B_0	1.16	1.81	2.70	3.14	2.20
B_1	3.21	3.94	5.48	5.99	4.65
B_2	2.17	3.58	4.92	4.74	3.85
B_3	3.24	4.24	5.80	6.48	4.94
Mean	2.44	3.39	4.72	5.08	15.64
CD (p=0.05)	0.85				
Potassium uptake					
B_0	6.13	6.98	9.73	9.94	8.19
B_1	9.35	10.86	13.31	14.20	11.93
B_2	9.56	12.23	14.46	14.79	12.76
B_3	9.72	12.24	15.60	20.47	14.50
Mean	8.69	10.57	13.27	14.85	47.38
CD (p=0.05)	2.26				

nitrogen and phosphorus. These results corroborate the findings of Khan *et al*. (2014), Rathore *et al*. (2010) and Kumawat *et al*. (2013).

CONCLUSION

On the basis of present study , it can be concluded that under agro climatic condition of zone IVa (Sub-humid Southern Plain and Aravali Hills) of Rajasthan, application of 20 kg N and 30 kg P_2O_5 ha^{-1} + Rhizobium + PSB (F_3B_3), is the better option for realizing higher productivity, content and uptake of nutrients of black gram and is the better option for improved fertility status of soil. The result of the present investigation reveals the significance of fertility levels with the combination of biofertilizers levels in black gram crop for maximization of yield and profits.

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Response of Wheat Varieties to Foliar Application of Bioregulators under Late Sown Condition

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Abstract: The field experiment to study the "Adaptation Strategies for Mitigating Adverse effect of Heat Stress in late sown Wheat [*Triticum aestivum (L.)* emend. Fiori & Paol]" conducted at research farm, RARI, Durgapura for two consecutive years during *rabi* seasons 2013–14 and 2014–15 on loamy sand soil. The twenty treatment combinations consisting of 4 varieties (Raj 4037, Raj 3765, Raj 4079 and DBW 17) and bioregulators (Control, Water spray, Salicylic acid, thioglycolic acid and thiosalicylic acid) were tested in split plot design with four replications with objective to select suitable varieties for heat tolerance and to identify suitable bioregulators for mitigating the adverse effect of heat stress. Variety Raj 4037 proved significantly superior to Raj 4079 and DBW 17 with respect to all growth parameters (Dry matter accumulation, LAI, LAD, CGR and NAR) but remained at par with Raj 3765. The maximum plant height was recorded with variety Raj 3765. Results further indicated that plant height, dry matter accumulation, LAI, LAD, CGR and NAR significantly increased with foliar application of 100 ppm salicylic acid over control and water spray. However, thioglycolic acid and thiosalicylic acid also found equally effective with salicylic acid.

Key Words: Wheat, Varieties, Growth Parameters, Bioregulator

Wheat [*Triticum aestivum (L.)* emend. Fiori & Paol)] is the most important staple food crop of the world and emerged as the backbone of India's food security. Variability in climate is the most important global environmental challenge facing humanity with implications for natural ecosystems and agriculture. The perusal of general circulation models (GCM s) on climate change indicate that rising levels of greenhouse gases are likely to increase the global average surface temperature by 1.5–4.5° C over the next 100 years. The difference of average temperature between the last ice age and present climate is 6° C. This will raise sea-levels, shift climate zones pole ward, decrease soil moisture and storms. Temperature is the major environmental variable which affect crop yield. Ideally the best temperature regime for optimum growth and yield of wheat crop is 20–22° C at sowing, 16–22° C at tillering to grain filling and slow rise of temperature to 32°C at harvesting (Sharma, 2000). When the temperature moves beyond this optimal range, it generates heat stress. According to Lobell and Field (2007), rising temperature had a negative effect on wheat yields. High temperature particularly during November sowing accelerates its growth by making the crop enter in to jointing stage too early, thus reducing tillering period (Harrison *et al.*, 2000). This result in reduced number of tillers and lastly reducing total crop yield.

Selection of appropriate variety with respect to date of sowing and expected temperature rise during the crop growth period is necessary to get an optimum yield under high temperature stress conditions in wheat crop. A number of new genotypes of wheat are playing an important role in the human nutrition and solving food problem but as a result of heat stress, the performance of these genotypes is often hampered, so it is necessary to develop heat tolerant genotype (Spiertz *et al.,* 2006). Breeding of crop varieties holding promise against environmental stress is an expensive and long term venture. Therefore, emphasis has been placed on exploiting prompt and inexpensive means of obtaining satisfactory yield from stresses lands. One of the programmatic approaches is the exogenous use of stress alleviating compounds, inorganic salts, natural and synthetic plant growth regulators and stress signaling molecules have been used based on their specific properties and roles to improve germination and subsequent growth in a number of grain, forage and horticultural crops.

Application of bioregulators in low concentration is reported to reduce biotic and abiotic stress in plants. Heat and drought stress in field crops can be managed by applying bioregulators like salicylic acid, thioglycolic acid, gibberlic acid, thiosalicylic acid and calcium chloride, which are able to induce long-term thermo- tolerance in plants and can be helpful in mitigating the yield reduction threats as well as are helpful in producing good quality grains (Wahid *et al.,*2007). Their application therefore holds a great promise as a management tool for providing tolerance to food crops against their stresses.

Hence the present investigation was planned to select suitable varieties for heat tolerance and bioregulators for mitigating the adverse effect of heat stress.

MATERIAL AND METHODS

A field experiment was conducted at Agronomy farm, R.A.R.I, Durgapura-Jaipur during *Rabi*, 2013-14 and 2014-15 on loamy sand soil. The twenty treatment combinations consisting of 4 varieties (Raj 4037,Raj 4079,Raj 3765 and DBW 17) and 5 bioregulators (control, water spray, salicylic acid, thiosalicylic acid and thioglycolic acid) were tested in split plot design with four replications. The soil was loamy sand in texture, alkaline in reaction (pH 8.1). The bioregulators were sprayed with knapsack sprayer at tillering and ear emergence stages as per layout plan. Five plants were selected randomly from each plot and tagged permanently. Height of individual plant was measured at 30, 60, 90 days stage and at harvest from base of the plant to the top of the main shoot. Total five plants were randomly selected from sampling rows of each plot for the assessment of dry matter distribution per plant. Leaves were detached from ligule. Stem, leaves and earhead thus separated were kept in separate paper bags aerated by making several holes over them. These samples were kept in sun for few days and then transferred to hot air oven for drying at 650C till a constant weight. Total dry matter accumulation was recorded. Data was statistically analysed by the standard procedure.

Leaf area was measured with the help of leaf area meter (LA-3100). After recording leaf area, these leaves were again mixed with the samples of dry matter estimation. The leaf area for each sample was averaged to give leaf area per plant. Land area per plant was used to compute Leaf Area Index (LAI)at each stage by following relationship (Watson, 1958)

LAI = Leaf area (cm2)/ Land area (cm2)

Leaf Area Duration (LAD) measure by method given by Power *et al.* (1967).

$$LAD = \frac{A_0 + A_1}{2} (t_1 - t_0)$$

Where,

'A' is leaf area index, 't' is the time in days and subscript refers to sampling. The observation interval was 30 days.

Mean Crop Growth Rate (CGR) of a plant was calculated from periodic dry matter recorded at different stages (Radford, 1967):

$$CGR\ (g\ m^{-1} day^{-1}) = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_1 = Total dry weight of plant at time t1 ; W_2 = Total dry weight of plant at time t2 ; t_1 = Time of first observation ; t_2 = Time of second observation

$$NAR\ (g\ m^{-2}\ leaf\ area\ day^{-1}) = \frac{Loge\ A_2 - Loge\ A_1}{(A_2 - A_1)} \times \frac{W_2 - W_1}{t_2 - t_1}$$

NAR is calculated by method described by Radford, 1967.

Where, A_1 = Total leaf area at time t1 ; A_2 = Total leaf area at time t2 ; W_1 = Total dry matter of plant at time t1 ; W_2 = Total dry matter of plant at time t2 ; t_1 = Time of first observation ; t_2 = Time of second observation

RESULTS AND DISCUSSION

Effect of varieties: Varieties differed significantly in their plant height at all the growth stages. Initially variety Raj 4037 constantly recorded the maximum height as compared to other varieties during both the years of studies and in pooled analysis. While, at later stages (60, 90 DAS and at harvest) the variety Raj 3765 (V3) recorded the maximum plant height and proved significantly superior to variety DBW 17. The shortest plants height with variety DBW 17 at all the growth stages during both the years of studies and in pooled analysis. Variety Raj 4037 accumulated the maximum and significantly higher dry matter accumulation/plant over Raj 4079 and DBW17, However it was at par with Raj 3765 at 60, 90 DAS and at physiological maturity. It is an established fact that growth, development and yield potential of variety is an outcome of genomic, environmental and agronomic interactions. Since, all the varieties were grown under identical agronomic (management) practices and environmental conditions the observed variation in overall growth of varieties seems to be due to their genetic milieu. Raj 4037 being at par with Raj 3765 recorded the maximum leaf area index and leaf area duration at different stages over rest of the varieties and also resulted in significantly higher crop growth rate (CGR) at 30-60 and 60-90 days over rest of the varieties. Among the tested varieties, Raj 4037 recorded maximum and significantly higher net assimilation rate (NAR) at 60-90 days over DBW 17 and was at par with variety Raj 3765 and Raj 4079.

The significant increase in biomass production under variety Raj 4037 could be ascribed to its higher tillering potential, which might have facilitated larger canopy development thus LAI. Raj 4037 also recorded higher dry matter accumulation in leaf, stem and ear head at all the stages of growth as compared to other varieties (Table 1). Similarly this variety Raj 4037 gave significantly higher LAI, crop growth rate, leaf area duration, and net assimilation rate as compared to other varieties (Table 2). The improvement in these growth parameters might have led to higher interception and absorption of radiant energy, resulting into greater photosynthesis and finally dry matter accumulation (Sharma *et al*., 2000).

Effect of bioregulators: The foliar application of bioregulators did not bought significant variation in plant height at 30 DAS. While, significant increase in plant height at 60, 90 DAS and at harvest stages was observed due to application of bioregulators. Among of bioregulators foliar application 100 ppm of salicylic acid (SA) recorded the highest plant height and proved superior to control and water spray and was at par with thioglycolic acid (TGA) and thiosalicylic acid (TSA) during both the years of experimentation as well as in pooled analysis (Table 1). Significant increase in dry matter accumulation per plant at 60, 90 DAS and at physiological maturity was due to foliar application of 100 ppm salicylic acid as compared to control and water spray and remained at par with thiosalicylic acid and thioglycolic acid. Effect of foliar application of 100 ppm salicylic acid resulted in significant increase in LAI at 60 and 90 DAS over control and was at par with TSA and TGA. Further, foliar application of 100 ppm salicylic acid significantly increased the crop growth rate (CGR), net assimilation rate (NAR) and leaf area duration (LAD) at different growth stages over control and water spray and being at par with TSA and TGA.

The favourable effect of salicylic acid on growth of plants might be due to account of improved photosynthetic efficiency. Thus the growth of wheat was improved with two spray of 100 ppm foliar spray of salicylic acid solution each at tillering and ear emergence stages. The effect of foliar spray of 100 ppm bioregulators at tillering and ear head emergence

Table 1. Effect of varieties and bioregulators on growth parameters (Pooled data of 2 years)

Treatments	Plant height (cm)			Dry Matter Accumulation (g plant−1)		
	60 DAS	90 DAS	AT Harvest	60DAS	90DAS	At Physiological maturity
			Varieties			
Raj 4037	38.07	78.96	81.58	2.44	7.61	13.17
Raj 4079	35.65	73.07	76.38	2.26	6.99	11.99
Raj 3765	38.46	79.77	82.66	2.35	7.32	12.56
DBW 17	33.27	67.41	70.39	2.06	6.21	10.73
CD (P=0.05)	1.35	3.14	3.06	0.10	0.32	0.56
			Bioregulators			
No spray (control)	33.23	68.51	71.50	2.10	6.19	11.07
Water spray	35.24	72.98	76.41	2.17	6.54	11.52
Thiosalicylic acid (100 ppm)	37.38	76.48	79.89	2.34	7.38	12.40
Salicylic acid (100 ppm)	38.49	79.14	80.87	2.42	7.58	13.04
Thioglycolic acid (100 ppm)	37.46	76.90	80.08	2.35	7.46	12.52
CD (P=0.05)	1.32	2.71	2.68	0.09	0.30	0.55

Table 2. Effect of varieties and bioregulators on physiological parameters. (Pooled data of 2 years)

Treatments	CGR (g $m^{-1}day^{-1}$)		NAR (g m−2 leaf area day−1)		LAI			LAD Weeks	
	30−60 DAS	60−90 DAS	30−60 DAS	60−90 DAS	30 DAS	60 DAS	90 DAS	30−60 DAS	60−90 DAS
				Varieties					
Raj 4037	1.58	4.30	6.46	5.40	0.25	2.51	3.96	5.62	10.99
Raj 4079	1.43	3.94	6.14	5.26	0.24	2.40	3.68	5.37	10.27
Raj 3765	1.49	4.14	6.25	5.34	0.25	2.43	3.89	5.44	10.75
DBW 17	1.25	3.45	5.65	4.94	0.23	2.28	3.38	5.11	9.51
CD (P=0.05)	0.013	0.043	NS	0.45	NS	0.09	0.11	0.22	0.40
				Bioregulators					
No spray (control)	1.30	3.41	5.99	4.89	0.22	2.23	3.42	5.00	9.57
Water spray	1.36	3.64	5.99	5.03	0.23	2.33	3.54	5.22	9.91
Thiosalicylic acid (100 ppm)	1.49	4.20	6.23	5.43	0.24	2.47	3.82	5.52	10.60
Salicylic acid (100 ppm)	1.55	4.30	6.25	5.38	0.26	2.50	3.95	5.62	11.04
Thioglycolic acid (100 ppm)	1.50	4.26	6.16	5.44	0.25	2.48	3.87	5.57	10.78
CD (P=0.05)	0.015	0.030	NS	0.58	NS	0.08	0.14	NS	0.45

were more pronounced than control and water spray investigation. The foliar application of bioregulators at tillering and ear head emergence by and large proved the best treatment and showed significant improvement in all the growth parameters over control and water spray. The dry matter accumulation and its partitioning was favorably influenced by bioregulators which led to improved CGR and NAR (Table 2). The positive effect on CGR, LAI, LAD and NAR provided a clue to such a possibility that salicylic acid might have resulted into creation of more photosynthetically active leaf area for longer period during vegetative and reproductive phases, leading to more adsorption and utilization of radiant energy which ultimately resulted in higher dry matter accumulation, more number of tillers and plant height.

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Influence of Sowing Environments on Yield Attributes and Yield of Wheat (*Triticum aestivum* L.) Varieties under System of Wheat Intensification

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Abstract: An experiment was conducted during the winter (*rabi*) season of 2014–15 at Varanasi, India, to evaluate the effect of sowing dates and varieties on growth, yield, removal of NPK and economics of wheat (*Triticum aestivum* L.). Eighteen treatment combinations comprising of three dates of sowing (November, 25, December, 02 and 09), three wheat varieties (HUW–234, HUW–510 and HUW–468) and two systems of sowing (standard practices and system of wheat intensification, SWI) were laid out using split–split plot design with three replications. The timely sowing of the crop (November, 25) improved the growth and yield attributes, grain and straw yield, NPK removal than the late sown crop. Among wheat variety 'HUW–234' recorded higher growth parameters, yield attributes, grain and straw yield and NPK removal than 'HUW–510' and 'HUW–468'. Relative economics analysis indicated the maximum net return (₹90674/ ha) and benefit: cost ratio (2.76) was found with wheat variety 'HUW–234' under November, 25 sown crop under SWI. Sowing on November, 25 was gave 9.67 and 34.7 per cent higher grain yield over December, 02 and 09, respectively. 'HUW–234' was gave 10.76 and 12.46 per cent higher grain yield over 'HUW–510' and 'HUW–468'. Further, per cent increase in grain yield under SWI at 20 cm20 cm over standard practice at 22.5 cm row spacing was 8.4.

Keywords: Soil fertility, Sowing dates, SWI, Wheat, Varieties

Wheat is an important cereal crop grown on 30.47 million ha area in India, producing 95.85 million tonnes of grain with an average productivity of 3146 kg ha^{-1} (Agriculture Statistics at a glance, 2015). Wheat yield is far below than the potential yield due to many factors of which sowing time being most important. Weather is one of the important factors influencing crop productivity. Among the factors, temperature is the driving force of plant development, day length and vernalization moderate its effect. Data indicates that in India alone around 13.5 million ha of wheat is heat stressed (Joshi *et al*., 2007). Hence, yield potential of wheat can be exploited by planting it at optimum time. Optimum planting time range of different varieties varies with regions depending on growing conditions of a particular tract which can be tested by sowing them at different dates. Consequently, different varieties with different genetic make–up mature at different rates but the difference is greater when sown early. In spite of cultivation of high–yielding varieties, early sowing and optimum doe of nitrogen, phosphorus and potassium are must for good harvest (Jat *et al*., 2013). Hence, yield potential of wheat can be exploited by planting it at optimum time. Moreover, technique of the system of rice intensification has been extended to wheat and other crops with observed significant results. To assess such finding with respect to wheat, an experiment was conducted to find optimum planting time of different varieties under system of wheat intensification.

MATERIAL AND METHODS

An experiment was carried out during winter (*Rabi*) season of 2014–15 at Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India (25°18′ N, 83°31′ E and 128.93 m above the mean sea level) under sub–tropical zone of Northern Gangetic Alluvial plains. The soil was sandy–clay loam in texture and classified as Inceptisol (*Typic Ustochrept*). It was low in organic carbon (0.26%), low in available nitrogen (206 kg N ha^{-1}), medium in available phosphorus (20 kg P_2O_5 ha^{-1}) and available potassium (180 kg K_2O/ ha). Eighteen treatment combinations comprising of three dates of sowing (25 November, 02 December and 09 December), wheat varieties ('HUW–234', 'HUW–510' and 'HUW–468') and two systems of sowing [standard practices at 22.5 cm and system of wheat intensification (SWI) at 20x20 cm] were laid out using split–split plot design with three replications. Recommended dose of fertilizer (RDF) for Varanasi region N–P_2O_5–K_2O (120–60–60 kg ha^{-1}) was applied uniformly to raise the experimental crop. Half of the recommended dose of nitrogen (60 kg ha^{-1}), full dose of phosphorus (60 kg P_2O_5 ha^{-1}) and potassium (60 kg K_2O ha^{-1}) were applied at time of sowing through urea, di–ammonium phosphate and muriate of potash, respectively. Remaining half dose of nitrogen (60 kg N ha^{-1}) was applied as top dressing in the form of urea at 26 and 48 DAS. In SWI, 25 kg well–developed seeds were selected by putting all the seeds into a 20% salt water solution and discarding those less-viable seeds which floated on the surface. The remaining seeds were treated with a biological mixture of 2 kg of well-decomposed compost or vermicompost, 3 L of cow urine, and 2 kg of jiggery well-mixed together in an earthen pot with 10 L of warm water (60˚C). The seeds were soaked in this mixture for 6–8 h, in successive lots of 5 kg. The seeds were then separated from the mixture by filtration and washed with clean water. The treated seeds were then kept in the shade for 10–12 h, wrapped in rough linen (gunny bag), and during this period the seeds fully sprouted. The sprouted seeds were sown in the field by dibbling, planting two seeds per hill, with the hills spaced in a square pattern of 20 × 20 cm apart. Seeds were sown at a depth of 2.5–3.0 cm, the soil having sufficient moisture to germinate the seeds. Seed rate was 125 kg/ ha in standard practice and 20 kg ha^{-1} for SWI. Five-irrigation were applied in November, 25 and December, 2 sown crop, four-irrigation were applied in December 9 sown crop. The total rainfall received during the crop growth was 131.1 mm. The weekly mean maximum and minimum temperature during the experimentation ranged from 14 to 38.9^{0}C and 7.1 to 24.8^{0}C, respectively. Grain and straw samples were dried, processed and analysed for their total N content by micro-Kjeldahl's, P by Vanadomolybdo phosphoric acid-yellow colour method and K was estimated by flame-photometer. Nutrient removal was estimated by multiplying the content with the oven-dry weight of biological yield. The samples were oven dried at 70^{0}C ± 2^{0}C till constant weight was achieved. The soil samples collected before sowing and after harvesting of the crop were analysed for organic carbon by Walkley and Black's method, available N by alkaline permanganate method, P by Olsen's method, K by Flame-photometer after extraction with 1 *N* NH_4OAC (*p*H 7). The LAI was measured by leaves of five plants taken from each penultimate rows and leaf area was recorded with a leaf area meter (Systronics 211). The LAI was worked out as: Leaf-area index = Total leaf-area (cm^2)/Land area.

RESULTS AND DISCUSSION

Growth parameters: In the present investigation, variation in plant height, chlorophyll content (SPAD value), tillers per running meter, dry matter accumulation (DMA)/ plant and leaf-area index (LAI) due to varieties, dates of sowing and system of sowing was found significant (Table 1). In case of plant height, November, 25 sown crop was significantly taller than December, 9 but at par with December, 02. Regarding DMA (g) per running meter, November, 25 was significantly higher than December, 9 and December 02. This might be attributed to maximum length of growing period available to November, 25 over December 02 and 09 sown crop. Cell division and cell expansion are more sensitive to low temperature. Temperature increase tends to stimulate growth which in turn results in dilution of carbohydrates and chlorophyll. Thus the findings confirm those of Baloch *et al*. (2010). In chlorophyll content (SPAD Value), November, 25 sown crop was significantly higher values as compared to December, 02 and 09 but these were also remained statistically at par with each other. LAI was the maximum in November, 25 which was at par with December, 02 and significantly superior over December, 09. This may be due to the decrease in temperatures, which in conformity with Suleiman *et al.* (2014) who reported that LAI increased with the reduction in temperatures during active leaf development. Among the varieties, plant height, chlorophyll content (SPAD value), tillers per running meter (No.), DMA/ plant and LAI were found the maximum with 'HUW-234', which may be genotypic character of this variety, suitable under the condition. The SWI was also recorded significantly higher values of the all growth parameters over standard practices due to seed treatment and proper spacing conditions. Dhar *et al*. (2016) also observed that SWI results in higher growth parameters.

Yield attributes and yield: Difference in effective tillers/ m^2, spike length, grains/ spike, 1000-grain weight, grain yield, straw yield and harvest index due to varieties, dates of sowing and system of sowing were found to be significant (Table 1). The maximum effective tillers/ m^2 was in November, 25 sown crop with the per cent increase by 16.8 over December, 09 which recorded the minimum value. The higher length of spike was in November, 25 i.e. 11.8 cm, was decreased with delay in date of sowing. The more grains/ spike were observed in November, 25 over December, 09 but at par with December, 02. Interaction effect between dates of sowing and varieties was significant in respect of grains/ spike. Further, among the dates of sowing, the maximum 1000-grain weight was in November, 25 i.e. 37.5 g where as the minimum value was recorded in December, 09 i.e. 33.1 g. The per cent increase in 1000-grain weight in November, 25 over December, 09 was 13.43. All these characteristics significantly decreased with delay in date of sowing. It might be due to longer and favorable period of ear formation resulting more spikelet's development and greater chances of producing long ears containing a large number of grains. Jat *et al*. (2013) also reported such results. Variety 'HUW-234' was significantly higher effective tillers/ m^2, spike length, grains/ spike and 1000-grain weight than 'HUW-468' but that was at par with 'HUW-510'. SWI was found significantly higher effective tillers/ m^2 over standard practices and recorded the highest effective tillers/ m^2, spike length, grains/ spike and 1000-grain weight this may be due to the seed treatment and proper aeration under SWI method. Kumar *et al*. (2015) obtained more effective tillers/ m^2 and 1000-grain

Table 1. Effect of sowing dates and system of sowing on growth parameters, yield attribute, yield and protein content of wheat varieties

Treatment	Plant height (cm) at harvest	Chlorophyl l content (SPAD value) at 90 DAS	Tillers per running meter (No.) at 90 DAS	Physiological maturity (Days)	Dry matter accumulati on (g/ m) at harvest	Leaf–area index at 90 DAS	Effective Tillers/ m^2 (No.)	Spike length (cm)	Grains/ spike (No.)	1000–grain weight (g)	Yield ($t\ ha^{-1}$)		Harvest index (%)	Protein content (%)
Dates of sowing (D)														
November, 25	97.6	38.8	118	105.2	199	4.6	333	11.8	38.2	37.5	3.83	6.08	38.6	10.4
December, 02	95.4	36.1	114	100.6	191	4.3	310	11.4	37.9	35.9	3.49	5.87	37.0	10.5
December, 09	93.2	34.2	108	93.5	186	3.9	285	10.8	34.9	33.1	2.84	5.12	35.8	10.9
CD (p=0.05)	2.92	2.11	4.1	4.1	4.6	0.34	16	0.38	1.08	1.34	0.045	0.078	0.87	0.34
Varieties (V)														
HUW–234	100.3	38.1	116	102.4	196	4.8	324	11.7	38.6	36.2	3.61	5.80	38.2	10.8
HUW–510	96.6	36.4	114	100.1	192	4.2	314	11.3	36.3	35.9	3.35	5.72	36.6	10.3
HUW–468	89.4	34.5	110	96.7	188	3.9	296	10.8	36.1	34.4	3.21	5.54	36.6	10.2
CD (p=0.05)	2.46	1.61	2.5	2.7	3.4	0.30	14	0.32	0.74	0.60	0.042	0.052	0.44	0.33
D x V	S	NS	NS	NS	NS	NS	NS	NS	S	S	S	S	S	NS
System of sowing (S)														
Standard	94.1	35.1	112	98.4	190	4.1	290	11.0	36.2	34.7	3.25	5.57	36.5	10.5
SWI	96.8	37.7	115	101.2	194	4.5	323	11.6	37.8	36.3	3.53	5.80	37.8	10.8
CD (p=0.05)	2.16	1.55	2.2	2.5	3.0	0.17	12	0.19	0.45	0.56	0.035	0.051	0.41	0.21
D x V x S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Standard practice at 22.5 cm line sown and SWI at 20 x 20 cm spacing; S, significant; NS, Non–significant weight under SWI as compared with conventional sowing (22.5 cm line) either of wheat cultivars 'DBW 39' or 'Raj 4229'. Interaction effect between dates of sowing and varieties was found significant in respect of 1000-grain weight during course of study. The highest grain yield was recorded in November, 25 (3.83 t ha^{-1}) and it's gave 9.67 and 34.7 per cent higher over December, 02 and 09, respectively. The major cause for higher grain and straw yield in November, 25 sown treatment was extended vegetative and reproductive phase as compared to the late sown crop. The late planted crop was adversely affected during the reproductive phase because of supra-optimal thermal stress which leads to farced maturity as crop duration was shortened from 100.6 to 93.5 days and reduced harvest index also found. Ram *et al*. (2012) observed that per cent decrease in grain and biological yield of wheat from December, 1 to January, 1 was 29.8 and 23.7, respectively. Variety 'HUW-234' exhibited the highest grain and straw yield. Further, the per cent increase in grain yield by SWI over standard practices was 8.4. This might be due to the wider spacing and proper aeration under SWI method. The Aga Khan Rural Support Programme, working in farmers fields in Bihar has reported that grain yield of wheat to the tune of 3.48 t ha^{-1} in SWI as compare to usual practice (2.63 t ha^{-1}) (Abraham *et al*., 2014). The interaction effect between dates of sowing and varieties was found significant on grain yield. The maximum straw yield was with November, 25 (6.08 t ha^{-1}) which was significantly superior over the December, 09 (5.11 t ha^{-1}). The magnitude of increase in straw yield over December, 02 and 09 to November, 25 was 3.68 and 19.04 per cent, respectively. Among the dates of sowing, the maximum and minimum harvest index was recorded under November, 25 (38.6%) and December, 09 (35.8%), respectively. Late sowing date recorded the lower value of harvest index such effect may be attribute to decrement in biological yield associate the late sowing. Variety 'HUW-234' was recorded significantly higher harvest index over 'HUW-510' and 'HUW-468'. Between the system of sowing, maximum harvest index was under SWI which was 37.75%. December, 9 sown crop recorded higher protein content than November, 25 and December, 2 sown but these were at par with each other. This higher protein content in low yield in late sown treatment may be because of dilution effect. Wheat variety 'HUW-234' recorded higher protein content than 'HUW-510' and 'HUW-468'. SWI was significantly higher protein content than standard practices.

Soil Fertility status and nutrient removal : Fertility of soil and nutrient removal (N, P and K) by crop varied significantly due to dates of sowing, varieties and system of sowing (Table 2). Soil organic carbon content and available NPK in the soil were significantly influenced by dates of sowing and higher

Table 2. Effect of sowing dates and system of sowing on organic carbon content, available NPK content in soil and removal of NPK by wheat varieties

Treatment	Organic carbon content in soil (%)	Available nutrients (kg ha^{-1})			Nutrient removal (kg ha^{-1})					
					Nitrogen		Phosphorus		Potassium	
		N	P_2O_5	K_2O	Grain	Straw	Grain	Straw	Grain	Straw
Dates of sowing (D)										
November, 25	0.29	182	22.6	165	66.5	35.0	12.5	4.13	15.9	79.3
December, 02	0.32	210	25.0	169	58.8	35.6	11.1	3.69	12.3	73.4
December, 09	0.36	233	28.1	176	49.4	31.8	7.8	2.86	10.0	63.4
CD (p=0.05)	0.03	20	2.86	8.8	3.19	2.13	0.83	0.33	0.79	2.68
Varieties (V)										
HUW-234	0.29	198	23.1	166	62.9	37.1	12.0	3.71	14.5	74.4
HUW-510	0.33	215	25.1	170	56.5	34.7	10.7	3.31	12.8	73.2
HUW-468	0.35	230	27.5	172	55.3	30.6	8.7	2.82	10.9	68.2
CD (p=0.05)	0.02	16	2.77	4.6	2.71	1.69	0.80	0.31	0.73	1.55
D x V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
System of sowing (S)										
Standard practice	0.33	218	24.3	168	55.5	32.1	10.2	3.56	11.7	71.1
SWI	0.35	228	26.2	172	61.0	36.1	12.4	4.06	13.8	72.9
CD (p=0.05)	0.02	12	1.72	3.6	1.84	1.08	0.70	0.29	0.58	1.26
Soil fertility status before	0.26	206.0	20.0	180.0						
D x V X S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Standard practice at 22.5 cm line sown and SWI at 20 x 20 cm spacing; NS, Non-significant values were in December, 9 sown crop than rest of the dates. Organic carbon content of soil significantly increased with the delay in sowing date, as plant vegetative growth decrease due reduced growing period of crop but crop has comparatively better roots which enhance organic carbon status of soil. Late sown (December, 9) crop decrease in NPK removal due to lesser yield of grain and straw maintained higher available of NPK content in soil. Among varieties, ′HUW‑468′ was found higher soil fertility status (organic carbon and available NPK) after harvest than ′HUW‑234′ and ′HUW‑510′. System of sowing did not influence on organic carbon content in soil. However, the highest available NPK content in soil after harvest were found under SWI. Dhar *et al.* (2016) reported that superior performance of the direct‑seeded version of SWI on all of the parameters measured, *viz.* plant height; root length and volume; grain, straw, and total biological yield; economic returns; and residual soil fertility, compared with the standard practices.Moreover, dates of sowing had a marked influence on total N, P and K removal. Timely sown crop (November, 25) brought about significant increase in N, P and K removal grain as well as straw of wheat. The removal of NPK by crop is mainly a function of yield of that plant material. With the delay in sowing, the growth and yield of crop reduced, resulting low removal of the nutrients. Jat *et al*. (2013) also found that the nutrients removal by grain and straw decreased with delay in sowing. November, 25 sown crop was significantly higher in NPK removal than December, 02 and 09 but in case of N content in straw it was at par with December, 2. Further, N, P and K removal by grain and straw were the maximum for wheat variety ′HUW‑234′ which was significantly higher than both ′HUW‑510′ and ′HUW‑468′. Between the systems of sowing, SWI was significantly higher NPK removal than standard practices.

Relative economics: The treatment combination November, 25 + HUW‑234 + SWI provided highest net return and B: C (₹90674 ha^{-1} and 2.76) due to highest biological production (grain and straw yield) than all the other treatment combinations (Table 3). Dhar *et al.* (2016) reported that the average cost of cultivation of SWI (averaged for the 2 years) was US$ 687 ha^{-1} as against US$ 467 ha^{-1} for standard recommended practices and the higher relative cost for SWI was more than compensated for by the significantly higher grain production, giving a net return which averaged US$ 1382/ ha for the 2 years compared with US$ 1020 ha^{-1} for standard recommended practices, thus 35% more.

Correlation: The correlation study in connection among grain yield and weather parameters during different

Table 3. Effect of sowing dates and system of sowing on cost of cultivation, yield, gross income, net return and benefit: cost (B:C) ratio of wheat varieties

Treatment combination	Cost of cultivation (x1000₹ ha^{-1})	Yield (t/ ha)		Gross income (x1000₹ ha^{-1})	Net return (x1000 ₹ ha^{-1})	B : C ratio
		Grain	Straw			
November, 25 + HUW‑234 + Standard practice	31.8	4.08	6.05	117.9	86.0	2.70
November, 25 + HUW‑234 + SWI	32.8	4.29	6.29	123.5	90.7	2.76
November, 25 + HUW‑510 + Standard practice	31.4	3.51	5.99	106.2	74.8	2.37
November, 25 + HUW‑510 + SWI	32.7	3.89	6.20	115.1	82.4	2.51
November, 25 + HUW‑468 + Standard practice	32.1	3.47	5.86	104.7	72.5	2.25
November, 25 + HUW‑468 + SWI	32.8	3.74	6.11	111.4	78.6	2.39
December, 02 + HUW‑234 + Standard practice	31.8	3.52	5.89	105.6	73.8	2.31
December, 02 + HUW‑234 + SWI	32.8	3.80	6.13	112.7	79.9	2.43
December, 02 + HUW‑510 + Standard practice	31.4	3.33	5.75	101.1	69.7	2.21
December, 02 + HUW‑510 + SWI	32.7	3.66	5.92	108.7	76.0	2.32
December, 02 + HUW‑468 + Standard practice	32.1	3.15	5.68	97.0	64.9	2.02
December, 02 + HUW‑468 + SWI	32.8	3.51	5.82	105.1	72.3	2.20
December, 09 + HUW‑234 + Standard practice	31.0	2.82	5.17	87.3	56.3	1.81
December, 09 + HUW‑234 + SWI	32.0	3.16	5.30	94.9	62.9	1.96
December, 09 + HUW‑510 + Standard practice	30.6	2.73	5.08	85.0	54.4	1.77
December, 09 + HUW‑510 + SWI	31.9	2.99	5.36	92.0	60.1	1.88
December, 09 + HUW‑468 + Standard practice	31.3	2.61	4.67	80.2	48.9	1.56
December, 09 + HUW‑468 + SWI	32.0	2.77	5.08	85.8	53.8	1.67

Market price of Grain, 20₹ / kg and Straw, 6₹/ kg

Table 4: Correlation coefficient for effect of weather parameters during different phenophases on grain yield of wheat

Phenophases	Rainfall	Max. Temperature	Min. Temperature	Max. Relative humidity	Min. Relative humidity	Sunshine hours	Pan evaporation
PS1	0.75**	0.93**	0.90**	-0.85**	-0.79**	0.94**	0.93**
PS2	-0.82**	0.84**	0.81**	-0.54	-0.85*	0.67	0.65**
PS3	0.80**	-0.70**	-0.79**	-0.92**	-0.86**	-0.70**	0.86**

*P=0.05; **P=0.01; PS1, Emergence to flowering; PS2, flowering to dough stage; PS3, dough stage to maturity

phenophases, *viz*. emergence to flowering (PS1), flowering to dough stage (PS2) and dough stage to maturity (PS3) revealed that grain yield had a significantly positive correlation with all the maximum and minimum temperature but was negatively correlated during PS3 stage (Table 4). The negative correlation during PS3 stage clearly shows that high temperature during this stage significantly inhibited the import of photosynthates and thereby decreased the sink potency.

Thus based on the experimental findings it was found that sowing of wheat cv. 'HUW-234' on November, 25 under system of wheat intensification at 20 cm x 20 cm spacing exhibited the most remunerative for achieving higher monetary return in eastern Uttar Pradesh.

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Organic Farming Practices: A Way for Sustainable Agriculture

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***Abstract*:** During last two decades, it was observed that a positive growth in the organic farming which helps to sustainable agriculture by using environmental friendly farming techniques. In this study, analysis the farmers′ attitude and various organic farming practices used in Tamilnadu was done. Totally 240 organic farmers were surveyed from four districts: Coimbatore, Erode, Salem and Dharmapuri. Attitude scale was developed and used for this study with five point Likert scale. The different farms and levels of adoption of organic farming techniques were conferred. The farm ecological practices, educational qualification and organic farming experience were significantly correlated with organic input production. The majority of respondent have positive attitude with the perception of organic farming system helps to maintain sustainable agriculture, environmental friendly methods.

Keywords: Organic farming, Sustainable agriculture, Farmers′ attitude

In recent decades, worldwide farmers and researchers have reacted to the sustainable agricultural models which encompass “farming by way of nature” with different ecology−based approaches, variously called natural, organic, low−input, alternative, regenerative, holistic, biodynamic, bio intensive and biological farming systems. All these farming concepts are having a vision of “farming by way of nature,” which has contributed to understand of an agro ecology that promotes biodiversity, recycles plant nutrients, protects soil from erosion, conserves and protects water, uses minimum tillage and integrates crop and livestock enterprises on the farm (Menalled *et al., 2008* & Ganeshan *et al., 2013*). The last two decades has witnessed a worldwide growth in the organic farming. Meanwhile, a growing movement has emerged to develop the sustainable farming practices. The concept of sustainable agriculture is still evolving and growing popularity as it encompasses both changing attitudes towards farming and developing environmental awareness (Menalled *et al., 2008*). The organic farming is one of the primitive farming practices, in which all the farming inputs were supplied from within the farm and allied farm activities. The natural food chains of organic farming facilitate a healthy eco system in the farm (Laepple, 2008).

The positive attitude of farmers as well as consumers towards organic farming and organic products encompass the substance of safe food as well as safe eco system (Nayakarathna *et al.,* 2013). During the green revolution period, the chemical base farming introduced to enhance the productivity to feed the population. Over the period, it has been realized that organic farming is one of the means to maintain the sustainable growth in agriculture. Hence, the farmers again shifted to the organic farming practices with integrated farm inputs systems to reduce the cost of production. In this study, the farmers′ attitude and various organic farming practices with healthy farm eco system used in Tamilnadu is analyzed.

MATERIAL AND METHODS

The study was conducted in four districts of Tamilndu: Coimbatore, Erode, Salem and Dharmapuri. In each district 60 respondents were selected from the registered farmers′ list of Tamilnadu Organic Certification Department (TNOCD). Totally 240 farmers were surveyed with the help of well structured interview schedule (2015−2016). In addition, the secondary data were collected from different published sources like research articles and department publications. Attitude scale was developed and used for this study with five point likert scale. The SPSS 20 package was used for this study to analyze the variables.

RESULT AND DISCUSSION

Demographic profile of organic farmers: The profile of organic farmers regarding education, land holding, experience in organic farming, source of information etc are documented in Table1.

Adoption of organic farming techniques : Among the various agronomic crop production practices 85.4 per cent were adopted tillage techniques with sticks, summer tillage and followed by seventy per cent of farmers adopted the mulching practices with live plants and plant wastes in the land preparation techniques. Especially, the application of organic mulches as a soil cover is effective in improving the quality of soil with high biomass and decrease the weed density (Sinkevičienė *et al.*, 2009). Some researchers

Table 1. General characteristics of organic farmers N=240

Variables	Frequency	Percentage
Gender		
Male	162	67.5
Female	78	32.5
Age (years)		
21-30	23	9.6
31-40	69	28.8
41-50	81	33.8
51-60	36	15.0
61 and above	31	12.9
Educational qualification		
Illetrate	0	0.0
Primary education	29	12.1
Secondary education	67	27.9
Graduation	59	24.6
Post Gratuation	37	15.4
Diploma and others	48	20.0
Farm Size (hectares)		
Large (more than 5)	53	22.08
Medium (2 to 5)	102	42.50
small/marginal(less than 2)	85	35.42
Membership of society/ cooperative		
Yes	193	80.4
No	47	19.6
Organic Farming experience (years)		
1 to 5	73	30.4
6 to 10	61	25.4
more then 10	106	44.2
Extension visit/ trainings		
Yes	188	78.3
No	52	21.7
Source of Information (multiple response)		
Friends/Neighbours/Relatives	214	89.2
Extension Agents/ officials	46	19.2
Radio	24	10.0
Television	21	8.8
Newspaper	68	28.3
Mobile-and mobile apps	112	46.7
others	13	5.4
Organic Inputs production		
Produce Own	181	75.4
Sourced outside	59	24.6

pointed out that increase in grain yield by mulching is attributed primarily to improve soil moisture regime and to decrease in soil temperature (Lal, 1974). In addition, though the drip/sprinkler irrigations are new technology, 72.5 per cent were adopted in their farm to use water efficiently. The another slash and burn technique was adopted by 61.3 for decompose the sugar cane trashes and *Parthenium hysterophorus* weed control etc. Meanwhile, due to environmental concern, 28.3 per cent of respondents were aware but not used and 5.8 per cent were discontinued the practice (Table 2).

Under the cropping pattern, crop rotation was adopted by around 89 per cent of farmers. It was evident that crop rotation to maximize the efficient use of the Nitrogen with soil quality as well as helps to control pest and diseases incidents (Alexander *et al*., 2009). Almost 83 per cent were grown tree/hedges plants in the farm for the purpose to reduce the wind intensity and to manage input needs. Also some reviews supported that the hedge plantations helps to insect hunters in the means of natural pest control (Nyakundi and Kamau, 2014). In addition, Mixed cropping pattern was followed by 49.6 per cent of respondents. Mean while, inter cropping pattern was followed by only 38.3 per cent of respondents. Because, inter cropping was more suitable for crops like plantation and vegetable crops than the crops like millets, pulses and cereals. Farm waste compost was one of the main manure used among the respondents (91.3 per cent) followed by application of organic manures (76.7 per cent) like panchakavya, jeevamirtham, horn manure etc. Subsequently, 51.3 per cent of respondent were applying green manures like sunhemp, dhaincha, nodulating leguminous crops etc.

Majority of farmers (94.2 %) adopted manual hoeing/weeding techniques for weed management. Similarly, 75 per cent of farmers used organic input for pest and disease control. Twenty seven per cent were practiced hand picking of insects as one of the pest control measure while, 26.3 per cent of respondents were not aware about the same. The handpicking is best for large, slow-moving pests, such as caterpillars, colorado potato beetles, and slugs etc (Ellis *et al*., 1996). Though light/pheromone traps was one of the new technique, 14 per cent were adopted and 32.9 per cent were evaluated the traps for adoption. Only 1.4 per cent of respondents discontinued the use of pheromone traps, due to high cost.Around 75.4 per cent used sun drying of farm produce. Natural way of storage techniques like farm storage structure for onion and other root crops etc., were used by 62.9 per cent. Approximately 14.6 per cent of farmers were not aware about the storage techniques. From the findings, it is obviously explained that farmers adopted seventeen out of eighteen listed organic farming practices with majority of respondents. This indicates that level of adoption of organic farming practices is little high; this could be as a result of the easy adoption of organic practices which are more related to the traditional practices. (Adesope *et al.,* 2012).

In addition, the information based on multiple choice

Table 2. Adoption of Organic Farming Techniques

S. No	Organic Farming Techniques	NA	AW	I	E	T	A	DC
I. Crop production techniques								
a. Land preparation and irrigation								
1.	Mulching practices	0(0)	5(2.1)	4(1.7)	29(12.1)	34(14.2)	168(70.0)	0(0)
2.	Tillage techniques−with sticks, summer tillage	6(2.5)	17(7.1)	9(3.8)	0(0)	3(1.3)	205(85.4)	0(0)
3.	Slash and burn	0(0)	68(28.3)	5(2.1)	4(1.7)	2(0.8)	147(61.3)	14(5.8)
4.	Drip/sprinkler irrigations	0(0)	8(3.3)	11(4.6)	25(10.4)	20(8.3)	174(72.5)	2(0.8)
b. Cropping pattern								
5.	Crop rotation	0(0)	3(1.3)	1(0.4)	9(3.8)	13(5.4)	214(89.2)	0(0)
6.	Inter cropping	0(0)	16(6.7)	2(0.8)	43(17.9)	87(36.3)	92(38.3)	0(0)
7.	Mixed cropping	2(0.8)	24(10.0)	18(7.5)	31(12.9)	46(19.2)	119(49.6)	0(0)
8.	Tree/hedges planting	0(0)	0(0)	9(3.8)	2(0.8)	30(12.5)	199(82.9)	0(0)
c. Manuring techniques								
9.	Organic manures	0(0)	4(1.7)	5(2.1)	3(1.3)	44(18.3)	184(76.7)	0(0)
10.	Green manure	0(0)	9(3.8)	29(12.1)	37(15.4)	42(17.5)	123(51.3)	0(0)
11.	Farm waste Compost	0(0)	0(0)	6(2.5)	1(0.4)	14(5.8)	219(91.3)	0(0)
12.	Vermi compost	0(0)	13(5.4)	63(26.3)	15(6.3)	55(22.9)	86(35.8)	8(3.3)
II. Crop protection techniques								
13.	Hand picking of insects	36(26.3)	57(23.8)	3(1.3)	28(11.7)	24(10.0)	65(27.1)	0(0)
14.	Mannual Hoeing/weeding	0(0)	12(5.0)	0(0)	0(0)	2(0.8)	226(94.2)	0(0)
15.	Organic input for pest and disease control	0(0)	2(0.8)	18(7.5)	16(6.7)	24(10.0)	180(75.0)	0(0)
16.	Light/pheromone traps	26(10.8)	16(6.7)	46(19.2)	79(32.9)	34(14.2)	35(14.6)	4(1.7)
III. Post harvest techniques								
17.	Natural way of storage techniques	35(14.6)	5(2.1)	8(3.3)	18(7.5)	23(9.6)	151(62.9)	0(0)
18.	Sun drying of farm produce	0(0)	59(24.6)	0(0)	0(0)	0(0)	181(75.4)	0(0)

Note: NA−Not Aware; AW−Awareness; I−interest; E−Evaluation; T−Trial; A−adoption; DC−discontinuance
Figures in parenthesis are in percentages

about the crops adopted by respondent indicate that 89.6 per cent respondent had vegetable crops, followed by 81.7,53.8, 32.7 ,30.8 and 21.3 per cent adopted the spices and plantation/ tree crops, fruits, pulses and cereals. At the same time only 5.4 per cent had flower crops. This variation was happened due to lower preference of organic flower crops than other crops in market.

Adoption of Ecological practices of farm: In the organic farm eco system, 98.3 per cent of farmers depend on cow for farming practices. Most of the farmers (85.0 per cent) were rearing birds like hen, turkey, duck and pegion etc. This farmland birds helps to control the pest population and help out to make organic manure (Garfinkel and Johnson, 2015). In addition, with their main crops to meet input demand, farmers cultivate herbs and trees with 85 and 80.4 per cent respectively (Figure 1). Particularly, tree species like neem tree (*Azadirachta indica*), pongam tree (*Pongamia pinnata)* etc., and herbs like erruku (*Calotropis gigantean* ,chilli (*Capsicum annuum*), ginger (*Zingiber officinale*) , garlic (*Allium sativum*) , turmeric (*Curcuma longa*) etc., were used in organic pest and disease control inputs (Caldwell *et al.,* 2013).

Relationship between organic input production and demographic and farm ecological practices: The variables like educational qualification, organic farming experience and farm eco system were positively correlated with organic input production include produced by their own and sourced from outside. This implies that there exist a parallel relationship between farmers experience and adoption which means that those with high farming experience have higher adoption level of own input production. Farm size and extension visit/ trainings were significantly correlated with 0.05 level, which reveals that while farm size and training experience increase, they adopted their own input production (Table 3).

Attitude of farmers towards organic farming: Majority of respondents (80.8 per cent) strongly agreed and 16.3 per cent agreed with positive attitude that organic farming system helps to maintain sustainable agriculture and cultivation practices of organic farming encompass environmental friendly methods. Similarly, nearly 74.6 per cent and 23.8 per cent of respondents strongly agreed and agreed respectively that organic farming helps to increase farm eco system.

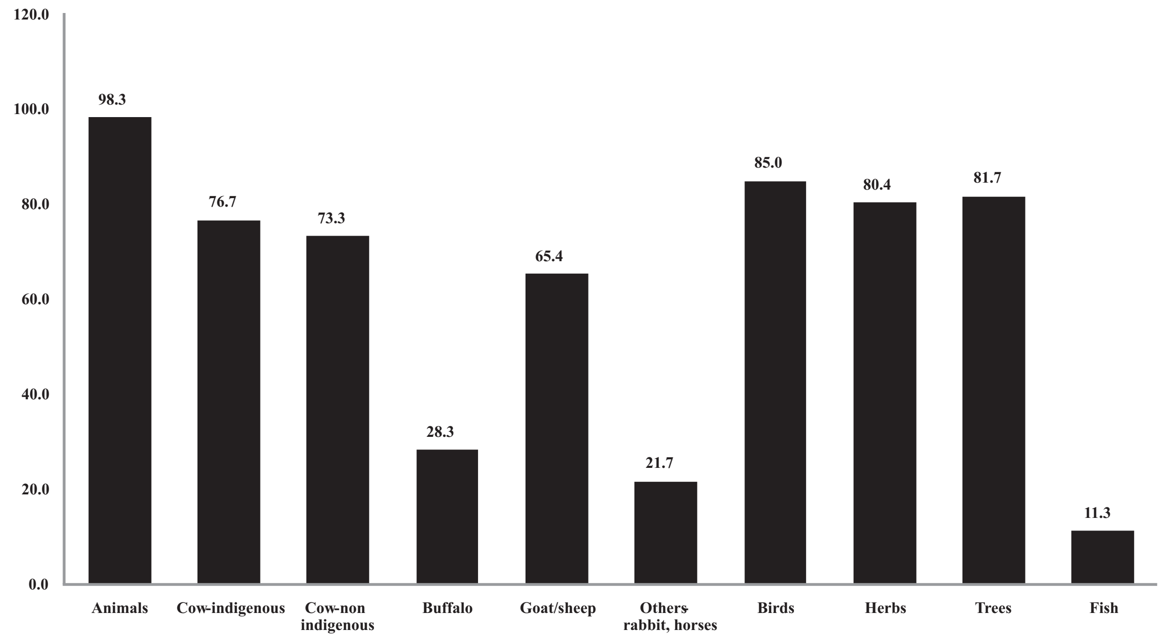

Fig. 1. The Organic Farm Eco System

Totally 76.4 per cent of respondents agreed that organic farming practices reduce the input cost; when 18.8 per cent fall on neutral with five per cent of disagree. Moreover, 51.7 per cent of respondents disagreed and 7.1 per cent strongly disagreed that organic farming practices helps to get more yield. Though organic farming produces safer food, there was less productivity than conventional. At the same time, 4.6 per cent agreed for high yield of organic farming practices (Table 4). While considering overall perception, majority of the farmers had positive attitude towards organic farming.

Table 3. Correlation coefficient of organic input production with demographic and farm ecological practices

Variables	R values
Gender	0.026
Age (years)	-0.175
Educational qualification	0.278**
Farm Size (hectares)	0.232*
Organic Farming experience (years)	0.308**
Extension visit/ trainings	0.221*
Membership of society/ cooperative	0.058
Farm eco practices	0.295**

* and ** = significant at the p<0.05 and 0.01 level ; N=240

CONCLUSION

All examined seventeen out of eighteen listed organic farming practices which encompass land preparation and irrigation, cropping pattern, manuring techniques, crop protection techniques and post harvest techniques were adopted by majority of respondents except light/pheromone traps. Less knowledge and awareness about light or pheromone traps among the farmers is the reason of non usage of the technique. Same way, it was insisted that there is a requirement to increase knowledge and awareness of some respondents on the techniques namely hand picking of insects, sun drying of farm produce, natural way of storage

Table 4. Attitude of farmers towards organic farming

Farmers' attitude (N=240)	SA	A	N	D	SD
Increase the soil health and wealth	158 (65.8)	82(34.2)	0	0	0
Reduce the input cost	16(6.7)	167(69.6)	45(18.8)	12 (5)	0
Increase the farm eco system	179(74.6)	57(23.8)	4(1.7)	0	0
Maintain sustainable agriculture	194(80.8)	39(16.3)	7(2.9)	0	0
All cultivation practices of organic farming encompass environmental friendly methods	119(49.6)	117(48.8)	4(1.7)	0	0
More yield than conventional practices	2(0.8)	9(3.8)	88(36.7)	124(51.7)	17(7.1)
Hhigh social values	53(22.1)	139(57.9)	22(9.2)	26(10.8)	0

Note: SA-Strongly Agree; A-Agree; N-Neutral; D-Disagree; SD-Strongly Disagree; Figures in parenthesis are in percentages techniques, mixed cropping and summer tillage techniques. It was found that most of the respondents perceived that organic farming practices increased the farm eco system. Further the farm eco system with animals, birds, trees herbs were highly correlated with own organic input production practice. Hence the production cost will be reduced through own input materials. In addition, the farmers have positive attitude and it was found that organic farming practices helps to maintain sustainable agriculture, have environmental friendly methods, increase farm eco system and the soil health and wealth (Rigby and Caceres, 2001). Consequently, it was concluded that organic farming practices is one of the efficient way to adopt sustainable agricultural practices.

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Analysis of Radiation Use Efficiency, Yield Attributes and Quality Parameters of *Basmati* Rice (*Oryza sativa* L.)

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Abstract: Field experiment was conducted to study the comparative performance of various *basmati* rice cultivars with respect to radiation use efficiency, yield attributes and quality parameters under different dates of transplanting. Treatments included three dates of transplanting *viz.* 25th June, 10th July and 25th July respectively in main plots and four cultivars namely CSR 30, PB 1121, PB 1509 and HB 2 in the subplots, resulting in 12 treatment combinations. Among different dates of transplanting, plant height and dry matter accumulation were significantly higher at all growth stages when crop was transplanted on 25th June as compared to the two subsequent dates. Better results in terms of yield attributes such as number of effective tillers, panicle length and panicle weight, number of grains per panicle, less number of unfilled spiklets per panicle, 1000 grain weight, harvest index, grain and straw yield were observed in the early transplanted crop. Also higher values for quality parameters like grain length and breadth, L/B ratio and head rice recovery were observed in the early transplanted crop. Maximum Radiation and Heat utilization efficiency were also observed in early transplanted crop.

Keywords: *Basmati* rice, Yield attribute, Quality parameters, Radiation use efficiency, Transplanting dates

Rice (*Oryza sativa* L.) is among one of the most important cereal crops grown under different hydrological conditions in Asia. About 90% production and consumption of world′s rice occurs in Asia (FAOSTAT, 2014). India holds second position in production of rice in the world with production of 105.48 million tonnes from 43.90 million hectares, with a productivity of 2390 kg/ha during 2015 (Economic survey, 2015–16).Time of planting is one of the most important factor in influencing the yield of the crop, delay in transplanting generally results in yield reduction which cannot be compensated by any other means. Singh *et al.* (2004) reported that delay in transplanting significantly reduced yield and yield attributes. Sowing date showed significant interaction with accessions for all traits. It means that their growth and yield performance varied among different sowing dates. Thus, by adjustment of transplanting time, the plant can take advantage of natural conditions favourable for its growth (BRRI, 2004). Therefore it is crucial to optimize the transplanting date and the information for transplanting *Basmati* rice at optimum time and potential genotypes for growing under eastern agroclimatic conditions of Haryana is still lacking. Based on the above propositions, the present study was undertaken to find out the optimum transplanting time and to select the *basmati* cultivar having high yield potential to increase production in *kharif* season.

MATERIAL AND METHODS

Site of the experiment: The field experiment was conducted at the research farm of Chaudhary Charan Singh Haryana Agricultural University, Rice Research Station, Kaul (Kaithal), Haryana, India. It is situated at 29° 51′N latitude and 76° 39′ E longitude with an elevation of 230.7 meters above the mean sea level.

Design and treatments: The experiment was laid out in a split plot design with four replications. The experiment consisted of 12 treatment combinations comprising of three different dates of transplanting (25th June, 10th July and 25th July) which were placed in main plots and four varieties (CSR 30, PB 1121, PB 1509 and HB 2) which were placed in sub–plots each of size 4.0 m x 3.6 m.

Crop husbandry: After harvest of wheat crop, field was given two ploughing with disc harrow each followed by planking in May and one day before transplanting of rice in June 2015, fields were flooded with water and puddled by passage of three harrowing followed by planking. Thirty days old seedlings were transplanted manually (one seedling per hill) on June 25th, July 10th and July 25th under puddle transplant rice plots at row spacing of 20 cm and plant spacing of 15 cm. Full dose of phosphorous (30 kg/ha) and $ZnSO_4$ (25 kg ha^{-1}) was applied at the time of preparatory tillage by broadcasting under transplanted plots. Nitrogen (60 kg/ha) was applied in three split doses i.e. 1/3rd at transplanting, 1/3rd at 21 days after transplanting (DAT) and remaining 1/3rd at 42 DAT in transplanted plots. Field was irrigated frequently so as to maintain the 5±2 cm level of standing water till 15 days after transplanting. Thereafter irrigation was given as and when required to maintain the saturated conditions of soil, with follow up irrigations at weekly interval keeping the rainfall in consideration. Irrigation was stopped one week before harvesting of crop. Pre−emergence herbicide pretilachlor 1.0 kg ha^{-1} was applied as broadcast in standing water at 3 DAT for control of weeds in transplanted basmati rice plots. Manual weeding was also done at 40 DAS/ DAT to avoid any infestation of weeds in the crop. The crop was harvested at full physiological maturity. All area of 0.5 m on each side of plot and one border row on both side of experimental plots were harvested first, thereafter the net area separately. The grain weight was recorded at 14 per cent moisture after threshing, cleaning and drying. The grain, straw and biological yield weights were expressed in kg ha^{-1}.

Yield attributes and quality parameters: The effective tillers were counted on four tagged plants and then converted into per square meter. Panicle length (in centimeter) was measured from ten randomly selected tillers of tagged plants from each plot at harvest and averaged to get length and weight of panicle. The numbers of grains and sterile (unfilled) spikelets from ten panicles selected at random from each plot were counted. One thousand filled grains from the produce of the net plots were counted and their weight was recorded. Produce of net plots was sun dried and threshed grains thus obtained were winnowed, cleaned and weighed. The grain yield recorded in kg per plot was standardized to 14% moisture. Dry weight of straw collected from net plots was recorded after sun drying for seven days. Ten milled rice grains were kept lengthwise and breadthwise on a graph paper and the average measurement was recorded as grain length and breadth respectively (in millimeters). The harvest index and L/B ratio was calculated as follows.

Harvest index = Economic yield (q ha^{-1}) / Biological yield (q ha^{-1}) ×100

L/B ratio = average length of kernel/average breadth of kernel.

For head rice recovery a sample of 100 g rough rice was taken from each plot and dried to 12–14 % moisture level. First Dehulling then milling was done using Satake rice huller (Japan).Broken and unbroken kernels were separated manually using sieves of size 2.36 mm, 2 mm, 1.7 mm, and 1.4 mm. Then kernels which were ¾ to complete in size were weighed to obtain head rice and expressed in percentage.

Agrometeorological indices

Radiation use efficiency (RUE) = Biomass yield / Radiation intercepted

Heat use efficiency (HUE) = Biomass yield / heat units utilized

RESULTS AND DISCUSSIONS

Number of effective tillers (m^{-2}): The 25th June transplanted crop had highest number of effective tillers per m^{-2} as compared to 10th July and 25th July transplanted crops during the growing season (Table 1). Similar results were obtained by Om *et al.* (1997) and Gill *et al.* (2006) who reported that maximum productive tillers were obtained when transplanting was done on 10th June. Kabir *et al.* (2014) also found that the number of effective tillers got decreased due to delay in transplanting. For late transplanting, low temperature at the pollen development stage may cause a sharp decline in fertile or filled spikelets particularly in the photosensitive cultivars. The variety PB 1509 produced highest number of effective tillers per plant at harvesting as compared to variety HB 2, CSR 30 and PB 1121 during the growing season.

Table 1. Effect of transplanting time on yield attributes of *Basmati* rice varieties

Treatments	Effective tillers (m^{-2})	Panicle length (cm)	Panicle weight (g)	Number of grains, panicle^{-1}	Unfilled spikelets, panicle^{-1}
Transplanting dates					
25th June	263.2	24.8	1.50	53.3	8.1
10th July	252.1	23.6	1.47	49.2	8.1
25th July	236.0	23.6	1.22	46.4	9.2
CD (p=0.05)	14.1	N.S.	0.07	1.2	N.S.
Varieties					
CSR 30	247.5	23.4	1.40	51.3	8.6
PB 1121	245.4	25.0	1.45	51.3	8.1
PB 1509	258.4	22.1	1.26	43.4	9.2
HB 2	250.4	25.6	1.47	52.6	8.0
CD (p=0.05)	8.9	1.2	0.05	2.5	N.S.

Panicle length (cm): Although there was no significant difference in panicle length among the different dates of transplanting but the 25th June transplanted crop had longest panicle as compared to the crop transplanted on 10th July and 25th July. Nahar *et al.* (2009) found that later transplanted plants suffered from lower temperature during panicle emergence stage which might resulted the reduced emergence i.e. shorter panicle. Among the varieties, the panicle length differs significantly. HB 2 produced largest panicle followed by variety PB 1121, CSR 30 and PB 1509 during crop season (Table 1).

Panicle weight: Significant differences in panicle weight were observed among the varieties under different dates of transplanting. The 25th June transplanted crop had highest panicle weight as compared to 10th July and 25th July during the crop season. Results were similar with Vishwakarma *et al.* (2016). Among the varieties, the panicle weight of HB 2 was highest followed by variety PB 1121, CSR 30 and PB 1509 during crop season (Table 1).

Number of grains/panicle: Significant differences in number of grains per panicle were observed among the varieties under different dates of transplanting. The 25th June transplanted crop had highest number of grains per panicle as compared to 10th July and 25th July during the crop season. The results were in conformity with Dawadi and Chaudhary (2013).Among the varieties, the number of grains per panicle were highest in HB 2 (52.6) followed by variety PB 1121, CSR 30 and PB 1509 during crop season (Table 1).

Number of unfilled spikelets panicle^{-1}: No significant difference was observed in number of unfilled spikelets per panicle among different transplanting time, however highest number of unfilled spikelets per panicle were recorded in the crop transplanted on 25th July .This is because late sowing of rice reduced maturity period, plant height, straw yield, panicle/m^2, filled grains/panicle, but per cent unfilled grains increased. The number of unfilled spikelets per panicle were highest in PB 1509 followed by variety CSR 30, PB 1121 and HB 2 during crop season (Table 1).

Grain yield: The grain yield of rice during the cropping seasons registered significant variation among different dates of transplanting. Highest grain yield was recorded by crop transplanted on 25th June followed by 10th July and 25th July. The delay in transplanting of rice, there was significant decrease in grain yield of rice. Among the varieties, the grain yield of variety HB 2 was maximum followed by PB 1121, CSR 30 and PB 1509. Oteng *et al.* (2013) reported that planting date can have a dramatic effect on crop development and yield. These findings were also supported by Soomro *et al.* (2001) and Sharma *et al.* (2011) who observed significant reduction in yield and yield contributing characteristics with delay in transplanting.

Straw yield: Among different dates of transplanting, the highest straw yield was recorded in the crop transplanted on 25th June which was at par with the crop transplanted on 10th July and was significantly higher as compared to the crop transplanted on 25th July. The straw yield was higher in the crop transplanted on 25th June because of higher number of tillers m^{-2}, longer plant height, higher dry matter accumulation and larger LAI which resulted in higher total biomass production of crop. It confirms the findings of Prasad *et al*. (2001). Among the varieties, the straw yield of CSR 30 was maximum followed by PB 1121, HB 2 and PB 1509.

Harvest index (%): Among different dates of transplanting, the highest harvest index was in the crop transplanted on 25th June followed by the crop transplanted on10th July and 25th July . Abid *et al* (2015) found that plants transplanted on 25th June attained maximum photoperiod, escaped low temperature injury and cold climate at heading, resulting in better translocation of photosynthates to grains, thus providing higher paddy yield of basmati rice. Limited radiation and shading effect, especially at heading stage, might have affected the yield of late transplanted rice. The improved harvest index might be due to the a higher dry matter (source) partitioning towards economic yield *i.e.* grain (sink), healthier and vigorous plant growth, improved plant height, increased crop growth rate and net assimilation rate which ultimately ended in the increased harvest index in the crop transplanted on 25th June. Among the varieties, the harvest index of variety HB 2 was maximum followed by PB 1509, PB 1121 and lowest harvest index was recorded in CSR 30.

1000-grain weight: No significant difference was observed in 1000-grain weight among different transplanting time, however highest 1000-grain weight was recorded in the crop transplanted on 25th June followed by crop transplanted on 10th July and 25th July. There was significant difference in 1000-grain weight among the varieties at harvest under different dates of transplanting. The 1000-grain weight was highest in HB 2 which was statistically at par with PB 1121 followed by variety, PB 1509 and CSR 30. Varieties HB 2, PB 1121 and PB 1509 were statistically at par (Table 2). Similar results were reported by Iqbal *et al.* (2008).

Quality parameters: No significant difference was observed in grain length and grain breadth among different transplanting time The grain length and breadth was maximum in variety HB 2 which was statistically at par with the grain length of PB 1121 and PB 1509, whereas, the shortest grain was observed in CSR 30. The various treatments did not show any significant difference in L/B ratio and head rice recovery, but maximum was observed in the crop transplanted on 25th June followed by crop transplanted

Table 2. Effect of transplanting time on yield attributes of *Basmati* rice varieties

Treatments	Grain yield kg ha^{-1}	Straw yield kg ha^{-1}	Harvest index (%)	1000 grain weight (g)
Transplanting dates				
25th June	3791	7469	37.02	28.3
10th July	3760	7127	35.18	27.9
25th July	3357	6585	33.62	27.3
CD (p=0.05)	161	512	1.37	N.S.
Varieties				
CSR 30	3464	8790	28.92	25.9
PB 1121	3740	6844	36.41	28.9
PB 1509	3439	5791	37.34	27.6
HB 2	3902	6816	38.42	28.9
CD (p=0.05)	152	511	1.83	1.2

Table 3. Effect of transplanting time on quality parameters of *Basmati* rice varieties

Treatments	Grain length (mm)	Grain breadth (mm)	L/B ratio	Head rice recovery (%)
Transplanting dates				
25th June	8.32	1.88	4.45	58.5
10th July	8.18	1.86	4.39	56.2
25th July	8.10	1.84	4.39	55.5
CD (p=0.05)	N.S.	N.S.	N.S.	N.S.
Varieties				
CSR 30	7.57	1.75	4.33	55.0
PB 1121	8.41	1.90	4.43	57.3
PB 1509	8.38	1.88	4.43	56.1
HB 2	8.43	1.92	4.45	58.5
CD (p=0.05)	0.26	0.06	N.S.	N.S.

Table 4. Effect of transplanting time on radiation use efficiency (RUE) of *Basmati* rice varieties at various growth intervals (g MJ^{-1})

Treatments	DAT				
	30	50	70	90	At Harvest
Transplanting dates					
25th June	0.27	0.75	2.08	2.02	1.5
10th July	0.25	0.72	1.85	1.99	1.43
25th July	0.25	0.5	1.67	1.96	1.17
Varieties					
CSR 30	0.28	0.82	2.04	2.34	1.66
PB 1121	0.24	0.57	1.57	1.84	1.68
PB 1509	0.26	0.67	2.25	1.89	0.39
HB 2	0.25	0.57	1.61	1.89	1.74
Mean	0.26	0.66	1.87	1.99	1.37

Table 5. Heat use efficiency (HUE) of *Basmati* rice varieties at various growth intervals under different transplanting time (g ha^{-1} °C^{-1} day^{-1})

Treatments	DAT				
	30	50	70	90	At Harvest
Transplanting dates					
25th June	0.10	0.28	0.86	0.89	0.69
10th July	0.10	0.27	0.78	0.86	0.68
25th July	0.10	0.25	0.78	0.83	0.62
Varieties					
CSR 30	0.11	0.33	0.88	1.00	0.73
PB 1121	0.09	0.23	0.69	0.81	0.76
PB 1509	0.10	0.27	0.97	0.81	0.33
HB 2	0.10	0.24	0.69	0.82	0.83
Mean	0.10	0.27	0.81	0.86	0.66

on 10th July and 25th July. Among the varieties the L/B and head rice recovery was maximum in HB 2 followed by PB 1121 and PB 1509 and the lowest was recorded in variety CSR 30.

Radiation use efficiency (RUE): Amongst the dates of transplanting 25th June transplanted crop exhibited maximum RUE of 2.08 gMJ^{-1} followed by 10th July and 25th July transplanted crop during the growth period (Table 4). RUE decreased with delay in transplanting. Higher RUE were recorded in variety CSR 30 (2.34 gMJ^{-1}) followed by variety PB 1509.

Heat use efficiency (HUE): Among the dates of transplanting, 25th June transplanted exhibited maximum HUE of 0.89 g ha^{-1} °C^{-1} day^{-1} followed by 10th July and 25th July transplanted crop. HUE decreased with delay in transplanting. Higher HUE was recorded in variety CSR 30 followed by variety PB 1509, HB 2 and PB 1121 during crop season. Similar results were obtained by Kaur and Dhaliwal (2014) who recorded maximum heat use efficiency in rice crop transplanted on 15th June as compared to 30th June and 15th July transplanting.

CONCLUSION

Yield attributes *viz.* maximum number of effective tillers, more panicle length and panicle weight, more number of grains per panicle, less number of unfilled spiklets per panicle, higher 1000 grain weight, higher grain and straw yield, more harvest index were significantly higher at all growth stages when the crop was transplanted on 25th June as compared to the crop transplanted on 10th July and 25th July. Also crop transplanted on 25th June gave better results in terms quality parameters such as more grain length and breadth, L/B ratio and head rice recovery. Also Maximum value of RUE and HUE were also observed in 25th June transplanted crop. On the basis of the results of 1 season study it can be said that crop transplanted on 25th June was best for *basmati* rice under eastern agroclimatic conditions of Haryana, however, there is need to conduct the long term study under different agro climatic conditions.

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Establishment of *in vitro* Micropropagation Protocol for Rose (*Rosa x hybrida*) cv. Raktagandha

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Abstract: An experiment was conducted to develop an efficient protocol for *in vitro* multiplication of hybrid tea rose cv. Raktagandha using axillary bud segments as explants. The highest explant survival (78.05 %) was obtained with carbendazim (0.2%) + diathane M-45 (0.2%) + 8-HQC (200 mg/l) for 3h on a horizontal shaker (120 rpm). Sucrose concentration of 30 g/l in the medium is optimal for *in vitro* shoot multiplication. Murashige and Skoog medium supplemented with 3.5 mg /l BAP + 0.1 mg/l NAA + 0.5 mg/l GA_3 was most effective for culture establishment and shoot proliferation with highest number of micro-shoots. Rooting of micro-shoots was induced on half-strength MS basal medium supplemented with NAA (0.5 mg/l) + IBA (0.5 mg/l). The regenerated plantlets hardened in glass jars filled with vermiculite + agropeat (1:2) moistened with half-strength MS medium salts and covered with polypropylene lids were successfully transferred to the glasshouse with good survival.

Keywords: Rose, Raktagandha, Micropropagation, *in vitro* regeneration

As population pressures increase and climate change produces additional production constraints, the challenge is to use plant tissue culture to develop sustainable and durable horticultural production systems from an environmental and human health perspective. Rose "Queen of Flowers" is an important horticultural and most popular ornamental plant in the World (Ozel *et al.,* 2006). Traditionally, hybrid-tea roses (*Rosa hybrid* L.) is considered to be one of the most prized flowers of the world because of their high ornamental value. As cut flower, it occupies top position in acreage, production and consumption. Roses are generally multiplied vegetatively by grafting and budding that are very slow and time consuming methods. Moreover, diseases and environmental hazards make the cultivar degenerate gradually. Micropropagation procedures have facilitated mass production of good quality plantlets giving a boost to rose floriculture industry. It is one of the most important techniques of tissue culture that offers cost-effective implication in commercial floriculture (Soomro *et al* . 2003). This technique allow producing roses with higher quality under a virus indexing programme, attending in this way the market demand. Protocol capable of producing a large number of good quality micro shoots can be successful. Keeping this in view, the present investigation was carried out to establish an efficient and reproducible protocol for rapid and large scale propagation of 'Raktagandha' an important cut rose cultivar.

MATERIALS AND METHODS

The present study was carried out at the Central Tissue Culture Laboratory, L.B.S. Centre, IARI, New Delhi during 2010-2012. Rose cultivar Raktagandha maintained at Centre for Protected Cultivation Technology, IARI, New Delhi was used for this experiment. The bud sticks having 3 to 4 matured axillary buds were selected from the middle portion of current season flowering shoots and were excised during morning hours into individual axillary bud segments (≥1.5 cm). The explants were washed with Teepol® (0.1%) solution for 5 min. followed by washing under running tap water for 15 min. The nodal segments were then treated with different pre-treatments such as: (i) carbendazim (0.2%) + 8-Hydroxy quinoline citrate (200 mg/l), (ii) carbendazim (0.2%) + diathane M-45 (0.2%) + 8-HQC (200 mg/l) along with control (distilled water) for 3 h on horizontal shaker (120 rpm). The pre-treated explants were then surface-sterilized with 0.1% mercuric chloride for 5 min. followed by two-three rinsing with autoclaved distilled water. The surface sterilized explants were cultured on MS medium supplemented with different concentrations of Benzylamino Purine (3.0 and 3.5), NAA (0.1 and 0.2 mg/l), and GA_3 (0.3 and 0.5 mg/l). The surface sterilized explants were cultured on media containing MS + BAP (3.5 mg/l) +1-Naphthalene-Acetic Acid (0.1 mg/l) + GA_3 (0.5 mg/l) with five different concentrations of sucrose (20, 30, 40, 50 and 60 g/l). After four weeks, individual micro-shoots (about 1 cm) were separated from the bunch and transferred onto fresh medium with the similar hormonal combination and a specific concentration of sucrose.

The sprouted shoots were then sub-cultured onto MS medium supplemented with different concentrations of BAP (3.0 and 3.5), NAA (0.1 and 0.2 mg/l), and GA_3 (0.3 and 0.5 mg/l) to find out the best treatment combination for shoot proliferation. The multiplied shoots on proliferation media were separated and individual micro-shoots were transferred onto elongation media comprising basal MS medium supplemented with various concentration of GA_3 (0.25, 0.5, and 1.0 mg/l) to standardize its optimum dose for micro-shoots elongation. Elongated shoots were then transferred individually in cultured vessels containing full-and half-strength of MS medium fortified with different concentrations of auxins like NAA and Indole-3-Butyric Acid individually or in combination for rooting. A dose of 40 g/l of sucrose was added for culture establishment and shoot proliferation and 60 g/l was added in rooting medium. The *in vitro* rooted plantlets were removed from flasks, washed thoroughly with autoclaved distilled water to remove the sticking agar-agar to roots and were then dipped in carbendazim (0.1%) for 10 sec. The plantlets were acclimatized in glass jars filled with vermiculite + agro peat (1:2) moistened with half-strength MS medium salts (macro+micro) and covered with polypropylene lids. The plantlets were kept in culture room (15 days) before transferring to greenhouse. For culture initiation, 20-25 explants were inoculated per treatment in three replications. The cultures were maintained at 25±1°C under fluorescent white light (47 µmol m^{-2} s^{-1}) at a photoperiod of 16/8 h light and dark cycles.

RESULTS AND DISCUSSION

Pre-treatment of explants with different fungicidal and bactericidal treatments had significant effect on survival of explants, microbial contamination, bud sprouting and days to bud sprouting (Fig. 1). The treatment (T_3) comprising carbendazim (0.2%) + diathane M-45 Indofil® (0.2%) + 8-hydroxy quinoline citrate (200 mg/l) for 3 h agitation gave the highest explants survival and bud sprouting, which were significantly superior compared to the other treatments. The pre-treatment of axillary bud explants with T_3 for 3h minimized microbial contamination significantly as compared to control. This pre-treatment also gave the earliest bud sprouting as compared to control. The fungicides used had both systemic and contact fungicides, thus gave efficient control of microbial infection. Similarly, 8-HQC was effective due to its bactericidal activities. Efficacy of these compounds has earlier been demonstrated by Prasad (1995) and Bharadwaj *et al*. (2006) in rose.

The maximum survival of explants (79.55%) and bud sprouting (73.60%) was with T_5 MS + BAP (3.5 mg/l) + NAA (0.1 mg/l) + GA_3 (0.5 mg/l) (Table 1; Fig. 3a). The minimum response was noted with hormone-free MS medium. The above treatment also gave the earliest (6.65) bud sprouting when comparing with other treatments, which was maximum delayed (11.13) in control. The efficacy of BAP in stimulating shoot proliferation has earlier been reported by Vijaya *et al*. (1991) and Kumar and Prateesh (2004). Earlier, Douglas *et al*. (1989) and Arnold *et al*. (1992) reported the efficacy of cytokinins in combination with an auxin or together with GA.

The maximum number of shoots sprouted multiplication

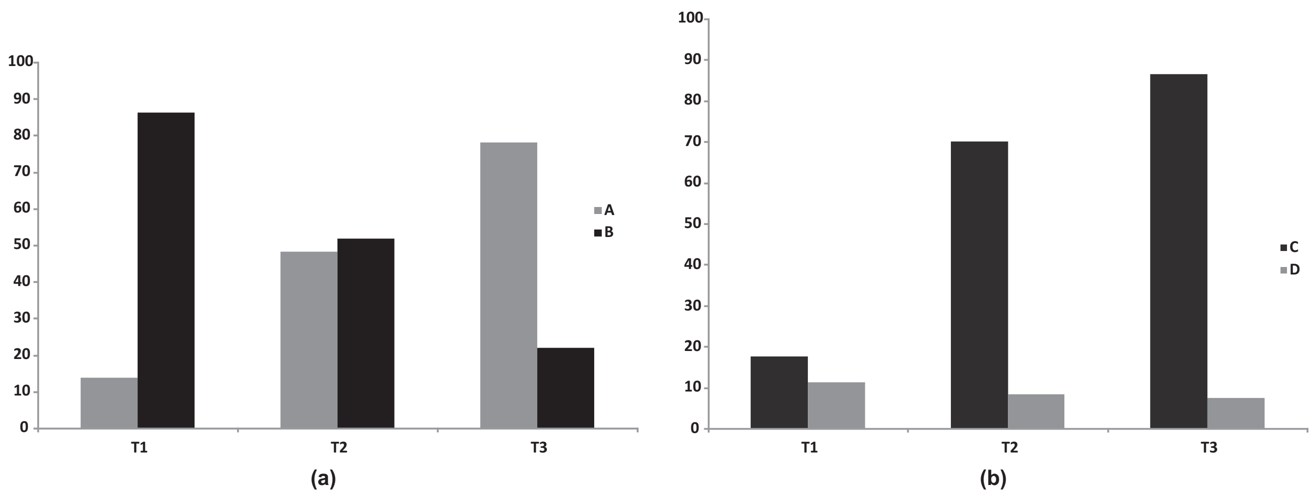
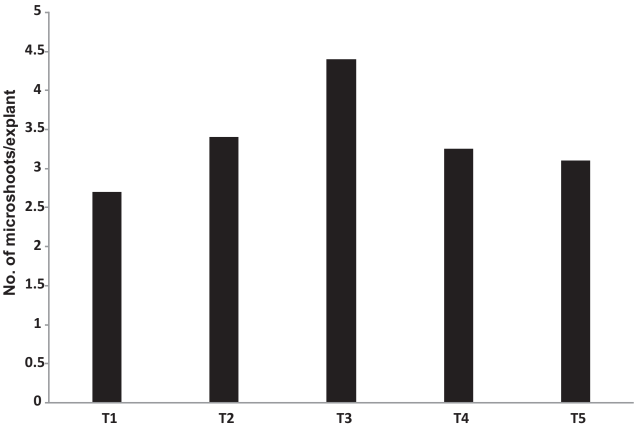


Fig. 1. Effect of different pre-treatments on *in vitro* culture initiation in hybrid tea rose cv. Raktagandha. T1 = control (distilled water) , T2 = carbendazim (0.2%) + mancozeb-45 (0.2%) + 8-HQC (200 mg/l) , T3 = carbendazim (0.2%) + mancozeb-45 (0.2%) + 8-HQC (200 mg/l); A = explant survival (%), B = microbial contamination (%), C = bud sprouting (%), D = days to bud sprouting

was with T_5 (Table ; Fig.3b). After first sub-culture maximum shoots per explants (3.25) was in T_5. Growth regulators at an optimum dose leads to good shoot proliferation and the same was observed in each sub-culture. The better results regarding shoot proliferation in tissue culture might be due to the role of optimum dose of BAP, which enhances axillary branching and multiple shoot formation. Superiority of BAP in shoot multiplication has earlier been shown by Scotti Compos and Pais (1990). It is also opined that in multiple shoots a proliferation may be due to loss of apical dominance (Bala *et al* . 2010; Douglas *et al* .1988; Singh and Syamal, 2001).



(T1, T2 , T3 l, T4 and T5 = 20,30,40,50 and 60 g of sucros/ l)

Fig. 2. Effect of different sucrose levels on shoot multiplication

Besides hormonal regime, other media components are also known to influence the *in vitro* growth response of rose cultures (Short and Roberts, 1991). Concentration of sucrose in the medium affect photosynthetic potential (Langford and Wainwright, 9) and rate of shoot multiplication. Sucrose concentration of the medium showed a distinct influence on the rate of shoot proliferation in cultures. Proliferation rate

Fig. 3. In vitro plant regeneration in Hybrid Tea rose cv. Raktagandha (a, b, c) Bud sprouting, Sprouting of shoots and shoot proliferation on MS + BAP (3.5 mg/l) + NAA (0.1 mg/l) + GA_3 (0.5 mg/l) (d) Elongation of shoots on MS + GA_3 (0.5 mg/l) (e) In vitro rooting on ½ MS + NAA (0.5 mg/l) + IBA (0.5 mg/l). (f) Gradual hardening in glass jar (g) Acclimatized plants in soil.

Table 1. Effect of growth regulators on *in vitro* explant survival, bud sprouting and shoot proliferation in Hybrid Tea rose cv. Raktagandha (RG)

Treatments	Explant survival (%)	Bud sprouting (%)	Days to bud sprouting	No. of shoots proliferated per explant		
				After first sub-culturing	After second sub-culturing	After third sub-culturing
MS + No hormone (control)	37.32 (37.67)	31.97 (34.45)	11.13	1.64	2.45	3.10
MS + BAP (3mg/l) + NAA (0.1mg/l) + GA_3 (0.3mg/l)	61.38 (51.60)	54.27 (47.48)	9.12	2.40	3.29	3.48
MS + BAP (3mg/l) + NAA (0.1mg/l) + GA_3 (0.5mg/l)	71.66 (57.86)	63.73 (53.00)	7.41	2.59	3.56	3.47
MS + BAP (3.5mg/l) + NAA (0.1mg/l) + GA_3 (0.3mg/l)	71.11 (57.52)	72.40 (58.34)	6.79	2.66	3.67	4.17
MS + BAP (3.5mg/l) + NAA (0.1mg/l) + GA_3 (0.5mg/l)	79.55 (63.15)	73.60 (59.1)	6.65	3.25	3.90	4.62
CD (p=0.05)	(2.72)	(1.21)	0.51	0.41	0.35	0.35

Table 2. Effect of basal medium strength and auxins on rooting of micro shoots in Hybrid Tea rose cv. Raktagandha (RG)

Treatments	Days to root initiation	Rooting (%)	Root length (cm)	Root quality	Plantlets growth
MS + No hormone (control)	30.693	14.17 (22.12)	1.207	St	Poor
MS + NAA (0.5mg/l)	20.267	20.77 (25.70)	1.330	S,Th,St	Good
MS + IBA (0.5 mg/l)	22.620	24.17 (29.46)	2.307	Th,S	Good
½ MS + NAA(0.5 mg/l) + IBA (0.5mg/l)	16.873	82.50 (65.30)	3.733	T,L	V. Good
½ MS + NAA(1.0 mg/l) + IBA (1.0 mg/l)	16.060	78.33 (62.29)	3.917	Th,L	V. Good
CD (p=0.05)	(0.905)	(3.60)	(0.431)		

The value given in parantheses denote the arc Sin $\sqrt{}$% values; T= thin, Th=thick, L=long, St=stunted, S=small

Table 3. Effect of different acclimatization strategies on survival of *in vitro* raised plantlets

Treatments	Survival (%)	Plantlet height (cm)	No. of leaves per plantlet
Plastic pot with polythene cover	74.26 (59.52)	6.27	3.90
Plantlet in glass jar with polypropylene lid	86.24 (68.40)	8.12	4.82
CD (p=0.05)	(4.81)	1.92	0.02

The value given in parantheses denote the arcsin $\sqrt{}$ % values

depicted by mean number of nascent shoots produced per culture in four weeks was highest in 40 g/l sucrose, intermediate in 30 and 50 g/l and lowest in 20 and 60 g/l (Fig. 2). Sucrose facilitates the induction of vascular tissue differentiation in cultures. Without exogenous sucrose, the formation of tracheary elements will be greatly reduced or absent. Langford and Wainwright (1988) reported that sucrose concentration of the medium incrementally influences the photosynthetic ability of *in vitro* growing shoots up to a certain level; but higher concentrations suppress the activity. This could be the reason for inferior growth response in 60 g/l sucrose as compared to 40 g/l in the present study.

The earliest root initiation (16.0 days) was noted on half-strength MS + NAA (0.5 mg/l) + IBA (0.5 mg/l) followed by half-strength MS + NAA (1.0 mg/l) + IBA (1.0 mg/l) (16.9 days) (Table 2;Fig. 3e). The time taken for root initiation was delayed in control (30.7 days). The highest rooting was observed for the treatment half-strength MS + NAA (0.5 mg/l) + IBA (0.5 mg/l). The rooting on reduced basal salt strength medium was significantly higher as compared to full-strength medium. The rooting percentage was maximum (82.5) on half-strength MS + NAA (0.5 mg/l) + IBA (0.5 mg/l) followed by half-strength MS + NAA (1.0 mg/l) + IBA (1.0 mg/l) (78.33) as compared to minimum in control (14.17). The longest root length (3.73 cm) was induced with half-strength MS+ NAA (0.5 mg/l) + IBA (0.5 mg/l). The qualitative data suggest that roots were not only few but stunted in medium devoid of auxins. When NAA was supplemented individually, roots were small stunted and thick while those cultured on medium supplemented with IBA had thin and long roots. Roots on half-strength medium supplemented with the dual auxins were of medium length and thin. It is evident from the study that there has been synergistic effect when the two auxins were employed together. Optimum role of two auxins has been reported earlier also by Singh and Syamal (2001) and Bharadwaj *et al*. (2006). The highest plantlet survival (86.24%), the plant height (8.12 cm) with good number of leaves (4.82 per plant) were in treatment where plantlets were acclimatized in glass jars filled with vermiculite + agropeat supplemented with half strength MS medium (macro + micro-organics) and covered with polypropylene lids as compared with, the plantlet survival in plastic pots covered with polythene bags (Table.3). The better results obtained in glass jars might be due to less open space but appropriate relative humidity as compared to those hardened in plastic pots covered with polythene bags. Efficacy of glass jars for *Rosa hybrida* has been earlier reported by Bala *et al*. (2010), Singh and Syamal (2001) and Bharadwaj *et al*. (2006). The results of present investigation demonstrate that rose cultivar Raktagandha can be multiplied *in vitro* employing the above protocol.

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Genetic Variability for Seed Yield and Protein Content in Lentil (*Lens culinaris* Medik. L.)

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Abstract: The genetic variability parameters for seed yield, its component and protein content of 21 lentil genotypes were observed during 2014–15 at Indira Gandhi Agriculture University Raipur . The genotypes exhibited a wide range of variability for all the traits studied. GCV was high only for wilt incidence score, while GCV was observed moderate for the traits *viz.*days to 50% flowering, number of primary branches plant^{-1}, number of pods plant^{-1}, number of seeds plant^{-1}, biological yield plant^{-1} and harvest index. High heritability coupled with high genetic advance as percentage of mean was for number of secondary branches plant^{-1}, number of pods plant^{-1}, number of seeds plant^{-1}, biological yield plant^{-1} and wilt incidence score, revealed that selection for these traits may be useful. High heritability coupled with moderate genetic advance as percentage of mean was for plant height, harvest index, number of seeds pod^{-1}, days to 50% flowering, Dal recovery, days to flower initiation and protein content.

Keywords: Lentil, Genetic variability, GCV, PCV, Heritability, Genetic advance, Protein content

One of the primary objectives of lentil breeders is to increase the grain yield. Generally, yield represents the final character resulting from many developmental and biochemical processes which occur between germination and maturity. Before yield improvements can be realized, the breeder needs to identify the causes of variability in grain yield in any given environment. Since fluctuation in environment generally affects yield primarily through its components, many researchers have analyzed yield through its components (Ishaq *et al*., 2000 and Esan, 2002). The individual yield components may contribute valuable information in breeding for yield. Yield when viewed from the mechanistic or geometric point of view is a product of its components. Knowledge of genetic variability, heritability and the association between traits being improved e.g. yield and other traits in the population is desirable to a plant breeder. This will enable him to know how the selection pressure exerted by him on one trait will cause changes in other traits. Furthermore, the direction and magnitude of such changes could be made manifest. Traits associated with yield may be used either as indirect selection criteria or in a selection index for higher yield. In the total area under lentil crop in our country is 1.42 million hectare hectares with annual production of 1.13 million tones with the productivity of 797 kg ha^{-1} (Anonymous 2013).

MATERIAL AND METHODS

The present study was carried out at College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur. The experimental material for the present investigation consisted of six divergent parents (Table 1) and their 15 hybrids. The experiment was laid out in a randomized complete block design with three replications. Each genotype was grown in a row of 2 meter length with row to row distance of 25 cm and 5–7 cm between plants. The data were recorded on days to flower initiation, days to 50% flowering, days to maturity, plant height, number of branches plant^{-1}, number of secondary branches plant^{-1},number of pods plant^{-1}, number of seeds pod^{-1}, number of seeds plant^{-1}, 100 seed weight, Protein content (%), biological yield plant^{-1}, seed yield plant^{-1}, harvest index(%), wilt incidence score (%) and dal recovery(%).

The days to flower initiation, days to 50% flowering and days to maturity were recorded on a whole plot basis and plant height, number of branches plant^{-1}, number of secondary branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, number of seeds plant^{-1}, biological yield plant^{-1}, seed yield plant^{-1}and harvest index were recorded from a random sample of five plants in each plot. Standard statistical procedure were used for the analysis of variance, genotypic and phenotypic coefficients of variation (Burton, 1952), heritability (Hanson *et al*., 1956) and genetic advance (Johnson *et al*., 1955).

RESULTS AND DISCUSSION

Genetic variability: The analysis of variance showed significant differences among genotypes for all the 16

Table 1. Accessions used in the study

Accession source	Accession name	Characteristics
PAU Ludhiana	LL 1122	High biomass+ resistant to rust+ Aschochyta blight
GBPUAT, Pantnagar	PL117	Wilt resistant
PAU, Ludhiana	LL1161	Resistant to blight +rust
GBPUAT, Pantnagar	PL02	Resistant to rust+ wilt+ stem rot+ Aschochyta blight
JNKV, Jabalpur	JL3	High yielding
IIPR, Kanpur	DPL62	Aphid tolerant

characters studied which provides an opportunity for selecting suitable genotypes with better performance for the traits (Table 2). In general the phenotypic coefficient of variation (PCV) were higher than the genotypic coefficient of variation (GCV) for all the characters, which suggests that the apparent variation is not only due to the genotypes but also due to the influence of environment.

Table 2. Mean sum squares due to genotypes for seed yield, its components and protein content in lentil

Name of the character	Mean Square value F_1+Parents		
	Replications	Genotypes	Error
Days to flower initiation	1.333	103.019**	1.517
Days to 50 per cent flowering	3.048	214.643**	7.398
Days to maturity	1.444	158.530**	24.228
Plant height (cm)	2.158	24.620**	2.298
Primary branches plant^{-1}	0.014	0.150**	0.020
Secondary branches plant^{-1}	0.098	11.835**	0.193
Pods plant^{-1}	5.397**	229.172**	11.33
Seeds pod^{-1}	0.005	0.037**	0.002
Seeds plant^{-1}	1.016	267.678**	5.379
100 seed weight (g)	0.011	0.059**	0.015
Protein content (%)	0.034	5.359**	0.056
Biological yield plant^{-1}	0.024	1.307**	0.058
Seed yield plant^{-1}(g)	0.008	0.034**	0.013
Harvest Index (%)	4.558*	47.140**	3.443
Wilt Incidence score (%)	0.042	0.251**	0.022
Dal recovery (%)	5.283**	88.675**	2.183

*, ** Significant at 5 and 1% levels, respectively

Genotypic and Phenotypic coefficients of variation: The phenotypic coefficients of variation were marginally higher than the corresponding genotypic coefficient of variation due to its interaction with environment. GCV and PCV are categorized as low (<10 %), moderate (10–20 %) and high (>20%) as suggested by Sivasubramanian and Madhavamenon (1973). Similarly the GCV was moderate for the traits *i.e.* days to 50% flowering, number of primary branches plant^{-1}, number of pods plant^{-1}, number of seeds plant^{-1}**,** biological yield plant^{-1} and harvest index**.** Tyagi and Khan (2010) also reported the similar finding for number of seeds plant^{-1}. The characters having low to moderate estimates of GCV, more variability needs to be generated. The phenotypic coefficient of variation was moderate for days to flower initiation, days to 50% flowering, plant height, number of primary branches plant^{-1}, number of pods plant^{-1}, number of seeds **pod^{-1},** number of seeds plant^{-1}, biological yield plant^{-1}, seed yield plant^{-1}, harvest index. Khan *et al*. (2006) also found moderate PCV for number of secondary branches plant^{-1}. The characters having low to moderate estimates of coefficient of variability, more variability needs to be generated. The phenotypic coefficient of variation was high for two traits *i.e.* number of secondary branches plant^{-1} (28.39%) and wilt incidence score (35.42%).

The estimates of phenotypic coefficient of variation in general, were higher than the estimates of genotypic coefficient of variation. This suggested that the apparent variation is not only due to the genotypes but also due to the influence of environment. The characters with high phenotypic coefficient of variation indicated more influence of environmental factors. Therefore, caution has to be exercised during the selection program because the environmental variations are unpredictable in nature and mislead the results.

Heritability and genetic advance: High heritability was recorded for protein content followed by days to flowering initiation, number of secondary branches plant^{-1}, number of seeds plant^{-1}, Dal Recovery, days to 50% flowering, biological yield plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, harvest index, wilt incidence score and plant height. Similar results were also reported by Tyagi and Khan (2010) for 100 seed weight, seed yield and number of branches plant^{-1}.Yadav *et al*. (2003) also found high heritability for seed yield plant^{-1}. Ashraf *et al*. (2008) reported high heritability for 100 seed weight, seed yield plant^{-1} and number of pods plant^{-1}. The moderate heritability was observed for the characters *viz*., number of primary branches plant^{-1} followed by days to maturity. Tyagi and Khan (2010) also showed moderate heritability for plant height. Singh and Singh (2004) also showed moderate heritability for plant

Table 3. Genetic parameters of variation for yield and its components in lentil genotypes

Characters	Mean	Range		PCV	GCV	h^2bs	GA as (%) of mean
		Min.	Max.				
Days to flower initiation	54.81	40.00	62.00	10.85	10.61	21.39	95.71
Days to 50 % flowering	65.71	49.67	75.00	13.31	12.65	24.77	90.32
Days to maturity	94.08	85.00	112.0	8.83	7.11	11.80	64.90
Plant height (cm)	30.98	25.53	34.53	10.07	8.80	15.85	76.40
Primary branches plant^{-1}	1.62	1.40	2.47	15.65	12.89	21.87	67.90
Secondary branches plant^{-1}	7.11	4.33	11.27	28.39	27.71	55.71	95.30
Pods plant^{-1}	46.71	33.42	61.93	19.62	18.24	34.95	86.50
Seeds pod^{-1}	1.17	1.05	1.52	10.14	9.25	17.37	83.12
Seeds plant^{-1}	53.90	39.90	79.47	17.87	17.35	34.69	94.20
100 seed weight (g)	3.46	3.22	3.66	4.97	3.50	5.08	49.62
Protein content (%)	23.37	19.77	25.67	5.78	5.69	11.54	96.95
Biological yield plant^{-1}	3.77	2.90	5.62	18.27	17.11	33.03	87.74
Seed yield plant^{-1}(g)	1.24	1.05	1.43	11.41	6.82	8.39	35.72
Harvest Index (%)	34.04	23.69	41.24	12.49	11.23	20.81	80.88
Wilt Incidence score (%)	0.89	0.71	1.58	35.42	31.20	56.62	77.60
Dal recovery (%)	67.88	58.07	77.07	8.26	7.88	15.49	91.05

height and number of primary branches plant^{-1}. Kumar and Dubey (2001) also noted that days to flowering showed moderate heritability value. These traits had moderate heritability as showed high influence of environment effects and genetic improvement through selection.

Genetic advance as percentage of mean was moderate in days to 50% flowering, number of primary branches plant^{-1}, days to flowering initiation, harvest index, number of seeds pod^{-1}, plant height, Dal Recovery, days to maturity and protein content. The character like seed yield plant^{-1}, number of seed pod^{-1}, number of pod plant^{-1} and number of secondary branch plant^{-1} showed moderate genetic advance as reported by Sharma and singh (2014), high heritability coupled with high genetic advance as percentage of mean was recorded for number of secondary branches plant^{-1}, number of pods plant^{-1}, number of seeds plant^{-1}, biological yield plant^{-1} and wilt incidence score.

High heritability coupled with moderate genetic advance as percentage of mean was recorded for plant height, harvest index, number of seeds pod^{-1}, days to 50% flowering, dal recovery, days to flower initiation, protein content. Gangele and Rao (2005), and Tyagi and Khan (2010) reported similar results for seed yield plant^{-1}. Moderate heritability coupled with moderate genetic advance as percentage of mean was found in number of primary branches plant^{-1}, and days to maturity. High to moderate heritability with moderate genetic advance as percentage of mean was recorded for protein content, days to flower initiation, dal recovery, days to 50% flowering, harvest index, plant height, number of primary branches plant^{-1} and days to maturity. It appears from the findings that these characters are less influenced by environmental effects and hence, selection for these traits may be effective. Low heritability coupled with low genetic advance as percentage of mean was in 100 seed weight and seed yield plant^{-1}. Similar results were also reported by Tyagi and Khan (2010) for number of seeds pod^{-1}. The result revealed that, these characters are highly influenced by environmental effects and hence, selection would not be effective for these traits.

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Genetic Diversity Analysis in Groundnut (*Arachis hypogaea* L.) Genotypes using D^2 Statistics

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Abstract: Genetic divergence using D^2 analysis of 93 genotypes of groundnut (*Arachis hypogaea* L.) were studied during *kharif* −2014 at the Instructional Farm, College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur for fifteen characters. Significant genotype mean square obtained for most of the characters, indicated the presence of adequate variability among the genotypes. The genotypes were grouped into 8 clusters. The clusters VI was the largest containing 18 followed by 16 in cluster VII, 15 in cluster I, 12 in cluster V and cluster VIII, 10 in cluster IV, 7 in cluster III and 3 in cluster II. Maximum intra cluster values were recorded for cluster V (D^2= 101.80) followed by cluster IV (D^2=93.89), cluster VII (D^2=83.72), cluster VIII (D^2=82.62), cluster I (D^2=80.82), cluster VI (D^2=80.46), cluster II (D^2=65.93) and cluster III (D^2=58.06). While, maximum average inter cluster value was obtained between cluster III and VIII. The diversity among the genotypes measured by intra-cluster & inter cluster distance was adequate for improvement of groundnut by hybridization and selection. The genotype included in the diverse clusters can be used as promising parents for hybridization programme to obtain high heterotic response and thus better segregants in groundnut.

Keywords: Genetic divergence, Cluster analysis, D^2 analysis, Groundnut (*Arachis hypogaea* L.)

Groundnut (*Arachis hypogaea* L.), is the sixth most important oilseed crop in the world and grown for its high amount of oil (45-50%) and digestable protein (25-30%) in nearly 100 countries of the world (Namrata *et al.,* 2016; Janila *et al.,* 2013). Groundnut is grown on 25.44 million ha worldwide with a total production of 45.22 million t and an average productivity of 1777.33 kg ha^{-1} (FAO, 2013). Developing countries constitute 97 percent of the global area and 94 percent of the global production of this crop which is mainly concentrated in Asia and Africa (Nigam *et al.,* 2004). The demand for high oil cultivars of groundnut in developing countries is higher due to extensive use for various uses. Total groundnut oil production in India during the year 2014−15 was 1.4 million tones. Recent polyploidization, self−pollination and the narrow genetic base of the primary gene pool in cultivated groundnut resulted in low genetic diversity that has remained a major bottleneck for its genetic improvement (Nigam *et al.,* 2004), but for breeding commercial groundnut cultivars with different objectives requires availability of genetically diverse genotypes to become the parents of a successful hybrid breeding programme which results in F1 with increased yield, wider adoption, desirable quality traits. To assess the existing genetic diversity among the genotypes D^2 technique of Mahalanobis (1936) is intensively and widely used in crop improvement programmes. For knowing the source of genes for particular trait within the available germplasm the evaluation of genetic diversity present within the germplasm is also very important. So, it is essential to know the genetic diversity of the existing genotypes before undertaking any crop improvement programme. Therefore, the present study was carried out to estimate the nature and magnitude of genetic diversity present in a collection of 93 genotypes of groundnut.

MATERIAL AND METHODS

Experimental material and plan of work: The experimental material for the present investigation consisted of 90 genotypes along with 3 checks of groundnut received from different origins (Table 1), which were obtained from the All India Coordinated Research Improvement Project on Groundnut, MPUAT, Udaipur. The experiment was conducted in an Augmented Design with six blocks during *kharif*- 2014 at the Instructional Farm, College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur. Each genotype was accommodated in a one row plot of 5.0 m length with a spacing of 30 cm between row and 10 cm between plants. The fertilizer in the experimental area was applied at the rate of 20 kg N ha^{-1} and 60 kg P ha^{-1} as it is a recommended dose for *kharif* cultivation of groundnut in the region. All the recommended agronomic cultural practices and plant protection measure were followed as and when required.

Traits observed: Observations were recorded on five

Table 1. List of genotypes used in the present study and their pedigree

Name of Genotypes	Pedigree	Origin
UG-3	Selection from ICGV98281	ICRISAT, Hyderabad
UG-4	Selection from ICGV98221	ICRISAT, Hyderabad
UG-6	ICGV93373 × ICGV92224	ICRISAT, Hyderabad
UG-9	ICGV95322 × ICGV96398	ICRISAT, Hyderabad
UG-10	ICGV93124 × (LI × ICGS44)	ICRISAT, Hyderabad
UG-15	ICGV93134 × (LI × ICGS44)	ICRISAT, Hyderabad
UG-16	ICGV93143 × (LI × ICGS44)	ICRISAT, Hyderabad
UG-17	GAJAH × (NU × ICGS44) × (LI × ICGS44)	ICRISAT, Hyderabad
UG-19	[{(ICGV86347 × ICGV8031) × JL-24} × Gajah × (NU × ICGV87883)]	ICRISAT, Hyderabad
UG-20	(ICGV2411 × ICG7637) × Gajah × ICGV	ICRISAT, Hyderabad
UG-21	(TAG-24 × ICG8666)	ICRISAT, Hyderabad
UG-22	(ICGV87290 × ICGV87846)	ICRISAT, Hyderabad
UG-24	(ICGV87290 × TAG-24)	ICRISAT, Hyderabad
UG-56	B-95 × HPS20-2	DGR, Junagadh
UG-57	BAU-13 × SEL12-2	ICRISAT, Hyderabad
UG-59	GG-20 × Kadiri-3	ICRISAT, Hyderabad
UG-60	ICGV86031 × TAG-24	DGR, Junagadh
UG-61	GG-20 × Chico2	DGR, Junagadh
UG-62	PBS20176 × NRCG48291	DGR, Junagadh
UG-64	(EDRGVT × ICGV03056)	ICRISAT, Hyderabad
UG-65	(EDRGVT x ICGV03206)	ICRISAT, Hyderabad
UG-67	B95 × Giri-1	DGR, Junagadh
UG-68	PBS20176 × NRCG4829-1	DGR, Junagadh
UG-69	P95 × GG-2	DGR, Junagadh
UG-71	GG-2 × JCA16	DGR, Junagadh
UG-85	ICGV86031 × TAG24	DGR, Junagadh
UG-86	(ICGS44 × CSMG84-1) × GG-2	DGR, Junagadh
UG-87	TAG-24 × ICGS75	DGR, Junagadh
UG-88	PBS20176 × Code26	DGR, Junagadh
UG-89	ICG × 000102	ICRISAT, Hyderabad
UG-90	ICGS76 × ICGV86031	DGR, Junagadh
UG-91	TAG-24 × ICGV76-1	DGR, Junagadh
UG-92	PBS29017 × NRCG4829	DGR, Junagadh
UG-93	(ICGS44 × CSMG84-1) × ICGV86031	DGR, Junagadh
UG-94	TAG-24 × ICGS76	DGR, Junagadh
UG-95	ICGS44 × CSMG84-1-2	DGR, Junagadh
UG-100	PBS20176 × Code26-1	DGR, Junagadh
UG-102	ICGS44 × CSMG84-1	DGR, Junagadh
UG-103	(ICGS44 × CSMG84-1) × GG-2	DGR, Junagadh
UG-104	PBS11039 × ICGV86031	DGR, Junagadh
UG-105	PBS11039 × TAG-24	DGR, Junagadh
UG-107	(ICGV86031 × TAG-24) × CGMS84-1	DGR, Junagadh
UG-108	ICGS76 × ICGV86031-1	DGR, Junagadh

Cont...

UG–109	ICG × 000103	ICRISAT, Hyderabad
UG–109	ICG × 000103	ICRISAT, Hyderabad
UG–110	ICGS44 × CSMG84–1	DGR, Junagadh
UG–111	PBS11039 × TAG24–1	DGR, Junagadh
UG–112	PBS29031 × ICGV86031	DGR, Junagadh
UG–113	ICGS44 × CSMG84–1	DGR, Junagadh
UG–114	ICGS76 × ICGV86031–2	DGR, Junagadh
UG–115	PBS11039 × NRCG4829	DGR, Junagadh
UG–116	ICGV03063	ICRISAT, Hyderabad
UG–117	Kadiri–3 × TKG19A	DGR, Junagadh
UG–118	ICGS–11 × SB×1–2	DGR, Junagadh
UG–119	ICG × 020153	ICRISAT, Hyderabad
UG–120	ICGS76 × ICGV86325	DGR, Junagadh
UG–122	J–83 × TG–41	DGR, Junagadh
UG–123	ICG × 020091	ICRISAT, Hyderabad
UG–124	CSMG84–1 × ICGV4747	DGR, Junagadh
UG–125	TAG–24 × ICGV4747	DGR, Junagadh
UG–126	CSMG84–1 × ICGV86031	DGR, Junagadh
UG–127	ICG × 020093	ICRISAT, Hyderabad
UG–128	ICG × 020041	ICRISAT, Hyderabad
UG–129	ICG × 990160	ICRISAT, Hyderabad
UG–130	ICG × 010014	ICRISAT, Hyderabad
UG–132	ICGS–11 × SB×1–1	DGR, Junagadh
UG–133	ICG × 040116	ICRISAT, Hyderabad
UG–134	ICG × 040117	ICRISAT, Hyderabad
UG–135	ICG × 040119	ICRISAT, Hyderabad
UG–136	ICG × 040120	ICRISAT, Hyderabad
UG–137	ICG × 020048	ICRISAT, Hyderabad
UG–138	ICG × 070064	ICRISAT, Hyderabad
UG–139	ICG × 050061	ICRISAT, Hyderabad
UG–140	ICG × 050062	ICRISAT, Hyderabad
UG–141	ICG × 050064	ICRISAT, Hyderabad
UG–142	ICG × 050066	ICRISAT, Hyderabad
UG–143	ICG × 050069	ICRISAT, Hyderabad
UG–144	ICG × 050072	ICRISAT, Hyderabad
UG–145	ICG × 050075	ICRISAT, Hyderabad
UG–146	GG–20 × ICGV91114	DGR, Junagadh
UG–147	GG–20 × ICGV91114–1	DGR, Junagadh
UG–148	ICGV91114 × ICGV86564	DGR, Junagadh
UG–149	PBS28014 × NRCG1463	DGR, Junagadh
UG–150	PBS26002 × PBS29017	DGR, Junagadh
UG–151	AK159 × NRCG5001	DGR, Junagadh
UG–152	AK159 × NRCG5001–1	DGR, Junagadh
UG–153	AK159 × NRCG5001–2	DGR, Junagadh
UG–154	ICG × 020106	ICRISAT, Hyderabad
UG–155	(TKG19A × Kadiri–3) × TKG19A	DGR, Junagadh

Cont...

UG–156	GG–20 × ICGV87250	DGR, Junagadh
UG–157	TKG19A × Kadiri–3	DGR, Junagadh
TG37A	TG25 × TG26	BARC, TROMBAY
PM–2	ICGV–86055 × ICG–(FDRs 10)	MPUAT, Udaipur
Pratap Raj Mungphali	Selection from ICGV 98223	MPUAT, Udaipur

randomly selected competitive plants of each genotype in each plot for various characters *viz.* plant height (PH), number of branches plant^{-1} (BN), number of mature pods plant^{-1} (MP), dry pod yield plant^{-1} (DPY), kernel yield plant^{-1} (KPY), sound mature kernel (SMK) except days to 50 per cent flowering (DF), days to maturity (DM) and 100–Kernel weight (KW), which were recorded on plot basis. Shelling percentage (SP), biological yield plant^{-1} (BY), harvest index (HI) were calculated by using formulas. For observation of Dormancy (D), germination count was made in the seeds incubated at 27 ºC ± 3 ºC, Oil content (OC) was determined by the Soxhlet′s Method (A.O.A.C., 1965) and average oil content in per cent was worked out and for calculating Protein content (PC), nitrogen content of kernels was obtained by the standard Micro Kjeldahl method (Lindner, 1944) then value of nitrogen obtained was converted to crude protein per cent by multiplying with a factor of 6.25 and average protein per cent was worked out. The mean data for all characters ware computed for the statistical analysis.

Statistical analysis: The variance for each trait was analysed as per procedure given by Federer (1956). Multivariate analysis of D^2 was done for all fifteen characters by using Mahalanobis Statistics (1936) and different clusters were formed by following the Ward (1963) method.

RESULTS AND DISCUSSION

The significant treatment mean square indicated adequate variability among the genotype for almost all characters (Table 2). On the basis of observed distance among genotypes, 93 genetically diverse genotypes were grouped into 8 clusters (Table 3). Cluster VI contains maximum number of genotypes i.e. 18 followed by 16 in cluster VII, 15 in cluster I, 12 in cluster V and cluster VIII, 10 in cluster IV, 7 in cluster III and 3 in cluster II.

On considering (Table 4) average inter cluster values, maximum was obtained between cluster III and VIII. While at intra cluster level, maximum values were recorded for cluster V (D^2= 101.80) followed by cluster IV (D^2=93.89), cluster VII (D^2=83.72), cluster VIII (D^2=82.62), cluster I (D^2=80.82), cluster VI (D^2=80.46), cluster II (D^2=65.93) and cluster III (D^2=58.06). UG–151 and UG–153 genotypes had one parent common but they are found in cluster III and VIII, respectively which are situated at maximum distance (Table 4), so clustering pattern revealed that genotypes from same origin showed no tendency to be in same cluster. As well as UG–133 genotype from ICRISAT, Hyderabad and UG–151 genotype

Table 2. Mean squares for various characters in groundnut

Character	Block	Treatment	Check	Germplasm	C v/s G	Error
DF	1.26	5.66**	0.72	5.77**	6.23**	0.46
DM	4.32	20.91*	2.39	21.04*	46.23*	6.72
PH (cm)	2.08	8.43*	6.06	8.27*	27.97**	2.31
BN	0.36	0.96**	0.01	0.97**	2.07*	0.22
MP	4.22	6.99**	2.08	5.54*	145.91**	1.57
DPY (g)	1.21	6.11**	4.25*	6.03**	16.89**	1.03
KPY (g)	0.46	3.31**	4.22**	3.21**	9.87**	0.53
KW (g)	6.22	27.40	44.89	24.27	271.11**	11.57
SMK (%)	10.92	22.77*	10.87	22.07*	109.14**	7.77
SP (%)	8.89	19.85*	22.39	19.95*	6.23	6.92
BY (g)	5.74	16.05	10.72	15.27	96.33**	9.20
HI (%)	6.19	34.92*	5.39	27.94*	715.23**	10.46
D	0.59	2.48**	3.56*	2.48**	0.31	0.56
OC (%)	1.11	7.14**	5.38**	6.76**	44.71**	0.53
PC (%)	0.84*	4.00**	0.21	3.30**	73.82**	0.24

*, ** Significant at 5 % and 1%, respectively

Table 3. Groundnut genotypes included in each cluster

Clusters	Number of genotypes	Name of genotypes
I	15	UG-59, UG-69, UG-88, UG-90, UG-107, UG-112, UG-114, UG-115, UG-116, UG-119, UG-123, UG-143, UG-151, TG37A and UG-5
II	3	UG-85, UG-104 and UG-141
III	7	UG-10, UG-15, UG-20, UG-64, UG-132, UG-136 and UG-151
IV	10	UG-9, UG-16, UG-86, UG-94, UG-95, UG-113, UG-129, UG-130, UG-134 and UG-142
V	12	UG-62, UG-65, UG-91, UG-100, UG-128, UG-133, UG-135, UG-137, UG-138, UG-144, UG-152 and PM-2
VI	18	UG-3, UG-17, UG-19, UG-22, UG-24, UG-56, UG-61, UG-68, UG-105, UG-117, UG-124, UG-127, UG-140, UG-145, UG-146, UG-150, UG-154 and UG-156
VII	16	UG-4, UG-6, UG-21, UG-57, UG-60, UG-71, UG-92, UG-102, UG-110, UG-110, UG-125, UG-139, UG-147, UG-148, UG-149, UG-153 and UG-157
VIII	12	UG-67, UG-87, UG-89, UG-93, UG-103, UG-108, UG-109, UG-111, UG-118, UG-120, UG-122 and UG-126

Table 4. Average intra and inter-cluster D^2 values in 93 genotypes of groundnut

Cluster	I	II	III	IV	V	VI	VII	VIII
I	80.82	362.90	272.25	128.59	122.98	85.56	133.86	208.80
II		65.93	268.63	232.56	435.55	211.70	319.69	340.40
III			58.06	219.04	128.36	340.40	139.47	572.64
IV				93.89	147.13	103.83	222.90	143.52
V					101.80	222.90	161.79	438.06
VI						80.46	187.96	148.59
VII							83.72	506.25
VIII								82.62

Diagonal value = intra cluster

Table 5. Cluster mean values of 15 different characters of 93 genotypes

Cluster/ Character	I	II	III	IV	V	VI	VII	VIII
DF	32.02	31.33	31.57	32.00	30.88	30.28	31.06	31.25
DM	107.67	113.00	108.14	101.90	106.35	108.22	109.75	102.50
PH (cm)	30.24	29.74	27.83	30.48	29.78	29.93	31.48	29.78
BN	6.27	6.27	6.70	6.60	5.68	6.47	6.27	6.63
MP	12.32	8.47	8.31	10.89	9.87	10.99	9.65	13.30
DPY (g)	13.75	12.07	9.87	12.46	11.37	13.43	10.74	16.43
KPY (g)	9.69	7.80	6.14	8.39	7.50	9.64	7.69	11.25
KW (g)	38.94	47.97	39.72	43.42	38.05	45.20	37.60	46.19
SMK (%)	83.16	90.91	80.86	88.54	81.06	88.93	82.23	89.28
SP	70.28	65.00	62.14	67.60	66.04	71.78	71.63	68.42
BY (g)	33.29	36.46	31.29	32.54	28.07	32.85	32.61	37.53
HI (%)	41.33	33.20	31.63	38.35	40.59	40.97	33.06	43.75
D	6.67	8.33	6.57	7.50	7.10	6.50	6.69	6.50
OC (%)	39.86	39.04	42.13	40.86	41.69	38.74	40.53	37.36
PC (%)	22.42	21.65	22.41	22.76	22.62	21.25	22.57	21.08

DF= Days to 50 per cent flowering, DM= Days to maturity, PH= Plant height, BN= Number of branches plant^{-1}, MP= Number of mature pods plant^{-1}, DPY= Dry pod yield plant^{-1}, KPY= Kernel yield plant^{-1}, KW= 100-Kernel weight, SMK= Sound mature kernel, SP= Shelling percentage, BY= Biological yield plant^{-1}, HI= Harvest index, D= Dormancy, OC= Oil Content, PC= Protein content

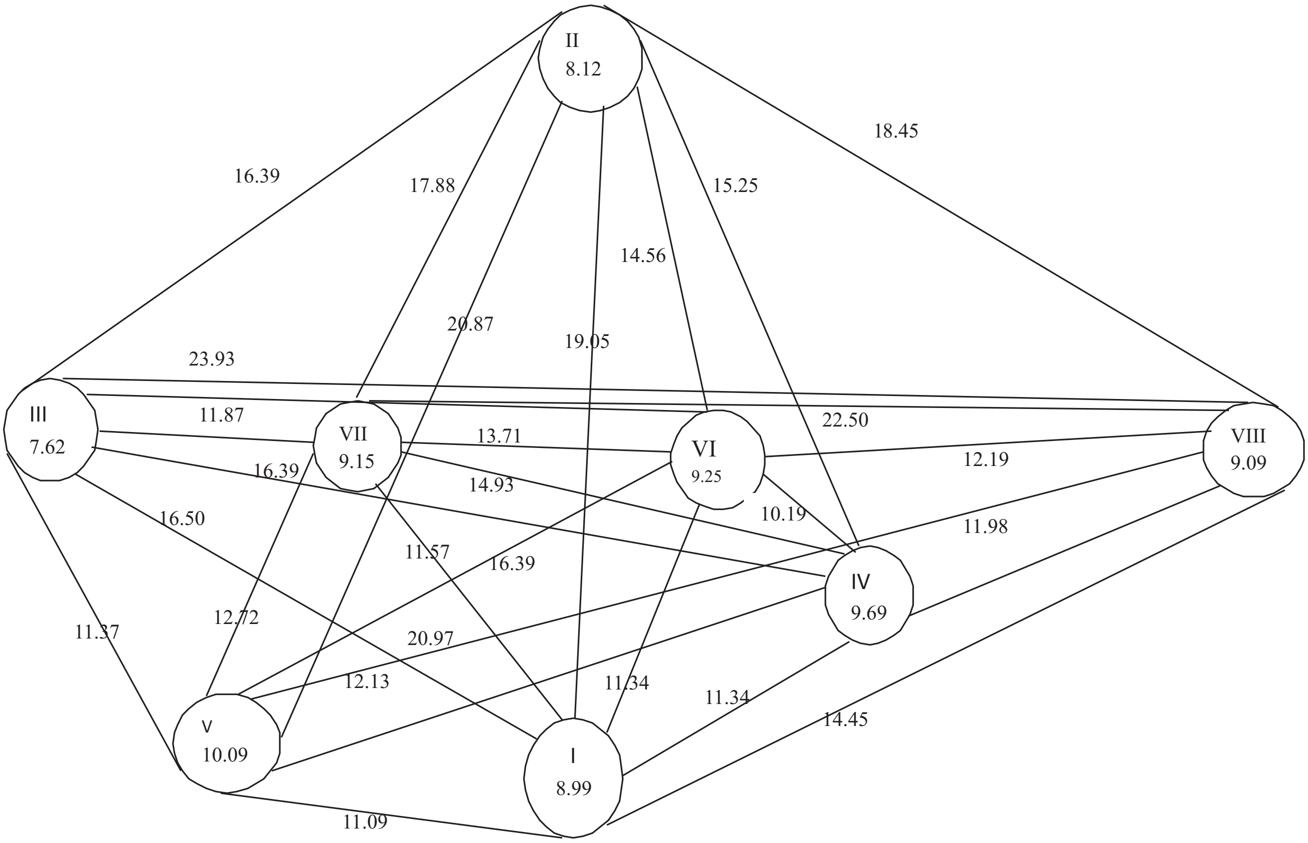

Fig. 1. Cluster diagram of 93 genotypes of groundnut based on $\sqrt{D^2}$

from DGR, Junagadh were in the same cluster III with minimum intra cluster value showing that geographical distance between the genotypes had no relation with the genetic divergence. These finding are in close agreement to earlier reported Islam e*t al.* (2005), Dolma *et al.* (2010), Zaman *et al.* (2010), Yadav *et al.* (2014) and Bhakal *et al.* (2015).

Inter-cluster distances were greater than intra-cluster distances revealing considerable amount of genetic diversity present among the genotypes. The mean values of cluster VIII ranked first for dry pod yield per plant (16.43g), kernel yield per plant (11.25g) 100 kernel weight (46.19), low oil content (37.36%) and early maturity (102.5 days) (Table 5). The mean values of cluster III ranked higher for oil content (42.13%) and protein content (22.41%). Same results also reported by Sarker *et al*. (2004), Khote *et al.* (2010) and Kumar *et al.* (2010) in groundnut.

CONCLUSION

Geographical distance between the genotypes had no relation with the divergence genetically present among them. Genotypes from distantly situated clusters like cluster III and VIII could be used to produce the desirable transgressive segregants and selecting better genotypes for those characters which are having high mean values in these clusters for future groundnut improvement programme.

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Effect of Gamma Radiations on Yield and Yield Attributing Characters of Two Cultivars of Dolichos Bean (*Lablab purpureus* L.) in M_2 Generation

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Abstract: The present investigation was carried out during 2015-16 at Dr. P.D.K.V., Akola with the objective to study the effect of different doses of gamma radiations on growth, yield and yield attributing characters of cultivars Deepali and Konkan Bhushan. The gamma radiation treatment on seeds was done at Bhabha Atomic Research Centre, Trombay, Mumbai. The seeds collected from M_1 generation of dolichos bean were sown in progeny rows to raise the M_2 generation according to the treatments (viz., 25 kR, 35 kR, 45 kR and 55 kR) of both cultivars along with control treatments. All the treatments of both cultivars with gamma radiations registered significant reduction in germination, vine length, survival, yield contributing characters viz., number of green pods per plant, green pod weight, green pod yield per plant, number of seeds per pod, seed yield per plant with increase in radiation doses. However, the significant increase in branches per vine and delayed flowering and pod set were observed with enhanced dose of radiation. Higher doses of gamma radiation had shown maximum variants among the population than lower doses, which ultimately results in maximum frequency of mutation.

Keywords: Lablab, dolichos bean, gamma radiation, M_2 generation

Dolichos bean (*Lablab purpureus L.)* belongs to the family Fabaceae (Leguminoceae), sub family Faboidene, tribe phaseoleae, sub tribe phaseolineae and the genus Lablab has included several distinct species names but, it is currently regarded as monospecific. Within this genus chromosome number varies, with 2n = 20, 22, 24 (Philip 1982). Within India, Lablab crop mostly confined to the peninsular region and cultivated in a large extent in Karnataka and adjoining districts of Tamil Nadu, Andhra Pradesh and Maharashtra. The efforts of improving the crop by utilizing indigenous and exotic germplasm have been useful in breaking the yield barriers resulting in compact plant type, reduced duration, photo-insensitivity and high yielding types (Shivashankar *et al.,* 1993). The approach of increasing the productivity by genetically improving the crop plants appears to be viable and eco-friendly in the present scenario. Growing such genetically improved varieties along with appropriate cultural practices can significantly boost the crop productivity. Success of a crop improvement programme depends on the availability of large genetic variability, which a plant breeder can combine to generate new varieties. This variability is the outcome of naturally occurring mutations (Hazra and Som, 1999). In nature, occurrence of natural variability in the form of spontaneous mutations is extremely low, which can be enhanced to several folds by using ionizing radiations or chemical mutagens. Mutation is an important source of variability in the organisms. The variability caused by induced mutation is not necessarily different from the variability caused by the spontaneous mutation during evolution. Mutation provides us the raw material for the genetic improvement of the commercial crops and occasionally a new cultivar also.

Gamma rays are the most energetic form of electromagnetic radiation, their energy level is from ten to several hundred kilo electron volts and they are considered as the most penetrating compared to other radiations (Kovacs and Keresztes 2002). Dolichos bean is a highly self pollinated (cleistogamous) crop and naturally variability percentage is very low. Gamma rays have tremendous capacity to create variability (Chakraborthy and Parthasarathy, 2003). Hence, this experiment is framed out to create the variability in dolichos bean by using gamma radiations.

MATERIAL AND METHODS

The present investigation was carried out during *Kharif* season 2015-16 at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola and the gamma radiation treatment on seeds of both cultivars was done at Bhabha Atomic Research Centre (BARC), Trombay, Mumbai. The seeds collected from M_1 generation of dolichos bean were sown in progeny rows to raise the M_2 generation according to the treatments (viz., 25, 35, 45 and 55 kR) of cultivars Deepali and Konkan Bhushan along with control treatments to evaluate the effect of gamma radiation on yield and other yield attributing characters. All the recommended cultural measures namely, irrigation, weeding and plant protection were carried out during the growth period of crop. In field, observation on the growth and yield parameters viz., seed germination percentage, survival percentage, vine length, number of branches per plant, days required for first flowering, days required fir 50% flowering, days required for first pod set, number of green pod per plant, green pod weight, green pod yield, number of seed per pod and seed yield per plant were recorded. Several morphological characters like tall, dwarf, early maturity, pod mutants, seed mutants, leaf mutants, chlorophyll mutants, flower mutants and inflorescence mutants are also observed.

RESULTS AND DISCUSSION

The effect of different doses of gamma radiations revealed that in gamma radiation treatments there is a gradual variation in all yield contributing characters of both cultivars of dolichos bean.

All the treatments had shown gradual decrease in germination percentage and survival percentage than the control. The lowest germination percentage in Deepali was observed in 25 kR and highest in 35 kR. In Konkan Bhushan, it was lowest in 55 kR and highest in 25 kR. This might be due to the fact that, an application of mutagen on seeds delayed the emergence of roots, reduction in vigour, low metabolic and enzymatic activity, losses in membrane integrity, which might leads to failure of germination (Kumar and Mishra, 2004; Kamau *et al.,* 2011; Avinash, 2013). The maximum reduction in survival percentage was observed in 25 kR in Deepali and 55 kR in Konkan Bhushan, while reduction was the minimum in 35 kR in Deepali and 25 kR in Konkan Bhushan. The decrease in survival percentage is attributed to the physiological disturbance or chromosomal damage caused to the cells of the plant by the mutagen (Thilagavathi and Mullainathan, 2011). Higher dosed of gamma radiation caused the higher reduction in plant survival (Sharma *et al.,* 2005; Kamau *et al.,* 2011).

The vine length was the maximum in non treated control of both cultivars. Similar observation were recorded by many earlier workers (Bolbhat and Dhumal, 2012; Gnanamurthy *et al.,* 2012; Ariramana *et al.,* 2014). Among the treatments the maximum vine length was observed in 25 kR and the minimum in 55 kR in both cultivars. The numbers of branches were increased in all mutagenic treatments when compared with the control. The maximum numbers of branches per plant were observed in 55 kR, while the minimum numbers of branches per plant were in 25 kR in both cultivars. The

Table 1. Effect of gamma radiation on yield and yield attributing characters of cv. Konkan Bhushan of dolichos bean

Characters\ Doses of gamma rays	Germination (%)	Vine length (cm)	No. of branches plant^{-1}	Days required for first flowering	Days required for 50% flowering	Days required for first pod set	No. of green pods plant^{-1}	Green pod weight (g)	Green pod yield plant^{-1} (g)	No. of seeds pod^{-1}	Seed yield plant^{-1} (g)	Reduction in survival (Mort.) (%)
T_1 – 25 kR	87.33	614.03*	5.50	144.70**	152.00	147.70*	109.35**	14.27**	1560.80**	5.00	141.30*	24.14
T_2 – 35 kR	90.00	605.00**	5.80	144.80*	153.65	149.75**	106.40**	13.97	1493.90**	4.80*	135.25**	14.44
T_3 – 45 kR	89.33	599.40**	6.55*	147.70**	155.70	151.35**	102.90**	12.99**	1410.10**	4.67**	129.80**	15.73
T_4 – 55 kR	88.33	474.75**	6.80*	152.35**	158.30	155.70**	94.05**	12.74**	1291.20**	4.04**	116.45**	18.39
T_5 – Control	98.67	626.67	5.73	141.67	146.33	146.00	116.30	14.03	1631.97	5.10	146.83	0.00

•* and ** significant at 5% and 1%

Table 2. Effect of gamma radiation on yield and yield attributing characters of cv. Konkan bhushan of dolichos bean

Characters\ Doses of gamma rays	Germi nation (%)	Vine length (cm)	No. of branches plant^{-1}	Days required for first flowering	Days required for 50% flowering	Days required for first pod set	No. of green pods plant^{-1}	Green pod weight (g)	Green pod yield plant^{-1} (g)	No. of seeds^{-1} pod	Seed yield plant^{-1} (g)	Reduction in survival (Mort.) (%)
T_1 – 25 kR	94.33	217.85	6.15	140.35**	146.30	145.10*	181.70	4.76	866.15**	4.11	97.55**	6.38
T_2 – 35 kR	92.67	200.75*	6.45	139.65**	148.00	143.60*	178.40*	4.57*	839.70**	4.02	92.50**	8.89
T_3 – 45 kR	87.33	171.20*	6.90	140.30**	148.10	146.85*	172.35*	4.38**	808.90**	3.79**	82.60**	29.89
T_4 – 55 kR	86.67	165.75*	7.45	143.3**	150.35	147.15*	168.85*	3.95**	785.85**	3.55**	79.95**	32.94
T_5 – Control	98.00	216.67	6.12	113.00	118.7	116.33	185.23	4.83	891.07	4.18	102.73	0.00

•* and ** significant at 5% and 1%

maximum branches per plant at higher doses of gamma rays might be due to the inhibitory effect of gamma radiations on auxin metabolism (Nawale, 2004; Priya Ranjan Tah, 2006).

All mutagenic treatments resulted in delay in first flowering, 50% flowering and first pod set when compared to control treatment. The earliest first flower was observed in 25 kR, while the delayed first flower was observed in 55 kR in both cultivars. The days required for 50% flowering from the date of sowing also showed the same trend. The earliest first pod set was observed in 25 kR, while the maximum delay was observed in 55 kR in both cultivars. The delay in flower initiation and pod set and this might be due to the reduction in the rate of various physiological processes of plant (Yaqoob and Rashid, 2001; Gnanamurthy *et al.,* 2012; Girija and Dhanavel, 2013). The numbers of green pods per plant were decreased in all mutagenic treatments as compared with control. The maximum numbers of green pods per plant was obtained in 25 kR and the minimum in 55 kR treatment in both cultivars. The highest green pod weight (weight of a single pod) and green pod yield per plant was observed in 25 kR and the lowest in 55 kR in both cultivars. All the mutagenic treatments had shown the reduced numbers of seed per pod and seed yield per plant as compared with control. The maximum numbers of seeds per plant also showed the same trend. In general, all mutagenic treatments registered slightly decrease in seed yield per plant with increasing doses of gamma radiations as compared to control. The highest seed yield per plant was observed in 25 kR and the lowest seed yield in 55 kR of both cultivars. The study of earlier workers shows that this reduction in green pod weight in gamma radiation treated plants might be due to chromosomal damage and inhibition of mitotic activity of cells which brought down the rate of cell division which might be resulting into poor pod growth in both varieties and the reduction in numbers of green pod per plant might be due to decrease in vine length of dolichos bean. Thus reduction in seed yield per plant might be due to the reduction in number of pod per plant and number of seeds per pod (Yaqoob and Rashid, 2001; Barshile *et al.,* 2006; Thilagavathi and Mullainathan, 2011; Avinash, 2013).

In the field investigation of cv. Deepali several morphological variation were observed. The morphological variants like, dwarf, tall, leaf shape, leaf size, extensive branching, early flowering, flower colour, rachis (inflorescence) branching small pod, long pod, yellow and white pod and chlorophyll mutants were observed. The variation in these mutants might be due to the chromosomal aberrations, changes in chromosome number, gene mutation and re-arrangement of different histogenic layers (Kamau *et al.,* 2011; Thilagavathi and Mullainathan, 2011; Gnanamurthy and Dhanavel, 2014).

CONCLUSION

All the radiation treatments had shown the wider range of variability in yield and other yield attributing characters than the control treatment of both cultivars. All the treatments resulted reduction in germination, vine length, survival, yield contributing characters viz., number of green pods per plant, green pod weight, green pod yield per plant, seeds per pod, seed yield per plant, while increase in branches per vine and delayed flowering and pod set with increasing dose of gamma radiation.

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Genetic Variation Deliniation among Fodder Pearl millet [*Pennisetum glaucum* (L.)] Accessions and Napier Grass Germplasm using SSR Markers

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Abstract: Pearl millet and Napier grass exhibits tremendous amount of diversity at both phenotypic and genotypic levels due to its high outcross breeding behavior. In this diversity study, A total of 14 primers in pearl millet and 10 primers in Napier grass out of 32 primers were polymorphic and amplified to a total of 21 and 32 alleles, respectively. The PIC value of the SSR primers ranged from 0.177 to 0.607 in pearl millet and 0.088 to 0.559 in Napier grass. The PIC value of a SSR marker provides an estimate for discriminatory power of the SSR marker by taking into account the number of alleles and thier relative frequencies. Among pearl millet, the highest dissimilarity index was found between A5/B1 and IP 20840 and ICMB 03333 and IP 20840 while in Napier grass, it was observed between FD 451 and FD 461 followed by FD 460 & FD 474. The dendrogram of both pearl millet and Napier grass germplasm had been grouped into three clusters. Among the three clusters, cluster II comprised of maximum of 21 accessions in pearl millet and 28 accessions in Napier grass followed by cluster III with 18 and 22 genotypes in pearl millet and Napier grass, respectively.

Keywords: PIC, Jaccard′s dissimilarity matrix, Dendrogram

Pearl millet Napier hybrid, an inter-specific hybrid between pearl millet *(Pennisetum glaucum),* small diploid genome (2n=2x=14) and Napier grass *(P. purpureum),* an allotetraploid (2n=4x=28) is a perennial grass (Reis *et al.* 2015). Several workers have reported the potential for improvement in yield and quality of pearl millet Napier hybrids over Napier grass. The hybridization between pearl millet and Napier grass is known to occur naturally since these are protogynous and cross pollinated and belong to same family and genus. In triploid hybrids between pearl millet (AA genome) and Napier grass (A′A′BB genome), the prevalence of seven bivalents (AA′) and seven univalents (B) has led to the suggestion of a high genomic affinity between the species, as well as establishing *P. purpureum* as the secondary gene pool of pearl millet (Zhang *et al.,* 2015). Pearl millet and Napier grass exhibits tremendous amount of diversity at both phenotypic and genotypic levels (Poncet *et al.,* 1998) due to its high outcross breeding behavior, originating from several independent domestication events and wide range of stressful environmental conditions. Due to this high outcrossing nature, the structure of genetic diversity and morphological data are inadequate in providing reliable information for the calculation of genetic distance and pedigree studies. The PCR based codominant Simple Sequence Repeats (SSR/microsatellites) are preferred for genotyping germplasm accessions and large mapping populations because of their reproducibility, abundance, amenability to high throughput screening. Though lot of works have been made earlier in pearl millet with regard to diversity studies for grain yield but studies on pearl millet for fodder yield and yield related traits were very limited. Similarly, in Napier grass in which most of the accessions were exotic and the information on their diversity is very sparse, the diversity of which need to be studied. Therefore, the present research work was attempted to study the diversity in the pearl millet and Napier grass at molecular level using SSR marker so as to evolve high biomass yielding pearl millet Napier hybrids.

MATERIAL AND METHODS

The experimental material under this study, conducted during *Kharif*, 2015-16 at MAS Laboratory, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore included 54 pearl millet accessions and 56 Napier grass germplasm in which molecular diversity was studied using 32 SSR primers.

DNA extraction: DNA was isolated from the 15 days young fresh leaves collected from each genotype using CTAB procedure as developed by Saghai Maroof *et al*. (1994) with suitable modification. Fresh leaves (1g) crushed using mortar and pestle in 1 ml of pre warmed (65^{0}c) CTAB extraction buffer [100mm Tris-HCl (pH-8.0), 0.5m EDTA (pH-8.0), 1.4M NaCl, 2% CTAB & 1% mercaptoethanol] and transferred to a 2ml centrifuge tube. The suspension was incubated in water bath at 65^{0}C for 1 hour with intermittent mixing. After incubation, around 600 µl of chloroform:Isoamyl alcohol (24:1) for protein extraction was added and inverted twice followed by centrifugation for 15 minutes at 5,500 rpm and transfer of aqueous layer to the new tubes. The nucleic acids were precipitated with 450µl of chilled isopropanol, washed with 70% ethanol, dried and finally resuspended in TE buffer [10mm Tris HCl (pH 8.0), 0.5 mm EDTA] containing RNAase (50ng/ml). This suspension was centrifuged at 5,500 rpm for 5min. The aqueous phase was added with 200µl of 3M sodium acetate (pH 5.2) and 200µl of chilled ethanol followed by incubatation for 2 hour at 20^{0}c and centrifugation at 5,500 rpm for 5 min. The supernatant was removed and pellet was washed with 70% ethanol twice. The pellet was again resuspended in TE buffer [10mM Tris HCl (pH 8.0), 0.5mM EDTA]. The DNA concentration was determined using the UV spectrophotometer at 280 nm (Sambrook *et al.,*1989).

Primers and PCR amplification: A set of 32 SSR primers were used for polymorphism studies as per the sequence information available in the published pearl millet literature. Of the 32 SSR primers, 14 primers in pearl millet and 10 primers in Napier grass revealed polymorphism which were retained for the present study which showed bands in the range of 100 to 250 bp. The amplification reactions of 10µl containing a 1.6µl of 10x *Taq* buffer A, 1µl of 100mM each dNTPS, 1µl of oligonucleotide primer (0.5 each of forward and reverse), 2µl of genomic DNA, 0.3µl of 3U/µl *Taq* DNA polymerase (Banglore genei Merck) and 4.1µl of autoclaved doubled distilled water were conducted in the Biorad Thermal Cycler, USA. The polymerase chain reaction (step down) cycling consisted of initial denaturation at 94^{0}C for 3 minutes, followed by 38 cycles of amplification, in which first 18 cycles contained initial denaturation at 94^{0}C for 45 seconds, annealing at 50-58^{0}C (based on annealing temperatures standardized for different SSR primers) for 1 minute and 72^{0}C for 1 minute renaturation. The next 20 cycles consisted of denaturation at 94^{0}C for 20 seconds, annealing at 53−58^{0}C for 45 seconds and 72^{0}C for 45 seconds. A final extension step at 72^{0}C for 10 min was followed by final hold at 4^{0}C. The amplified products were resolved on a 3% SFR agarose gel (super fine resolution agarose) stained with ethidium bromide at 120V for 2 hr using a horizontal submarine gel electrophoresis system (Genei). A 100 bp DNA ladder was run alongside the amplified products to determine their approximate band size. The gels were photographed using CCD Camera attached to a gel documentation system (Bio−Rad, Gel Doc^{TM} XR$^+$, USA) with the biocapture software and scoring was carried out manually in terms of position of the bands relative to the ladder sequentially from the smallest to the largest-sized bands. Reconfirmation of null allele was done and the bands which were appearing as artifact or bands which were either diffused or highly faint and null alleles even after reconfirmation were not considered for analysis. To analyze the genetic relationships among the materials under study, pair-wise genetic dissimilarity between genotypes was computed separately for SSR data, using Dice dissimilarity coefficient based on the proportion of shared alleles using software Darwin 6.0 version (Perrier *et al.*, 2003). Tree construction was done following unrooted NJ tree using dissimilarity matrix. The polymorphism information content (PIC) was determined as per Senior and Henn (1993), which is equal to 1-ΣP_{ij}^2 where P_{ij} is the frequency of j_{th} allele at i_{th} locus summed across all alleles in the locus. Alleles with frequency of less than 0.20 were considered as rare alleles and such allele representing a particular genotype was considered as unique allele for that genotype.

RESULTS AND DISCUSSION

A total of 14 primers in pearl millet and 10 primers in Napier grass out of 32 primers were found to be polymorphic and amplified to a total of 21 and 32 alleles, respectively. Among these primers, the number of alleles ranged from two to four with an average of 2.29 in pearl millet and 2.3 in Napier. In this study, highest number of alleles (3) was observed in primer PSMP2027,PSMP2063 & PSMP2273 in pearl millet while in ICMP 3002 (4) and PSMP 2248 in Napier grass. The observed results coincides with the study made by Singh *et al.* (2013), who have mentioned low level of polymorphism (3 alleles) in pearl millet and Satyavathi *et al.* (2009) reported an average of 2 alleles per locus. An average of 4.5 alleles per locus was reported by Stitch *et al*. (2010). The Polymorphic Information Content (PIC) value of a SSR marker provides an estimate for discriminatory power of the SSR marker by taking into account not only the number of alleles that are detected but also the relative frequencies of those alleles (Bertin *et al.,* 2005). The PIC value of the SSR primers ranged from 0.177 to 0.607 in pearl millet and 0.088 to 0.559 in Napier grass (Table 1). Based on the PIC values of the most informative loci, it was possible to greatly reduce the number of loci employed in cultivar discrimination (Singh *et al*., 2013). The PIC was the highest for SSR primer ICMP 3014 followed by PSMP 2266, PSMP 2235, CTM 10 and CTM 27 and the lowest for the primer ICMP 3002 in Napier grass. In pearl millet, PIC value was highest for primer PSMP 2261 followed by PSMP 2249, PSMP 2231 and PSMP 2224 and lowest in PSMP 2273. Among 24 polymorphic primers, nine (> 0.40) showed higher PIC values, which can be used for further genetic diversity studies. Similar results for PIC value were obtained by Thudi *et al.* (2010), Satyavathi *et al.*

Table 1. PIC value of different polymorphic primers in pearl millet and Napier grass

Pearl millet				Napier grass			
S. No.	Marker name	No. of polymorphic alleles	PIC value	S. No.	Marker name	No. of polymorphic alleles	PIC value
1.	PSMP 2063	3	0.403	1.	ICMP 3002	4	0.088
2.	PSMP 2085	2	0.324	2.	ICMP 3028	2	0.271
3.	PSMP 2273	3	0.177	3.	PSMP 2222	2	0.307
4.	PSMP 2043	2	0.216	4.	CTM 27	2	0.399
5.	PSMP 2201	2	0.348	5.	CTM 10	2	0.448
6.	PSMP 2069	2	0.183	6.	CTM 08	2	0.299
7.	PSMP 2013	2	0.299	7.	PSMP 2235	2	0.544
8.	CTM 27	3	0.187	8.	PSMP 2248	3	0.380
9.	PSMP 2261	2	0.607	9.	PSMP 2266	2	0.544
10.	PSMP 2231	2	0.429	10.	ICMP 3014	2	0.559
11.	PSMP 2224	2	0.407				
12.	PSMP 2045	2	0.348				
13.	PSMP 2249	2	0.582				
14.	PSMP 2027	3	0.225				

(2013) and Bashir *et al*. (2014) in pearl millet.

Dissimilarity index: The marker data was also used to study the genetic relationship among genotypes from which a dissimilarity matrix was generated using Jaccard's dissimilarity matrix leading to preparation of dendrogram constructed by UPGMA cluster analysis (Kumar *et al.,* 2006). Jaccard's dissimilarity matrix ranged from 0.13 to 0.95 in Napier grass and from 0.22 to 0.95 in pearl millet. Higher the dissimilarity between the germplasm, better the scope to include them in the breeding programme. Among the 54 accessions of pearl millet, the highest dissimilarity index was between A5/B1 and IP 20840 and ICMB 03333 and IP 20840 followed by ICMB 04444 and ICMV 05555, ICMB 10999 and IP 20840, A5/B3 and CO 7 while the least dissimilarity index was between RFBJ 2 and RFBJ 89 followed by RFBJ 1 and CO 7, RFBJ 3 and GP 16021, RFBJ 1 and RFBJ 3. In Napier grass, the highest dissimilarity index was between FD 451 and FD 461 followed by FD 460 and FD 474, FD431 and FD 463, FD 457 and FD 473 while the least dissimilarity index was between FD 438 and FD 466 followed by FD 452 and FD 471, FD 443 and FD 476, FD 463 and FD 477. The germplasm with high dissimilarity index can be used in the hybridization to get useful segregants while the germplasm having less dissimilarity index cannot produce good segregants as they had lower genetic diversity. In the present study, the DNA banding pattern was scored for all the Napier grass and pearl millet germplasm. A data matrix was generated and analyzed using clustering methods of the DARwin's based on Jaccard's dissimilarity coefficient with an unweighted pair group method of arithmetic average (UPGMA). The dendrogram of both pearl millet and Napier grass germplasm had been grouped into three clusters. Among the three clusters, cluster II comprised of maximum of 21 accessions in pearl millet (Fig.1) and 28 accessions in Napier grass (Fig. 2) followed by cluster III with 18 and 22 genotypes in pearl millet and Napier grass, respectively. Cluster I has six genotypes in Napier and 15 genotypes in pearl millet. Gupta *et al.* (2012) reported that many of the genotypes evolved had common parents in their genetic backgrounds. The common parentage among the genotypes was also a reason for lower genetic diversity. To conclude, the germplasm with more dissimilarity index in pearl millet and Napier may be recommended for developing high biomass yielding quality pearl millet Napier hybrids. There

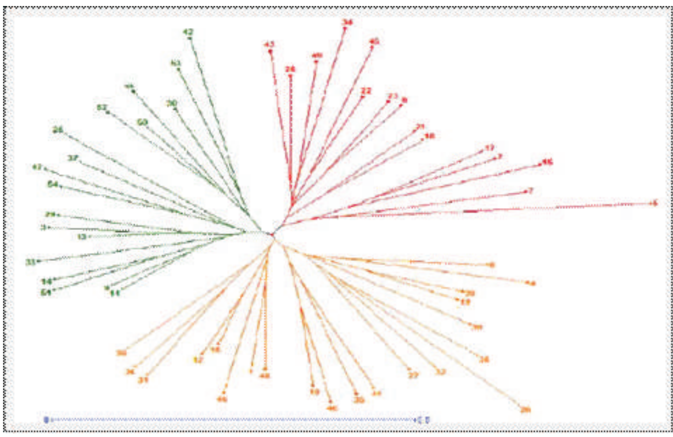

Fig. 1. Cluster tree diagram showing molecular diversity in pearl millet

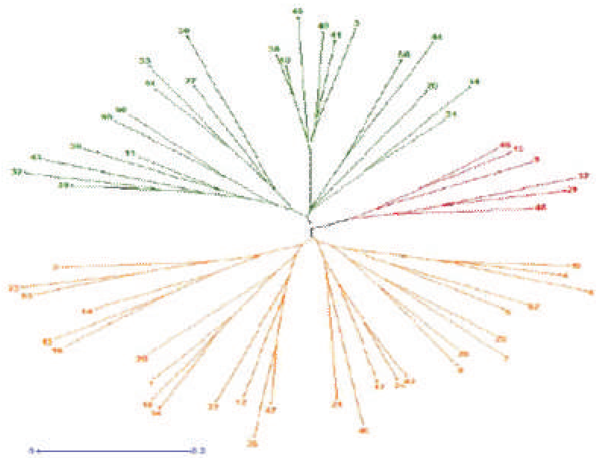

Fig. 2. Cluster tree diagram showing molecular diversity in Napier grass

are many more pearl millet microsatellites and conserved intron–spanning primer (CISP) markers (Feltus *et al*., 2006) for *Pennisetum* available (Budak *et al*., 2003; Mariac *et al*., 2006; Yadav *et al*., 2007, 2008; Rajaram *et al*., 2013), which can be further tested for cross amplification in Napier grass and pearl millet then utilized for further downstream studies. The markers identified in this study can be used further for germplasm conservation and management, genetic map construction, as well as marker–assisted selection for economically important traits, such as biomass yield, frost tolerance, and disease resistance in Napier grass breeding programs.

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Heterosis Studies in Vegetable Cow Pea [*Vigna unguiculata* (L.) Walp.] For Yield and QualityTraits

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Abstract: The experimental material composed of three lines, eight testers and their twenty-four hybrids produced by using line × tester mating design were evaluated for standard (economic) heterosis and heterobeltiosis in vegetable cowpea during *rabi* 2014-15. Analysis of variance shown significant differences among the parents and hybrids for all the characters studied except days to germination and incidence of cowpea mosaic virus. Mean squares due to parents *vs* hybrids were also significant for most of the traits showing the chance for the improvement through using the variability present. PGCP14 × Pusa Sukomal exhibited highest (28.90) *per se* for seed yield per hectare, whereas, hybrid Pant Lobia 3 ×Pusa Sukomal showed highest *per se* performance for seed yield per plant, seed yield per hectare dry pod weight per plant and also showed good *per se* for number of pods per plant, zinc content (27 mg/kg of seed), iron content (47.35 mg/kg of seed), with maximum positive significant economic heterosis (68.46%) for seed yield per plant, and lowest incidence of cowpea mosaic virus. Hybrid Pant Lobia-1 × PGCP13 showed highest *per se* (36.85) performance along with maximum positive significant economic heterosis for zinc content. Hence these hybrids appear to be very promising combination for actual exploitation, may offer best possibilities for selection of transgressive segregants for yield and quality traits in subsequent generation.

Keywords: Cow pea, Heterobeltiosis, Standard heterosis, Yield traits, Quality traits

Cowpea [*Vigna unguiculata* (L.) Walp.] belongs to the subfamily *Faboideae* (*Papilionoideae*) of the family fabaceae (*Leguminosae*) with a chromosome number of 2n=22 (Summerfield *et al*., 1983). It is an annual crop, one of the most important and widely cultivated legumes in the world, particularly in Africa, Latin America, some parts of Asia and Northern America (Xiong *et al*., 2016). Cowpea is majority used as a pulse crop; however, it also uses as fodder or as a vegetable in many parts of the world (Behura *et al*., 2015; Muchero *et al*., 2009). Cowpea is highly self-pollinated vegetable legume and the scope for exploitation of hybrid vigour will depend on the magnitude and direction of heterosis found. Heterosis for yield and other attributing traits in legumes were first reported by Pal (1945). The heterotic response over the check as well as better can be desirable to identify the true heterotic cross combinations (Patel *et al*., 2009). Therefore, the present study was carried out to estimate heterosis for yield and yield contributing traits along with micronutrient content in cowpea.

MATERIAL AND METHODS

Experimental material and site: The experimental materials consisted 11 parents including three lines and eight testers (Table 1) were crossed in line × tester mating design to obtain 24 F_1 hybrids during *kharif*- 2014 at Breeder Seed Production Center, G.B.P.U.A.&T. Pantnagar, Uttarakhand. These 24 hybrids along with 11 parents including one of the parent Pant Lobia-3 as a standard check, were evaluated in randomized block design with two replications, in a single row plot, maintaining crop geometry of 45 x 15 cm (Row to plant) in *rabi*- 2014-15. The recommended package of practices were adopted to raise a healthy crop.

Traits observed: The data were recorded from five randomly selected competitive plants and on plot basis on fourteen quantitative and two qualitative traits (Table 2).

Statistical analysis: Relative heterosis/mid parent heterosis was calculated as per procedure suggested by Shull (1908). Heterobeltiosis /better parent heterosis was calculated as per procedure suggested by Fonesca and Patterson (1968). Economic heterosis/standard heterosis were calculated as per procedure suggested by Briggle (1963).

Micronutrient analysis: Micronutrient *i.e*. Zinc and Iron was analyzed by atomic absorption spectrophotometer.

Table 1. Parents used in line x tester mating design

Source	Parent
Lines (Female)	
BSP, Pantnagar	Pant Lobia-1, Pant Lobia-3 (Check)
PCPGR, Pantnagar	PGCP14
Testers (Male)	
PCPGR, Pantnagar	PGCP13,PGCP28,PGCP29,PGCP52,PGCP61, PGCP62,PGCP63,Pusa Sukomal

Table 2. Analysis of variance for sixteen characters

	Replicates	Genotypes	Parents	Crosses	Parent vs crosses	Error
DF	1	34	10	23	1	34
DG	2.414	1.929*	1.745	1.957*	3.117	1.179
G (%)	58.314**	47.953**	24.162**	46.767**	313.148**	27.926
DF	0.357	11.473**	5.136**	9.996**	108.805**	1.710
DPM	1.429	13.044**	7.709**	15.390**	12.416**	10193
PN	0.215	27.727**	44.386**	20.60**	24.903**	1.923
PL (cm)	2.727	26.448**	34.175**	24.056**	4.194*	0.877
PH (cm)	0.353	45.946**	42.064**	46.975**	61.107**	1.572
SN	0.051	10.516**	40.463**	12.453**	16.488**	1.808
DPW (g)	0.718	38.877**	11.961**	51.816**	10.462**	1.199
SWP (g)	0.149	14.229**	10.944**	16.125**	3.461	0.375
SW(g)	1.924	9.426**	8.467**	9.928**	7.468*	2.353
SY (q/ha.)	1.824	36.301**	26.027**	40.96**	31.87**	1.85
S (%)	0.538	44.054**	32.107**	51.081**	1.898	4.84
ICMV	0.914	0.626	0.536	0.688	0.110	0.473
Iron content	1.417	542.928**	823.56**	389.15**	1273.43**	0.466
Zinc content	0.693	49.305**	66.244**	32.14**	274.52**	0.347

***, **-** Significant at 5% and 1% level, respectively.days to germination (DG), germination per cent (G), days to 1st flowering (DF), days to pod maturity (DPM), number of pods per plant (PN), pod length (PL), plant height (PH), number of seeds per pods (SN), dry pod weight per plant (DPW), seed weight per plant (SWP), 100-seed weight (SW), seed yield per hectare (SY), shelling percent (S), incidence of cowpea mosaic virus (ICPV) and iron content, zinc content, respectively

RESULTS AND DISCUSSION

The significant difference in mean sum squares was observed among the parents and hybrids for all the characters studied except days to germination and incidence of cowpea mosaic virus, indicating that material used had significant variability for different traits. Similar results were found by Uma *et al.* (2010), and Meena *et al*. (2009). Variances due to parents *vs* hybrids were also found significant for all the traits except days to germination, shelling percent and incidence of cowpea mosaic virus, and thus there has been a chance for the improvement.

In the present investigation number of crosses exhibited heterotic response over mid parent and better parent for different traits under study. However, apart from indicating genetic interaction, the measures of heterosis over mid or better parents are of relatively less importance than those of standard or economic heterosis. Hence, it is better to measure heterosis in terms of superiority over standard check variety, rather than over mid or better parent. The presence of heterobeltiosis indicated that over dominance played an important role in the expression of all these traits (Bisen *et al.,* 2017). However, its magnitude and number of hybrids which exhibited significant heterobeltiosis were variable (Table 3). The degree of heterosis changes from cross to cross for all the traits. Looking to the performance of hybrids with respect to dry pod weight per plant, the heterosis ranged from -32.41 to 43.98 per cent, -33.40 to 30.05 per cent and -39.53 to 56.97 per cent over mid parent, better parent and check variety, respectively. All the cross combination exhibits significant relative heterosis. Five cross combination showed heterobeltiosis and nine showed economic heterosis in desired direction (positive). Pant Lobia-3 × Pusa Sukomal showed maximum value for heterobeltiosis and economic heterosis. Similar results were obtained by Kharde *et al.* (2014). The varied degree of heterosis for pod yield in cowpea has been reported by Patil *et al.* (2005) and Meena *et al.* (2009). The similar cross i.e. Pant Lobia-3 × Pusa Sukomal also exhibited highest magnitude of heterobeltiosis and standard heterosis for seed weight per plant (17.68, 68.46) and seed weight per hectare (14.01, 65.38).

PGCP14 × PGCP52 flowers earlier than better parent (HB) and standard check (SH). Seventeen crosses showed significant economic heterosis ranged from -7.50 to -18.75 percent in negative direction. Similar results were obtained by Shashibushan and Chaudhari (2000) and Patel (2009). For number of pods per plant 16 crosses expressed positive heterobeltiosis whereas 23 crosses showed significant economic heterosis which ranged from-18.45 to 100.85 %. The cross PGCP14 × PGCP29 showed maximum economic heterosis. Similar results were obtained by Sawarkar (1998), Kumar *et al.* (1999), Mehta (2000) and Patel *et al.* (2009). Eight crosses showed significant heterobeltiosis and 15

Table 3. Range of heterosis, best crosses and number of crosses showing significant heterobeltiosis (HB) and standard heterosis (SH) for 16 characters in cowpea

Characters	General mean		Cross having best mean value	Range of heterosis		No of crosses showing significant and desirable heterosis		Best crosses	
	parents	crosses		HB	EH	HB	EH	HB	EH
DG	4.95	4.50	Pant Lobia-3 × PGCP29	-46.15 to 30.00	-25.00 to 62.50	14	7	Pant Lobia-3 × PGCP52 (-46.15)	Pant Lobia-3 X PGCP29 (-25.00)
G (%)	87.44	82.89	PGCP14 × PGCP52	-18.62 to 3.83	-14.51 to 12.19	3	7	Pant Lobia-1 × PGCP63 (3.83)	PGCP14 × PGCP62 (12.19)
DF	38.23	35.54	Pant Lobia-3 × PGCP29	-18.51 to -7.50	-7.50 to -18.75	16	17	PGCP14 × PGCP52 (-18.51)	PGCP14 × PGCP52 (-17.50)
DPM	63.86	64.77	Pant Lobia-3 × PGCP52	-5.92 to 5.38	-5.92 to 6.20	22	18	Pant Lobia-1 × Pusa Sukomal (-5.92)	PGCP14 × PGCP13 (-5.92)
PN	15.96	17.24	PGCP14 × PGCP29	-19.231 to	-18.45 to 100.85	16	23	PGCP14 × Pusa Sukomal (22.26)	PGCP14 × PGCP29 (100.85)
PL (cm)	16.50	17.02	Pant Lobia-1 × Pusa Sukomal	-23.50 to 23.31	-5.28 to 88.77	8	15	PGCP14 × PGCP63 (23.31)	Pant Lobia-1 × Pusa Sukomal (88.77)
PH (cm)	43.40	41.39	Pant Lobia-3 × PGCP13	-40.25 to -2.96	-43.60 to -10.43	22	23	Pant Lobia-3 × PGCP13 (-40.25)	Pant Lobia-3 × PGCP13 (-43.60)
SN	21.84	21.00	PGCP14 × PGCP63	-35.570 to	-42.953 to 19.46	4	8	PGCP14 × PGCP63 (15.21)	PGCP14 × PGCP63 (19.46)
DPW (g)	14.90	13.85	Pant Lobia-3 × Pusa Sukomal	-33.40 to 30.05	-39.530 to 56.97	5	9	Pant Lobia-3 × Pusa Sukomal (30.05)	Pant Lobia-3 × Pusa Sukomal (56.97)
SWP (g)	14.55	14.07	Pant Lobia-3 × Pusa Sukomal	-35.570 to	-27.38 to 68.46	6	18	Pant Lobia-3 × Pusa Sukomal (17.68)	Pant Lobia-3 × PusaSukomal(68.46)
SW(g)	13.17	12.46	PGCP14 × Pusa Sukomal	-36.14 to 18.21	-28.69 to 60.08	4	16	PGCP14 × Pusa Sukomal (18.21)	PGCP14 × Pusa Sukomal (60.08)
SY (q/ha.)	21.72	20.26	PGCP14 × Pusa Sukomal	-36.765 to	-32.96 to 65.38	4	17	Pant Lobia-3 × Pusa Sukomal (18.73)	Pant Lobia-3 × Pusa Sukomal (65.38)
S (%)	67.23	67.59	Pant Lobia-1 × PGCP52	-13.42 to 10.62	-3.19 to 10.54	8	14	Pant Lobia-1 × PGCP52 (10.62)	PGCP14 × PGCP29 (10.54)
ICMV	1.23	1.31	Pant Lobia-1 × PGCP62	-66.66 to 50	-50 to 150	10	4	Pant Lobia-1 × PGCP62 (66.66)	Pant Lobia-1 × PGCP62 (-50)
Iron content	42.05	25.91	Pant Lobia-1 × PGCP52	-47.82 to 95.57	-16.700 to	14	20	Pant Lobia-1 × PGCP28 (95.57)	PGCP14 × PGCP29 (103.92)
Zinc content	51.23	30.18	Pant Lobia-1 × PGCP13	-35.47 to 40.37	-25.38 to 16.24	4	13	Pant Lobia-3 × PGCP29 (40.37)	Pant Lobia-1 × PGCP13 (16.24)

crosses showed significant economic heterosis among which PGCP14 × PGCP63 and Pant Lobia–1 × Pusa Sukomal recorded highest heterobeltiosis and standard heterosis for pod length, respectively. Similar trends of results were reported by Bhushana *et al.* (2000) and Patil *et al.* (2005). For number of seeds per pod, 4 crosses showed significant heterobeltiosis and 8 crosses showed significant economic heterosis among which cross PGCP14 × PGCP63 observed as the best one having highest heterobeltiosis and economic heterosis (15.210, 19.463), respectively. Saini *et al.* (2004) and Kajale *et al.* (2013) have also observed the similar results.

Regarding 100–seed weight highest heterobeltiotic and standard heterotic crosses was PGCP14 × Pusa Sukomal. For the same trait 4 crosses showed significant and positive heterobeltiosis and 16 crosses showed significant and positive standard heterosis. For shelling percentage 8 crosses showed significant heterobeltiosis and 14 crosses showed significant economic heterosis in desired direction. As for the commercial importance, PGCP14 × PGCP 29 was found to be best combination. Similar results were reported by Kamai *et al.* (2014). Maximum seed yield per hectare was recorded for PGCP14 × Pusa Sukomal (28.900). For the trait 4 crosses showed significant heterobeltiosis in desired direction, whereas 17 cross combination showed significant economic heterosis in positive direction. Among which Pant Lobia–3 × Pusa Sukomal exhibited highest value. Results on incidence of cowpea mosaic virus shown that out of 24 crosses 10 crosses showed heterobeltiosis and 4 crosses showed significant economic heterosis in desired direction (negative), respectively. Pant Lobia–1 × PGCP62 exhibited highest heterobeltiosis (–66.667) and economic heterosis (−50.00). Similar findings were obtained by Singh, (2014). Cross PGCP14 × PGCP29 (103.920) was the best combination for economic heterosis, whereas maximum value for heterobeltiosis was shown by Pant Lobia–1 × PGCP28 (95.570) for iron content in grains. The estimates of heterobeltiosis and economic heterosis for zinc content in grains shown that four cross combination showed significant heterobeltiosis and five crosses showed significant economic heterosis in desired direction, respectively. Cross Pant Pant Lobia–3 × PGCP29 and Pant Lobia–1 × PGCP13 expressed maximum heterobeltiosis (40.373) and economic heterosis (16.240), respectively.

CONCLUSION

Parents Pant Lobia–1, Pant Lobia–2 and PGCP14 among the lines and PGCP13, PGCP28, PGCP−29, PGCP62 and Pusa Sukomal among the testers may provide as a potential base material for further improvement in yield, its components and micronutrients in cowpea breeding programme. Crosses Pant Lobia–3 × Pusa Sukomal, PGCP14 × Pusa Sukomal, Pant Lobia–3 × PGCP63 and Pant Lobia–3 × PGCP5 exhibited high value of significant standard heterosis and heterobeltiosis for seed yield per hectare and its contributing traits. Pant Lobia–1 × PGCP52 and Pant Lobia–1 × PGCP13 (103.03) showed maximum value for economic heterosis for iron content and zinc content, respectively. These crosses may offer best possibilities for selection of transgressive segregants for yield and quality traits in subsequent generation to make improvement.

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Exploration of Potential of Indigenous and Exotic Lentil (*Lens culinaris* Medik.) Genotypes for Yield and Earliness with respect to Climate Resilient

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Abstract: The investigation was carried out to assess the genetic variability and inter-relationship and path coefficient analysis among the fifteen characters in relation to seed yield in forty nine genotypes of lentil including four checks viz., HUL 57, Arun, Noori and KLS 218 in heat stress condition during *Rabi 2015-16.* On the basis of grain yield and its attributing traits genotypes GP-2961, PL-234 and LKH-2 were identified as promising heat tolerant genotypes of lentil. Analysis of variance revealed significant difference among forty nine genotypes of lentil for all characters, except number of primary branches per plant indicating presence of sufficient variability among the genotypes for various traits. High GCV and PCV were observed for plot yield, plant stand at harvest and number of pods per plant suggested the presence of sufficient variability in genotypes which broaden the scope for genetic improvement through selection of these characters. High estimates of heritability coupled with high genetic advance and moderate to high GCV were observed for number of pods per plant; biological yield per plant, plot yield and plant stand at harvest. Grain yield per plant exhibited positive and highly significant correlations with number of pods per plant, biological yield per plant and plant height while, negative and highly significant association with days to 1st flowering, days to 50% flowering and days to maturity. Path coefficient analysis revealed that harvest index showed maximum and positive direct effect on seed yield followed by biological yield per plant, number of pods per plant and number of primary branches per plant. Thus present study revealed that harvest index was the most positive direct contributor towards grain yield followed by biological yield per plant, number of pods per plant and number of primary branches per plant. Since these characters also exhibited significant and positive correlation with grain yield per plant and Therefore, during selection maximum emphasis should be given to the improvement of these primary yield contributing characters viz. harvest index was the most positive direct contributor towards grain yield followed by biological yield per plant, number of pods per plant and number of primary branches per plant and could be relied upon for selection of genotypes to improve genetic yield potential of lentil under heat stress condition. Breeding strategies for improvement of yield potential in lentil genotypes under heat stress would aim on selection of plants having condition harvest index, biological yield per plant, number of pods per plant and number of primary branches per plant and using these associated characters may be useful to the breeder to formulate appropriate breeding plans for selection of the lentil genotype which tolerate high temperature conditions.

Keywords*:* Lentil (*Lenis culinaris* Medik.), Genetic variability, Correlation coefficient, Path coefficient analysis

Lentil (*Lens culinaris* Medikus) is an important cool-season legume crop of rainfed agriculture for diversification and intensification of cereal-based cropping systems worldwide. Globally, lentil is cultivated on an around 4.6 million hectares with annual production of 4.95 million tonnes and productivity 1095 kilogram per hectare. India shares about 1.03 mt (28%) of global lentil production by cultivating it on 1.47 mha area (Project Coordinators Report AICRP on MULLaRP, 2015-16). It is versatile source of nutrients for man, animals and soil containing, on an average, 25.1, 59, 0.5 and 2.1 percent protein, carbohydrate, fat and minerals and sufficient amount of vitamins, viz. vitamin A 16 IU; thiamine 0.23 mg and vitamin C 2.5 mg per gram lentil. The area occupied under lentil in Bihar is 196.40 thousand hectares with the production 194.10 thousand tonnes and productivity 989 kilogram per hectare (Project Coordinators Report AICRP on MULLaRP, 2015-16). Lentil is sensitive to climate variation. In lentil, flowering is known to be very sensitive to changes in external environment especially in temperature and photoperiod. Heat stress at reproductive stage causes heavy loss in grain yield of lentil. Therefore, in coming years, high temperature can be an important constraint in lentil production, if night temperature rises by at least 2 °C. Due to this in India, northern part can have higher levels of warming by 2050, while its central and north-eastern parts now have about 11.7 mha as fallow after late harvest of rice and delayed sowing of lentil in these areas encounters force maturity due to high temperature (Subbarao *et al.*, 2001). Thus, heat tolerant cultivars can provide not only an opportunity of horizontal expansion of lentil cultivation in rice-fallow lands of Bihar but also can help to increase lentil productivity by minimizing the yield losses occurring due to forced maturity. It can be visualized that the increases in temperature will have more adverse effects on lentil crops. Crop improvement depends largely on the genetic variability which is available for exploitation through various methods of plant breeding. In lentil, the amount of variability that is available for selection is relatively limited due to various genetic bottlenecks. Determination of genetic diversity in lentil is the first step when formulating breeding plans .Hence, success of breeding plans in lentil depends upon genetic diversity and the extent of genetic variability, choice of parents for hybridization and selection procedure adopted. There is need to emphasized the importance of genetic divergence in selection of parents for hybridization. D^2 statistics developed by Mahalanobis (1936) is a powerful tool to measure genetic divergence among the genotypes. Therefore, identification of heat tolerant genotypes in available germplasm and their utilization can help to tackle situation of terminal heat stress through development of heat tolerant cultivars.

MATERIAL AND METHODS

The experiment was conducted during Rabi, 2015–16 at the Pulse Research Farm, Bhitti, Bihar Agricultural University, Sabour, (Bhagalpur), Bihar, India in a simple lattice design with two replications and the crop was sown in first week of December, 2015.The investigation was carried out to assess the genetic variability and inter-relationship and path coefficient analysis among the important fifteen characters in relation to seed yield in forty nine genotypes of lentil including four checks viz., HUL 57, Arun, Noori and KLS 218. All the genotypes were grown in 4 rows of 4 m length with distance of 30 cm between rows and 10 cm between plants. Five competitive plants were taken at random from each row to record data on the following fifteen characters viz. plant height (cm), number of primary branches plant^{-1}, number of seeds pod^{-1}, number of pods plant^{-1}, 1000 seed weight (g), grain yield plant^{-1} (g), biological yield plant^{-1}. Days to 1st flowering, days to 50% flowering, days to maturity, plant stand at harvest, days to harvest, wilt incidence (%) and plot yield were recorded on plot basis. Standard statistical procedure were used for the analysis of variance, genotypic and phenotypic coefficients of variation (Burton, 1952), heritability (Hanson *et al*., 1956) and genetic advance (Johnson *et al*., 1955). The genotypic and phenotypic correlation coefficients were computed using genotypic and phenotypic variances and co-variances (Al Jibouri *et al.,* 1958). The path coefficient analysis was done according to the method by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The analysis of variance (Table 1) revealed the significant differences among the genotypes for all the traits, except number of primary branches per plant indicating presence of sufficient variability among the genotypes for various traits. This indicates that there is ample scope for selection of promising genotypes from the present gene pool for yields and its components. Estimates of different genetic parameters viz. genotypic variance, phenotypic variance, genotypic coefficient of variation, phenotypic coefficient of variation, heritability (broad sense), genetic advance and genetic advance as percent of mean for fourteen characters are presented in Table 2. A wide range of variation for PCV was observed from 4.102 % (days to harvest) to 83.69 % (wilt incidence) while, GCV varied from 3.50 % (days to harvest) to 82.98 % (wilt incidence). Higher magnitudes of PCV were recorded for wilt incidence, plot yield, number of pods per plant, biological yield per plant, grain yield per plant and harvest index while, moderate estimates of PCV were observed for days to first flowering, days to 50 % flowering, number of primary branches per plant, number of seeds per pod and 1000 seed weight across the environment and low estimates for other traits, whereas, higher magnitude of GCV was recorded for plant stand at harvest, number of pods per plant, grain yield per plant, biological yield per plant, plot yield, wilt incidence and harvest index. The higher magnitude of genotypic coefficient of variation and phenotypic coefficient of variation were recorded for plot yield followed by plant stand at harvest and number of pods per plant while moderate to low estimates for other characters suggested the presence of sufficient variability in genotypes which

Table 1. Analysis of variance for fifteen quantitative traits for 49 Lentil genotypes under heat stress condition

Characters	Replications (d.f.=01)	Mean sum of squares of Treatments (d.f.=48)	Error (d.f.=36)
Days to 1st flowering	0.163	132.819**	0.786
Days to 50% flowering	8.582	117.757**	3.113
Days to Maturity	12.500	104.864**	2.651
Plant stand of harvest	700.449	4431.277**	399.240
Days to harvest	10.449	48.924**	10.294
Plant Height (cm)	0.708	19.759**	2.352
Branches plant^{-1}	0.010	0.166	0.217
Seeds Pod^{-1}	0.163	0.208*	0.098
Pods Plant^{-1}	5.878	2259.699**	13.116
1000 seed weight (g)	6.380	30.985**	2.216
Grain Yield Plant^{-1} (g)	0.000	1.236**	0.113
Biological Yield Plant^{-1}	1.183	421.636**	3.891
Plot Yield (g)	188.037	19115.980**	200.914
Harvest index	_0.00049	9.12065	1.374
Wilt incidence (%)	0.032	6.134**	0.097

*,**= Significant at 5 and 1% levels, respectively

broaden the scope for genetic improvement through selection of these characters. In general phenotypic coefficients of variation were greater than their corresponding genotypic coefficients of variation for all the traits, which suggested that the apparent variation is not only due to the genotypes but also due to the influence of environment. The characters with high phenotypic coefficient of variation indicated more influence of environmental factors. Therefore, caution has to be exercised during the selection program because the environmental variations are unpredictable in nature and may mislead the results. Similar findings were reported for characters like plant height, number of pods per plant and seed yield (Harer and Deshmukh, 1992; Jagtap and Mehetre, 1994). High estimates of heritability were observed for the traits, days to 1st flowering, days to 50% flowering, days to maturity, plant stand at harvest, days to harvest, plant height, number of pods per plant, 1000-seed weight, grain yield per plant, biological yield per plant, plot yield, wilt incidence and harvest index which suggested that the characters are least influenced by the environmental factors and also indicates the dependency of phenotypic expression which reflects the genotypic ability of cultivars to transmit the genes to their off-springs. Similar results were also reported by Bicer and Sarkar (2008), Younis *et al*. (2008), Rasheed *et al.* (2008), Rao and Yadav (1988), Chauhan and Sinha (1998) while, number of primary branches recorded moderate heritability. High estimates of heritability coupled with high genetic advance and moderate to high GCV were observed for number of pods per plant, biological yield per plant, plot yield and plant stand at harvest which suggested that these characters can be considered as favorable attributes for the improvement through selection and this may be due to additive gene action (Panse, 1957) and thus, could be improved upon by adapting selection without progeny testing. Similar results have also been reported by Yadav *et al.* (2003). Dixit and Dubey (1985) who reported the highest heritability estimate for days to flowering, however, moderate heritability (59.7%) was observed for seed yield. Erskine *et al*. (1985) reported highest heritability estimate for average seed weight (98%) and Lakshmi *et al.* (1986) and Rathi *et al.* (2002) recorded higher heritability for 100-seed weight and Dayachand (2007) reported higher estimates of broad-sense heritability for days to maturity.

Knowledge of nature and magnitude of associations among different characters are important on three counts. Indirect selection is important when desirable characters have low heritability measure in one sex only. The efficiency of indirect selection is measured as a correlated response (Falconer, 1960). Knowledge of correlation is required when selection is to be made on several characters at a time through some simultaneous selection model (Singh, 1972). Even if, the objective is to make selection on a single trait, the knowledge of correlation is essential to avoid the undesirable correlated changes in other characters. In general, magnitude of genotypic correlation was higher than their corresponding phenotypic correlation coefficients in most of the characters suggesting that a strong inherent association exists for the traits studied and phenotypic selection may be rewarding. Similar results were also reported by Pathak *et al.*

Table 2. Estimates of genetic parameters of fifteen traits of lentil genotypes under heat stress condition

Characters	MEAN	$\Sigma\sigma^2 g$	$\Sigma\sigma^2 p$	$\Sigma\sigma^2 e$	GCV	PCV	h2 (bs) %	GA	GA as % of mean
Days to Ist flowering	66.571	66.017	66.802	0.786	12.69	12.75	0.991	17.32	24.994
Days to 50% flowering	71.214	57.322	60.435	3.113	11.313	11.531	0.963	16.284	21.329
Days to maturity	116.52	51.107	53.758	2.651	6.665	6.781	0.966	15.726	12.323
Plant stand at harvest	208.796	2016.019	2415.258	399.24	22.832	24.552	0.865	91.326	40.472
Days to harvest	135.163	19.315	29.609	10.294	3.501	4.102	0.728	8.32	5.41
Plant Height (cm)	34.9	8.703	11.055	2.352	8.818	9.65	0.835	5.793	15.45
Branches plant^{-1}	2.214	-0.026	0.191	0.217	10.962	14.933	0.539	0.367	-5.465
Seeds pod^{-1}	1.837	0.055	0.153	0.098	14.905	17.582	0.719	0.478	15.67
Pods plant^{-1}	84.796	1123.292	1136.408	13.116	41.118	41.308	0.991	71.495	80.95
1000 seed weight (g)	24.637	14.384	16.601	2.216	15.306	16.488	0.862	7.211	29.52
Grain Yield Plant^{-1} (g)	2.802	0.562	0.675	0.113	29.886	31.709	0.888	1.626	50.27
Biological yield plant^{-1}	35.408	208.873	212.763	3.891	37.366	37.827	0.976	26.923	83.31
Plot yield (g)	178.775	9457.536	9658.449	200.914	49.345	50.176	0.967	178.719	110.888
Harvest index	8.378	3.781	5.34	1.558	23.21	27.582	0.708	3.371	40.235

Where, L= late, $\Sigma\sigma^2 g$ = genotypic variance, $\Sigma\sigma^2 p$ = phenotypic variance, $\Sigma\sigma^2 e$ environmental variance ,GCV= genotypic coefficient of variation, PCV= phenotypic coefficient of variation, GA= genetic advance

(1986). Higher magnitude of genotypic correlation helps in selection for genetically controlled characters and give a better response for seed yield improvement than that would be expected on the basis of phenotypic association alone (Robinson *et al.*,1951).

Grain yield per plant (Table 3) exhibited positive and highly significant correlations with number of pods per plant, biological yield per plant and plant height while, negative and highly significant association with days to 1st flowering, days to 50% flowering and days to maturity. Similar findings of correlation of grain yield per plant with yield and yield contributing characters were also reported by Karadavut (2009), Tyagi and Khan (2011) and Singh *et al.* (2012). Days to 1st flowering showed positive significant association days to 50 % flowering, days to maturity while significantly negative correlation was observed for number of pods per plant, 1000 seed weight. Days to 50 % flowering showed positive significant association with days to maturity while significantly negative correlation was observed for number of pods per plant and 1000 seed weight. Plant stand at harvest showed positive significant association with plot yield, days to harvest, biological yield per plant and number of primary branches per plant showed negative significant association with plant stand at harvest. Days to harvest showed positive significant association with number of primary branches per plant and plot yield while, plant height showed positive significant association with biological yield per plant and plot yield. Number of primary branches per plant showed positive significant association with number of seeds per pod. Number of seeds per pod showed positive significant association with plot yield whereas, negative significant association with wilt incidence. Number of pods per plant showed positive significant association with biological yield per plant and plot yield. 1000 seed weight showed non−significant association with biological yield per plant, harvest index and plot yield and wilt incidence across the environment. Biological yield per plant showed positive significant association with wilt incidence while negative significant association with harvest index.

Knowledge of correlation alone is often misleading as the correlation observed may not be always true. Two characters may show correlation just because they are correlated with a common third one. In such cases, it becomes necessary to study a method which takes into account the causal relationship between the variables in addition to the degree of such relationship. Path coefficient analysis measures the direct influence of one variable upon the other and permits separation of correlation coefficients into components of direct and indirect effects. Portioning of total correlation into direct and indirect effects provide actual information on

Table 3. Estimation of phenotypic correlation coefficient for fifteen different quantitative characters in Lentil under heat stress condition

Character	Days to 50%f flowering	Days to maturity	Plant stand At harvest	Days to harvest	Plant height cm	Branch $Plant^{-1}$	Seeds Pod^{-1}	Pods $plant^{-1}$	1000-seed weight	Grain yield $Pplant^{-1}$	Biological Yield $Plant^{-1}$	Harvest index	Plot yield	Wilt incidence %
Days to 1st Flowering	0.9784**	0.7400**	0.1472	0.1672	-0.0241	0.1646	0.0584	-0.2157*	–0.2330*	-0.3302**	-0.0735	-0.171	-0.0716	0.0092
Days to 50% Flowering		0.7593**	0.1593	0.1838	-0.0427	0.1344	0.0066	-0.2203*	-0.2311*	-0.3052**	-0.0455	-0.173	-0.0923	0.0668
Days to Maturity			0.0555	0.2011*	0.0355	0.1378	-0.0366	-0.2829**	-0.0507	-0.2701**	-0.0359	-0.148	-0.1666	0.1866
Plant Stand At harvest				-0.3108**	0.1063	-0.2198*	0.0057	-0.0720	-0.1893	-0.3099**	-0.4272**	0.223	0.2505*	-0.1364
Days to harvest					-0.1141	0.2922**	-0.0452	-0.0805	0.0658	0.0044	0.0900	-0.13	-0.2685**	0.0412
Plant Height (cm)						0.0351	0.0957	0.1478	0.1371	0.2249*	0.2203*	-0.024	0.2247*	-0.0865
Branches/ Plant							0.2027*	-0.1227	0.0630	-0.0443	-0.0082	-0.105	-0.1756	-0.1728
Seeds/ Pod								0.1086	0.0992	-0.0129	-0.0441	-0.03	0.2494*	-0.2142*
Pods/ Plant									-0.1358	0.6511***	0.5282**	-0.071	0.3592**	-0.0019
1000-seed Weight (g)										0.0780	0.0919	-0.004	-0.1112	-0.0152
Grain Yield/ Plant (g)											0.7107**	0.1376	0.1738	0.1608
Biological Yield/ Plant (g)												-0.56**	0.0038	0.2855**
Harvest index													0.156	-0.122
Plot Yield (g)														-0.0541

Table 4. Direct (diagonal) and indirect effects of component traits attributing to grain yield per plant in lentil under heat stress condition

Character	Days to 1st flowering	Days to 50% flowering	Days to maturity	Plant stand At harvest	Days to harvest	Plant height cm	Branches plant^{-1}	Seeds pod^{-1}	Pods plant^{-1}	1000–seed weight	Biological yield plant^{-1}	Harvest index	Wilt incidence (%)	Genotypic correlation with grain yield plant^{-1}
Days to 1st flowering	-0.4532	-0.4434	-0.3353	-0.0667	-0.0758	0.0109	-0.0746	-0.0265	0.0977	0.1056	0.0333	0.0804	-0.0042	-0.3302
Days to 50% flowering	0.2720	0.2780	0.2111	0.0443	0.0511	-0.0119	0.0374	0.0018	-0.0612	-0.0642	-0.0127	-0.0626	0.0186	-0.3052
Days to maturity	-0.0273	-0.0280	-0.0369	-0.0020	-0.0074	-0.0013	-0.0051	0.0014	0.0104	0.0019	0.0013	-0.0028	-0.0069	-0.2701
Plant stand at harvest	-0.0094	-0.0102	-0.0035	-0.0638	0.0198	-0.0068	0.0140	-0.0004	0.0046	0.0121	0.0272	-0.0010	0.0087	-0.3099
Days to harvest	0.0003	0.0003	0.0003	-0.0005	0.0017	-0.0002	0.0005	-0.0001	-0.0001	0.0001	0.0002	0.0006	0.0001	0.0044
Plant height (cm)	-0.0020	-0.0036	0.0030	0.0089	-0.0096	0.0838	0.0029	0.0080	0.0124	0.0115	0.0185	-0.0004	-0.0072	0.2249
Branches plant^{-1}	0.0061	0.0050	0.0051	-0.0081	0.0108	0.0013	0.0369	0.0075	-0.0045	0.0023	-0.0003	0.0065	-0.0064	-0.0443
Seeds pod^{-1}	-0.0012	-0.0001	0.0008	-0.0001	0.0009	-0.0020	-0.0042	-0.0207	-0.0022	-0.0021	0.0009	0.0002	0.0044	-0.0129
Pods plant^{-1}	-0.0787	-0.0804	-0.1032	-0.0263	-0.0294	0.0539	-0.0448	0.0396	0.3648	-0.0495	0.1927	-0.0085	-0.0007	0.6511
1000-seed weight (g)	-0.0048	-0.0047	-0.0010	-0.0039	0.0013	0.0028	0.0013	0.0020	-0.0028	0.0205	0.0019	0.0001	-0.0003	0.0780
Biological yield plant^{-1} (g)	-0.0323	-0.0200	-0.0158	-0.1877	0.0396	0.0968	-0.0036	-0.0194	0.2320	0.0404	0.4393	-0.5862	0.1254	0.7107
Harvest index	-0.1200	-0.1212	-0.1040	0.1560	-0.0910	-0.0165	-0.0735	-0.0213	-0.0501	-0.0025	-0.3929	0.7018	-0.0855	0.1376
Wilt incidence (%)	0.0003	0.0020	0.0055	-0.0040	0.0012	-0.0025	-0.0051	-0.0063	-0.0001	-0.0004	0.0084	0.0094	0.0293	0.1608

R SQUARE = 0.6681 , RESIDUAL EFFECT =0.5761

contribution of characters and thus form the basis for selection to improve the yield.

Path coefficient analysis revealed (Table 4) that harvest index showed maximum and positive direct effect on seed yield followed by biological yield per plant, number of pods per plant and number of primary branches per plant. Thus present study revealed that harvest index was the most positive direct contributor towards grain yield followed by biological yield per plant, number of pods per plant and number of primary branches per plant. Since these characters also exhibited significant and positive correlation with grain yield per plant and hence improvement in these component characters would result in the improvement of grain yield per plant. Therefore, during selection maximum emphasis should be given to the improvement of these component characters. Similar findings were also reported by Younis *et al.* (2008), and Tyagi and Khan (2011). Hence these traits could be used for the improvement of seed yield resulting in the development of high yielding varieties of lentil under heat stress condition. On the basis of grain yield and its attributing traits genotypes GP-2961, PL-234 and LKH-2 were identified as promising heat tolerant genotypes of lentil.

CONCLUSION

The above findings revealed that under heat stress condition harvest index, biological yield per plant, number of pods per plant and number of primary branches per plant could be used for the improvement of grain yield resulting in the development of high yielding varieties of lentil under heat stress condition. The identified promising heat tolerant genotypes may be used as donor in lentil hybridization programme. Breeding strategies for improvement of yield potential in lentil genotypes under heat stress would aim on selection of plants having condition harvest index, biological yield per plant, number of pods per plant and number of primary branches per plant and using these associated characters may be useful to the breeder to formulate appropriate breeding plans for selection of the lentil genotype which tolerate high temperature conditions.

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Study of Pollen Fertility in CMS based Pigeonpea [*Cajanus cajan* (L.) Millspaugh] Hybrids

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***Abstract*:** CMS based hybrid combinations involving three male sterile and two restorer lines of pigeonpea (*Cajanus cajan)* were studied to determine the pollen fertility behavior of the hybrids. Two F_1 hybrids (ICP 2043 A x ICP 2506 & ICP 2043 A x ICP 9174) carrying A_4 cytoplasm showed >90% pollen fertility with good pod setting and appeared to be true F_1 hybrid. Of these, the hybrid, ICP 2043 A x ICP 2506 gave the highest yield (15.93 g). The hybrid (ICP 2043 A x ICP 2506) also recorded highest pollen fertility along with another hybrid (ICP 2043 A x ICP 9174). A total of 10 SSR markers were used for diversity analysis and identification of male sterile/fertile plants among CMS, restorers and hybrids. None of the markers were able to discriminate between the male/fertile plants. The study showed that ICP 2043 A CMS line can be utilized for full exploitation of heterosis to produce hybrids with better pollen fertility and male sterility gene specific markers should be used for identification of sterile or fertile plants.

Keywords*:* CMS lines, Restorer lines, Hybrids, Pollen fertility/sterility, Pigeonpea

Pigeonpea [*Cajanus cajan* (L.) Millspaugh] (2n=2x=22) is an important food legume crop, which belongs to the family Fabaceae. Pigeonpea is invariably cultivated as an annual crop in tropics and sub-tropics under rainfed agriculture by resource-poor farmers because crop is cultivated with low inputs. Globally, pigeonpea is grown on ~6.22 m ha land in more than 20 countries with an annual production of ~4.74 MT (FAOSTAT 2015). Hybrid breeding technology has played an unparalleled role in global food security and in the last few decades its power has been demonstrated in various field, vegetable, and other crops with several fold increases in their productivity. Cytoplasmic-genic male sterility has been used since long time to improve the yield level of pigeonpea. It is the only food legume where cytoplasmic-genic male sterility is being exploited for commercial use of hybrids. The discovery and use of stable male sterile lines and their fertility restoration in breeding of development of hybrids to exploit hybrid vigour at commercial scale in pigeonpea are a landmark achievement (Saxena *et al*., 2005). This new pigeonpea hybrid breeding technology is capable of substantially increasing the productivity of pigeonpea (Saxena and Nadarajan 2010) and thereby, it leads to have greater impact on Indian pulse production (Tikle *et al*., 2015). In pigeonpea hybrid, the dominant fertility restoring nuclear genes are transmitted from male parent which allow seed set on the hybrid plants. Moreover, the genetic male sterility (GMS) based pigeonpea hybrids has not been commercialized because of high seed cost and difficulties in maintaining the genetic purity (Saxena *et al*., 2006, Saxena and Nadarajan, 2010). However, the expression of fertility restoration among testers may vary from 0 (complete male-sterility) to 100 % (full fertility). In certain cases environment also plays an important role in the expression of pollen fertility (Kaul, 1988). Therefore, identification or breeding new hybrid parents (especially restorer parents which not only provide stability to the hybrids but also produce high yields) with desirable agronomic and market preferred traits on regular interval basis are required for the success and sustainability of any commercial hybrid breeding program.

Presently, seven CMS systems in pigeonpea have been developed by integrating the cytoplasm of wild species with the genome of cultivated species (*Cajanus cajan*) through inter-specific hybridization followed by selection and backcrossing (Saxena *et al*., 2010). Of these, A_4 CMS system derived from *C. Cajanifolius* cytoplasm (Saxena *et al*., 2005) has shown great promise because of its stable expression under various agro-climatic conditions, availability of reliable maintainers (B lines) and stable fertility restoration. Therefore, the CMS-based hybrid technology in pigeonpea (*Cajanus cajan* (L.) Millsp.) is new and it is now based on A_4 CMS-system (Saxena and Kumar, 2013).

Further, the pollen fertility is an important character to evaluate the restoration of fertility and amount of viable pollens produced by particular hybrid which is a basic need for the successful production of high yielding CMS-based hybrids of pigeonpea. Taking the above information into consideration, the present study was undertaken to assess the pollen fertility/sterility of CMS A, B, R lines and their hybrids carrying A_4 cytoplsam.

MATERIAL AND METHODS

Plant Material: In the present study, a set of two cytoplasmic–genic male sterile (CMS) lines MA CMS 25 A (developed at BHU from a cross of *C. Scarabaeoides* x *C. Cajan* cv. IPA 94–1) and GT–33 A (developed at SK Nagar, Gujarat) containing A_2 cytoplasm, whereas the other CMS line, ICP 2043 A (developed at ICRISAT) has A_4 cytoplasm. These 3 cytoplasmic–genic male sterile (CMS) lines along with their corresponding B lines namely, CMS 25 B, GT 33 B & ICP 2043 B and two restorer lines viz., ICP 2506 and ICP 9174 were grown at Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during *kharif* 2014–15. The seeds of ICP 2043 A x ICP 2506 and ICP 2043 A x ICP 9174 were harvested separately. The harvested seed of the crosses along with selfed seed of each of their B and R line were planted in 4 m length plot with inter and intra row spacing of 75 x 25 cm, respectively in two replications. The experiment was conducted under bee proof nylon net to avoid any out crossing and thereby avoiding or minimizing the chance of genetic impurity. Observations on ten randomly selected competitive plants from each of crosses (A, B, R lines and their hybrids) were recorded for flower colour, anther colour, leaf colour, pod colour, seed colour, plant type, days to 50% flowering, days to maturity, plant height, number of primary branches, number of secondary branches, pods plant^{-1}, pod lengh, seeds pod^{-1}, 100 seed weight and seed yield plant^{-1}.

Screening for pollen fertility: Pollen fertility/sterility test of each of the CMS A or B lines, restorers and their hybrids was done to confirm the stability of fertility or sterility behavior of the lines. Data on pollen fertility/sterility was recorded on each plant of each entry at 50% flowering stage at temperature 33^{0}C in the February/March, 2015. To determine the variation in pollen fertility in each generation, three fully developed floral buds were collected randomly from each plant and the anthers were squashed in 2% aceto–carmine stain on a micro slide and examined under a light microscope using 10x magnification. Five microscopic fields for each sample were examined. Mean of the five microscopic fields was calculated and the proportion of fertile pollens was expressed in percentage. Pollen fertility/sterility test of each of the CMS A or B lines, restorers and their hybrids was done to confirm the stability of fertility or sterility behavior of the lines. Based on percent pollen fertility, the plants were classified as fertile (90% and more), partially fertile (11–90%) and sterile (10% and less). following Kyu and Saxena (2011) with few modifications.

DNA amplification: Young leaf tissues from 15–days old plantlets were collected for genomic DNA extraction (Doyle and Doyle, 1987). In order to check the integrity of the genomic DNAs, 3–5 µl samples of the genomic DNAs along with the gel loading dye were individually loaded on to an ethidium bromide stained 0.8% agarose (Fischer Scientific, Pittsburgh, USA) gel. After 2 hrs of electrophoresis in 1× TAE buffer, the gel was visualized under UV light. A thick band without any smear in the upper part of gel was indicative of high molecular weight and good quality genomic DNA. A total of ten pigeonpea SSR markers (Table 3) on association of pigeonpea specific SSR markers were selected from the work of Burns *et al*. (2001) (Table 3). Polymerase chain reaction (PCR) reaction mixture (15 µl) consisted of 20–25 ng of genomic DNA, 200 µM dNTPs, 2 mM $MgCl_2$, 1 unit *Taq* DNA polymerase (MBI Fermentas, Hanover, USA), 1× PCR buffer and 0.6 mM reverse and forward primers. DNA amplification was carried out in a Thermal Cycler (Mastercycler gradient, Eppendorf, Hamburg, Germany) with a PCR profile which included an initial denaturation step at 94°C for 3 min followed by 35 cycles with a denaturing step at 94°C for 30 s, a primer annealing step at optimum annealing temperature for 30 s and an extension step at 72°C for 1 min. After the last cycle, samples were kept at 72°C for 5 min for final extension. The amplification products were separated electrophoretically in 2.5% agarose gels containing 0.05 µg/ml ethidium bromide and prepared in 1*x* TAE buffer. The amplification products were examined under UV light and photographed using a gel documentation system (Gel DocTM XR+, Biorad Laboratories, Hercules, USA). SSR banding profile from only that genotype × primer combination, which gave consistent amplification for all the genotype and without any blank lane/unclear bands, was included in this study. The amplified fragment was scored as ′1′ for the presence and ′0′ for the absence of a band generating the 0 and 1 matrix. These binary data matrix was then utilized to generate genetic similarity data. The SIMQUAL program was used to calculate Jaccard′s similarity coefficients. The resulting similarity matrix was used to construct UPGMA (Unweighted Pair Group Method with Arithmetic Mean) based dendrogram.

RESULTS AND DISCUSSION

Pollen fertility test: In the present study, all the plants of the restorers (ICP 9174 and ICP 2506) showed pollen fertility ranging from 96.55 to 100 per cent whereas two hybrids exhibited pollen fertility 82.025 per cent (ICP 2043 A x ICP 2506) to 91.75 per cent (ICP 2043 A x ICP 9174). Among the three cytoplasmic–genic male sterile (CMS) lines (MA CMS 25 A, GT 33A and ICP 2043 A), ICPA 2043 recorded maximum pollen sterility (100%) followed closely by GT 33A

(98.76%) and MA CMS 25 A (69.26%). However, the plants in the cytoplasmic-genic male sterie (CMS) lines also exhibited greater variability for pollen sterility. The maximum variability for pollen sterility was in MA CMS 25 A ranged from 15.79 to 100 percent followed by GT 33 A ranged from 93.94 to 100 per cent, whereas all the plants in the ICP 2043 A were recorded complete sterility (100%). The single plant progenies of male sterile line (A line) showing 100 percent pollen sterility with similar phenotype were retained and other plants of A line showing segregation for plant type and pollen sterility were rejected. Similarily, the corresponding B lines (maintainer lines) recorded variability for pollen fertility ranged from 79.61 to 100 per cent. In which, MA CMS 25 B recorded pollen fertility ranged from 84.30 to 100 per cent, GT 33 B (from 90.63 to 100 per cent) and ICP 2043 B (from 79.61 to 98.31 per cent). In B lines also, only those single plant progenies which expressed 100% pollen fertility, with homogenous expression in phenotype were retained and used them for maintaining A lines. F_1 hybrids were evaluated on the basis pollen fertility restoration and pod setting rate. F_1 hybrid of ICP 2043 A x ICP 2506 recorded 91.75% pollen fertility with more than 30 pods, whereas the hybrid of ICP 2043 A x ICP 9174 showed 82.025% pollen fertility with less rate of pod setting (05). F_1 plants in the two crosses were male-fertile which reveals the dominance of the fertility restoring genes over the CMS system. The results are in agreement with Saroj *et al*., (2015) where the variability of pollen fertility restoration as well as pod setting rate when evaluated 132 F_1 hybrids. However, the 3 cytoplsamic-genic male sterile (CMS) lines also exhibited variability for the pod setting rate with their corresponding B lines.

Morphological traits: The plant type of all the CMS lines and their hybrids were of semi spreading and indeterminate type except MA CMS 25 A and B which were found to be of semi compact type (Table 1). Similarly, leaves of all the CMS lines as well as their hybrids were of green/dark in colour. The flower colour of MA CMS 25 (A and B) was reddish yellow, ICP 9174 was purple vein petals, ICP 2506 was fully yellow and rest of the A, B, and hybrids exhibited yellow flower. The anthers of all the CMS lines were white translucent, whereas B lines, restorers as well as the hybrids exhibited yellow anther lobe with powdery texture. The pods colour of MA CMS 25 A/B, GT 33 A/B and ICP 9174 were green with dark blackish streaks, whereas the ICP 2043 (A & B lines) and ICP 2506 were found to be green and purple pods respectively. Seeds all the CMS lines as well as their hybrids were brown colour expect the restorer ICP 9174 which was to be dark purple.

Quantitative traits: The plant height in the hybrid ICP 2043 A x ICP 9174 (113 cm) was at par with respective restorer, ICP 9174 (114 cm). The seed yield plant^{-1} was highest in the hybrid, ICP 2043 A x ICP 2506 (15.93 g). In addition to this, the hybrid ICP 2043 A x ICP 2506 also recorded highest pollen fertility. As for complete exploitation of heterosis in CMS hybrids, hybrids with good pollen fertility is essential along with the other yield contributing characters (Wanjari *et al*., 2007; Sudhir kumar *et al*., 2015). Thus, ICPA 2043 can be expected to prove to be a good CMS line which can be utilized in the production of hybrids in pigeonpea.

Cluster analysis and genetic similarity: A total of 10 SSR markers were used for validation and diversity analysis among 10 pigeonpea genotypes. Out of ten primers used, five primers were found to be polymorphic (Table 3). Four markers namely, CCac003, CCttc006, CCtc013 and CCac036 amplified three alleles while marker CCttc008 amplified two alleles and rest of the markers amplified single allele. Thus, a total of 19 alleles generated with ten primers. However, the above said makers also showed their corresponding PIC value ranged from 0.0 to 0.85 with an average PIC of 0.54. The maximum polymorphism information content was shown by primer CCttc006 (0.85) followed by primer CCac003 (0.83) and CCac036 (0.79),

Table 1. Morphological characters of CMS, Restorers and their hybrids

Lines/ Hybrids	Plant type	Pod colour	Flower colour	Anther colour	Leaf colour
MA CMS 25 B	Semi compact	Striped Green	Reddish Yellow	Powdery Yellow	Dark Green
MA CMS 25 A	Semi compact	Striped Green	Reddish Yellow	Translucent White	Dark Green
GT-33 B	Semi spreading	Striped Green	Yellow	Yellow	Dark Green
GT-33 A	Semi spreading	Striped Green	Yellow	Translucent White	Dark Green
ICPB 2043	Semi spreading	Green	Yellow	Powdery Yellow	Dark Green
ICPA 2043	Semi spreading	Green	Yellow	Translucent White	Dark Green
ICP 9174	Semi spreading	Striped Green	Yellow with purple petal veins	Powdery Yellow	Green
ICP 2506	Compact	Purple	Fully Yellow	Powdery Yellow	Green
ICPA 2043 A X ICP 9174	Semi spreading	Striped Green	Yellow	Powdery Yellow	Green
ICPA 2043 A X ICP 2506	Semi spreading	Purple	Yellow	Powdery Yellow	Green

whereas the lowest PIC was shown by primers CCB7 and ICPM131 (Table 3). The high level of polymorphism was observed among ten genotypes which revealed the presence of wide genetic base.

The dendrogram exhibited that the ten pigeonpea genotypes and hybrids were grouped into two clusters, *i.e.,* cluster I and II with similarity coefficient (S_{ij}) ranging from 0.44 to 0.82 (Fig 1) due to diversification in genotypes. Cluster I was further differentiated into three sub-clusters namely IA, IB and IC. Cluster IA consisted of three genotypes, namely MA CMS 25A, GT 33 B and MA CMS 25 B, whereas, Cluster IB consisted of two genotypes, *i.e.,* ICP 2043 B and ICP 2043 A x ICP 2506 and Cluster IC consisted of two genotypes, namely ICP 9174 and ICP 2043 A x ICP 9174. Then, Cluster II consisted of three genotypes namely, GT 33A, ICP 2506, ICP 2043A. As per the similarity coefficient (S_{ij}), the maximum similarity coefficient (0.82) was observed between MA CMS 25A and GT 33B, whereas, minimum similarity coefficient (0.29) was observed between ICP 2043A and ICP 2043A x ICP 9174, and GT 33 A and ICP 9174 (Table 4). However, the genetic similarity among the two groups was found to be 0.44.

The present study indicate that tested SSR markers failed to discriminate among male sterile and male fertile lines but they succeeded to show greater amount of genetic diversity among pigeonpea genotypes and also placed two isogenic lines namely MA CMS 25 A and MA CMS 25 B in one cluster. This may be due to their common gene combinations except male sterility gene. Further, it is suggested to use male sterility gene specific markers to see their efficacy for discrimination and their use in early identification of

Table 2. Observations on quantitative characters of lines and hybrids

Line/ Hybrids	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of Primary branches	No. of Secondary branches	No. of seeds plants^{-1}	No. of pods plant^{-1}	Pod length (cm)	No. of seeds pod^{-1}	100 seed wt. (g)	Yield plant^{-1} (g)
MACMS-25B	116	238	92.11	8.28	0	33	13.17	4.9	3.28	9.88	7.91
MACMS-25A	112	0	117.9	7.8	1	111.5	49.6	5.66	3.7	11.51	15.56
GT-33B	88	241	68.17	8.83	2.83	44.17	14.5	5.62	4.27	6.98	3.23
GT-33A	65	0	88.5	10.25	5.38	69.63	23.5	5.53	3.83	9.8	9.07
ICP-2043 B	94	236	114	11.67	1.75	91.42	44.58	5.32	3.57	11.36	13.57
ICP-2043A	95	0	108.17	14.67	4.17	122.5	49.67	5.19	3.4	10.03	14.88
ICP 2043 × ICP-9174	135	240	113.4	13.6	4	75.2	30.4	5.23	3.52	10.7	7.91
ICP-9174	122	242	114	9.57	19.71	118	42.43	5.17	3.57	6.85	8.96
ICP 2506	120	235	101.25	16.75	7	52	5.23	130.5	2.5	8.47	11.69
ICPA 2043 × ICP 2506	118	236	96.5	9.5	5.5	78.5	5.47	235	2.99	8.53	15.93
Mean	106.5	166.8	104.46	10.33	6.6	72.25	29.45	5.21	3.29	9.85	8.89
CV (%)	19.4	69.02	20.44	24.23	112.09	53.69	54.73	6.73	33.47	19.51	51.32

Table 3. Number of alleles, polymorphism information content (PIC) and details of SSR primers used in the present study

Primer Names	Primer Sequence (5′-3′)	No of Alleles	PIC
CCac003	F-TGCTTCAAGTTGCCTACCAG	3	0.83
CCttc006	F-GTAGAGGAGGTTCCAAATGACATA	3	0.85
CCB2	F-CCATAATCCAATCCAAATCC	1	0.64
CCB7	F-CAACATTTGGACTAAAAACTG	1	0
CCtc013	F-CTTCTCCCTGCCTCTTTTCC	3	0.71
CCtta015	F-AACACGCACCTCAATTCCA	1	0.36
CCac036	F-ATCGGCTTTTGTCTTGATGA	3	0.79
ICPM127	F-CGAGCTCGAATTGACCCTAT	1	0.51
ICPM131	F-CTACCTTGGCCAACCATTCT	1	0
CCttc008	F-TCACAGAGGACCACACGAAG	2	0.68
Mean		19	0.54

Table 4. Jaccard's similarity coefficient among 10 pigeonpea genotypes

	MA CMS 25A	GT 33A	ICPA 2043	MA CMS 25B	GT 33B	ICPB 2043	ICP 2506	ICP 9174	ICPA 2043 x ICP 2506	ICPA 2043 x ICP 9174
MA CMS 25A	1.00									
GT 33A	0.58	1.00								
ICPA 2043	0.58	0.64	1.00							
MA CMS 25B	0.75	0.43	0.43	1.00						
GT 33B	0.82	0.73	0.58	0.62	1.00					
ICPB 2043	0.64	0.31	0.31	0.46	0.50	100				
ICP 2506	0.58	0.64	0.50	0.54	0.46	0.31	1.00			
ICP 9174	0.58	0.29	0.50	0.54	0.46	0.42	0.38	1.00		
ICPA 2043 x ICP 2506	0.73	0.38	0.38	0.54	0.58	0.70	0.38	0.64	1.00	
ICPA 2043 x ICP 9174	0.58	0.38	0.29	0.54	0.46	0.42	0.50	0.64	0.64	1.00

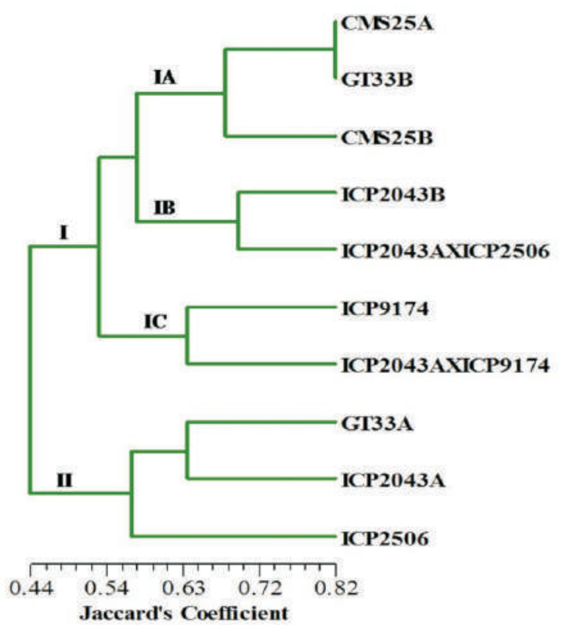

Fig. 1. UPGMA based cluster analysis of 10 pigeonpea genotypes using 10 SSR markers

sterile/fertile plants.

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Characterization and Similarity of Rice (*Oryza sativa* L.) Germplasm Lines through SSR Markers

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Abstract: The rice germplasm lines (226) which were being maintained at Tiloundha, Patna and Sabour locations of Bihar were evaluated during 2012 to 2015 and data were collected on various parameters. The three year average of morphological data was converted into 0, 1 matrix and similarity coefficient between the accessions indicated 45, 16 and 17 accessions each in Tiloundha, Patna and Sabour collections, respectively had more than 60% similarity. Based on the molecular profiling, 90% similarity was found between the new combinations of 21, 2 and 4 accessions of Tiloundha, Patna and Sabour collected germplasm, respectively. The 60% morphological similarity between T69/71 and S6/7 showed 90% similarity at molecular level which indicated duplications of these accessions. Hence SSR markers based molecular fingerprinting could identify genetically distant genotypes and sort-out the duplications in morphologically close accessions.

Keywords: Dendrogram, Morphological traits, Rice Germplasm, Similarity coefficient, SSR markers

Rice has a vast germplasm of cultivated and wild species (Nakagahra *et al.*, 1997; Vaughan *et al.,* 2003) and genetic diversity in germplasm is greater than any other crop. It includes the widely cultivated *Oryza sativa* which further comprises three subspecies i.e. *indica*, *japonica* and *javanica*. The other cultivated species *O. glaberrima* is confined to the African sub continent. Landraces are great reservoir of gene pool of rice and are considered to be an intermediate stage in the domestication process from wild ancestor to the cultivated rice (Khush, 1997; Lu *et al.,* 2005; Garris *et al.,* 2005). Additionally, wild relatives of rice provide potentially valuable resource for the improvement of cultivated rice (Ren *et al.*, 2003). Evaluation of germplasm collection in crops is essential for maintenance of diversity and identification of valuable genes. Diversity assessment at morphological, physiological and molecular basis is widely used tools for germplasm characterisation in rice. The morphological and physiological traits are the oldest and most important markers in crops but they have limitations of low polymorphism, low heritability, late expression and vulnerability to environmental influences (Muthusamy *et al.*, 2008). DNA based molecular markers are extensively used for the study of genetic variability because these are not affected by environmental factors. The SSR markers are most important markers in rice due their reproducibility, multiallelic nature, hypervariability, co-dominance inheritance, relative abundance and genome wide coverage. These markers are being used for evaluating genetic diversity and relationships among rice germplasm for conservation or utilisation (Sharma *et al.*, 2007).

Molecular analysis in conjugation with morphological and agronomic evaluation of germplasm is recommended because they increase resolving power of genetic diversity analysis and provide complementary information. The present study deals with morphological characterisation of 226 rice germplasm lines which were collected from different sources and being maintained at Bihar Agricultural University Sabour. The morphologically similar accessions were further screened through SSR makers to validate the morphological similarity at molecular level.

MATERIAL AND METHODS

Collections of germplasm comprising 226 lines were grown at Rice Research Farm of Bihar Agricultural University Sabour during 2013-15. For convenience, the germplasm collections were abbreviated as '*T*', '*P*' and '*S*', respectively after the names of Tiloundha, Patna and Sabour locations.

Morphological observations: Morphological observations of five randomly selected plants were taken at maturity stage on plant height, number of tillers per plant, flag leaf length and panicle length. Grain length (L), grain breadth (B) and L/B ratio was taken at post harvest stage. The observations from five plants were averaged to get the final morphological data of the trait. The quantitative data based on the morphological traits were categorised into regular interval to make them binary data in 0, 1 matrix and similarity and diversity between the genotypes in Tiloundha, Patna and Sabour collections were estimated using Jacards method. The similarity coefficient between the lines was calculated through UPGMA (unweighted pair group method with arithmetic averages) method.

SSR markers: SSR markers were selected from the panel of

50 standard SSR markers as suggested by IRRI, Philippines (http://archive.gramene.org/markers/microsat/50_ssr.html) (Table 1).

DNA isolation, purification and quantification: Genomic DNA from individual single plant was extracted from 3 week old seedling using CTAB method (Doyle and Doyle, 1990). The isolated DNA samples were electrophorised in 0.8% (w/v) agarose gel in 1X Tris‒Acetate‒EDTA [TAE: 40 mM Tris‒Cl, 0.1% (v/v) acetic acid and 1 mM EDTA] buffer for checking the quality and quantity of the samples. On the basis of visualization of nucleic acids the DNA samples were further diluted to a uniform concentration of 50 ng/µl.

PCR amplification using SSR markers: PCR was carried out with the diluted DNA samples of plants using the SSR primers in automated thermal cycler (Applied Biosystems). The reaction was carried out in 12 µl reaction volume containing 2 µl (100 ng) of extracted genomic DNA, 1.2 µl 10X PCR buffer, 2.5 mM $MgCl_2$, 0.125 mM of dNTPs, 0.4 µM of forward and reverse primer and 0.3U of *Taq* DNA Polymerase. Template DNA was initially denatured at 94ºC for 4 min followed by 35 cycles (30 seconds denaturation at 94 ºC, 40 sec annealing at 55 ºC, 40 sec of primer extension at 72 ºC) of PCR amplification, and final extension of 72 ºC for 10 min followed by hold at 4 ºC.

Table 1. List of SSR markers used for the diversity study of germplasm accessions

Name of the SSR marker	Forward primer (5′‒3′)	Reverse primer (5′‒3′)	Motif	Chr.
RM312	GTATGCATATTTGATAAGAG	AAGTCACCGAGTTTACCTTC	(ATTT)4 (GT)9	1
RM5	TGCAACTTCTAGCTGCTCGA	GCATCCGATCTTGATGGG	(GA)14	1
RM237	CAAATCCCGACTGCTGTCC	TGGGAAGAGAGCACTACAGC	(CT)18	1
RM283	GTCTACATGTACCCTTGTTGGG	CGGCATGAGAGTCTGTGATG	(GA)18	1
RM431	TCCTGCGAACTGAAGAGTTG	AGAGCAAAACCCTGGTTCAC	(AG)16	1
RM495	AATCCAAGGTGCAGAGATGG	CAACGATGACGAACACAACC	(CTG)7	1
OSR 13	CATTTGTGCGTCACGGAGTA	AGCCACAGCGCCCATCTCTC	(GA)n	3
RM489	ACTTGAGACGATCGGACACC	TCACCCATGGATGTTGTCAG	(ATA)8	3
RM338	CACAGGAGCAGGAGAAGAGC	GGCAAACCGATCACTCAGTC	(CTT)6	3
RM55	CCGTCGCCGTAGTAGAGAAG	TCCCGGTTATTTTAAGGCG	(GA)17	3
RM514	AGATTGATCTCCCATTCCCC	CACGAGCATATTACTAGTGG	(AC)12	3
RM124	ATCGTCTGCGTTGCGGCTGCTG	CATGGATCACCGAGCTCCCCCC	(TC)10	4
RM161	TGCAGATGAGAAGCGGCGCCTC	TGTGTCATCAGACGGCGCTCCG	(AG)20	5
RM334	GTTCAGTGTTCAGTGCCACC	GACTTTGATCTTTGGTGGACG	(CTT)20	5
RM413	GGCGATTCTTGGATGAAGAG	TCCCCACCAATCTTGTCTTC	(AG)11	5
RM507	CTTAAGCTCCAGCCGAAATG	CTCACCCTCATCATCGCC	(AAGA)7	5
RM437	ATCCCTCCTCTGCTCAATGTTGG	TCAGGGAGGGTCCTAGCTACTGG	(AG)13	5
RM162	GCCAGCAAAACCAGGGATCCGG	CAAGGTCTTGTGCGGCTTGCGG	(AC)20	6
RM510	AACCGGATTAGTTTCTCGCC	TGAGGACGACGAGCAGATTC	(GA)15	6
RM11	TCTCCTCTTCCCCCGATC	ATAGCGGGCGAGGCTTAG	(GA)17	7
RM118	CCAATCGGAGCCACCGGAGAGC	CACATCCTCCAGCGACGCCGAG	(GA)18	7
RM125	ATCAGCAGCCATGGCAGCGACC	AGGGGATCATGTGCCGAAGGCC	(GCT)8	7
RM25	GGAAAGAATGATCTTTTCATGG	CTACCATCAAAACCAATGTTC	(GA)18	8
RM152	GAAACCACCACACCTCACCG	CCGTAGACCTTCTTGAAGTAG	(GGC)10	8
RM433	TGCGCTGAACTAAACACAGC	AGACAAACCTGGCCATTCAC	(GT)10	8
RM447	CCCTTGTGCTGTCTCCTCTC	ACGGGCTTCTTCTCCTTCTC	(CTT)8	8
RM105	GTCGTCGACCCATCGGAGCCAC	TGGTCGAGGTGGGGATCGGGTC	(CCT)6	9
RM271	TCAGATCTACAATTCCATCC	TCGGTGAGACCTAGAGAGCC	(GA)15	10
RM171	AACGCGAGGACACGTACTTAC	ACGAGATACGTACGCCTTTG	(GATG)5	10
RM144	TGCCCTGGCGCAAATTTGATCC	GCTAGAGGAGATCAGATGGTAGTGCATG	(ATT)11	11
RM536	TCTCTCCTCTTGTTTGGCTC	ACACACCAACACGACCACAC	(CT)16	11
RM277	CGGTCAAATCATCACCTGAC	CAAGGCTTGCAAGGGAAG	(GA)11	12
RM19	CAAAAACAGAGCAGATGAC	CTCAAGATGGACGCCAAGA	(ATC)10	12

Data analysis: The gel images were scored using a binary system that recorded as ′1′ and ′0′ for the presence and absence of bands, respectively. From the binary data, the similarity coefficient values between the germplasm lines were derived with Jaccard′s correlation analysis using NTSYSpc version 2.1 (Rohlf, 1998). This software was also used to construct a UPGMA (Unweighted Pair Group Method with arithmetic averages) dendrogram showing Nei distance based interrelationship among the genotypes.

RESULTS AND DISCUSSION

The germplasm accessions in the present study were collected from different regions/parts of Bihar. Some of the collections were from Indian Institute of Rice Research, Hyderabad and International Rice Research Institute, Philippines. Average and range of pre and post harvest morphological data of 226 lines in Tiloundha, Sabour and Patna germplasm collections taken on eight parameters has been given in Table 2. Three years data of 2012, 2013 and 2015 were averaged to get final mean value of each trait.

The mean value of days of 50% flowering, plant height, panicle length and flag leaf length in Tiloundha collected germplasm was higher as compared to Patna and Sabour germplasm. Tiller number, grain length and L/B ratio was higher in Sabour germplasm accessions whereas grain breadth was higher in Patna germplasm. On the basis of morphological data, the germplasm accessions were classified into different categories as per the national guideline of DUS (distinctness, uniformity and stability) guidelines given by Rani *et al.* (2006). All the accessions of Tiloundha were tall and late maturing whereas the collection from Patna and Sabour were semi-dwarf to tall with medium to late maturity. The panicle length was medium to long in Tiloundha accessions whereas it was short to medium in both Patna and Sabour accessions. Based on the grain length and L/B ratio, the grains of Tiloundha collections fall into short to medium slender category whereas Patna and Sabour accessions had long, medium and short slender grained category (Table 3).

The quantitative data based on the 0, 1 matrix of the morphological traits were analysed to get the similarity between the genotypes in Tiloundha, Patna and Sabour. The entries showing more than 65% similarity coefficient have been mentioned in the Table 4. 44 different combinations of 45 entries in Tiloundha, 9 combinations of 16 entries in Patna and 14 combinations of 17 entries in Sabour collection, had more than 65% similarity on the morphological traits.

Higher similarity percentage between the accessions raised a doubt of duplications of entries which might be aroused during collection or maintenance of lines year after year. Hence, in order to further estimate the extent of similarities at molecular level between entries, molecular diversity between the entries through NTSYS was analysed after carrying out the PCR using SSR markers. Out of thirty three SSR markers, the amplification of eight SSR markers in Tiloundha and two SSR markers in Patna and Sabour collections were not clear and hence didn′t scored. The molecular diversity analysed through the scoring of amplified products, showed 56 alleles in Tiloundha, 63 alleles in Patna and 61 alleles in Sabour germplasm collections, respectively. The PIC value of 0.449 in Tiloundha with RM5 and 0.500 with RM161 and RM55, respectively in Patna and Sabour germplasm accessions were found to be highest (Table 5).

The genetic similarity analysis using UPGMA clustering agreed with the neighbouring joining data (Figure 1). At 0.5 Nei distance, six clusters in Tiloundha and five clusters in Sabour and Patna collections were formed. In this molecular similarity, 21 out of 45 entries in Tiloundha collection showed

Table 2. Morphological trait data in Tiloundha, Sabour and Patna germplasm collections (2012-2015)

Trait	Germplasm collection		
	Tiloundha (Total lines=74)	Patna (Total lines=93)	Sabour (Total lines=59)
	Mean (Range)		
Days of 50% flowering	122 (117-126)	110 (92-126)	110 (94-123)
Plant height (cm)	150 (133-178)	115 (84-149)	138 (93-185)
Tiller No.	11 (8-16)	11 (8-17)	12 (8-16)
Panicle length (cm)	27 (24-30)	24 (20-27)	26 (22-31)
Flag leaf length (cm)	29 (22-37)	26 (20-35)	29 (24 -34)
Grain length (mm)	4.7 (3.8 −5.9)	6 (4.26-7.22)	6 (3.8-8.1)
Grain breadth (mm)	1.6 (1.4 – 1.9)	2 (1.53-2.12)	2 (1.3-1.9)
L/B ratio	3 (2.3 – 3.9)	3 (2.66-4.28)	3 (2.4-4.7)

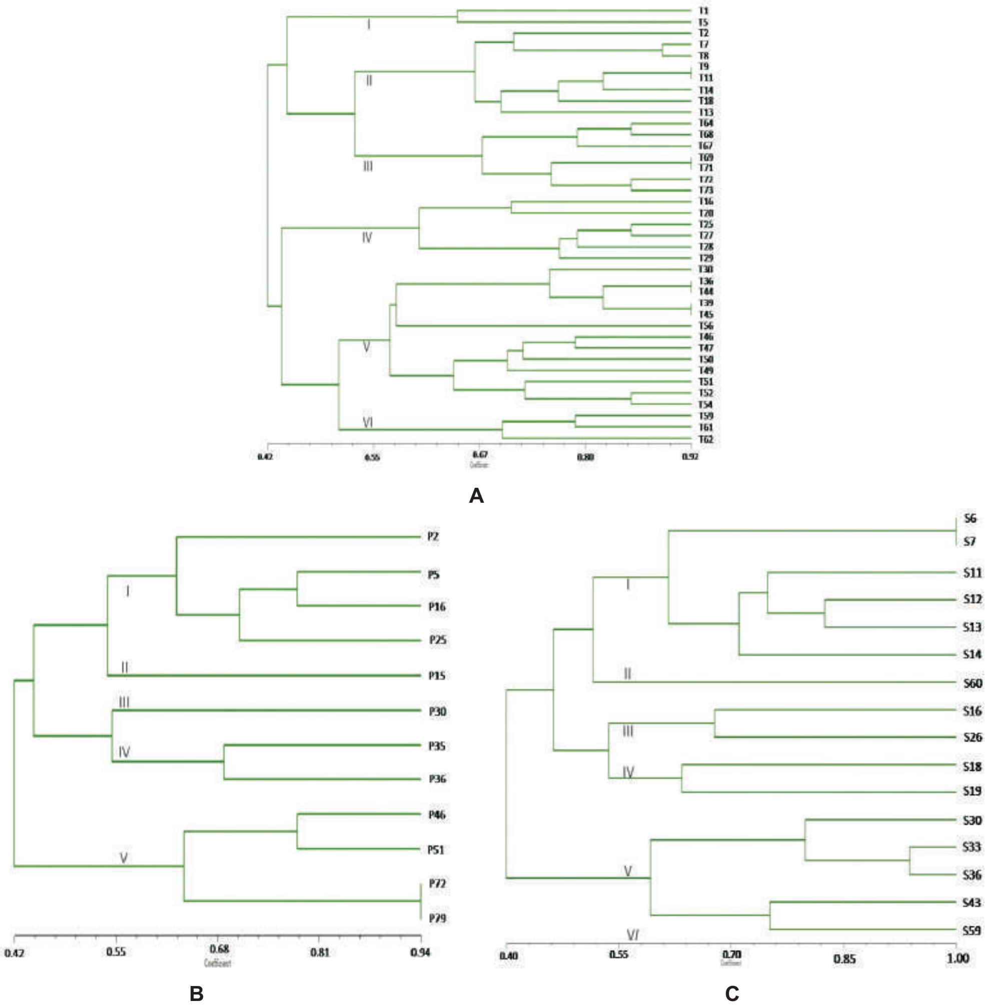

Fig. 1. A rooted neighbour-joining tree showing the genetic relationships among genotypes in Tiloundha (A), Patna (B) and Sabour (C) collections.

Table 4. Details of entries having more than 65% Jacard′s similarity coefficient based on the 0, 1 matrix of morphological data

Germplasm	Combination of lies showing more than 65% similarities with each other	Total entries
Tiloundha Collection	T1/5, T7/8, T2/11, T9/13, T8/14, T8/18, T16/20, T24/25, T7/27, T8/27, T29/30, T18/39, T44/46, T51/50, T52/36, T40/54, T45/55, T51/55, T46/55, T49/56, T29/59, T30/59, T62/64, T46/67, T49/67, T29/68, T30/68, T64/68, T67/68, T56/61, T47/61, T29/62, T29/64, T30/64, T59/64, T69/71, T28/72, T29/73, T30/73, T50/73, T61/74, T71/74, T61/75, T74/75	45
Patna Collection	P2/5, P2/25, P30/38, P16/51, P46/79, P36/114, P114/115, P15/117, P35/120	16
Sabour Collection	S4/6, S6/7, S13/14, S14/18, S18/19, S16/26, S12/30, S18/33, S4/43, S6/36, S11/59, S43/60, S30/60, S6/60	17

Note: T, P and S stands for Tiloundha, Patna and Sabour germplasm collections

90% similarity at molecular level. Similarly in Patna and Sabour germplasm collection 2 and 4 entries showed more than 90% similarity respectively (Table 6).

The new combination of germplasm accessions in all three collections (except similarity between T69 and 71 and between S6 and 7) appeared which showed more than 90 percent similarity at molecular level. The combination of genotypes which showed 60% similarity on morphological basis had less than 90 or even 60 percent less similarity at molecular level in all the three collections. The occurrence of higher morphological and molecular (> 90%) similarity between accessions T69/71 and S6/7 indicated duplications.

Table 3. Classification of germplasm collections on the basis of morphological traits

Morphological traits	Levels	Number of germplasm accessions		
		Tiloundha	Patna	Sabour
Date of 50% flowering	Medium (91–110 days)	Nil	50	25
	Late (111–130 days)	75	43	34
Plant height (cm)	Semi-dwarf (≤110cm)	Nil	40	6
	Intermediate (111–130cm)	Nil	27	16
	Tall (≥130cm)	75	26	37
Panicle length (cm)	Short (16–20cm)	Nil	82	19
	Medium (21–25cm)	19	10	39
	Long (26–30cm)	55	Nil	1
Grain Shape	Long Slender (L ≥6mm; L/B ≥3)	Nil	56	21
	Short Slender (L < 6mm; L/B ≥3)	34	26	25
	Medium Slender (L < 6mm; L/B=2.5 to 3.0)	46	11	16
	Long Bold (L ≥6 mm; L/B < 3)	Nil	Nil	Nil
	Short Bold (L< 6; L/B< 2.5mm)	5	Nil	2

There are several reports of rice germplasm characterisation on morphological and molecular basis. Mahure *et al.* (2011) characterised 38 aromatic rice cultivars on the basis of UPGMA based cluster analysis of morphological traits. Molecular characterisation of rice germplasm using SSR markers is reported by Patel *et al.* (2015), Matin *et al.* (2012) and Pervaiz *et al.* (2010). Characterisation of rice germplasm both on morphological and molecular basis has been observed by Roy *et al.* (2014), Shakil *et al.* (2015) and Lang *et al.* (2014). Rahman *et al.* (2011) documented the genetic diversity of 21 rice varieties in respect of 13 morphological, 14 physiological traits and at molecular level using 34 SSR markers.

The present investigation reveals that SSR markers based molecular fingerprinting could serve as a tool in the identification of genetically distant genotypes as well as in sorting of duplications in morphologically close accessions. The utilisation of 31 SSR markers in the analysis of rice germplasm collections showed a high level of polymorphism which gave sufficient information for the identification of the genotypes as well as isolation of duplicate entries. Hence, the characterisation of rice germplasm only on the basis of morphological attributes may give wrong information due to the large effect of environmental factors. This should be validated on molecular basis for the actual insight into the allelic diversity among the germplasm accessions.

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Table 5. PCR amplification of SSR makers used for molecular characterisation of Tiloundha, Patna and Sabour morphologically similar accessions

Name of the marker	No. of allele			PIC Value		
	Tiloundha collection	Patna collection	Sabour collection	Tiloundha collection	Patna collection	Sabour collection
RM 55	2	2	2	0.295	0.375	0.500
RM 5	3	3	2	0.449	0.417	0.469
RM 271	3	2	1	0.224	0.375	0.000
RM 124	3	1	2	0.380	0.000	0.219
RM 152	1	3	3	0.000	0.269	0.318
RM 312	1	1	1	0.000	0.000	0.000
RM 334	1	3	3	0.000	0.417	0.370
RM 338	2	1	3	0.426	0.000	0.411
RM 413	3	2	1	0.231	0.278	0.000
RM 507	3	2	2	0.394	0.486	0.219
RM 510	1	2	2	0.00	0.375	0.318
RM 514	2	2	3	0.097	0.278	0.372
RM 11	3	4	2	0.371	0.361	0.430
RM 19	3	2	3	0.385	0.250	0.409
RM 25	2	3	2	0.405	0.380	0.375
RM 105	2	1	2	0.473	0.00	0.305
RM 118	3	3	2	0.444	0.361	0.469
RM 125	1	2	1	0.000	0.500	0.00
RM 161	3	3	2	0.338	0.361	0.492
RM 162	2	3	2	0.484	0.413	0.387
RM 171	3	2	1	0.331	0.375	0.00
RM 237	2	2	3	0.142	0.486	0.411
RM 433	2	1	1	0.260	0.000	0.000
RM 447	2	1	1	0.473	0.360	0.321
RM 489	3	3	2	0.268	0.255	0.305
OSR 13	−	1	2	−	0.00	0.430
RM 144	−	3	2	−	0.361	0.305
RM 536	−	3	1	−	0.269	0.00
RM 277	−	2	2	−	0.444	0.492
RM 495	−	1	2	−	0.00	0.492
RM 431	−	2	3	−	0.444	0.359
Total	65	63	61			

Table 6. Entries having more than 90% Jacard′s similarity coefficient based on the 0, 1 matrix of molecular data

Germplasm	Combination of lies showing more than 65% similarities with each other	Total entries
Tiloundha collection	T7/8,T9/11,T11/14,T27/28,T27/29,T36/39,T36/44,T39/45, T44/45, T52/54, T64/67, T64/68,T69/71, T71/72 and T72/73	21
Patna collection	P72/79	2
Sabour collection	S6/7, S36/33	4

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Pollinator Diversity and Relative Abundance of Insect Visitors on Apple (*Malus domestica* Borkh) In Kashmir Valley

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Abstract: The present investigation was undertaken to estimate the availability (diversity and abundance) of the native pollinators of Kashmir valley in three districts-during-2011-12. The apple flowers were visited by 59 insect species belonging to 28 families and five orders Hymenoptera, Diptera, Lepidoptera, Coleoptera and Odanata. Hymenoptera were represented by 12, Diptera by 10, and rest by 2 family each. Overall, maximum number of 27 and 24 species of Hymenoptera and Diptera registered their occurrence in selected apple orchards followed by Lepidoptera and Coleoptera, each of which represented by 5 species. The peak intensity of Hymenoptera, Lepidoptera, Coleoptera visitors was observed between 10-11am, when the temperature of the orchards ranged between 21.5 to 22.3 °C, whereas, for Diptera peak intensity was between 8-9am at comparatively lower temperature ranging 15.9 to 16.3 °C. Irrespective of different day hours, the Hymenoptera recorded maximum visitors (74.94%) followed by Diptera (18.86%), Lepidoptera (3.38%) and Coleoptera (3.04%).

Keywords: Apple, Pollination, Diversity, Insect species, Hymenoptera, Diptera

Pollination is one of the most important mechanisms in the maintenance and promotion of biodiversity and, in general, life on earth. Pollinators are extremely diverse, with more than 20,000 pollinating bee species and numerous other insect and vertebrate pollinators (Thapa *et al*., 2006). Pollinator communities are well known to vary considerably across environmental gradients and among bio-geographic regions. Insect pollinators mostly bees are necessary for pollination of 75% crops that are used directly for human food worldwide (Potts *et al.,* 2010) and the total annual economic value of crop pollination worldwide is about $153billion (Gallia *et al.,* 2009). Mattu (2013) emphasized that flower-visiting insects provide an important ecosystem function to global crop production through their pollination services. In recent years apple has emerged as the leading cash crop of Kashmir amongst temperate fruit crops, representing 98% of total fruit production and fetching a higher income to the state. Despite the last few years the production per hectare has come down inspite of increase in area under apple cultivation. Apple has a gametophytically self incompatible (SI) system, which prevents inbreeding and promotes out crossing (Stern *et al*., 2001), and fruit set depends strongly on cross pollination (Delaney and Tarpy, 2008). Cross pollination is brought by insect pollinators that visit flowers for the nectar and/or pollen collection. Even under same environmental conditions, a variety of insects have been reported to visit the apple blossom and many of them are efficient pollinators as individuals but the services are often provided by unmanaged pollinator communities (Kluser and Peduzzi, 2007). The necessity of relying so heavily on one species of managed pollinators (*Apis Mellifera*) is now being questioned (Blitzer *et al*., 2016). So, there is a need for changed strategies and look for other possible inputs such as full use of under-utilized and eco-friendly resources like the conservation of the native pollinators which provide much of the pollination services needed for apple production and may enhance fruit quality regardless of honeybee visitations. In order to formulate effective conservation there is urgent need to generate information regarding the native species. As little information is available related to abundance and efficacy of native insect visitors in apple orchard ecosystems of Kashmir valley Therefore, present investigation was conducted to collect various insect visitors and work out their relative abundance in different apple orchards of Kashmir valley.

MATERIAL AND METHODS

Study Area: The study was conducted in three apple orchards (one hectare each) located at three different districts of Kashmir viz., Anantnag, Srinagar, and Baramulla during 2011-12. The selection of the site was given an important focus in order to obtain the average data representing native insect fauna in apple orchards of Kashmir valley.

Collection and identification of the pollinators: Various insect pollinators visiting apple blossoms were collected by using cone type insect collecting nets. Sweeps were made throughout blooming period. Insects were preserved as dry specimen. Collected insects were sorted out in the laboratory and got identified at insect Identification laboratory, Division of Entomology, IARI, New Delhi.

Table 1. Insect visitors of apple bloom with taxonomic status in three districts of Kashmir during 2011–12

Order	Family	Genus/Species	Anantnag	Srinagar	Baramulla
Coleoptera	Coccinellidae	*Coccinella eptumpunctata* L.	✓	✓	✓
		Hippodamia variegata (Goeze)	✓	X	✓
	Chrysomelidae	*Altica cyanea* Weber	✓	✓	✓
Hymenoptera	Apidae	*Apis mellifera*	✓	✓	✓
		Apis cerana indica F	✓	✓	✓
		Eucera vernalis (Morawitz)	X	✓	X
		Anthophora sp. indet	✓	✓	✓
		Xylocopa sp	✓	✓	✓
		Anthophora confuse Smith	✓	X	✓
		gen.et. sp. indet	✓	X	✓
		Bombus funerarius Smith	✓	✓	✓
		Thyreus nitidulus (Fabricius)	X	✓	X
	Halictidae	*Lasioglossum* sp.	✓	✓	✓
		Ceratina hieroglyphica Smith	✓	✓	X
		Halictus sp	✓	✓	✓
		Ceratina sp	✓	X	X
		Polistes maculipennis Saussure	X	✓	X
	Vespidae	*Polistes* sp.indet.	X	✓	X
		Odynerus sp.	✓	✓	X
		Polistes sp	X	X	✓
		Vespa auraria Smith	✓	✓	✓
	Andrenidae	*Andrena gravida* Imhoff	X	✓	✓
	Ichneumonidae	*Pimpla* sp.	✓	X	✓
	Megachilidae	*Megachile* sp.	X	✓	✓
		Osmia sp.	✓	✓	X
	Sphecidae	*Pison punctifrons* Shuckard	✓	✓	X
	Sapygidae	*gen.et.* sp. indet.	X	X	✓
	Pompilidae	*gen.et.* sp. indet.	X	✓	✓
	Tenthredinidae	*Athalia proxima* Klug	✓	X	✓
	Scoliidae	*Megascolia haemorrhoidalis*	X	X	✓
	Eumenidae	*Rhychium* sp	✓	✓	X
Diptera	Syrphidae	*Eristalis soliatus* Walker	✓	✓	✓
		Eristalinus sp.indet.	✓	✓	X
		Didea fasciata Macquart	X	✓	✓
		Scaeva pyrastri L	X	✓	✓
		Syrphus baltiatus De Geer	✓	✓	✓
		Syritta sp.indet	✓	X	X
		Sphaerophoria sp.indet	X	X	✓
		Syritta orientalis (L.)	X	✓	X
		Eristalis tenax (L.)	✓	✓	✓
		Eristalis arbustorum (L.)	✓	X	X
		Eristalis sp.indet	X	✓	✓
		Sphaerophoria scripta (L.)	✓	✓	X
		Helophilus trivittatus (F.)	X	X	✓

Cont..

	Bombylidae	*Bombylus major* L.	X	✓	X
		gen.et sp.indet	X	✓	X
	Bibionidae	*Bibio* sp.indet	X	✓	✓
	Stratiomyiidae	*gen.et* sp.indet	X	✓	X
	Calliphoridae	*Chrysomyia* sp.indet	X	✓	✓
		Pseudopyrellia sp.indet	X	✓	✓
	Asilidae	*Machinus* sp.indet	X	✓	✓
	Fannidae	*Fanna* sp.indet.*	✓	✓	X
	Muscidae	*Musca domestica*	✓	✓	✓
	Sarcophagidae	*Sarcophaga* sp.indet.	X	✓	X
	Dryomyzidae	*gen.et* sp.indet	✓	✓	X
Lepidopteran	Brassicae	*Pierus brassicae*	✓	✓	✓
	Pieridae	*Cynthia cordui* (Linn)	✓	✓	X
	Pieridae	*Colias romonovi* Gr. Gosh	✓	X	X
Odonata	Coenagrionidae	*Ischnura pumilio*	✓	✓	X
	Libellulidae	*Libellula quadrimaculata*	✓	X	✓

Relative abundance: Observations on relative abundance of insect pollinators was made during flowering period, 10 trees of uniform size, age and vigour were selected at random throughout the orchards at all the three locations. The branches of experimental trees were chosen in such a way, that they were of approximately same dimensions with respect to their spread, phase of flowering, number of flowers and height above the ground. The observations were started two days after the commencement of flowering and recorded right from the initiation to the cessation of flight activities throughout the day at hourly intervals. The counts of insect visits were taken in one square meter bloom area for fifteen minutes in the beginning of each hour, replicated five times, between mornings (0800–0900,0900–1000, and 1000–1100h) and evening (1500–1600, 1600–1700, and 1700–1800h) for seven sunny days at each location and average counts at these hours gave abundance of an insect pollinator for the particular day.

RESULTS AND DISCUSSION

Diversity of Insect visitors: During the 2011–12, a total of 59 insect visitors belonging to 5 orders and 28 families of class insect were recorded from apple bloom from three districts of Kashmir valley. Out of these, 27 insect visitors belonged to Hymenoptera, 24 to Diptera, 3 to Lepidoptera, 3 to Coleopteran and 2 to Odonata. The information on diversity of insect visitors of apple in Kashmir is very scanty and the present investigation on insect pollinator diversity is first detailed finding. Many investigators have reported diverse findings and the present findings draw the support from the observations of Mattu and Bhagat (2015), who reported that apple flowers in Solan (H.P) were visited by 39 species of insects belonging to 6 orders and 19 families of class Insecta. Similar results registered by Raj *et al.* (2012) also showed that apple flowers were visited by 46 species of insect species belonging to 5 orders and 17 families. However, in the present investigation the 59 insect visitors although belonged to 5 orders but were distributed among 29 families. A similar survey conducted by Park *et al.* (2010) revealed a total of 81 species of bees visiting apple blossom and reported that native bees such as *Andrena, Osmia* and *Bombus* were effective vectors of apple pollen .Similar findings were also reported by Hussain *et al.* (2012), the results of which confirmed that 9 species of insects belonged to five genera of order Hymenoptera. The findings of the study are also supported by the work of Verma and Chauhan (1985), who reported 44 species of which 16 species belonged to Hymenopterans, 11 to Dipterans, 9 to Lepidopterans, 7 to Coleopterans and 1 to Hemiptera. The recent findings are in tune with the results of Saeed *et al* (2012) who confirmed that pollinator community was composed of 15 insect species belonged to three orders and 10 families. Dashad and Sharma (1993) reported a total of 19 insects belonging to 11 genera under 6 families, while as Thakur (2005) reported 48 species of insects belonging to 5 orders and 18 families of class insect. Differences in number of species recorded recorded by different workers including the present investigation are attributed to differences in agroclimatic conditions of the localities, differential adaptability of a particular native species to its local environmental conditions or due to orientation of other insect visitors to apple during bloom.

Relative Abundance of Major Insect Pollinators

Hourly fluctuations in the population: Results on hourly

Table 2. Relative Abundance of insect pollinators in Anantnag (2011–12)

Hours of observation/	No. of pollinators/m^2 branch/15minutes											
	Apis mellifera	*Apis cerana*	*Lasioglossum moroi*	*Bombus funerarius*	*Xylocopa fenestrata*	*Vespa auraria*	*Halictus confusus*	*Eristalis tenax*	*Syrphus balteatus*	*Musca domestica*	*Pieris brassicae*	*Coccinella septumpunctata*
8-9 am	3.436 ±0.183	3.457 ±0.131	1.379 ±0.076	0.750 ±0.064	0.514 ±0.057	0.050 ±0.017	0.471 ±0.057	3.300 ±0.071	2.929 ±0.061	2.993 ±0.089	0.036 ±0.019	0.650 ±0.069
9–10 am	3.907 ±0.195	3.557 ±0.075	2.871 ±0.148	1.193 ±0.150	0.771 ±0.143	0.757 ±0.143	0.636 ±0.086	1.114 ±0.045	1.329 ±0.115	1.943 ±0.087	1.386 ±0.089	0.857 ±0.091
10–11 am	5.321 ±0.222	4.443 ±0.166	3.657 ±0.215	1.379 ±0.221	1.450 ±0.279	1.029 ±0.257	1.079 ±0.090	1.736 ±0.066	1.679 ±0.115	1.300 ±0.102	2.043 ±0.099	1.200 ±0.110
3-4 pm	5.121 ±0.145	4.414 ±0.103	3.186 ±0.153	1.279 ±0.293	1.121 ±0.207	0.842 ±0.143	0.821 ±0.092	1.871 ±0.087	2.000 ±0.141	1.486 ±0.140	1.600 ±0.085	1.107 ±0.087
4-5 pm	3.093 ±0.143	2.636 ±0.110	2.479 ±0.123	1.236 ±0.264	1.079 ±0.264	0.807 ±0.193	0.779 ±0.094	2.229 ±0.072	2.314 ±0.117	2.614 ±0.061	1.514 ±0.099	1.107 ±0.086
5-6 pm	1.921 ±0.086	2.143 ±0.106	1.486 ±0.105	1.021 ±0.007	0.779 ±0.150	0.000 ±0.000	0.450 ±0.081	1.829 ±0.076	1.979 ±0.100	1.671 ±0.087	0.000 ±0.000	0.757 ±0.088
Mean	3.80	3.44	2.51	1.143	0.95	0.58	0.71	1.85	2.04	1.83	1.10	0.95

Values are Mean±S.E based on 10 observations

Table 3. Relative abundance of insect pollinators on apple in Srinagar (2011–12)

Hours of observation/ timings	No. of pollinators/m^2 branch/15minutes											
	Apis mellifera	*Apis cerana indica*	*Lasioglossum moroi*	*Bombus funerarius* Smith	*Xylocopa fenestrata*	*Vespa auraria*	*Halictus confusus*	*Eristalis tenax*	*Syrphus balteatus*	*Musca domestica*	*Pieris brassicae*	*Coccinella septumpunctata*
8-9 am	3.879 ±0.103	4.036 ±0.140	1.014 ±0.089	1.064 ±0.207	1.236 ±0.679	0.107 ±0.070	0.479 ±0.076	2.650 ±0.151	2.750 ±0.087	2.514 ±0.072	0.050 ±0.025	0.693 ±0.096
9–10 am	4.136 ±0.127	4.293 ±0.133	1.864 ±0.136	0.782 ±0.676	0.557 ±0.457	1.214 ±0.200	0.814 ±0.105	2.143 ±0.073	2.193 ±0.097	1.771 ±0.097	0.757 ±0.071	1.014 ±0.100
10–11 am	4.629 ±0.148	4.693 ±0.119	2.500 ±0.113	1.557 ±0.043	1.193 ±0.022	1.500 ±0.114	0.971 ±0.105	1.400 ±0.095	1.600 ±0.127	2.043 ±0.104	1.321 ±0.110	1.129 ±0.113
3-4 pm	4.343 ±0.112	3.757 ±0.152	2.200 ±0.134	1.269 ±0.398	1.436 ±0.436	1.067 ±0.990	0.893 ±0.098	1.786 ±0.082	1.600 ±0.121	1.229 ±0.121	1.029 ±0.106	1.121 ±0.115
4-5 pm	4.086 ±0.145	3.771 ±0.129	1.879 ±0.118	1.193 ±0.207	0.721 ±0.637	0.793 ±0.193	0.779 ±0.087	2.297 ±0.097	2.379 ±0.128	2.121 ±0.111	0.807 ±0.100	1.116 ±0.115
5-6 pm	3.693 ±0.109	2.536 ±0.163	1.329 ±0.099	0.651 ±0.578	0.605 ±0.509	0.054 ±0.054	0.721 ±0.101	2.271 ±0.119	1.921 ±0.105	1.779 ±0.089	0.000 ±0.000	0.771 ±0.091
Mean	3.961	3.848	1.798	1.086	0.958	0.789	0.776	2.091	2.074	1.910	0.661	0.982

Table 4. Relative Abundance of insect pollinators on apple in Baramulla (2011– 12)

Hours of observation/ timings	No. of pollinators/m² branch/15minutes											
	Apis mellifera	*Apis cerana indica*	*Lasioglossum moroi*	*Bombus funerarius Smith*	*Xylocopa fenestrata*	*Vespa auraria*	*Halictus confusus*	*Eristalis tenax*	*Syrphus balteatus*	*Musca domestica*	*Pieris brassicae*	*Coccinella septumpunctata*
8–9 am	3.879 ±0.103	4.03	1.014 ±0.089	1.064 ±0.207	1.236 ±0.679	0.107 ±0.070	0.479 ±0.076	2.650 ±0.151	2.750 ±0.087	2.514 ±0.072	0.050 ±0.025	0.693 ±0.096
9–10 am	4.136 ±0.127	4.293	1.864 ±0.136	0.782 ±0.676	0.557 ±0.457	1.214 ±0.200	0.814 ±0.105	2.143 ±0.073	2.193 ±0.097	1.771 ±0.097	0.757 ±0.071	1.014 ±0.100
10–11 am	4.629 ±0.148	4.693	2.500 ±0.113	1.557 ±0.043	1.193 ±0.022	1.500 ±0.114	0.971 ±0.105	1.400 ±0.095	1.600 ±0.127	2.043 ±0.104	1.321 ±0.110	1.129 ±0.113
3–4 pm	4.343 ±0.112	3.757	2.200 ±0.134	1.269 ±0.398	1.436 ±0.436	1.067 ±0.990	0.893 ±0.098	1.786 ±0.082	1.600 ±0.121	1.229 ±0.121	1.029 ±0.106	1.121 ±0.115
4–5 pm	4.086 ±0.145	3.771	1.879 ±0.118	1.193 ±0.207	0.721 ±0.637	0.793 ±0.193	0.779 ±0.087	2.297 ±0.097	2.379 ±0.128	2.121 ±0.111	0.807 ±0.100	1.116 ±0.115
5–6 pm	3.693 ±0.109	2.536	1.329 ±0.099	0.651 ±0.578	0.605 ±0.509	0.054 ±0.054	0.721 ±0.101	2.271 ±0.119	1.921 ±0.105	1.779 ±0.089	0.000 ±0.000	0.771 ±0.091
Mean	3.961	3.848	1.798	1.086	0.958	0.789	0.776	2.091	2.074	1.910	0.661	0.982

fluctuation (Tables 2–4) of different insect visitors during different hours of the day at all the locations showed that population density of pollinating insects varied during different hours of the day. *Apis mellifera* L. was predominant during all the periods of the day and was more frequent between 10–11am (21.5 to 22.3 °C) at all the three locations. Similarly, population of all other insect visitors was higher between 10–11am at Anantnag, Baramulla and Srinagar i.e. A*pis cerana indica* (Fabricius), *Lasioglossum moroi* (Fabricius), *Bombus funerarius* Smith, *Xylocopa fenestrata* (Fabricius) *Vespa auraria* Smith, *Halictus confuses* Smith, *Pieris brassicae* (L.) and *Coccinella septumpunctata* L. These findings are in confirmity with the findings of Neelima and Kumar (1997), who reported that insect visitors (*Apis mellifera* and *Apis cerana indica* F.) were more frequent in the morning hours (10–11am) than in the evening (4–5pm). Kaur and Kumar (2013) registered maximum number of insect visitors at 12:00pm when air temperature ranged between 15 to 32 °C and the graph declined rapidly after 03:00pm.

However, frequencies of Dipterans like *Eristalis tenax* (L.), *Syrphus balteatus* De Geer and *Musca domestica* at Anantnag, Baramulla and Srinagar at 8–9am when the temperature of the orchards were low (15.9 to 16.3°C). Furthermore, different timings in the peak activity of different bee species reflect the ecological adaptation of each bee species and this behavior avoids the competition between the closely related species or ecotypes to utilize the available resources (Semida and Elbanna, 2006).

Comparative Abundance of Major Insect Pollinators

The hymenptera were most abundant insect pollinators of apple collectively in all the three districts constituting about 71.08 per cent of total and were represented by three important families. The Hymenoptera were followed by Diptera spread over 2 families syrphidae and musidae The Coleopteran and Lepidoptera represented by families, coccinellidae and brassicae. Among species, *Apis mellifera* L. was the most abundant and frequent pollinator followed by *Apis cerana indica* F. These results corroborate the findings of Raj (2012), who also reported the Hymenopterans (*Apis mellifera* L. and *Apis cerana Indica* F.) hipterans (*Musca domestioca* and *Eristalis angustimarginalis*) as the most important important insect pollinators on apple. The higher population of Hymenopterans in experimental orchards may be due to their being native species and thus having better adaptability to local environmental conditions as also supported by the findings of Raj *et al.* (2012). Mattu and Bhagat (2015) also reported hymenopterans (45.59%)and dipterans (37.12%) as the most abundant. insect pollinators of apple.

Table 5. Comparative abundance of insect visitors population in Kashmir

Order	Family	Genus/species	Comparative abundance	Population (%)	Family (%)	Order (%)
Hymenoptera	Apidae	*Apis mellifera*	4.086±0.152*	22.19	52.24	71.08
		Apis cerana indica	3.514±0.170	19.08		
		Xylocopa fenestrata	1.162±0.044	6.31		
		Bombus funerarius	0.858±0.035	4.66		
	Vespidae	*Vespa auraria*	0.711±0.087	3.86	3.86	
	Halictidae	*Lasioglossum moroi*	2.013±0.249	10.93	14.98	
		Halictus confuses	0.744±0.027	4.05		
Dipteran	Syrphidae	*Eristalis tenax*	1.473±0.120	8.00	15.01	20.21
		Syrphus balteatus	1.291±0.039	7.01		
	Muscidae	*Musca domestica*	0.958±0.030	5.20	5.20	
Lepidopteran	Brassicae	*Pieris brassicae*	0.850±0.128	4.61	4.61	4.61
Coleopteran	Coccinellidae	*Coccinella septumpunctata*	0.951±0.016	5.61	5.61	5.61

CONCLUSION

The present studies suggested that besides honey bees the population of other native bees range from abundant to insignificant on apple bloom e.g., *Xylocopa fenestrata*, *Lassioglossum moroi*, *Halictus confusus*, *Syrphus baltaitus, Eristalis tenax*. The emerging technology of managed bees need to be exploited for future pollination services. Their breeding techniques and mass rearing can be standardized and synchronized with the appropriate blooming stage which fully compensate the relative inefficiencies of apple pollination.

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Cultural and Physiological Characters of *Curvularia lunata* Causal Agent of Leaf Spot in Maize

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Abstract: Curvularia leaf spot, caused by *Curvularia lunata* (Wakker) Boedij is an important disease of maize in India. *C. lunata* gave maximum dry mycelial weight of 268.74 mg on seventeenth day after incubation and was optimum period for incubation. Among the solid media tested, the maximum colony diameter (90.00 mm) was on potato dextrose agar and Richards agar. Among the various liquid media tested, maximum dry mycelial weight was in potato dextrose medium, followed by Richards medium. The diverse response of *C. lunata* to different temperature and different pH levels was observed. The maximum colony diameter of the fungus was at 25^o and 30^oC (90.00mm) and maximum dry mycelial weight was at 30^oC (285.41 mg). The maximum dry mycelial weight was at pH 5.5–6.0.

Keywords: Curvularia leaf spot, *Curvularia lunata*, Maize, Cultural, Physiological studies

Maize (*Zea mays* L.) is one of the important cereal crops in the world agricultural economy and grown in more than 160 countries in tropical, sub-tropical and temperate regions. In India, maize is the third most important cereal crop after rice and wheat. But, maize is being plagued by an array of diseases which include the leaf spot of maize caused by *Curvularia lunata.* The incidence of this disease was first reported in India as *Curvularia clavata* from Varanasi region of Uttar Pradesh (Mandokhot and Basu Chaudhary, 1972). It causes significant damage to maize upto 60 percent due to great loss of photosynthetic area of the crop (Li-FuHua *et al.,* 2006). This disease is an important seed and soil borne disease prevalent mostly in subtropical and tropical regions. Despite extensive damage caused by the pathogen, scanty literature is available. Keeping in view of the destructive nature of the disease, the present investigation was under taken to know the suitable media, temperature and pH required for the growth of the fungus.

MATERIAL AND METHODS

The experiment was conducted at Department of Plant Pathology, University of Agricultural Sciences, Dharwad, Karnataka, during 2014-15.

Growth phase of *Curvularia lunata* in liquid media: Thirty ml of potato dextrose broth was added into each of 100 ml conical flask and sterilized. The growth of the fungus was studied 16 times at two days interval from 3 days after inoculation. The flasks were inoculated with 5 mm discs of *Curvularia lunata* from actively growing culture and incubated at 28 ± 2^oC. Each treatment was replicated thrice. Three flasks were harvested separately at a time, starting from the third day onwords up to 31^{st} day by leaving gap of 48 h between two successive harvests. The cultures were filtered through previously weighed Whatman No. 42 filter paper of 12.5 cm diameter, which were dried to a constant weight at 60^oC in an electric oven prior to filtration. The mycelial mat on the filter paper was thoroughly washed with sterile distilled water to get rid of the salts likely to be associated with the mycelial mat. The filter paper along with the mycelial mat was dried to a constant weight at 60^oC for 48 hrs, cooled in a desiccators and weighed immediately on an analytical balance. The difference between final and initial weight of filter discs were taken as the weight of the mycelia.

Growth of *Curvularia lunata* on different solid media: The cultural characters of the *Curvularia lunata* was studied on nine different solid media. The composition and preparation of the different solid media were obtained from Ainsworth and Bisby's Dictionary of the fungi (Hawksworth *et al.*, 1983). Twenty ml of each medium was poured into 90 mm diameter Petri plates. After solidification, 5 mm discs of *Curvularia lunata* from actively growing culture was cut using a cork borer and a single disc was placed upside down at the centre of Petri dish. Each set of experiment was replicated thrice and the plates were incubated at 28±2^0C. The measurement of the colony diameter was taken when the maximum growth was attained in any one of the tested media. Then cultural characters such as colony diameter, colony color, type of margin and sporulation were also recorded. The sporulation was graded as follows.

Growth of *C. lunata* in different liquid media: The

Description (conidia/ microscopic filed [400 X])	Grade	Score
>30	Excellent	++++
20–30	Good	+++
10–20	Fair	++
<10	Poor	+

composition and preparation of different liquid media used were the same as that of solid media except that agar was not added. Thirty ml of different liquid media were added into each of 100 ml conical flasks. These flasks were then sterilized at 121.6^o*C* temperature, 15 lbs pressure for 15 min. The flasks were inoculated with 5 mm mycelial discs obtained from periphery of 10 days old culture and incubated at 28±2^o*C* for 17 days. Each treatment was replicated thrice. Dry mycelial weight in each treatment was recorded.

Temperature studies: The growth of *C. lunata* was tested at 10, 15, 20, 25, 30, 35, 40 and 45^o*C* by using the best media which is obtained through cultural studies. Twenty ml of media was poured into 90 mm diameter petri plates. After solidification, 5 mm disc from actively growing cultures were cut and inoculated to solidified petri plates and incubated in the incubators adjusted to required temperature levels. Each treatment was replicated thrice. After incubation period, radial growth from solid media was recorded. The growth of *C. lunata* was also tested in liquid media as mentioned above. Thirty ml of media was poured into 100 ml conical flask. 5 mm disc from actively growing cultures were cut and inoculated into flasks. Three replications were maintained for each treatment. These flasks were incubated at 28±2^o*C* for 17 days. The mycelial growth was harvested and dried in hot air oven and the dry weights were recorded by using electronic digital balance.

pH studies : *Curvularia lunata* was grown on 30 ml potato dextrose broth with selected pH range of 5.0, 5.5, 6.0, 6.5, 7.0, 7.5 8.0, 8.5 and 9. The pH levels were adjusted by adding 0.1 N alkali (NaOH) or acid (HCl). A seven day old five mm mycelial disc from actively growing culture was inoculated separately into conical flasks containing 30 ml medium at different pH levels. Three replications were maintained for each pH level. These flasks were incubated at 28±2^o*C* for 17 days. The mycelial growth was harvested and dried in hot air oven and the dry weights were recorded by using electronic digital balance.

RESULTS AND DISCUSSION

Growth phase of *Curvularia lunata* in potato dextrose broth: There was significant difference among the incubation periods (Table 1). The dry mycelial weight of *C. lunata* gradually increased (126.70 mg) from third day of inoculation and reached maximum (268.74 mg) on seventeenth day and it was significantly superior over all other treatments. It showed a declining trend from nineteenth day with 254.67 mg dry mycelial weight to thirty-first day (219.67 mg). The results revealed that maximum growth of the fungus was obtained on 17th day of incubation and this indicating the optimum incubation period was seventeen days. The increase in the mycelial dry weight from third to seventeenth day can be attributed due to presence of nutrients in the medium and the fungus showed gradual increase in the weight by utilizing them to the maximum extent. The decrease in the dry mycelial weight from seventeenth day onwards may probably be due to autolysis of the mycelium and exhaustion of nutrients in the medium. Similar results were observed by Sumangala and Patil (2010).

Table 1. Growth phase of *Curvularia lunata* in potato dextrose broth

Days after incubation	Mean dry mycelial weight (mg)
3	126.70
5	193.71
7	195.71
9	200.72
11	218.67
13	221.22
15	253.74
17	268.74
19	254.67
21	250.00
23	249.00
25	235.67
27	227.69
29	224.67
31	219.67
C.D. (p=0.01)	3.88

Growth characters of *Curvularia lunata* on different solid media: The fungus recorded the maximum colony diameter (90.00 mm) at 10 days of incubation period on potato dextrose agar and Richards agar, these two media supported the better growth due to the presence of some vitamins, which are essential for growth and development of organism followed by malt extract peptone dextrose agar (82.33 mm) (Table 2). Mehi *et al.* (2014) found that among the solid media potato dextrose agar and host leaf extract agar were found best. Sumangala and Patil (2010) reported that potato dextrose agar and Sabouraud's agar recorded the good growth of the pathogen.

The fungus showed deep black color colony with irregular

Table 2. Morphological characters and sporulation of *Curvularia lunata* on different solid media

Media	Colony color	Colony characters	Mean colony diameter (mm)	Sporulation
I) Synthetic media				
Czapek's agar	Deep black	Good growth, entire colony black in color, no distinct ring formation and black color irregular margin.	71.00	+++
Richards agar	Deep grayish	Excellent growth, white to grayish cottony growth, no distinct ring formation and black color regular margin.	90.00	+
II) Semisynthetic media				
Potato dextrose agar	Deep black	Excellent growth, center of the colony having puffy growth surrounded by whitish grey growth, ring not distinct and black color irregular margin.	90.00	++++
Sabouraud's agar	Whitish	Poor growth, center of the colony grey in color, raised puffy growth, surrounded by whitish ring and white color irregular margin.	31.67	+
V-8 juice agar	Whitish grey	Poor growth, center of the colony raised and whitish grey, surrounded by distinct whitish ring and white color irregular margin.	27.00	+
Malt extract peptone dextrose agar	Blackish	Good growth, center of the colony black in color, no distinct ring formation and white color irregular margin.	82.33	+++
III) Nonsynthetic media				
Oat meal agar	Grayish	Good growth, center of the colony grayish with puffy growth, no distinct ring formation and black color irregular margin.	75.67	+++
Potato carrot agar	Deep black	Good growth, center of the colony deep black, no distinct ring formation and black color irregular margin.	50.00	+
Corn meal agar	Black	Good growth, center of the colony deep black, no distinct ring formation and black color regular margin.	56.67	++++
CD (p=0.05)			1.81	

++++: Excellent, >30 conidia per microscopic field at 400X +++ : Good, 20-30 conidia per microscopic field at 400X ++ : Fair, 10-20 conidia per microscopic field at 400X +: Poor, <10 conidia per microscopic field 400X at 400X

margin on potato dextrose agar, Czapek's agar, potato carrot agar, malt extract peptone dextrose agar and corn meal agar. Mycelial growth on Richards agar and oat meal agar was greyish in color with irregular margin. Poor growth with whitish color colony with irregular margin was observed on V-8 juice agar and Sabouraud's agar. Excellent sporulation was in corn meal agar and potato dextrose agar. Good sporulation was observed in Czapek's agar, malt extract peptone dextrose agar and oat meal agar. Poor sporulation was noticed in Richards agar, Sabouraud's agar, V-8 juice agar and potato carrot agar. Similar type of observations were also given by Mehi *et al.* (2014).

Growth of *C. lunata* in different liquid media: There was significant difference between the liquid media (Table 3). Potato dextrose medium supported the maximum growth (289.00 mg) and was significantly superior over other media followed by Richards medium with 269.00 mg dry mycelial weight. The minimum growth was observed in V-8 juice medium (168.33 mg). However potato carrot medium and corn meal medium were statistically on par with each other.

Table 3. Growth of *Curvularia lunata* in different liquid media

Media	Mean dry mycelial weight (mg)
Corn meal broth	219.00
Czapek's dox broth	241.67
Malt extract peptone dextrose broth	251.67
Oat meal broth	235.00
Potato carrot broth	220.33
Potato dextrose broth	289.00
Richards broth	269.00
Sabouraud's broth	213.33
V-8 juice broth	168.33
CD (p=0.01)	2.90

The ability of a fungus to grow more on potato dextrose agar and Richards medium indicated the requirement of nutrients present in that medium for *C. lunata.* Mehi *et al.* (2014) found that among the liquid media Richards and Czapek's agar were the best.

Effect of different temperature levels on the growth of *C. lunata*: The maximum colony diameter of the fungus was recorded at 25^o*C* and 30^o*C* (90.00 mm), which were significantly superior over to all other treatments and showed a declining trend as the temperature increases (Table 4). There was no growth of the fungus was observed at 45^o*C*. The growth of the fungus was also observed on potato dextrose broth at different temperatures. The maximum dry mycelial weight (285.41 mg) of the fungus was at 30^o*C*, followed by 25^o*C* (282.49 mg). Growth of the fungus was not observed at 40^o*C* and above (Table 5). The results revealed that optimum temperatures were found to be 25^o*C* and 30^o*C* for growth. Similar results were also obtained by Sumangala and Patil (2010) and Mehi *et al.* (2014).

Effect of different pH levels in growth of *C. lunata* in potato dextrose broth*:* Growth of the pathogen was seen in all the tested pH ranges from 5.0–9.0, similar report was given by Zakia *et al.* (2012). *C. lunata* grew well at 6.0 pH where it has recorded the maximum dry mycelial weight of 288.00 mg and at pH 5.5 it recorded the 287.67 mg of dry mycelial weight, these are on par with each other. The least dry mycelial weight was observed at pH 8.5 (209.00 mg) and pH 9 (208.18 mg), these are on par with each other. pH levels 7.5 and 8.0 also statistically on par with each other. Similar type of observations were recorded by Okunowo and Ogunkanmi (2009) and Sumangala and Patil (2010).

From the studies it can be concluded that for better growth with maximum sporulation of *C. lunata* potato dextrose agar can be used. The temperature range of 25^{0}C to 30^{0}C and soil pH ranged from 5.5–6.0 were found suitable for growth of the fungus, these favorable conditions can cause the maximum disease severity.

Table 4. Growth of *Curvularia lunata* at different temperature levels on potato dextrose agar

Temperature (^{0}C)	Mean colony diameter (mm)
10	28.00 (5.39)*
15	44.00 (6.70)
20	74.33 (8.68)
25	90.00 (9.54)
30	90.00 (9.54)
35	88.33 (9.45)
40	10.00 (3.32)
45	00.00 (1.00)
C.D. (p=0.01)	(0.29)

* √x+1 transformed values

Table 5. Growth of *Curvularia lunata* at different temperature levels on potato dextrose broth

Temperature (^{0}C)	Mean dry mycelial weight (mg)
10	30.83 (5.64)*
15	81.42 (9.08)
20	215.49 (14.71)
25	282.49 (16.84)
30	285.41 (16.92)
35	267.93 (16.40)
40	00.00 (1.00)
45	00.00 (1.00)
C.D.(p=0.01)	(0.14)

* √x+1 transformed values

Table 6. Growth of *Curvularia lunata* at different pH levels on potato dextrose broth

pH	Mean dry mycelial weight (mg)
5.0	256.67
5.5	287.67
6.0	288.00
6.5	242.98
7.0	226.30
7.5	218.00
8.0	217.00
8.5	209.00
9.0	208.18
C.D. (p=0.01)	2.95

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Modelling Food Grain Production in Perspective of Climate Change

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***Abstract*:** In the present paper, time series data on rainfall, fertilizer consumption and food grain production have been analyzed and studied and food grain production have been modelled using structural time series modelling. It was found that both monsoon as well as annual rainfall was not following uniform distribution. Also, a decreasing trend in fertilizer response was observed. The structural time series model was fitted and the food grain production was forecasted using the fitted model. It was forecasted that in 2016, the total food grain production will be 266.66 million tones with 95 % confidence interval (244.99-288.33).

***Keywords*:** Climate change, Food grain production, Fertilizer, Structural time series model, Malthus model

Climate change is any significant long-term change in the average weather conditions of region (or the entire Globe) over a significant period of time (Mahato *et al*., 2014). These changes may occur tens, hundreds or perhaps millions of year. But increased in human activities like industrialization, urbanization, deforestation, agriculture etc. leads to emission of green house gases and due to this the rate of climate change has increased. The important characteristic of global change is the alteration of rainfall patterns, with probable increases in rainfall variability (IPCC, 2007). It is predicted that there will be higher frequencies of extreme precipitation, decrease in rainy days and longer drought periods (IPCC, 2007). These changes could affect the processes such as nutrient cycling, plant growth, or population and community dynamics (Weltzin *et al*., 2003). It is predicted that global atmospheric temperature will rise by approximately 4˚C by 2080. Due to global warming, the hydrological cycle is expected to accelerate and the rate of evaporation from land and sea will increase. Thus, rainfall is assumed to rise in the tropics and higher latitudes, but decrease in the already dry semi-arid to arid mid-latitudes and in the interior of large continents. The areas where water is scare will generally become drier and hotter. Both rainfall and temperatures are predicted to become more variable, with a consequent higher incidence of droughts and floods, sometimes in the same place (Turral *et al*., 2011). Alterations in atmospheric composition can also affect food production due to its impacts on plant physiology. The recent studies conducted at the Indian Agricultural Research Institute show that in future, there will be a loss of 4 to 5 million tons in wheat production with every rise of 1° C temperature throughout the growing period. If the temperature goes up by 2° C, rice production is assumed to decrease by almost a tone/hectare. If maximum and minimum temperature rises by 3°C and 3.5°C respectively, then Soyabean yields in M.P will decline by 5% compared to 1998 (Mahato *et al*., 2014).

Climate change affects agriculture in many ways due to changes in average temperatures, rainfall, pests and diseases incidence and thus affecting the total food grain production. In the present paper, time series data on rainfall, fertilizer consumption and food grain production have been taken from secondary sources. The rainfall data have been analyzed and uniformity of rainfall has been tested. The trend in uses of fertilizer has been studied to investigate the response of fertilizer. Also, forecasting of total food grain production has been done using structural time series model.

MATERIAL AND METHODS

The time series data on rainfall, fertilizer consumption and food grain production from 1950-51 to 2014-15 have been collected from directorate of economics and statistics, department of agriculture and co-operation, Govt. of India and open government data platform, India. The data on rainfall has also been studied to investigate the changes in rainfall pattern. The data on fertilizer consumption and food grain production have been analyzed to study the response of fertilizer to total food grain production. Regression model is applicable only when there is linear relationship between dependent and independent variables and it fulfil the assumptions of least square. In case of nonlinear relationship, nonlinear model has ability to capture nonlinear relationship. Malthus model that capture nonlinear relationship, has been applied to model amount of fertilizer per unit of food grain production (AFPFG). The statistical analysis was done using SAS 9.3 (SAS Institute India Private Limited). The Malthus model is given as under. The parameters of monomolecular growth model have been estimated using marquardt method in SAS 9.3.

$$Y_t = 1 - (1 - ae^{bt})$$

Where

Y_t= AFPFG at time t; a is y at time t=0; a and b are parameters to be estimated

The structural time series model like local linear trend model described by Harvey (1996) is used for forecasting the food grain production (FGP). The structural time series model has been fitted using PROC UCM available in SAS 9.3. A structural time series model is set up in terms of its various components like trend, cyclic fluctuation and seasonal variation, i.e.

$$Y_t = T_t + C_t + S_t + \varepsilon_t$$

In absence of seasonal and cyclic component, above equation reduces to

$$Y_t = \mu_t + \varepsilon_t \,;\, \mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t \,;\, \beta_t = \beta_{t-1} + \xi_t$$

Where

Y_t= FGP at time t; μ_1 is trend component of the model; β_1 is slop at time t

Here, $\varepsilon_t, \eta_t \text{ and } \xi_t$ are the disturbance terms which follow Gaussian distribution with mean 0 and variance $\sigma^2_\varepsilon, \sigma^2_\eta \text{ and } \sigma^2_\xi$ 44called hyper parameters of the model.

RESULT AND DISCUSSIONS

The rainfall data both monsoon rainfall and annual rainfall were analyzed using PROC UNIVRIATE available in SAS 9.3 for goodness of fit to uniform distribution. The monsoon rainfall were not following uniform distribution in all the three method of test as p value is less than 0.05 (here, null hypothesis is that the data follow uniform distribution). In case of annual rainfall, out of three methods, one method showed that the annual rainfall follow uniform distribution as p value is 0.062 (>0.05) and two methods showed that the annual rainfall were not following uniform distribution. Thus, it was concluded that both monsoon as well as annual rainfall were not following uniform distribution (Table1; Figure1).

The data on fertilizer consumption (in thousand tonnes) and total food grain production indicated that fertilizer response is decreasing. During 1980, 0.043 unit of fertilizer was used in production of each unit of food grain but in 2010−11, increased to 0.115 which indicate that fertilizer response to crop is decreasing (Figure 2a). The Malthus model was used to fit the AFPFP (Table 2). The parameters estimates are significant because the standard error is less than the corresponding parameter estimates. The fitted model is highly significant as p value is < 0.0001 (Figure 2b). On the basis of available secondary data, the AFPFP have been forecasted for the year 2017, 2018, 2019 and 2020 and the forecasted value was 0.141, 0.146, 0.150 and 0.155, respectively.

The structural time series model described by Harvey (1996) was fitted and the food grain production was forecasted using the fitted model. The model was fitted using PROC UCM procedure available in SAS 9.3. Both, the level and slope were found highly significant as p value is <0.0001 (Table 3). The forecast of food grain production along with

Table 1. Goodness of fit for uniform distribution of monsoon rainfall and annual rainfall

Test method	p value	
	Monsoon	Annual
Kolmogorov−Smirnov	0.044	0.062
Cramer−von Mises	0.025	0.049
Anderson−Darling	0.025	0.041

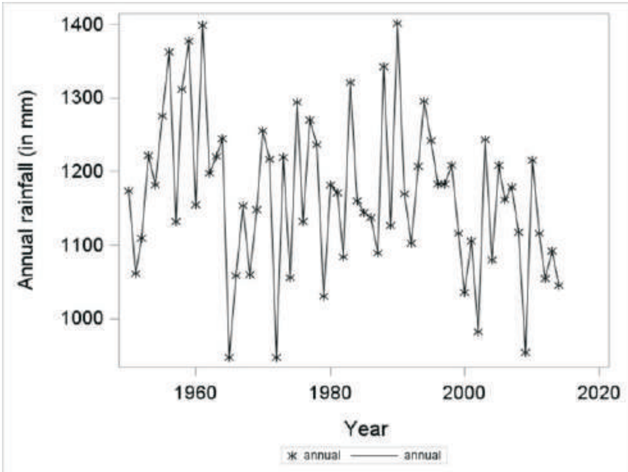

Fig. 1. Scatter plot for annual rainfall

Table 2. Parameters estimates and ANOVA table

Parameters	Estimates	Standard error of the estimates
a	0.0168	0.00209
b	−0.0318	0.00237

Source	DF	Sum of squares	Mean square	F value	p value
Model	2	0.2032	0.1016	1028.24	<0.0001
Error	33	0.0032	0.000099		
Uncorrected total	35	0.2065			

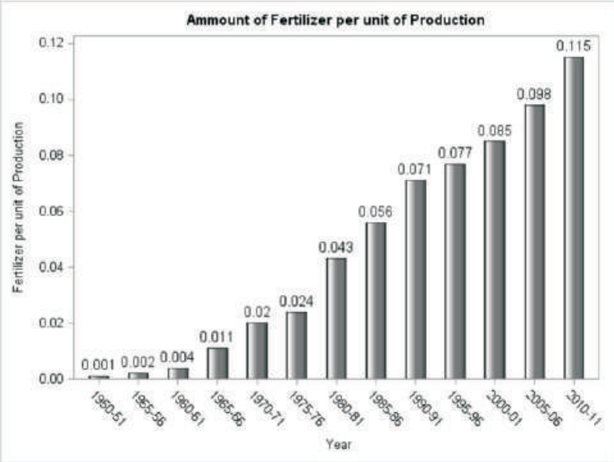

Fig. 2(a). Year wise AFPFP

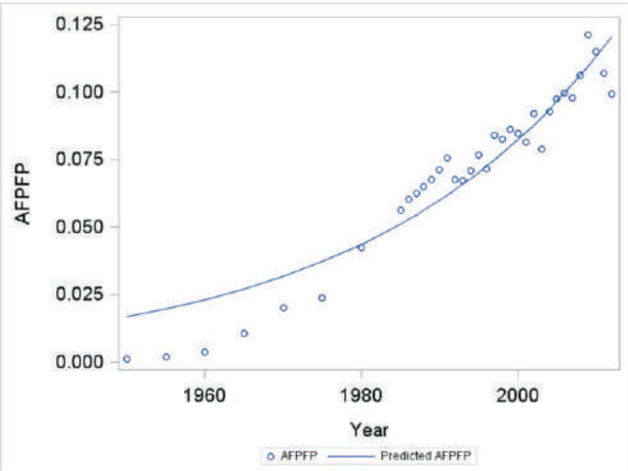

Fig. 2(b). Fitted Malthus model for AFPFP

their confidence interval is given in Table 4. The model is good fit as it captures almost all the scatter points properly (Fig 3).

CONCLUSIONS

Both monsoon as well as annual rainfall was not following uniform distribution. The amount of fertilizer used to produce per unit of food grain (AFPFP) is increasing rapidly. The Malthus model was used to fit the AFPFP and on the basis of available secondary data, the AFPFP have been forecasted.

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Table 3. Estimates of the components and significance

Components	Estimates	Standard error	p value
Level	259.026	4.907	<0.0001
Slope	3.818	0.774	<0.0001

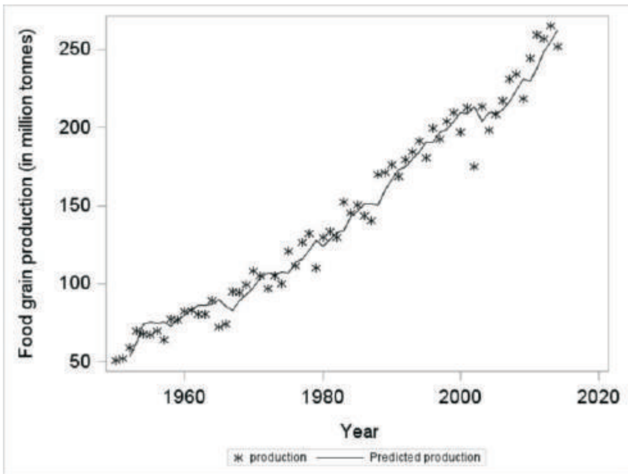

Fig. 3. Fitted model for food grain production

The structural time series model was used and the food grain production was forecasted using the fitted model. Both, the parameters like level and slope of the structural time series model were found highly significant. The forecast of food grain production along with their confidence interval was done. The fitted structural time series model was found good fit as it cover almost all the scatter points properly.

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Periodic Changes in Light Intensity under *Populus deltoides* Based Agroforestry System in North-Western India

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Abstract: An experiment was conducted to study the light intensity pattern at monthly interval at different times of the day under different spacings of poplar based agroforestry system. Wheat crop was sown during two consecutive *Rabi* seasons under different spacings of 7 and 8 years old poplar (5× 4 m, 10 × 2 m and 18 × 2 × 2 m) and in control (sole crop) field. Under this study, the results revealed that as the day progressed the light intensity increased upto 1300 hr (1:00 pm) and after that it declined again under both the systems during both the years (pooled data). The pattern of light intensity under different spacings of poplar were observed in the increasing order from December to February, however, it was reduced during the month of March. Among different spacings of poplar plantation, the maximum light intensity (897.1 Lux) was found in paired row planting (18 × 2 × 2 m) than 10 × 2 m (736.4 Lux) and 5 × 4 m (466.4 Lux) at 1300 hr in February 2014-2015. On the basis of two years average, the highest per cent decrease in light intensity over control was recorded in the month of March (80.0%) under 5 m × 4 m spacing and it followed the order: February (70.0%) > January (69.8%) > December (69.7). The light intensity received by the sole crop was significantly higher in all the months at different times of the day than different spacings of poplar during both the years of experimentations.

Keywords: Agroforestry system, Light intensity, Monthly interval, Poplar, Spacing

Agroforestry is a land use option that increases livelihood security and reduces vulnerability to climate and environmental change (Dhyani *et al.,* 2009). It is considered as one of the viable options for diversification in irrigated agro-ecosystem for economic upliftment of the farmers. In addition, it is a natural resource conserving system and comparatively less resource depleting system than conventional agriculture. Furthermore, tree-based intercropping systems can result in more diversified economies for both short- and long-term products and provide a market for both agronomic and forest crops (e.g., corn, wheat, soybeans, cereals, etc.). With these potential benefits, successful tree-based intercropping systems will minimize competitive interactions between non-woody (annual agricultural crop) and woody (tree) components while exploiting beneficial interactions between these components (Thevathasan *et al.,* 2004).

However, competition for light has been comprehensively studied in a wide range of tropical and temperate agroforestry systems and general models developed at various levels of spatial and temporal disaggregation (Charbonnier *et al.,* 2013). Competition for light is one of the key interactions between trees and crops. Trees reduce the amount of sunlight reaching to soil and crops through shading. Light capture is influenced by both environmental and plant factors such as tree leaf area, leafing phenology, crown structure and crown management. Thus, poplar based agroforestry system can play a significant role in this proposal. Due to its fast growth, high price, less competition with associated crops, pruning tolerant nature and the ability to provide substantial production on a short rotation of 6 to 8 years this species has been grown by farmers in Punjab, Haryana and Uttar Pradesh, which improves the physico-chemical properties of soil through addition of organic matter in the soil and provides alternate sources of income and employment to the rural poor (Puri and Nair, 2004; Singh *et al.,* 2016). In poplar, leaf fall starts in October and by the month end about 13% leaves fall, which gradually increase to 27 and 84% by the end of November and December, respectively though regulated by climatic factors. The trees become totally leaf less in January and February. New flush of leaves starts appearing by end March and the trees are fully flush by end April. Poplar being deciduous in nature is more favourable for winter crops when shading is not a problem and a significant amount of light was expected to penetrate through the canopy to the under-story crop, and the elliptical symmetry of the canopy was thought to block less sunlight penetration to the under-story. Therefore, this paper examines the periodic changes in light intensity at monthly interval under poplar based agroforestry system, provides advise on which spacing of poplar is best for maximizing light intensity and offers possible solutions where yields of agricultural crops are impaired in tree-based intercropping systems, as primarily influenced by tree shading.

MATERIAL AND METHODS

The present study was conducted during 2013–14 and 2014–15 in already established 7 and 8 years poplar plantation at CCS Haryana Agricultural University, Hisar, Haryana (29° 09' N latitude and 75° 43' E longitude at an elevation of 215 m above mean sea level), situated in the arid region of North-Western India. The climate is subtropical-monsoonic with an average annual rainfall of 350-400 mm, 70-80 per cent of which occurs during July to September. The summer months are very hot with maximum temperature ranging from 40 to 45°C in May and June whereas, December and January are the coldest months (lowest January temperature as low as 0°C). The site received 447.9 mm rainfall during 2014–15. The mean weekly values of weather parameters viz., temperature, relative humidity and rainfall recorded at the meteorological observatory located CCS Haryana Agricultural University, Hisar during the experimental period (Figure 1). Wheat crop was grown under during two consecutive rabi seasons of 7 and 8 years poplar plantation spaced at (5 × 4 m, 10 × 2 m and 18 × 2 × 2 m) and in control field. Light intensity was measured by electronic digital Luxmeter under different spacings of poplar canopy as well as control (devoid of tree) at a wheat crop surface. The observations were recorded at monthly interval under poplar based agroforestry system and in open area from December to March in both consecutive years at 0070, 0090, 1100, 1300, 1500 and 1700 hours.

RESULTS AND DISCUSSION

The poplar plantation have significant effect on the availability of light intensity to annual crop at all the stages of monthly interval and among different spacings of poplar plantation, the maximum light intensity (897.1 Lux) was recorded in paired row planting (18 × 2 × 2 m) than 10 × 2 m (736.4 Lux) and 5 × 4 m (466.4 Lux) at 1300 hr in February 2013-2014 (Pooled data).

The pattern of light intensity under different spacings of poplar were observed in the increasing order from December to February, however, it was reduced during the month of March when the new foliage of poplar plantation appears. The light intensity received by the sole crop was significantly higher in all the months than different spacings of poplar. The interaction effect between spacing and time period were found to be significant. The reduction in light intensity may be due to canopy area of trees, which covered the annual crops. Reduction in light intensity to the annual crops may be variable according to the age of tree. The difference in the light intensity in sole crop and poplar-intercropped was lesser in the months from December to February, but it increased considerably after mid of March as the tree foliage became very dense at that time. These results are in agreement with the findings of Luedeling *et al.* (2016) who reported that poplars are leafless during the cropping season or heavily pruned thereby, competition can be substantial. Among different **spatial arrangements** of poplar, the maximum light intensity was observed in paired row spacing (18 × 2 × 2 m) however, in closer spacing (5 × 4 m) it was significantly less. These results are also in conformity with the earlier findings of Bhandari *et al.* (2015) in poplar based agroforestry systems, where the light intensity varied from 1.12 kLux

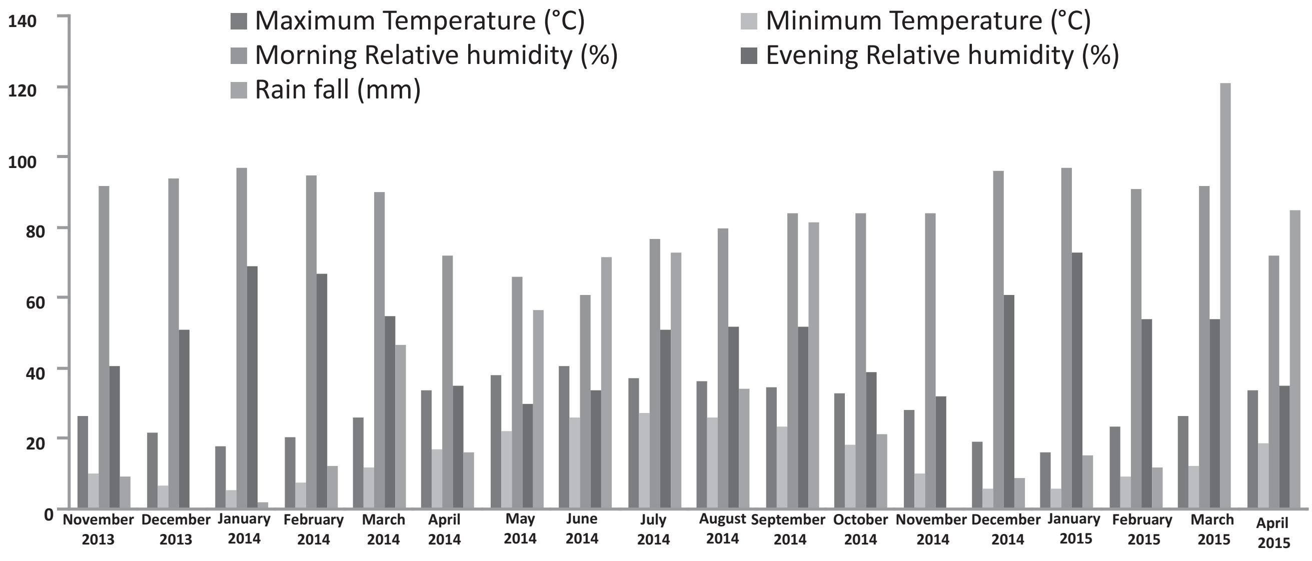

Fig.1. Monthly weather data of experimental site from November 2013 to April 2015

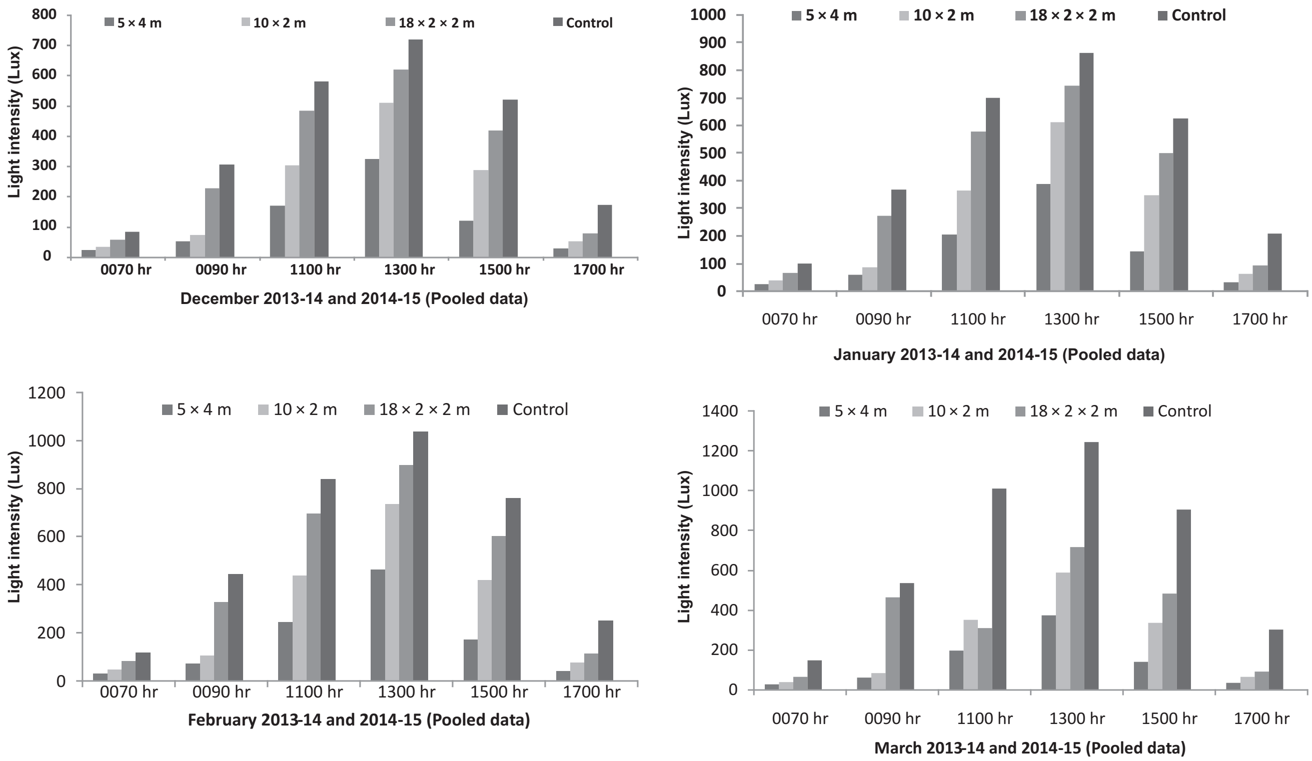

Fig. 2. Light intensity (Lux) under different spacings of poplar canopy (A, B, C & D) and in open during wheat growing season

during end of December to 31.49 kLux during the mid of March under poplar canopy, however, the light intensity in control plots ranged from 2.14 kLux during end December to 53.92 kLux during May. Kumar (2003) also reported that the PAR availability was higher in open field as compared to different agroforestry systems.

On the basis of two years average, the highest per cent decrease in light intensity over control was recorded in the month of March (80.0%) under 5 × 4 m spacing and it followed the order: February (70.0%) > January (69.8%) > December (69.7). However, among different spacings with respect to different months, the maximum per cent decrease in light intensity over control was also recorded in March under 5 × 4 m spacing (80.0%) followed by 10 × 2 m (64.8%) and 18 × 2 × 2 m (48.6%) based on average of different times of the day and two years (pooled data). The per cent of light intensity reduced significantly with the decrease in spacing of poplar under different spatial arrangements. These results are in agreement with the findings of Ahlawat *et al.* (2012) who reported that crops under agroforestry could get only 15.6 and 15.1% of total light. These results are in agreement with the findings of Jha and Gupta (2003) who reported that open area received 96.42 per cent higher light as compared to agroforestry system because there were no trees on the field during the study period.

CONCLUSION

This study demonstrates that on the basis of two years average, paired row planting (18 × 2 × 2 m) was best for the availability of light intensity to annual crop at all the stages of monthly interval throughout the day followed by 10 × 2 m spacing under poplar plantation. In the closer spacing 5 × 4 m of poplar plantation, the per cent of light intensity reduced significantly with the decrease in spacing due to more canopy area of trees. The pattern of light intensity under different spacings of poplar were observed in the increasing order from December to February, however, it was reduced during the month of March when the new foliage of poplar plantation appears. However, the light intensity received by the sole crop was significantly higher in all the months than different spacings of poplar.

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Effect of Planting Dates and Crop Geometry on the Growth and Yield of Pigeonpea Cultivars

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Abstract: Field experiment pertaining to the effect of planting dates and geometry on the growth and yield of Pigeonpea cultivars in context of limited irrigation was conducted during four consecutive years (2008 – 09 to 2011–12) at Zonal Research Station, Chianki(24.25° N and 84.04°E with an altitude of 228.6 m above the mean sea level) under Birsa Agricultural University, Ranchi, India. Treatments were three levels of planting dates25 th June, 25th July and 25th August in main plot, three spacing (60 , 75 and 90 cm) in sub plot and two cultivars (ICPH2671 and Bahar) in sub−sub plot. The total dry matter production per plant was significantly higher in cultivar ICPH2671 at 75 cm row spacing in all the three planting dates. The highest leaf area index was also observed in cultivar ICPH2671 but at 60 cm spacing i.e. planting date of 25th June. Planting date had no significant effect on leaf area index.The maximum yield was in cultivar ICPH2671 at 75 cm row spacing in all the three planting dates.From the present study, it is evident that the 75 cm row spacing and cultivar ICPH2671 is suitable for pigeonpea to get the maximum yield.

Keywords **:** Climate change, Crop geometry, Planting date, Pigeonpea

Climate change impacts on agriculture are being witnessed all over the world, but countries like India are more vulnerable in view of the high population depending on agriculture and excessive pressure on natural resources. The warming trend in India over the past 100 years indicate accelerated warming of 0.21°c per every 10 years since 1970 (Krishna Kumar 2009). This may further aggravate yield fluctuation of many crops.Several adaptation and mitigation strategies like cropping pattern, cultivars, planting date, crop geometry may reduce the effect of changed climate.

Pigeonpea (*Cajanus cajan* L. Millsp.) is a tropical crop grown in India, predominantly during the kharif season either as a sole crop or as inter crop. The productivity of pigeonpea is limited by a number of factors such as agronomic, pathogenic, entomological, genetic and their interaction with environment. Among different agronomic practices, date of sowing, choice of suitable geometry (row spacing) for a particular genotype and adaptation of particular genotype to the particular climatic condition is essential. Most genotypes of pigeonpea are photoperiod− sensitive and therefore sowing date has an important influence on the vegetative and reproductive processes in the changing scenario of climate. So the present study was undertaken to quantify the responses of pigeonpea to planting dates, plant geometry and genotypes in terms of leaf area index, yield attributing characters and yield.

MATERIAL AND METHODS

Field experiments were conducted at Zonal Research Station, Chianki (24.25° N and 84.04°E with an altitude of 228.6 m above the mean sea level) under Birsa Agricultural University, Ranchi, Jharkhand, India during four consecutive years (2008–09 to 2011–12) to investigate the performance of pigeonpea cultivars planted at three different dates and different crop geometry with a view to select the optimal date and spacing for each of the cultivars.Climatically, the area is sub–tropical with annual average rainfall of 1179 mm (Sah *et al*., 2008). The soil is sandy loam having pH 6.2, organic carbon 0.37%, with available nitrogen, phosphorus and potassium114, 18 and 128 kg/ha. The experiment design was split–plot based on randomized complete block design, in three replications; with the planting date (25th June, 25th July and 25th August) in main plots, spacing(60x25 cm^2, 75x25 cm^2 and 90x25 cm^2)in sub plots and cultivars (ICPH2671 and Bahar) in sub–sub plots. Plot size was 6.0 m x 4.0 m). The entire quantity of recommended dose of fertilizer for pigeonpea (20N:40P_2O_5:20K_2O Kg ha^{-1}) was applied as basal dose at the time of sowing. Growth and yield components were recorded in the five randomly selected plants. Leaf area index was worked out by dividing the leaf area per plant by land area occupied by the plant. After maturity, the whole plot were harvested and traits including: plant height, leaf area index , total dry matter production per plant, number of pods per plant, 100 seed weightand yield were recorded.

RESULTS AND DISCUSSION

Significantly higher plant height (135.2 cm) was in cultivar

Table 1. Plant height (cm) and dry matter accumulation (gm/plant)as influenced by date of planting and row spacing in pigeonpea (Pooled mean of 4 years)

Date of planting	Spacing	Cultivars					
		ICPH2671		Bahar		Mean	
		Plant height	Dry matter accumulation	Plant height	Dry matter accumulation	Plant height	Dry matter accumulation
25th June	60 cm	120.8	202.0	135.2	180.2	128.0a	191.1c
	75 cm	116.0	212.6	129.6	192.8	122.8a	202.7b
	90 cm	112.1	219.2	125.4	200.1	118.75b	209.65a
Mean		116.3a	211.26a	211.26a	191.03b		
25th July	60 cm	119.6	192.2	132.8	171.6	126.20a	192.3b
	75 cm	114.6	202.1	125.9	182.5	120.25a	196.15b
	90 cm	109.3	208.6	123.0	190.2	116.15b	199.4a
Mean		114.5a	200.96a	127.23b	181.43b		
25th August	60 cm	75.2	160.8	79.5	144.5	77.35a	152.65c
	75 cm	72.1	170.2	75.8	154.8	73.95a	162.5b
	90 cm	68.0	175.8	71.2	160.2	69.60b	168.0a
Mean		71.76a	168.93a	75.5b	153.16b		

Any two means not sharing a common letter in a column or row differ significantly at 5% probability level

Table 2. Leaf area indexand number of pods / plant as influenced by date of planting and row spacing in pigeonpea (Pooled mean of 4 years)

Date of planting	Spacing	Cultivars					
		ICPH2671		Bahar		Mean	
		Leaf area index	Number of pods $plant^{-1}$	Leaf area index	Number of pods $plant^{-1}$	Leaf area index	Number of pods $plant^{-1}$
25th June	60 cm	0.53	175.6	0.48	107.5	0.50a	141.55b
	75 cm	0.30	207.0	0.26	127.8	0.28b	167.40a
	90 cm	0.21	100.7	0.15	78.6	0.18c	89.60c
Mean		0.34a	161.1a	0.24b	104.6b		
25th July	60 cm	0.48	135.8	0.42	97.4	0.45a	116.6b
	75 cm	0.26	183.0	0.20	108.4	0.23b	145.7a
	90 cm	0.17	108.7	0.12	56.3	0.14c	82.5c
Mean		0.30a	142.5a	0.24b	87.36b		
25th August	60 cm	0.41	94.2	0.36	88.0	0.38a	91.1b
	75 cm	0.22	124.5	0.18	89.7	0.20b	107.1a
	90 cm	0.15	77.3	0.11	62.9	0.13c	70.1c
Mean		0.26a	98.6a	0.21b	80.2b		

Any two means not sharing a common letter in a column or row differ significantly at 5% probability level

Baharat 60 cm row spacing in the planting date of 25th June.Wider spacing of 75 cm row spacing was significantly better. Total dry matter production per plant was significantly higher in cultivar ICPH2671 at 75 cm row spacing in all the three planting dates. The highest leaf area index was also observed in cultivar ICPH2671 but at 60 cm.Planting date had no significant effect on leaf area index. This result in conformity with Wilson *et al*. (2012). The maximum number of pods per plant was in cultivar ICPH2671 in all the three planting dates at row spacing of 75 cm. The significantly higher 100 seed weight was in cultivar ICPH2671 at 75 cm row spacing i.e.32.0 gm in 25th June of planting, 30.1 gm in 25th July of planting and 22.8 gm in 25th August of planting. The highest yield was recorded in cultivar ICPH2671 at 75 cm row spacing in all the three planting dates i.e. 28.63 q/ha in 25th June of planting, 18.47 q/ha in 25th July of planting and 8.69 q/ha in 25th August of

Table 3. 100 Seed weight (gm)and yield (q ha^{-1}) as influenced by date of planting and row spacing in pigeonpea (Pooled mean of 4 years)

Date of planting	Spacing	Cultivars					
		ICPH2671		Bahar		Mean	
		100 Seed weight	Yield	100 Seed weight	Yield	100 Seed weight	Yield
25th June	60 cm	29.2	25.9	23.4	20.1	26.3b	23.0b
	75 cm	32.0	28.63	26.2	23.8	29.1a	26.21a
	90 cm	26.1	22.85	20.8	19.04	23.5c	20.94c
Mean		29.1a	25.79a	23.46b	20.98b		
25th July	60 cm	27.5	15.2	22.1	14.3	24.8b	14.75b
	75 cm	30.1	18.47	25.0	15.74	27.5a	17.10a
	90 cm	24.2	16.82	19.3	13.57	21.7c	15.19b
Mean		27.26a	16.83a	22.13b	14.53b		
25th August	60 cm	20.0	6.34	17.1	5.07	18.5b	5.70b
	75 cm	22.8	8.69	18.0	7.55	20.4a	8.12a
	90 cm	16.9	6.60	14.3	4.95	15.6c	5.77b
Mean		19.9a	7.21a	16.46b	5.85b		

Any two means not sharing a common letter in a column or row differ significantly at 5% probability level

planting. Egbe *et al.* (2013) also reported that the effect of cultivars and interaction effects of date of planting x cultivars were significant. The study revealed that the first sowing date (25th June) with row spacing of 75 cm was significantly better than combinations. The row spacing of 75 cm was significantly superior to all other row spacing. The row spacing of 60 cm and 90 cm were statistically at par with each other. Interaction of sowing dates and row spacing indicated that all sowing dates performed well under 75 cm row spacing. The cultivar ICPH2671 was significantly superior to cultivar Bahar. From the present study, it may be concluded that the 75 cm row spacing and cultivar ICPH2671 is suitable for pigeonpea to get the maximum yield.

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Influence of Weather Factors on Development of Marssonina Leaf Blotch of Apple caused by *Marssonina coronaria* [(Ell. & J. J. Davis) J. J. Davis] in Kashmir Valley, India

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Abstract: Marssonina leaf blotch (MLB) is emerging as the most destructive disease of *Malus spp.* and causes premature defoliation. The present study was conducted in the experimental orchards of SKUAST-K and experimental orchard ganderbal to carry out the influence of weather parameters on disease intensity during the 2014. The maximum infection rate of 0.198 and 0.156 unit/day was observed during 3rd and 4th week of July in district Srinagar and in Ganderbal respectively, under the natural epiphytotic conditions. The percent disease intensity showed the positive correlation with the maximum and minimum relative humidity and rainfall. However, negative correlation was established with the maximum and minimum temperature in both the districts.

Keywords: Apple blotch, *Marssonina coronaria*, meteorological parameters

Apple (*Malus × domestica* Borkh.) is the most important fruit crop of the world and has been under cultivation since time immemorial. In India, apple is mainly cultivated in North Western Himalayan region which include states of Himachal Pradesh, Jammu and Kashmir and Uttrakhand, North Eastern hilly regions of Arunachal Pradesh, Manipur and Sikkim. In recent years, the area under apple production has increased manifold from 133.1 thousand hectares in 2008-09 to 161.7 thousand hectares in 2015-16 with a production of 1332.8 to 1966.4 thousand metric tonnes, respectively (Anonymous, 2016).Among various pests responsible for yield loss marssonina leaf blotch of apple is wide spread foliar disease of *Malus spp.* and results in premature defoliation leading to reduction in photosynthetic area and deteriorating fruit quality, besides pre harvest fruit drop (Kumar and Sharma, 2014).This was first reported from Japan by Miyake (1907) and in India from H.P by Sharma and Gautam (1997). Meagre research has been conducted in our country to find out correlation of macro-climate and MLB disease development and this necessitated carrying out the present study under temperate region of the country. The present study will also indicate the role of weather factors on the disease development of Marssonina leaf blotch of apple.

MATERIAL AND METHODS

The role of various meteorological factors on disease intensity and infection rate (unit/day) of Marssonina blotch of apple was assessed during the year 2014. Five apple trees were randomly selected and tagged in June 2014 at SKUAST-K, Srinagar and KVK-Ganderbal. The trees were kept unsprayed during the course of study. The weather variables were temperature (minimum, maximum), relative humidity (minimum, maximum) and rainfall during the study period was procured from the meteorological observatory of SKUAST-K and Indian Meteorological Department, Srinagar. Tagged plants were examined regularly for first appearance of disease and subsequently at 7 days interval beginning from the day of disease development. Weekly means of the temperature, relative humidity and rainfall that prevailed prior to each disease scoring were correlated with disease development. Multiple regression analysis was conducted to determine the effect of individual as well as combined weather factors on disease development. Growth of disease development in terms of apparent infection rate (unit/day) was calculated (Vander plank, 1963).

$$r = \frac{2.3}{t_2 - t_1} \times \log \times \frac{x_2\,(1 - x_1)}{x_1\,(1 - x_2)}$$

Where; r =apparent infection rate (unit/day); x_1 and x_2 = disease intensity at time t_1 and t_2, respectively; t_2-t_1 = time interval; x_1 = disease intensity at time t_1; x_2 = disease intensity at time t_2

The disease intensity was recorded using 0-5 scale of Yin *et al*. (2013) as given below:

Per cent disease intensity (PDI) was calculated as:

$$\text{Per cent disease intensity} = \frac{\Sigma\,(n \times v)}{N \times G} \times 100$$

Where, Ω = Summation; n = Number of diseased leaves; v = Numerical value of the category; N = Total number of leaves examined; and G = Highest grade value

Category	Numerical value	Description rating (% leaf area infected)
I	0	No evidence of disease on leaf
II	1	1–10%
III	2	11–30%
IV	3	31–50%
V	4	> 50%
VI	5	Leaf fall

RESULTS AND DISCUSSION

In district Srinagar disease initiated with the intensity of 4.0 per cent in July and attained a peak disease intensity of 92.2 per cent in 1st week of October. The disease appeared when the mean atmospheric temperature both maximum and minimum were 33 and 19.5°C, respectively and mean relative humidity both maximum and minimum were 81.7 and 44.8 per cent, respectively. Gradual increase in mean minimum relative humidity from 44.0 to 88.4 per cent, coupled with rainfall favoured the gradual increase of disease from 4.0 to 92.2 per cent. In district Ganderbal with the intensity of 3.0 per cent in July , attained a peak disease intensity of 91.0 per cent in 2nd week of October. The disease initiated when the mean atmospheric temperature both maximum and minimum were 32.3 and 21.3°C, respectively and mean relative humidity both maximum and minimum were 73.0 and 53.0 per cent, respectively. Gradual increase in mean minimum relative humidity from 53.0 to 82.0 per cent, coupled with rainfall favoured the gradual spread of disease from 3.0 to 91.0 per cent. These studies indicated that maximum disease development during the periods of highest rainfall and relative humidity.

The disease intensity was negatively correlated with mean maximum and minimum temperature. However, disease intensity exhibited positive correlation with mean maximum and minimum relative humidity and mean rainfall. The positive correlation of weather factors with the disease intensity may be attributed to the high relative humidity and

Table 1. Influence of weather parameters on development of Marssonina blotch of apple in Srinagar

Date of observation		Disease intensity (%)	Infection rate (r)	Average temperature (°C)*		Average relative humidity*		Average rainfall (mm)*
Month	Week			Max.	Min.	Max.	Min.	
July	II	0.0	0.00	28.9	16.2	78.8	59.4	1.94
	III	4.0	0.198	33.0	19.5	81.7	44.8	0.20
	IV	9.2	0.118	32.1	17.3	77.0	44.1	0.16
August	I	11.8	0.035	31.4	16.3	77.7	51.1	0.00
	II	18.2	0.062	28.0	15.5	80.1	54.0	6.50
	III	26.0	0.049	29.3	13.0	79.5	52.4	1.05
	IV	42.6	0.069	25.07	12.8	85.1	64.0	5.90
September	I	55.6	0.039	17.6	12.7	95.7	88.4	24.6
	II	67.2	0.026	25.1	14.6	89.5	57.4	0.61
	III	79.0	0.023	28.1	11.1	82.0	51.0	0.00
	IV	86.2	0.013	26.6	9.9	84.0	54.4	0.94
October	I	92.2	0.009	28.2	10.7	91.1	49.1	0.00
Correlation coefficient				–0.495	–0.875	0.671	0.183	0.065

*Mean of seven days

Table 2. Influence of weather parameters on development of Marssonina blotch of apple in Ganderbal

Date of observation		Disease intensity (%)	Infection rate (r)	Average temperature (°C)*		Average relative humidity*		Average rainfall (mm)*
Month	Week			Max.	Min.	Max.	Min.	
July	III	0.0	0.00	31.5	19.2	72.0	46.0	1.6
	IV	3.0	0.156	32.3	21.3	73.0	53.0	1.3
August	I	8.2	0.143	31.8	19.3	75.0	55.0	0.1
	II	12.8	0.063	31.5	18.9	75.0	46.0	0.0
	III	23.4	0.086	28.1	15.8	76.0	47.0	7.3
	IV	32.2	0.045	26.5	14.8	80.0	63.0	2.5
September	I	40.0	0.031	21.1	14.8	90.0	82.0	19.7
	II	49.2	0.029	22.8	14.9	94.0	70.0	5.8
	III	66.8	0.043	27.1	13.3	85.0	51.0	0.1
	IV	77.2	0.020	27.1	12.7	81.0	46.0	0.8
October	I	85.0	0.013	28.3	13.3	77.0	51.0	0.0
	II	91.0	0.009	24.6	12.4	80.0	55.0	4.1
Correlation coefficient				–0.582	–0.922	0.450	0.065	0.003

*Mean of seven days

better rainfall and optimum temperature during the period essential for disease initiation and development. Sharma (2003) also reported that disease was positively correlated with the relative humidity and rainfall. Thakur *et al*. (2005) observed that continuous average temperatures above 20°C and 70 per cent relative humidity for 5-6 days induce defoliation process. The temperature of 20°C and 100 per cent relative humidity were optimal for the conidial germination of *Marssonina coronaria* during 24 hours of incubation (Sharma *et al*., 2009).

CONCLUSION

The maximum disease development occurs during the periods of highest rainfall and relative humidity and thus suggest the relation between environmental factors and disease development. The percent disease intensity showed the positive correlation with the maximum and minimum relative humidity and rainfall. However, negative correlation was established with the maximum and minimum temperature in both the districts.

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Sensitivity Analysis of DSSAT CROPGRO-Cotton Model for Cotton under Different Growing Environments

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Abstract: The field experiment was conducted at the research area of the Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar, during the *kharif* season of 2015-16. The main plots treatments consisted of three date of sowing 2nd week of May (D1), 3rd week of May (D2) and 1st week of June (D3) and sub-plots consisted of three varieties (Pancham 541, SP 7121 and RCH 791.Increasing daily maximum temperature (1 to 5ºC above during crop season)led to decrease in the yield and similar condition in decreasing maximum temperature (5ºCbelow) but percent increase in yield in decreasing daily maximum temperature 1 to 4ºC below.The highest benefits were obtained by increasing minimum temperature 1ºC to the tune of above and below during crop season, the effect of percent change in yield was maximum in RCH 791 (22.8 and 26 % from the base yield) followed by SP 7121 (16.3 and 24 % from the base yield) and Pancham 541 (13.3 and 18 % from the base yield).Similarly, increase in rainfall amount from 2015-16 crop season produced increased the yield of cotton crop but decreases also led to decrease in the seed cotton yield gradually.

Keywords: Cotton, DSSAT, Sensitivity analysis

The Decision Support System for Agrotechnology Transfer (DSSAT) is the major product of the IBSNAT (International Benchmark Site Network for Agrotechnology Transfer) project, initiated in 1982 (Uehara and Tsuji, 1998). Although this project ended in 1993, its developers have expanded since then and continue to update and maintain this software under the auspices of ICASA. The central components of the DSSAT software are crop simulation models and programs to facilitate their application in different regions of the world. It is the quantitative tool based on scientific knowledge that can evaluate the effect of climatic, edaphic, hydrological and agronomic factors on crop growth and yield. The decision support system for agro-technology transfer (DSSAT) has been in use for the last 15 years by researchers worldwide (Hoogenboom *et al*., 2012; Jones *et al*., 2003). This package incorporates models of 28 different crops with software that facilitates the evaluation and application of the crop models for different purposes.

DSSAT was developed to assess yield, resource use and risk associated with different crop production practices (Tsuji *et al.,* 1994). The system DSSAT is an example of a management tool that enables farmers to match the biological requirement of a crop to the physical characteristics of the land and ambient air to attain specified objectives. DSSAT software could help the decision makers to implement future agriculture strategies under different scenarios related to agriculture practices with the use of measured site -specific pedological, physiological, agronomical and meteorological data.

Jost and Cothren (2000) also evaluated the cotton cultivars for earliness and other yield contributing traits and observed varied performance. De Gui *et al.* (2003) studied the effects of genetic transformation on the yield and yield components and concluded that higher yields of cultivars were mainly caused by higher number of bolls per plant.

The study of impact of climate change on crops needs simulation model, as it provide a means to quantify the effects of climate, soil and management on crop growth, productivity and sustainability of agricultural production. These tools can reduce the expensive and time consuming field experimentation as they can be used to extrapolate the results of research conducted in one season or location to other season, location, or management (Boomiraj *et al.*2007).

MATERIAL AND METHODS

The field experiment was conducted at the research area of the Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar, during the *kharif* season of 2015-16. The main plots treatments consisted of three date of sowing and the sub-plots consisted of three varieties. The twenty seven treatment combinations were tested in random block design with three replications.

Daily maximum temperature was recorded at 2:27 PM placed in Single Stevenson screen. The daily minimum temperature was recorded at 7:27 AM. Daily rainfall amount was recorded by rain gauge both automatic and standard rain gauge about 50meter away from the experiment site.

Input data for CROPGRO-Cotton model

'CROPGRO-Cotton' is a physiological based dynamic crop growth simulation model which is responsive to daily weather inputs. The minimum data required for running CROPGRO-Cotton are given in Table1.

Inputs required for creating a new soil profile for DSSAT Crop Model

II. Surface Information

1. Colour Brown
2. Drainage Moderate well

Table 1. List of input required by CROPGRO-Cotton model

Input Variables	Acronym	Units
Site data		
Latitude	LAT	Degree
Longitude	LONG	Degree
Elevation	ELEV	M
Average air temperature	TAV	˚C
Height of temperature measurement	TMHT	M
Height of wind measurement	WMHT	M
CO_2 concentration		ppm
Daily weather data		
Maximum temperature	TEMPMAX	˚C
Minimum temperature	TEMPMIN	˚C
Rainfall	RAIN	Mm
Sun Shine hours	SSH	hours
Soil characteristics		
Soil texture	SLTX	
Soil local classification	SLDESC	
Soil family SCS system	TACON	
Soil depth	SLDP	M
Colour, moist	SCOM	
Albedo (fraction)	SALB	Fraction
Evaporation limit	U	Cm
Drainage rate (fraction day^{-1})	SWCON	Fraction day^{-1}
Runoff curve number	CN2	
Mineralization (0 to 1 scale)	SLNF	
Photosynthesis factor (0 to 1 scale)	SLPE	
pH in buffer determination method	SMPX	
Potassium determination method	SMKE	
Lower limit drained	LL(L)	cm^3cm^3
Upper limit drained	DUL(L)	cm^3cm^3
Upper limit drained	SAT(L)	cm^3cm^3
Saturated hydraulic conductivity	SWCN(L)	$cmhr^{-1}$
Bulk density moist	BD(L)	gcm^{-3}
Organic carbon	OC(L)	%
Clay (<0.002 mm)`	CLAY(L)	%
Silt(0.05 to 0.002 mm)	SILT(L)	%
Coarse fraction (>2 mm)	STONES(L)	%
Total nitrogen	TOTN(L)	%
pH in buffer	PHKCL(L)	
Cation exchange capacity	CEC(L)	$Cmolkg^{-1}$
Root growth factor 0 to 1	SHF(L)	
Management data		
Sowing date	YRPLT	
Emergence date	IEMERG	
Plant population at seedling	PLNATS	$Plantm^{-2}$
Planting method (TP/direct seeded)	PLME	
Planting distribution (row/broadcast/hill)	PLDS	
Row spacing	ROWSPS	Cm
Row direction (degree from north)	AZIR	
Plants per hill	PLPH	
Seed rate	SDWTRL	$kgha^{-1}$
Sowing depth	SDEPTH	Cm
Irrigation dates	IDLAPL(J)	
Irrigation amount	AMT(J)	Mm
Method of irrigation	IRRCOD(J)	
Fertilizer application dates	FDAY(J)	
Fertilizer amount N	ANFER(J)	$kgha^{-1}$
Fertilizer type	IFTYPE(J)	
Fertilizer application method	FERCOD(J)	
Fertilizer incorporation depth	DFERT(J)	Cm
Tillage date	TDATE(J)	
Tillage implement	TIMPL(J)	
Tillage depth	TDEP(J)	Cm
Residue management	LNRES	
Chemical applications	LNCHE	
Environment modification	LNENV	
Harvest details		
Harvest	HDATE(J)	
Harvest stage	HSTG(J)	
Harvest component	HCOM(J)	
Harvest percentage	kg ha^{-1}	%

I. General Information

1. Country : INDIA	2. Site Name: CCSHAU, HISAR
3. Latitude: 29° 10	4. Longitude: 75° 46
5. Soil Data source: NBSS	6. Soil Series name: NINDANA
7. Soil Classification: Typic ustochrept	

3. % slope ONE
4. Runoff potential Moderately low
5. Fertility factor (0 to 1) ONE
6. Runoff Curve Number
7. Albedo
8. Drainage rate

III. Layer-wise soil information: No. of layers depends on the location. Here layers up to 120 cm depth are shown in Table 2.

Calibration of the model

Calibration of model involves computing and adjusting certain model parameters or relationships to make the model work for any desired location. When using a crop model, one has to estimate the cultivar characteristics if they have not been previously determined. The model requires twenty cultivar specific genetic coefficients. These genetic coefficients were computed as per details given below:

Parameters	**Description of parameters**
EXPON	Number of experiment used to estimate cultivar parameters
ECO#	Code for the ecotype to which this cultivar belongs
CSDL	Critical Short Day Length below which reproductive

	development progresses with no day length effect (for short day plants) (hour)
PPSEN	Slope of the relative response of development to photoperiod with time (Positive for short day plants) (1/hour)
EM–FL	Time between plant emergence and flower appearance (R1) (photothermal days)
FL–SH	Time between first flower and first pod (R3) (photothermal days)
FL–SD	Time between first flower and first seed (R5) (photothermal days)
SD–PM	Time between first seed (R5) and physiological maturity (R7) (photothermal days)
FL–LF	Time between first flower (R1) and end of leaf expansion (photothermal days)
LFMAX	Maximum leaf photosynthesis rate at 30^0 C, 350 vpm CO^2 and high light (mg CO^2/m^2–s) —from Reddy Adv. Agron. 1997Ω
SLAVR	Specific leaf area of cultivar under standard growth conditions (cm^2/g)
SIZLE	Maximum size of full leaf (three leaflets) (cm^2)
XFRT	Maximum fraction of daily growth that is partitioned to seed+shell
WTPSD	Maximum weight per seed (g)
SFDUR	Seed filling duration for pod cohort at standard growth conditions (photothermal days)
SDPDV	Average seed per pod under standard growing conditions (#/pod)
PODUR	Time required for cultivar to reach final pod load under optimal conditions (photothermal days)
THRSH	Threshing percentage. The maxi. ratio of seed (seed/(seed+shell))
SDPRO	Fraction protein in seeds (g(protein)/g(seed)
SDLIP	Fraction oil in seed (g(oil)/g(seed)

RESULTS AND DISCUSSION

Maximum temperature

The results indicated that increasing daily maximum temperature (1 to 5ºC above) led to decrease in the yield and similar trend was observed in decreasing maximum temperature (5ºC below crop season 2015–16) but percent increase in yield in decreasing daily maximum temperature 1 to 4ºC below (Fig. 1). The effect of percent increase in yield was higher in SP 7121 followed by Pancham 541 and RCH 791. The simulated results indicated that decrease in maximum temperature was beneficial in comparison to increase because high respiration and reduced supply of carbohydrates. Similar results were reported by Singh *et al*. (2008).

Minimum temperature

The increase in daily minimum temperature by 1 to 3 ºC and decreased by –1 to –3 ºC for crop season of 2015–16 then yield was increased but after 4 to 5 ºC above and below from crop season 2015–16 then yield was decreased (Fig. 2). The highest benefits were obtained by increasing minimum temperature 1ºC to the tune of above and below during crop season, the effect of percent change in yield was maximum in RCH 791 (22.8 and 26 % from the base yield) followed by SP 7121 (16.3 and 24 % from the base yield) and Pancham 541 (13.3 and 18 % from the base yield).

Rainfall

Increasing rainfall led to the increase in the yield but start decreasing from 50% above the crop season as compared to 40% (Fig. 3). Model predicted higher yield reduction in case of RCH 791 followed by Pancham 541 and SP 7121. The percent increase in yield was maximum in SP 7121 (20.8 % from the base yield) followed by Pancham 541 (15.4 % from the base yield) and RCH 791 (13.1 % from the base yield). Similar, were reported by earlier workers Singh *et al*. (2008).

CONCLUSION

A change of ± 3^0C in daily minimum temperature and decreasing

Table 2. Layer–wise soil information for input of DSSAT model.

Depth (bottom) Cm	Master Horizon	Clay %	Silt %	Stones %	Organic Carbon %	pH in water	Cation Exchange Capacity C mol/kg
5	AP	10.7	22.3	–99	0.41	8.1	11.4
29	A1	13.4	25.0	–99	0.26	8.4	12.4
57	B2	14.3	26.2	–99	0.26	8.3	13.4
80	B2	16.0	27.9	–99	0.23	8.3	17.4
103	B2	16.5	28.3	–99	0.22	8.2	17.7
127	B3	16.9	28.7	–99	0.20	8.3	19.5

Depth (bottom) Cm	Lower limit	Drainage Upper Limit	Saturation	Bulk Density g/cm3	Saturated Hydraulic Conductivity Cm/hr	Root growth Factor 0.0–1.0
15	0.091	0.183	0.412	1.49	2.59	1.00
29	0.100	0.196	0.407	1.59	2.59	0.644
57	0.105	0.203	0.410	1.50	2.59	0.423
80	0.112	0.215	0.410	1.50	2.59	0.254
103	0.114	0.218	0.410	1.50	2.59	0.160
127	0.116	0.220	0.411	1.50	2.59	0.100

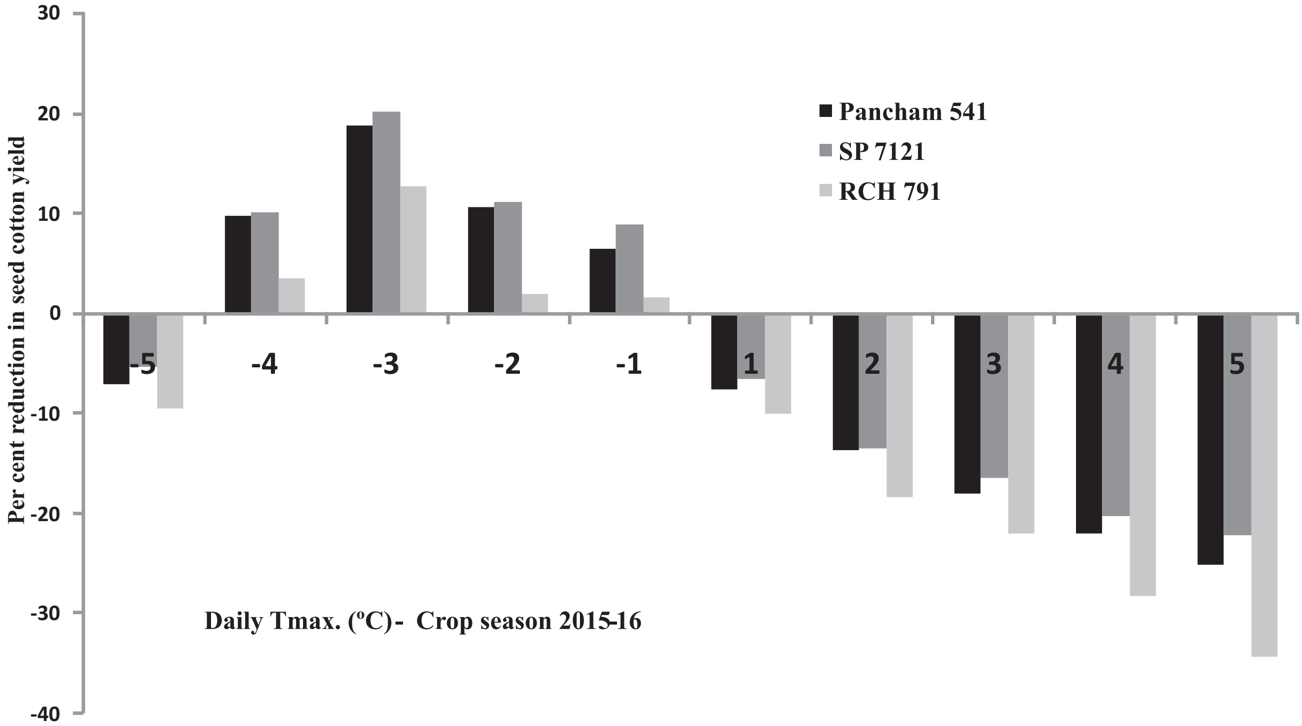

Fig. 1. Sensitivity analysis tested maximum temperature with DSSAT model for percent change in seed cotton yield

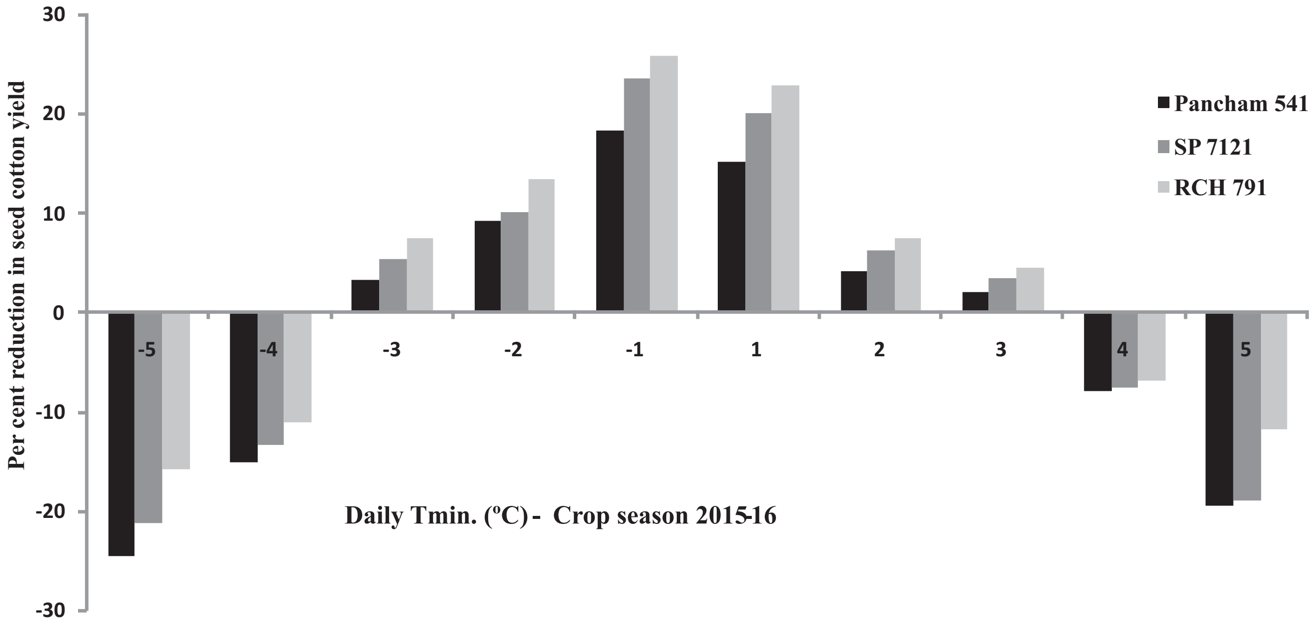

Fig. 2. Sensitivity analysis tested minimum temperature with DSSAT model for percent change in seed cotton yield

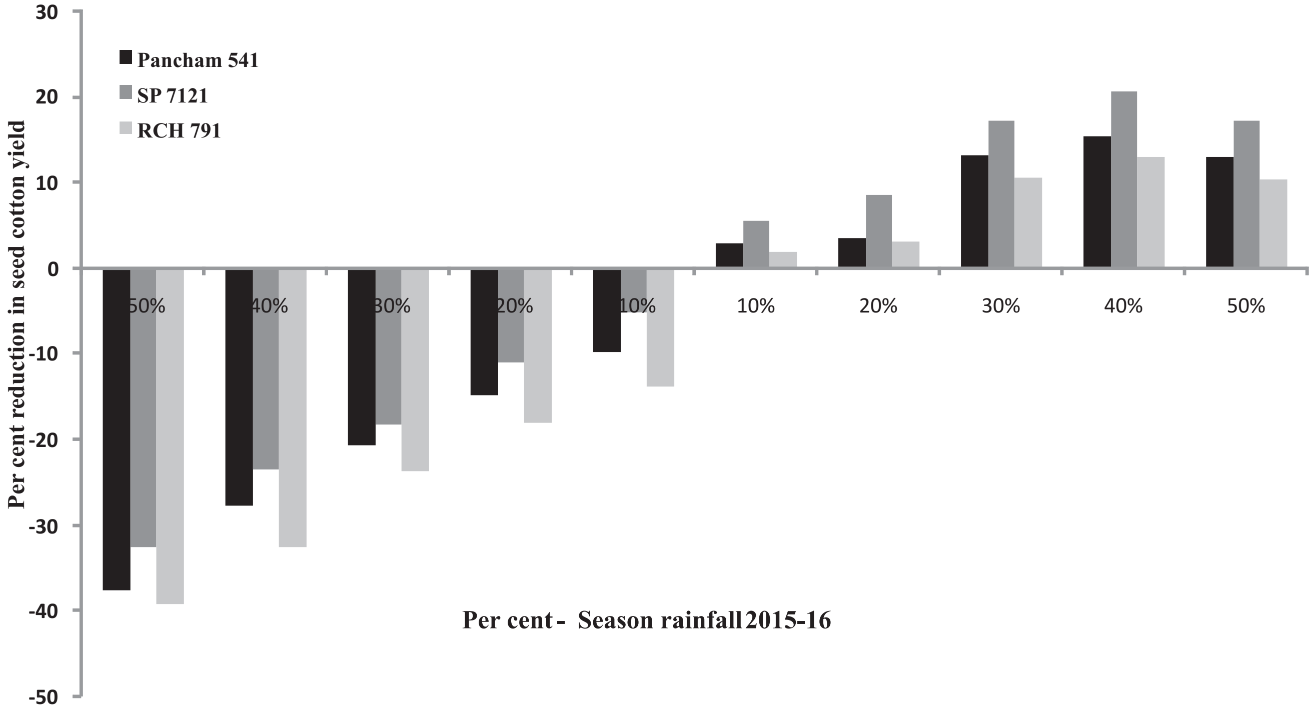

Fig. 3. Sensitivity analysis was carried out for percent change in seed cotton yields of rainfall using DSSAT model

maximum temperature upto 4^{0}C from 2015–16 crop season value produced higher yield in cotton crop. Maximum temperature (–1 to –4^{0}C) and minimum temperature within ± 3^{0}C was beneficial for cotton crop. Similarly, increase in rainfall increased the yield of cotton crop but decreases also led to decrease in the seed cotton yield gradually. Rainfall decreases the cotton yield gradually.

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Evaluation of Different Substrates for Cultivation of 'Pink Pleurotus'[Pleurotus djamor (Rumph.ex.Fr.) *boedijn*] Mushroom

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Abstract: The study was conducted to evaluate different substrates for cultivation of Pink Pleurotus mushroom *Pleurotus djamor* (Rumph.ex.Fr.). Different substrates paddy straw, wheat straw, oats straw, chinar leaves, popular leaves and apple leaves. All the substrates were cut and soaked in water overnight after draining excess water filled the substrates into polythene bags then spawned the bags. All the substrates were suitable for cultivation of Pink Pleurotus. However yield, benefit cost ratio and biological efficiency varied with different substrates. Paddy straw was found most efficient substrates producing highest yield(1500g) followed by wheat straw while lowest yield (524.65g) was recorded in chinar leaves. The highest biological efficiency (75.00%) and substrates to yield ratio(1:0.75) was recorded with paddy straw followed by wheat straw where biological efficiency and substrates to yield ratio was (67.68%) and (1:0.67) respectively. The biological efficiency (26.20%) and substrates tyield ratio (1:0.26) was recorded with Chinar leaves.

Keywords: *Pleurotus djamors*, Substrates, Cultivation, Yield

Mushrooms often called as 'Queen of vegetables', are in fact a group of higher fungi, belonging to the class Basidiomycetes or Ascomycetes. Mushrooms are known to have a broad range of uses, both as food and medicine. As a food item, the nutritive value of mushrooms lies between that of meat and vegetables (Maria *et al.*, 2000). Among commercially cultivated mushrooms, members of genus *Pleurotus* are well known edible fungi appreciated for their excellent flavour and taste (Shah *et al.*, 2004) and broader adaptability under varied agro-climatic conditions (Baysal *et al.*, 2003). 'Pink Pleurotus' [*Pleurotos djamor* (Rumph. ex. Fr) Boedijn] is edible mushroom more popular throughout the world particularly in Asia and European countries as they have simple and low cost production technology and exhibit higher biological efficiency (Patil, 2012). The present studies was taken on *Pleurotus djamor* because this species can be cultivated on a wide variety of lignocellulosic substrates, playing an important role in managing organic wastes whose disposal could otherwise be problematic. The different substrates for cultivation of 'Pink Pleurotus'.

MATERIAL AND METHODS

The pure culture of *Pleurotus djamor* (Rumph. ex. Fr.) Boedijn used in present investigation was procured from Directorate of Mushroom Research, Chambaghat, Solan. The culture was multiplied further in tubes containing potato dextrose agar medium. Locally available cheap agriculture residues were evaluated for cultivation of 'Pink Pleurotus'.

Paddy straw, wheat straw and oats straw was procured from Mushroom Research and Training Centre, SKUAST (Kashmir), Shalimar, while apple leaves, chinar leaves and poplar leaves were collected from university campus.

Vernacular name	Botanical name	Plant part used
Wheat	*Triticum aestivum*	Straw
Paddy	*Oryza sativa*	Straw
Oats	*Avena sativa*	Straw
Apple	*Malus domestica*	Leaves
Chinar	*Platanus orientalis*	Leaves
Poplar	*Poplus alba*	Leaves

Substrate preparation: The procedure described by Patil (2012) was followed for substrate preparation. Each substrate was chopped into 2 to 3cm pieces and separately soaked in water overnight. The substrates were then separately dipped in hot water for 30 minutes for sterilization. The substrates were taken out of hot water and squeezed lightly by hands to remove excess of water .Two kilograms (on dry weight basis) of each substrate was then filled in polythene bags (35 × 45cm) and pressed gently.

Substrates supplementation: All the substrates *viz*., paddy straw, wheat straw, oats straw, apple leaves, chinar leaves and poplar leaves were evaluated alone and no supplement was added to any substrate.

Filling and spawning: Filling and spawning of substrates was done simultaneously. Filling of substrates in the polythene bags was done in layers. Multi layered spawning technique was adopted for spawning of substrates and 2 per cent spawn was used. The corners and lower centre at the base of polythene bags were cut with scissors and holes were made to avoid any accumulation of water in the bags. Each treatment was replicated ten times and the bags were arranged in completely randomized design. These bags were then incubated at 25 ± 2°C temperature inside the cropping room.

Colonization of substrates: The spawned bags were incubated for spawn colonization for about 20 days. Room temperature of 25 ±2ºC and relative humidity of 80 to 90 per cent was maintained during this period. The walls and floor of cropping room were watered daily to maintain requisite humidity. The maximum and minimum temperature and relative humidity of incubation room was recorded daily. When the substrates were fully covered by the spawn, resulting in block formation, the polythene bags were removed and blocks left for frutication. The colonized substrate blocks were kept on the iron stall shelves. The blocks were kept humid by spraying water as and when required.

Cropping room environment: A temperature of 25 ± 2ºC and relative humidity of 80 to 90 per cent was maintained during spawn run phase in the cropping room. However, a low temperature of 20 to 25 ºC was maintained during fruiting phase. The windows with wire mesh were kept open for four hour daily during cropping period to maintain sufficient aeration. The blocks were also watered daily with the help of sprayer to maintain sufficient moisture in the post spawn run phase.

Harvesting: When inward curling of margins of sporocarps/fruitbodies started, they were harvested. The fruitbodies were harvested by cutting them at the base of sporocarp with the help of sharp edged knife. The data regarding total number of flushes, number of sporocarps, weight of sporocarps, total yield and duration of crop on each substrate was recorded.

Benefit cost ratio: The cost of cultivation of 'Pink Pleurotus' was based on 10 bags per treatment with each bag containing 2kg of substrate (on dry weight basis). The expenses of cost of substrate, polythene bags, spawn and labour charges were calculated to find out the benefit : cost ratio.

Monitoring: The bags were constantly monitored for appearance of any contaminations or competitor moulds.

RESULTS AND DISCUSSION

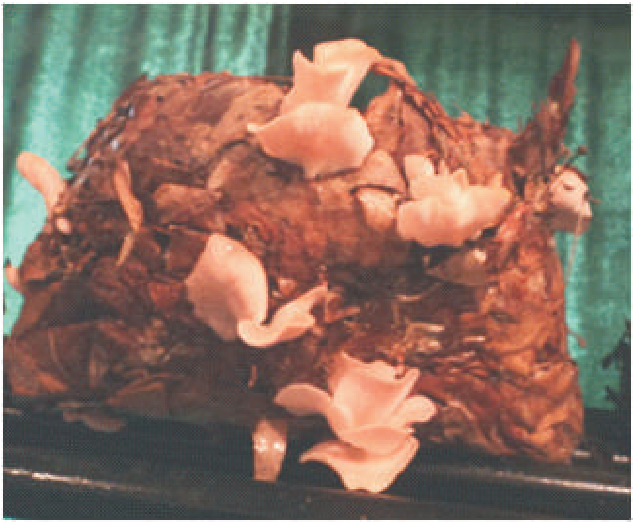
All the substrates supported the growth of 'Pink Pleurotus'. However time required for complete spawn run, sporocarp initiation and first flush/harvest differed with different substrates. A minimum time of 13 day were taken by the paddy straw and wheat straw substrates for complete spawn run while maximum time (21.40 days) were taken by the chinar leaves. Spawn run in oat straw, apple and poplar leaves was completed in 14.20, 18.10 and 18.40 days respectively. All the substrates varied in time taken for sporocarp initiation and production of first flush. The time taken for sporocarp initiation ranged from 14.60 to 25.00 days while time taken for first flush ranged from 19.70 to 28.40. Minimum time was taken by paddy straw and wheat straw for initiation of sporocarp and production of first flush while chinar leaves took maximum time for the same. Poplar leaves and apple leaves were equally efficient substrates for initiation of sporocarp and took around 20 days. However, the first flush/harvest was produced by apple leaves in 24.40 days and poplar leaves in 26.80 days. The slow spawn run, sporocarp initiation and production of first flush in chinar leaves may be attributed to its texture and composition. Furthermore, since the mushrooms are saprophytic in nature, the slower rate of decomposition of chinar leaves may be one of the possible reasons responsible for slow growth and frutification of 'Pink Pleurotus'. Different workers across the globe have investigated spawn run on various substrates. The results of present investigation are in agreement with the findings of Chauhan *et al*. (2012) who reported that spawn run and pin head formation on wheat straw was completed in 12.75 and 14.25 days, respectively while Sharma (2005) recorded 11.50 and 13.30 days for spawn run and 15.80 and 16.50 days for sporocarp initiation of 'Pink Pleurotus' on paddy straw and wheat straw, respectively. Pala *et al*. (2012) reported that apple leaves and chinar leaves took 25 to 28 days and 30 to 34 days for complete spawn run while Jan−Shaheen (2001) recorded 16 days for complete spawn on oats straw for oyster mushroom. The results of other scientists who findings are in conformity with present finding are Patra and Pani (1995), Shah *et al*. (2004), Rajak *et al*. (2011) and Sidhant *et al*. (2013). All the three straw substrates were highly efficient than leafy substrates with regards to number of flushes. Paddy straw produced highest yield (1500.00g) followed by wheat straw while lowest yield (524.65g) was in chinar leaves. The production of oyster mushroom in paddy straw was very high, because the paddy straw contain all the essential micronutrients for the development of mushroom such as minerals, vitamins, amino acids (Govindaraju, 2013)..

Biological efficiency of 'Pink Pleurotus' to utilize the substrate for producing yield varied with different substrates. Highest biological efficiency (75.00 %) was on straw substrates than on leafy substrates (47.19 %). The substrate to yield ratio was superior in case of paddy straw (1: 0.75) followed by wheat straw (1: 0.67) and oats straw (1:0.51). Among leafy substrates, apple leaves resulted in highest

Paddy straw

Oat straw

Apple leaves



Chinar leaves

Poplar leaves

Wheat straw

Plate 1. Sporocarps of “Pink Pleurotus” (*Pleurotus djamor)* on different substrates

Table 1. Evaluation of different substrates for cultivation of pink *pleurotus*

Substrates	Complete spawn run(DAS)	Sporocarp initiation (DAS)	1st flush (DAS)	Total flushes	Average No. of sporocarps	Average weight of sporocarp (g)	Yield (kg/q)	Biological efficiency (%)	Benefit : Cost Ratio
Paddy straw	12.60	14.60	19.70	4	28.19	13.47	75.02	75.00	2.00:1
Oats straw	14.20	16.00	22.80	4	23.33	11.22	51.98	51.95	1.30:1
Apple leaves	18.10	20.20	24.40	4	20.73	8.56	47.19	47.15	1.44:1
Chinar leaves	21.40	25.00	28.40	4	14.12	6.91	26.20	26.20	1.00:1
Poplar leaves	18.40	20.40	26.80	4	20.32	8.38	44.59	44.59	1.31:1
Wheat straw (check)	13.00	15.00	20.10	4	26.03	13.11	67.68	67.68	1.52:1
C.D ($p \leq 0.05$)	0.555	0.488	0.526	NS	NS	NS	0.221	0.005	

*DAS−Days after spawning

substrate to yield ratio (1:0.47) followed by poplar leaves (1: 0.44) and chinar leaves (1:0.26).The substrate to yield ratio indicate the potential of substrate to produce yield and confirm the suitability of substrate. The results of present investigation on biological efficiency are in conformity with the investigations of various researchers. Sidhant *et al*. (2013) recorded biological efficiency of 'Pink Pleurotus' (*P. eous*) as high as 67.20 per cent in wheat straw. Khan *et al*. (2013) reported 85.00 and 77.00 per cent biological efficiency of *Pleurotus* spp. in paddy and wheat straw while Sofi *et al*. (2014) recorded 63.00 per cent biological efficiency of *P. ostreatus* in wheat straw.

Cultivation of 'Pink Pleurotus' on different substrates resulted in different benefit cost ratios. Highest benefit cost ratio (2:1) was recorded in straw substrates than leafy substrates (1.44 :1). However, all the substrates resulted in significant benefit cost ratios and cultivation of 'Pink Pleurotus' can be undertaken on all the evaluated substrates depending upon their availability.

Since mushroom cultivation practice does not require arable land and any significant capital investment, it therefore, is a viable and attractive activity for rural, peri−urban and urban dwellers. Mushroom cultivation is suitable for all job seeking groups including women and youth. Currently, mushroom cultivation is regarded as the most profitable agri−business and environment−friendly method for recycling of the vast agricultural waste whose disposal could otherwise be problematic.

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Variations in Soil Properties under different Land use Systems in Western Central table land Agro-climatic Zones of Odisha

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Abstract: Land use is one of the main drivers of many processes of environmental change influencing the soil properties. This study investigates the effect of land use and land cover on some soil chemical and physical properties. For this composite soil samples were collected from rice-rice, rice-mustard cropping system, fallow land, forest vegetation and mango plantation in three replications at 0-0.15m and 0.15-0.30 m depth. The study focused in quantifying a range of soil properties influenced by different types of land use system. Soil properties showed significant difference between land-uses. The soils were moderately acidic to slightly acidic with soil organic carbon (SOC) content of medium to high status. Bulk density of soils was typically high in the sub-surface soil layers. Water holding capacity and cation exchange capacity of soils under forest vegetation was higher among all the land uses. However, significant differences existed in soil depths also for a range of soil parameters determined (pH, SOC, WHC, $CaCO_3$ and clay content). Correlation matrix also showed dynamic relationships among the various soil properties. Therefore, a dataset was designed to assess differences in soil organic carbon content and related soil properties across a range of land-use types.

Keywords: Land use types, land cover, soil properties, SOC and WHC

Land use is one of the main drivers of many processes of environmental change, as it influences basic resources within the landscape, including the soil properties and determines the ecosystem stability and sustainability of the agricultural production system (Gonzalez *et al.,* 2014). In developing countries like India, agriculture had always played a central role in the country's economy. Although agriculture has always been the mainstay of the economy, it is characterized by very low growth rate. The rapidly increasing population has led to a declining availability of cultivable land and attracts attention in sustainable production system. It is apparent that soil is one of the most important and determinant factors that strongly affects crop production and is the foundation resource for nearly all land uses and the most important component of sustainable agriculture (Mulugeta and Karl, 2010). Therefore, assessment of soil properties with respect to land use types, management practices is useful and is the primary indicator for sustainable agricultural production system. Understanding the effect of land use patterns on soil properties is useful for devising land management strategies and assessment of such land use-induced changes in soil properties is essential for addressing the issue of agro-ecosystem transformation and sustainable land productivity (Yao *et al.,* 2010). Changes in land use and management practices often modify most soil morphological, physical, chemical and biological properties to the extent reflected in agricultural productivity (Heluf and Wakene, 2006) leading to a marked effect on the soil organic matter stock (Yeshaneh, 2015). Soil organic matter not only plays a major role in soil fertility enhancement by affecting physical and chemical properties, but also controls soil microbial activity by serving as a source of mineralizable carbon and nitrogen. Many studies indicated that inappropriate land use management leads to low soil structure stability, loss of soil organic matter, reduction in nutrient stock, reduction in soil organic carbon (Hartemink *et al.,* 2008). Soil organic carbon and total nitrogen were high in natural forest while these were low in cultivated fields (Yifru and Taye, 2011). Soil organic matter content, CEC and other soil properties were lower in cultivated soils than adjacent forest land (Yitbarek *et al.,* 2013). Contrary to the above studies, land-use change did not lead to change in some soil chemical properties rather only change in soil physical properties (Geissen *et al.,* 2009).

It is hardly possible to draw conclusion on the effect of land cover and land use change on properties of soil resource unless studies on local spatial scale are undertaken. Standing from this existing condition the effect of land use pattern on some chemical and physical properties of soils was examined.

MATERIAL AND METHODS

Soils used: Composite soil samples (0-0.15 & 0.15-0.30m depth) were collected from different land use patterns viz., rice-rice, rice-mustard, fallow, forest and mango plantation following standard protocols from different locations of

Bargarh district under the Western Central table land Agro−climatic zones of Odisha. The soils of the study areas were mostly mixed red and yellow type (haplustalfs, paleustalfs and ustochrepts) with annual rainfall of about 1350mm and mean annual temperature of 30−35°C.

Methods Used: Moist soil samples were collected with the help core sampler and kept in moisture box for estimation of bulk desnsity and water holding capacity of soils (Jackson, 1973). The soil samples were further air dried, processed to pass through 2mm sieve and analyzed for different soil parameters. Soil pH was measured in soil:0.01M $CaCl_2$ solution :: 1:2.5 (Jackson, 1973). Oxidisable organic carbon content was determined by the wet oxidation method of Walkley and Black (1934), electrical conductivity and clay content of soils were determined by standard protocols. The $CaCO_3$ content of soils was determined by the method outlined by Black (1965) and cation exchange capacity (CEC) by the method outlined by Jackson (1973).

Statistical Calculation: Statistical calculations were made by using the SPSS software version 20.0. Correlation matrix was drawn among the soil properties to justify their relationship.

RESULTS AND DISCUSSION

Soil physical properties: Soil physical properties were influenced by the variation in land use pattern. Results showed significant difference ($p<0.01$) in clay contents among land use types. The highest average clay content was recorded under surface soils (0−0.15m) of rice−rice cropping system (256 gkg^{-1}) and the lowest in the surface soils (0−0.15m) of forest vegetation (190.1gkg^{-1}). Although the clay content did not maintain any definite pattern along the soil depth, in forest soils an increase in clay content was witnessed. Such occurrence might be due to the movement of clay−organic matter complex with the downward percolating water and its subsequent accumulation in lower depth. Clay content maintained significant positive correlation with soil pH ($r=0.750$; $p<0.01$) significant but negative with $CaCO_3$ content ($r=-0.617$; $p<0.01$). Even though, the average bulk density (BD) values of the soils under different land use types are in the acceptable range for plant growth, relatively the highest (1.46 Mg m^{-3}) average value of BD was obtained under sub−surface (0.15−0.30m) soils of fallow land (Table 1). Comparatively lower average BD values were reported in soils under forest and mango plantation. This could be due to their higher organic matter content owing to high leaf fall and residues addition. This can be supported from the significant negative relationship between soil organic carbon (SOC) content and BD values ($r= -0.389$; $p< 0.05$). This result is in harmony with the research findings reported by Sakin (2012); Chandel *et al.* (2015).

The water holding capacity (WHC) showed a significant variation in capacity of soils to hold water under various land use types. It ranged from 35.3% in sub−surface soils (0.15−0.30m) of rice−rice land use to 56.0% in the surface soils (0−0.15m) of forest vegetation. The higher water holding capacity of forest land use might be due to high organic matter content which increases the water stable aggregates improving capacity of soils to hold a good amount of water under such system. This can be well understood from the relationship obtained between SOC and WHC of soils ($r= 0.898$) and also from their regression equation (Table.2). In general a declining trend of water holding capacity was reported along the soil depth which could be due to increased compaction and low organic matter content at lower depth. Similar results reported by Khan and Kamalakar (2012) and Joshi and Negi (2015).

Table 1. Soil properties under different land use systems

Land use	Depth (m)	pH	SOC (gkg−1)	BD (Mg m^{-3})	CEC [Cmol(p^+)kg^{-1}]	EC (dSm^{-1})	$CaCO_3$ (gkg^{-1})	Clay (gkg^{-1})	WHC (%)
Rice−rice	0−0.15	6.38	5.83	1.43	10.8	0.28	26.9	256.0	40.6
	0.15−0.30	6.49	5.13	1.45	12.2	0.24	27.4	263.0	35.3
Rice−mustard	0−0.15	6.22	4.50	1.35	10.4	0.24	24.8	225.2	41.0
	0.15−0.30	6.30	4.00	1.39	10.4	0.22	25.8	230.4	35.8
Fallow	0−0.15	6.13	6.50	1.41	16.1	0.18	21.4	223.0	45.8
	0.15−0.30	6.21	5.20	1.46	17.6	0.15	22.9	202.8	41.9
Forest	0−0.15	5.96	10.10	1.35	24.9	0.10	17.4	190.1	56.0
	0.15−0.30	6.09	8.13	1.39	22.5	0.13	16.0	199.2	53.8
Mango plantation	0−0.15	6.04	9.13	1.36	22.6	0.12	16.8	234.5	50.5
	0.15−0.30	6.15	7.96	1.39	20.7	0.11	16.3	222.2	48.8

EC−Electrical conductivity, SOC−Soil organic carbon, BD−Bulk density, CEC−Cation exchange capacity, WHC−Water holding capacity

Table 2. Relationship between SOC, CEC and WHC of soils under different land use systems

Regression equation	Correlation coefficient (R^2)
CEC = 0.1707+ 2.5061 SOC	0.83
WHC = 24.01+ 3.1547 SOC	0.80

Soil chemical properties: The analysis of variance revealed that the soil pH was significantly affected by land use types ($p<0.05$). The soils were moderately acidic to slightly acidic in nature. Numerically soil pH ranges from 5.96 in the surface soil (0–0.15m) of forest vegetation to 6.49 in the sub–surface (0.15–0.30m) soils of rice–rice land use. The lowest pH in forest vegetation could be due to higher uptake of basic cations by the diverse vegetation and also due to high addition of plant residues which on decomposition leads to production of organic acids increasing the soil acidity. In general, an increase in soil pH was noticed along the soil depth. This might be due to increase in bases with depth and their incomplete downward leaching (Khan and Kamalakar, 2012). Soil pH maintained significant relationship with electrical conductivity (r= 0.729) and $CaCO_3$ content (r= 0.827) of soils irrespective of land use types. The data on SOC content (gkg^{-1}) ranged from 4.0 to 10.1 (Table.1). All soils of the study area fall under medium to high category of SOC content. The highest amount of SOC was in the surface soils (0–0.15m) of forest vegetation while lowest in sub–surface soils (0.15–0.30m) of rice–mustard land use. The possible reason for such occurrence could be due to high amount of residues addition resulting increased content of SOC in the former. A declining trend of SOC content was observed along the soil depth in the entire land use pattern considered. The surface soils of all land use pattern was higher in organic carbon than sub–surface soils. A general trend of decreasing organic carbon content with depth was reported by Khan and Kamalakar (2012).

Cation exchange capacity [Cmol (p^+) kg^{-1}] of soils varied from 10.4–24.9, being highest in surface (0–0.15m) soils of forest vegetation and the lowest in surface (0–0.15m) and sub–surface (0.15–0.30m) soils of rice–mustard land use. The possible reason for comparatively high CEC in soil under forest and mango plantation could be the high soil organic matter (SOM) content. This result is in harmony with the findings of Muche *et al.* (2015). The CEC of soils maintained strong relationship with SOC content (r= 0.915) of soils. This relationship justifies the reason for high CEC of soils under forest and mango plantation. It seems that CEC of soils stemmed to be from the SOC content of soils (Table 2). The electrical conductivity (dSm^{-1}) of soils were not so high to cause salinity problem to crops (Table 1). Comparatively higher values of electrical conductivity reported in soils of rice–rice and rice–mustard land uses, which could be due to the salts originated from the applied fertilizers. Similar magnitude of electrical conductivity in various soils of Hyderabad was reported by Khan and Kamalakar (2012). The result revealed that $CaCO_3$ content (gkg^{-1}) of soils did not maintain any definite pattern of occurrence along the soil depth. It ranged from16.0 gkg^{-1} to 27.4 gkg^{-1} soils of different land uses. The occurrence of $CaCO_3$ in soils may be due to calcification or inherited from parent materials. The amount of $CaCO_3$ reported in the present study corroborated with the findings of Khan and Kamalakar (2012).

Relationship among the soil properties: All the soil properties considered in the present study maintained dynamic relationship among themselves (Table 3). Soil organic carbon content maintained significant negative correlation with BD of soils indicating that with decline in SOC content the BD of soils increase and vice–versa. The SOC content showed strong correlation with CEC of soils. The $CaCO_3$ content maintained strong relationship with all other soil properties except the BD of soils. Soil pH maintained significant positive correlation with $CaCO_3$ content (r= 0.827) while strong negative correlation with water holding capacity (r= –0.821) of soils. Water holding capacity of soils had strong relationship with SOC content (r= 0.898) and CEC of soils (r=

Table 3. Correlation matrix among the different soil properties

	pH	EC	SOC	BD	CEC	$CaCO_3$	WHC	Clay
pH	1							
EC	0.729**	1						
SOC	–0.756**	–0.700**	1					
BD	0.533**	0.241	–0.389*	1				
CEC	–0.798**	–0.848**	0.915**	–0.292	1			
$CaCO_3$	0.827**	0.810**	–0.845**	0.356	–0.897**	1		
WHC	–0.821**	–0.743**	0.898**	–0.422*	0.893**	–0.885**	1	
Clay	0.750**	0.676**	–0.461*	0.317	–0.665**	–0.617**	–0.678**	1

* and**. Correlation is significant at the 0.05 and 0.01 level

0.893). Such relationships reported by many researchers (Sakin, 2012; Joshi and Negi, 2015; Chandel *et al.,* 2015).

CONCLUSION

The magnitude of the various soil properties determined in the collected soils differed significantly which seems to be due to the variation in land use patterns. All the soil properties determined showed a significant depth effect indicating that soil properties differed significantly between the soil depths sampled. Bulk density was typically lower in the surface soil layers compared to deeper soils. Soil pH had significantly lower values in the surface soil layer compared to sub-surface soil layer across all land-uses sampled while soil organic carbon and water holding capacity of soils both declined significantly with increasing soil depth. Comparing the various land-use systems studied, it was therefore clear that high SOC content in soils optimized all other soil properties. So, in order to restore the soil properties in a particular landscape, retaining trees and forest is the most effective option.

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Genetic Diversity Analysis in Peach (*Prunus Persica* L.) Cultivars using RAPD Markers

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Abstract: Thirty five RAPD primers were used to assess molecular polymorphism in seven popular cultivars of peach. A total of 234 amplified products were obtained out of which 220 were polymorphic and 14 were monomorphic. Average polymorphism across seven cultivars was found to be 95.34%. All the cultivars were distinguishable with the combination of polymorphic bands generated by various primers. Some primers also produced unique alleles in specific cultivars which could be used to distinguish them. Analysis of this polymorphism profile, generated using NTSYS software, grouped the seven cultivars into two major clusters at a similarity coefficient of 0.62. First cluster comprised of Partap and Shan-e-Punjab, where as the remaining five cultivars fell in second cluster. The similarity indices between different cultivars ranged from 0.531 to 0.889 with an average of 0.661 across all the cultivars. A maximum similarity value of 0.889 was observed between Flordasun and Flordaprince whereas Partap and Prabhat were genetically most diverse with similarity value of 0.531.

Keywords: Peach, RAPD, Genetic Diversity, Molecular markers

Peach [*Prunus persica* (L.) Batsch] is a species well adapted to temperate and subtropical regions, between latitudes of 30º and 45º North and South (Westwood, 1978). The knowledge of genetic variability among the species is an essential prerequisite for their preservation as well as the success of any breeding programme (Lima *et al*., 2011), hence precise cultivar identification and characterization is essential for improving and securing peach cultivation in the world. The relatively narrow range of morphological traits and limited number of polymorphic isozyme systems are not adequate to discriminate all the cultivars of any given species. Furthermore, many phenotypic traits are developmentally regulated or influenced by the genotype-environment interaction. The advent of molecular markers has been of great interest in this regard and is being proved as valuable tools in the characterization and evaluation of genetic diversity among different species. Different molecular markers including Randomly Amplified Polymorphic DNA (RAPD) (Yang *et al.,* 2001; Bakht *et al.,* 2013), Amplified Fragment Length Polymorphism (AFLP) (Tavaud *et al.,* 2003), Simple Sequence Repeat (SSR) (Wunsch and Hormaza, 2004; Li *et al.,* 2006), Random Amplified Microsatellite Polymorphism (RAMP) (Cheng *et al., 2001,* 2007) and Expressed sequence tags derived microsatellite markers (EST-SSRs) (Sorkheh *et al., 2016)* have been successfully employed for genetic diversity analysis in peaches. Among these molecular markers RAPD (Randomly amplified polymorphic DNA), a PCR based marker RAPD analysis can be used to identify many useful polymorphisms quickly and efficiently, and as such, it has tremendous potential for use in cultivar identification

The advent of the polymerase chain reaction (PCR) and PCR-based techniques such as randomly amplified polymorphic DNA (RAPD) has increased the popularity of using DNA fingerprinting as a tool in fruit breeding (Williams *et al.* 1990; Nybom, 1994). The correct molecular characterization of varieties can prevent the confusion with other varieties with similar morphological characteristics, and enhance its use in peach breeding programs. Taking into consideration the significance of RAPD markers in different breeding programmes, the present study was undertaken to characterize seven commercial cultivars of peach with unknown pedigree, to investigate the genetic similarities and their possible genetic relationships with each other.

MATERIAL AND METHODS

Plant material and DNA 3xtraction: A total of seven cultivars were selected for the study wherein four cultivars Partap, Shane-e-Punjab, Early Grande, and Flordaprince were collected from PAU, Ludhiana and the remaining Flordasun, Prabhat and Sharbati were from HAU, Hisar. The study was conducted at Haryana Agricultural University, Hisar. Fresh young leaves were collected from each cultivar, frozen in liquid nitrogen and kept at -70°C until used for DNA extraction. DNA was extracted by CTAB method (Murray and Thompson 1980) with certain modifications. About five gram of leaf tissue was hand homogenized to fine powder in liquid nitrogen. The powder was transferred to 50ml polypropylene centrifuge tube containing 15 ml of pre-warmed (65ºC) DNA extraction buffer (2% CTAB, 20mM EDTA, 1.4M NaCl, 100mM Tris-HCl, pH 8.0 and 2% β-mercaptoethanol) and incubated at 65ºC for 90 minutes. After incubation the contents were emulsified with an equal volume of chloroform: octanol (24:1) solution for 5 minutes by inversion. The contents were centrifuged for about 10 min at 8000 rpm. After centrifugation the upper aqueous phase was transferred to a pre-sterilized centrifuge tube and again extracted with 10 ml of chloroform: octanol (24:1) solution twice. Following centrifugation the upper aqueous phase was collected and DNA was precipitated with equal volume of ice cold iso-propanol. DNA was pooled out using sterile glass hooks and washed in Wash buffer-I (76 % Ethanol and 0.2 M Sodium acetate) for 20 minutes followed by 2 minutes washing in Wash buffer-II (76% Ethanol and 10mM Ammonium acetate). Further the DNA was air-dried at room temperature and dissolved in appropriate volume of TE (Tris 10mM, EDTA 1mM) buffer. The RNA contamination was removed by giving RNase treatment at 37 ºC for 1 hr. Before PCR, concentration of DNA and protein was determined using U.V spectrophotometer at 260 nm and 280 nm and quality was analyzed using the DNA on 0.8% agarose gel alongside uncut λ DNA as standard. Finally the DNA was diluted in TE to a concentration of 25ng/µL for use in PCR analysis.

Polymerase chain reaction: A total of thirty five random decamer primers, obtained from Operon Technologies™, USA, were used for RAPD analysis. Amplification was carried out in a 10 µL reaction volume containing 10 X PCR assay buffer (50mM KCl, 10mM Tris HCl, 1.5 mM MgCl2), 100µM each of dNTPs, 1 µM of primer, 2.0 units of Taq. DNA polymerase (Genetix, India and Biogene, India.) and 50ng template DNA. Amplification reaction was carried out in PTC-100 programmable thermal cycler (MJ research and Biometra personal), with an initial denaturation step for 3 minutes at 94^{0}C followed by 45 cycles of amplification. Each cycle consisted of denaturation at 94^{0}C for 45 seconds, primer annealing at 45^{0}C for 30 seconds and extension at 72^{0}C for 2 minutes followed by final extension at 72^{0}C for 10 minutes. The PCR products were separated on 1.5% agarose gel in 1 X TBE buffer using ethidium bromide staining. The size of amplified fragments was determined by using standard DNA markers (Gene RulerTM 100 bp DNA ladder). PCR amplified products were visualized under UV light and photographed using VSD Image Master (Pharmacia, Biotech). To test the reproducibility of the RAPD markers, the reactions were repeated at least twice.

Data Analysis: Amplified products for RAPD analysis were scored based on the presence (1) or absence (0) of band for each primer. Banding pattern for each primer was scored by visual observations, where only clear and unambiguous bands were scored. The size (in nucleotide base pairs) of the amplified bands was determined based on its migration relative to molecular size marker (DNA ladder from Bangalore Genie, Pvt. Ltd. India). The data entry was done into a binary data matrix as discrete variables. Jaccard's coefficient of similarity was measured and a dendrogram based on similarity coefficient was generated by using the unweighted pair-group method with arithmetic mean (UPGMA). The computer package NTSYS-PC was used for cluster analysis.

RESULTS AND DISCUSSION

DNA fingerprints varied according to the combination of primers and genomic DNA of samples. Out of 35 primers used to assess genetic diversity among the seven cultivars of peach, only 29 were found to be reproducible, while rest of the primers resulted in either no amplification or smeared profiles. These 29 primers yielded 234 bands/ fragments. The number of amplified fragments ranged from 3 (OPB-04, OPB-05) to 12 (OPBA-09) for various primers with an average of 8.07 bands per primer (Table 1). The size of amplified DNA fragments ranged from 100-1500 bp. Out of 234 bands, 220 bands were polymorphic bands and rest was monomorphic (Fig. 1). The range of polymorphism was 77.78 (OPA-05) to 100 % (with 19 primers) with average of 95.34%. A total of six primers produced nine unique alleles in seven cultivars (Table 2). These primers can be utilized to distinguish one or a few cultivars from the rest of cultivars. Our results strengthened the earlier reports that RAPDs can be used for the estimation of genetic diversity in crop

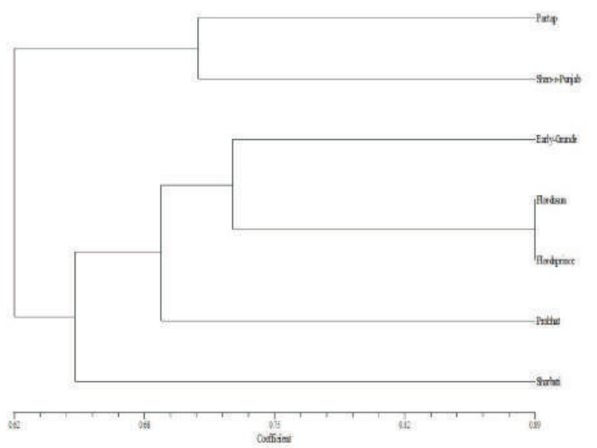

Fig. 1. UPGMA dendrogram showing clustering pattern among seven peach cultivars

Table 1. Amplified DNA bands and polymorphism generated among peach cultivars using 29 RAPD primers

Primer	No. of bands	Monomorphic bands	Polymorphic bands	Percentage of Polymorphism	Range of Molecular Size(bp)
OPA-01	10	0	10	100.00	200-1200
OPA-05	9	2	7	77.78	200-1200
OPA-12	10	0	10	100.00	200-1200
OPA-14	7	1	6	85.71	200-1000
OPB-04	3	0	3	100.00	600-1300
OPB-05	3	0	3	100.00	1000-1500
OPB-14	7	1	6	85.71	200-900
OPE-05	10	0	10	100.00	200-1200
OPE-06	8	0	8	100.00	300-1450
OPE-07	9	0	9	100.00	300-1200
OPBA-01	4	0	4	100.00	700-1500
OPBA-02	7	0	7	100.00	300-1500
OPBA-03	8	0	8	100.00	190-1500
OPBA-04	7	1	6	85.71	200-1500
OPBA-05	6	1	5	83.33	500-1200
OPBA-06	8	0	8	100.00	350-1500
OPBA-07	7	0	7	100.00	500-1400
OPBA-08	11	1	10	90.91	250-1500
OPBA-09	12	0	12	100.00	100-1500
OPBA-10	4	0	4	100.00	500-1200
OPBA-11	7	0	7	100.00	500-1500
OPBA-12	7	1	6	85.71	200-1000
OPBA-13	8	0	8	100.00	250-1400
OPBA-14	10	1	9	90.00	200-1200
OPBA-15	11	0	11	100.00	200-1500
OPBA-16	10	1	9	90.00	200-1500
OPBA-18	10	1	9	90.00	200-1500
OPBA-19	10	0	10	100.00	300-1500
OPBA-20	11	0	11	100.00	200-1500
Total	234	14	220		
Mean	8.07	0.48	7.59	95.34	

enhancement programs. In fact, we obtained a high number of polymorphic bands (220), which is considerably important compared to values among different peach cultivars using various RAPD primers (Dirlewanger *et al*., 1998). Studies on peach cultivars using RAPD markers even revealed a wide genetic polymorphism between 12 to 80% (Bakht *et al*., 2013). Previous molecular studies on other prunus species like plum also revealed 20 to 98% polymorphism using RAPD markers (Shimada *et al*., 1999; Lisek *et al*., 2007; Liu *et al*., 2007; Hend *et al*., 2009). The pair-wise comparison of the RAPD profiles based on both shared and unique amplification products was made to generate a similarity index. The similarity indices estimated on the basis of 29 primers between different cultivars ranged from 0.531 to 0.889 with an average of 0.661 across all the cultivars (Table 3). A maximum similarity value of 0.889 was observed between Flordasun and Flordaprince whereas Partap and Prabhat were found to be genetically most diverse with similarity value of 0.531.

The hierarchical cluster analysis based on similarity indices values identified two major clusters at a similarity coefficient of 0.62 (Fig.1). First cluster comprised of Partap and Shan-e-Punjab, where as the remaining five cultivars fell in second cluster. Second cluster at a similarity coefficient of 0.65 divided into two sub clusters. Sub cluster-I comprised cultivar Sharbati and remaining four cultivars fall in sub cluster-II. Sub cluster-II again divided into two groups at the similarity coefficient of 0.69. The Group-I comprised of only cultivar Prabhat which was out grouped in Sub cluster-II. Group-II comprised of Early Grande, Flordasun and

Table 2. Primers capable of amplifying unique alleles from different cultivars of peach

Primer	Total Bands	No. of Unique Alleles	Allele Size (bp)	Cultivars
OPA-05	9	1	700	Pratap
OPB-14	7	1	500	Sharbati
OPE-06	8	2	450 & 500	Pratap and Shan-e-Punjab
OPBA-06	8	2	400 & 750	Early Grande and Sharbati
OPBA-08	11	1	1500	Early Grande
OPBA-11	7	2	500 & 1100	Prabhat and Florda Prince

Table 3. Similarity matrix data (NTSYS PC) among the peach cultivars obtained using RAPD markers

Cultivars	Partap	Shan-e-Punjab	Early-Grande	Flordasun	Flordaprince	Prabhat	Sharbati
Partap	1.000						
Shan-e-Punjab	0.712	1.000					
Early-Grande	0.619	0.671	1.000				
Flordasun	0.579	0.675	0.730	1.000			
Flordaprince	0.549	0.675	0.730	0.889	1.000		
Prabhat	0.531	0.642	0.645	0.693	0.738	1.000	
Sharbati	0.579	0.630	0.642	0.623	0.645	0.678	1.000

Flordaprince. Group-II again divided into two subgroups at the similarity coefficient of 0.72 where Early Grande was out grouped from Group-II. The maximum similarity was obtained between Flordasun and Flordaprince; they were in the same group with the similarity coefficient of 0.89.

Genetic relationship among different peach cultivars was also visualized by performing principle component analysis (PCA) based on RAPD data (Fig. 2). The result of PCA was comparable to the cluster analysis as evident from the (Fig. 1 and 2). Cultivars grouped within the same cluster in the dendrogram were also occupying the same positions in three-dimensional scaling. The cultivars which were lying nearer to each other in three dimensions PCA were more similar to one another than those lying apart. Cultivars Flordasun and Flordaprince were the closest, followed by Flordaprince and Prabhat. Partap and Prabhat were farthest or most diverse and dissimilar to all other cultivars. This clearly shows that the significant genetic diversity exists among these major peach cultivars. Hence, these cultivars should be preserved as valuable genetic resources for breeding. The high genetic diversity present among these cultivars suggests that they must have been originated from genetically divergent parents or have a long history of adaptation to their respective microclimatic regions. Similar conclusions were made by Bakht *et al*. (2013) while assessing the genetic diversity of twelve peach genotypes by RAPD analysis. Forty primers discriminated all twelve peach genotypes and cluster analysis revealed that the various peach genotypes were grouped into 5 classes. Group I and II and V had only one genotype each. Group III and IV comprised of 3 and 6 genotypes

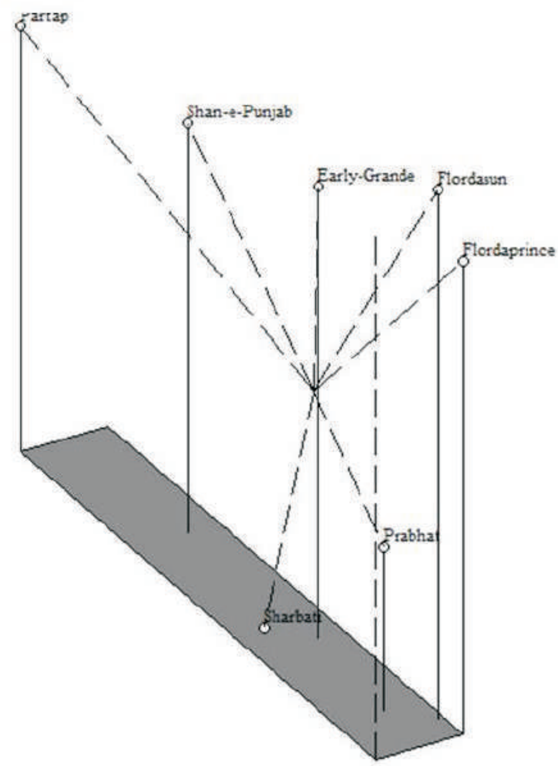

Fig. 2. Three Dimensional PCA (Principle Component Analysis) scaling of seven peach cultivars using RAPD Markers

CONCLUSION

Peaches in most cases could be well distinguished from each other by RAPD analysis, as selection based on molecular markers analysis is likely to be more effective as it is more closely linked to the genetic constitution of a genotype. These results so obtained by the RAPD analysis may provide useful information for genetic improvement, germplasm conservation, pedigree analysis, cultivar identification and genetic diversity studies in peach. From the clustering pattern and genetic relationship obtained using RAPD markers, breeders can identify diverse cultivars from different clusters and can employ them in their future breeding programmes.

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Correlation and Path Analysis of Yield and Economic Traits in Chilli (*Capsicum annuum* L.)

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Abstract: An experiment was carried out in spring summer season of 2014 using 30 chilli genotypes to study the association of various growth, yield and quality traits to develop a reliable set of traits for indirect selection.The genotypic coefficients were higher in the magnitudes relative to corresponding estimates of phenotypic coefficients, which indicated high heritability of the traits under study. The fruit yield per plant showed highly significant positive association with dry matter percent, average dry fruit weight, weight of seeds per plant and pericarp thickness which shows that these character are responsible for determining high yield. The significantly negative correlation with days to 50 ripening inferred that early ripening had higher yield over those having late. Path coefficient analysis revealed that the maximum direct effect was by weight of seeds per plant followed by average dry fruit weight which shows its more accountability for higher yield. Therefore, it may be possible to improve fruit yield by selecting the accessions on the basis of above characters.

Keywords: Chilli, Correlation, Path analysis, Yield, Direct effect

India is the world's largest producer, consumer and exporter of chilies (*Capsicum annuum* L.) in the world. The average dry chilli yield of the country is low as compared to the progressive chilli producing countries like USA, Korea and Taiwan due to coverage of large area under low yielding genotypes (Maurya *et al*., 2016). Improving productivity of chilli through developing high yielding varieties with desirable qualities could reverse the existing trend of low productivity of this crop (Sreelathakumary and Rajamony, 2002; Verma *et al.,* 2004). Hence, it is highly important to develop high yielding varieties/hybrids to meet out the increasing demand. Since yield is a complex trait and its direct improvement is difficult, governed by a large number of component traits, Knowledge of inter-character relationship is very important in plant breeding for indirect selection for characters that are not easily measured. However, under complex situation, correlation alone become insufficient to explain relationships among characters and thus path analysis of economic yield components with yield is important. Therefore, field investigation was carried out with a view to study the character association and direct and indirect effect of independent characters on dependent chilli yield by assessing the thirty genotypes of chilli at Vegetable Research Center, GBPUAT, Pantnagar (Uttarakhand).

MATERIAL AND METHODS

Thirty genetically diverse genotypes of chilli comprising of established varieties and different lines were grown in a randomized block design with three replications during spring summer season of the year 2014 at G.B. Pant University of Agriculture and Technology, Pantnagar. The seedlings were transplanted at a distance of 60 × 50 cm. All the cultural practices were fallowed to raise the good crop. The five randomly selected plants in each plots were used to record observations on number of primary branches per plants, stem diameter (cm), days to 50 percent ripening, fruit length (cm), periferi width (cm), number of seeds per fruit, weight of seeds per fruit (mg), 100 seed weight (mg), seed husk ratio, dry matter percent, average dry fruit weight (mg), weight of seeds per plant, oleoresin content, pericarp thickness and yield per plant (g). The phenotypic correlation coefficient, genotypic correlation coefficient and direct and indirect effect were computed by using the procedure given by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The estimates of genotypic correlations were higher in magnitude than the estimates of phenotypic correlation coefficients for almost all the character combinations which suggested the predominance of genotypic effects over environmental factors (Table 1). The fruit yield per plant showed highly significant positive association with dry matter percent, average dry fruit weight, weight of seeds per plant and pericarp thickness which shows that these character are responsible for determining high yield. The above result is supported by the finding of Munshi *et al.* (2000), Gogoi and

Table 1. Phenotypic (rP) and genotypic (rG) correlation coefficients among yield and yield attributing traits in chilli

Character		Primary branches	Stem diameter	50% ripening	Fruit length	Periferi width	Number of seeds	Weight of seeds	100 seed weight	Seed husk ratio	Dry matter %	Average Fruit weight	Weight of seeds/ plant	Oleoresin content	Pericarp thickness	Yield
Primary branches	rG	1	0.197	0.043	-0.141	-0.289**	0.098	0.201	-0.007	-0.267*	0.288**	-0.276**	0.427**	0.191	-0.163	0.070
	rP		0.135	0.049	-0.119	-0.255*	0.107	0.196	-0.007	-0.250*	0.267*	-0.235*	0.364**	0.161	-0.163	0.060
Stem diameter	rG		1	0.422**	-0.071	-0.219*	-0.042	0.010	-0.024	0.190	-0.022	-0.434**	-0.063	-0.192	-0.475**	-0.296*
	rP			0.338**	-0.036	-0.217	-0.007	0.034	-0.013	0.163	-0.048	-0.373**	-0.019	-0.166	-0.379**	*
Days to 50%	rG			1	-0.221*	-0.353**	-0.184	-0.086	0.010	0.154	-0.208*	-0.656**	-0.398**	-0.015	-0.180	-0.692*
	rP				-0.187	-0.285**	-0.140	-0.067	-0.000	0.151	-0.172	-0.603**	-0.324**	-0.022	-0.178	*
Fruit length	rG				1	0.306**	0.153	0.180	0.189	0.237*	-0.321**	0.328**	-0.074	0.229*	0.316**	0.115
	rP					0.300**	0.139	0.169	0.176	0.229	-0.294**	0.316**	-0.062	0.214*	-0.307**	0.114
Periferi width	rG					1	0.302**	0.372**	0.385**	-0.032	-0.235*	0.586**	-0.072	0.308**	0.271**	0.145
	rP						0.245*	0.312**	0.363**	-0.023	-0.167	0.550**	-0.088	0.290**	0.244*	0.139
Number of seeds/fruit	rG						1	0.803**	-0.165	-0.451**	0.192	0.151	0.613**	0.056	0.029	0.209*
	rP							0.808**	-0.145	-0.415**	0.176	0.143	0.566**	0.051	0.047	0.179
Weight of seeds/fruit	rG							1	0.374**	-0.269*	-0.043	0.278**	0.550**	0.213*	0.116	0.157
	rP								0.368**	-0.250*	-0.035	0.261*	0.520**	0.201	0.129	0.133
100 seed weight	rG								1	0.205	-0.380**	0.275**	-0.179	0.137	0.194	-0.122
	rP									0.202	-0.356**	0.264*	-0.152	-0.137	0.192	-0.114
Seed husk ratio	rG									1	-0.279**	-0.042	-0..353**	0.145	-0.237*	-0.190
	rP										-0.266*	-0.041	-0.320**	0.144	0.222*	-0.184
Dry matter %	rG										1	-0.069	0.433**	0.092	-0.130	0.338**
	rP											-0.019	0.373**	0.087	-0.128	0.341**
Average fruit	rG											1	0.225*	0.107	0.593**	0.720**
	rP												0.156	0.105	0.542**	0.684**
Weight of seeds/pla	rG												1	0.110	0.096	0.705**
	rP													0.092	0.101	0.689**
Oleoresin content	rG													1	0.005	0.062
	rP														0.004	0.057
Pericarp thickness	rG														1	0.407**
	rP															0.372**
Yield	rG															1
	rP															

Table 2. Path coefficient analysis among yield and yield attributing traits in chilli

Character	Primary branches	Stem diameter	50% ripening	Fruit length	Periferi width	Number of seeds	Weight of seeds	100 seed weight	Seed husk ratio	Dry matter %	Average Fruit weight	Weight of seeds/plant	Oleoresin content	Pericarp thickness	Correlation with yield
Primary branches	-0.0426 -0.0027	0.0003 0.0046	0.0095 0.0039	-0.0206 -0.0095	0.0086 0.0136	0.0029 0.0027	-0.1362 -0.1086	-0.0008 -0.0004	0.0323 0.0177	0.0127 0.0130	-0.2301 -0.1791	0.4134 0.3110	-0.0027 0.0014	0.0283 0.0126	0.070 0.060
Stem diameter	-0.0084 -0.0027	0.0019 0.0343	0.0923 0.0268	-0.0104 -0.0029	0.0065 0.0115	-0.0012 -0.0001	-0.0067 -0.0190	-0.0029 -0.0008	-0.0230 -0.0115	-0.0009 -0.0023	-0.3620 -0.2840	-0.0605 -0.0158	0.0027 -0.0014	0.0825 0.0292	-0.296** -0.242*
50% ripening	-0.0018 -0.0010	0.0008 0.0116	0.2187 0.0792	-0.0324 -0.0150	0.0105 0.0152	-0.0055 -0.0035	0.0583 0.0373	0.0012 0.00003	-0.0187 -0.0106	-0.0092 -0.0083	-0.5470 -0.4588	-0.3858 -0.2775	0.0002 -0.0002	0.0313 0.0137	-0.692** -0.625**
Fruit length	0.0060 0.0024	-0.0001 -0.0012	-0.0484 -0.0148	0.1467 -0.0150	-0.0091 -0.0160	0.0046 0.0035	-0.1217 -0.0937	0.0232 0.0115	-0.0287 -0.0162	-0142 -0.0143	0.2737 0.2410	-0.0713 -0.0526	-0.0032 0.0019	-0.0549 -0.0236	0.115 0.114
Periferi width	0.0123 0.0052	-0.0004 -0.0074	-0.0772 -0.0025	0.0449 0.0240	-0.0299 -0.0534	0.0091 0.0062	-0.2521 -0.1726	0.0472 0.0237	0.0036 0.0016	-0.0103 -0.0081	0.4888 0.4187	-0.0695 -0.0751	-0.0044 0.0025	-0.0471 -0.0188	0.145 0.139
Number of seeds/fruit	-0.0041 -0.0021	-0.00008 -0.0002	-0.0402 -0.0110	0.0224 0.0111	-0.0090 -0.0130	0.0303 0.0253	-0.5141 -0.4471	-0.0202 -0.0095	0.0547 0.0293	0.0084 0.0085	0.1263 0.1090	0.5933 0.4839	-0.0008 0.0004	-0.0050 -0.0036	0.209* 0.179
Weight of seeds/fruit	-0.0085 -0.0040	0.00002 0.0011	-0.0188 -0.0053	0.0263 0.0136	-0.0111 -0.0166	0.0243 0.0204	-0.6777 -0.5535	0.0459 0.0241	0.0325 0.0176	-0.0018 -0.0017	0.2322 0.1989	0.5325 0.4446	-0.0030 0.0017	-0.0202 -0.0099	0.157 0.133
100 seed weight	0.0002 0.0001	-0.00005 -0.0004	0.0022 0.00003	0.0277 0.0141	-0.0115 -0.0193	-0.0050 -0.0036	-0.2535 -0.2038	0.1227 0.0654	-0.0248 -0.0142	-0.0167 -0.0173	0.2295 0.2008	-0.1729 0.1300	-0.0019 0.0012	-0.0336 -0.0148	-0.122 -0.114
Seed husk ratio	0.0113 0.0051	0.0003 0.0056	0.0337 0.0119	0.0347 0.0183	0.0009 0.0012	-0.0137 -0.0105	0.1821 0.1381	0.0252 0.0132	-0.1212 -0.0708	-0.0123 -0.0129	-0.0349 -0.0314	-0.3414 -0.2739	-0.0020 0.0012	0.0411 0.0171	-0.190 -0.184
Dry matter %	-0.0123 -0.0054	-0.00004 -0.0016	-0.0455 -0.0136	-0.0471 -0.0236	0.0070 0.0089	0.0058 0.0044	0.0288 0.0193	-0.0465 -0.0233	0.0338 0.0188	0.0441 0.0486	-0.0576 -0.0145	0.4191 0.3193	-0.0013 0.0007	0.0226 0.0098	0.338** 0.341*
Average fruit weight	0.0117 0.0048	-0.0008 -0.0128	-0.1434 -0.0477	0.0481 0.0254	-0.0175 -0.0293	0.0046 0.00036	-0.1886 -0.1446	0.0337 0.0172	0.0050 0.0029	-0.0030 -0.0009	0.8344 0.7614	0.2179 0.1335	-0.0015 0.0009	-0.1029 -0.0418	0.720** 0.684**
Weight of seeds/plant	-0.0182 -0.0074	-0.0001 -0.0006	-0.0871 -0.0257	-0.0108 -0.0049	0.0021 0.0046	0.0186 0.0143	-0.3727 -0.2877	-0.0219 -0.0099	0.0427 0.0226	0.0191 0.0181	0.1878 0.1188	0.9682 0.8556	-0.0015 0.0008	-0.0167 -0.0078	0.705** 0.689**
Oleoresin content	-0.0081 -0.0033	-0.0003 -0.0057	-0.0033 -0.0017	0.0335 0.0171	-0.0092 -0.0154	0.0017 0.0012	-0.1441 -0.1110	0.0167 0.0089	-0.0175 -0.0101	0.0040 0.0042	0.0892 0.0801	0.1068 0.0788	-0.0144 0.0088	-0.0009 -0.0003	0.062 0.057
Pericarp thickness	0.0069 0.0033	-0.0009 -0.0130	-0.0394 -0.0141	0.0463 0.0246	-0.0081 -0.0130	0.0008 0.0011	-0.0789 -0.0714	0.0237 0.0125	0.0286 0.0157	-0.0057 -0.0062	0.4945 0.4127	0.0931 0.0865	-0.00007 0.00003	-0.1737 -0.0772	0.407** 0.372**

Gautam (2003), Bhardwaj *et al.* (2007) and Krishna *et al.* (2007). Fruit yield per plant showed highly significant and negative correlation with days to 50 percent fruit ripening means plant having late ripening produce less yield as compared to those plant which takes less days to 50 percent ripening; Ahmed *et al.* (2006) and Jogi *et al.* (2013) also reported similar results. Oleoresin content had highly significant and positive correlation with periferi width. The trait is correlated with yield does not imply that it is a component of yield, hence partitioning of phenotypic correlation into direct and indirect effects was also performed through path analysis by taking yield as dependent variable and other traits as independent variables. The analysis of data revealed that every component character has a direct effect on yield (Table 2). Maximum direct effect was in weight of seeds per plant followed by average dry fruit weight which shows its more accountability for higher yield. Kumar *et al*. (2003) also reported similar finding. Therefore, it may be possible to improve fruit yield by selecting the accessions on the basis of characters which showed significant positive correlation with yield.

On the basis of above finding it can be concluded that the characters, dry matter percent, average dry fruit weight, weight of seeds per plant and pericarp thickness which exhibited highly significant positive correlation with fruit yield per plant indicates the useful of these traits for improving upon fruit yield in chilli.

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Assessment of Genetic Variation among Different Provenances of *Acacia nilotica* CPTs for Seed Traits

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Abstract: *Acacia nilotica,* belonging tofamily Fabaceae*,* is one of the most important, versatile and multipurpose tree species. Seeds collected from 6 different geographical locations were evaluated for different pod and seed characteristics. Considerable morphological and physiological variations between provenances for all the pod and seed traits were among the seed sources. Among various parameters, seed weight, pod length and seeds per pod were most heritable traits, followed by genetic advance. Characters with greater genetic influence can be directly screened/selected for the improvement of this potential tree species in arid and semi-arid region of India for raising quality plating material.

Keywords: *Acacia nilotica*, Seed, Pod, Heritability, Genetic Advance

Acacia nilotica, belonging to family Fabaceae*,* is one of the most important, versatile and multipurpose tree species found in dry areas of the Indian sub-continent and Africa. The species seldom occurs above 500 m or in areas with more than annual 1500 mm of rainfall, except on gravelly porous soils on the river beds and can grow on a variety of soils, compact sandy loam, shallow stony, riverine alluvial, black cotton, alluvial loam, saline, mild alkaline, ravines and soils containing calcareous concretions. Genetic variation in *Acacia nilotica* has mainly been investigated using morphological and physiological traits. This differentiation is usually pertinent to habitat conditions. Morphological variation is strongly influenced by various environmental factors and morphological variability signifies the adaptation of the species to its environment and it may be genetically determined or environmentally introduced. Thus morphological differentiation seems to have an evolutionary significance that result in the gradual adaptation of the species to its environment (Mahmood and Abbas, 2003; Hussain and Mahmood, 2004). *Acacia nilotica* has wide ecological amplitude and is found growing in a variety of habitats. The species is remarkable variable for various morphological expressions such as leaf, stipular spines morphology, pod and seed characteristics. The population of the species can be differentiated even at a very short distance. The available literature reveals that a little work has been done on genetic variation in *Acacia nilotica*. Keeping in view the above facts, the present study was initiated to find extant genetic variation in *Acacia nilotica* among different geographical sites on the basis of seed and pod traits.

MATERIAL AND METHODS

An intensive survey was conducted at six eco-geographical regions viz. Firozpur (Punjab), Roopnagar (Punjab), Sonipat (Haryana), Dausa (Rajasthan), Nagaur (Raj.) and Hanumangarh (Raj.) for selection and collection of quality pods from candidate plus tree selection (CPTs) during the year 2014-15. Sufficient number of pods was collected from ten individual trees from each provenance, keeping an isolation of 200 m to provide a sample of prevailing genetic variation in the population. Collected pods were sun dried and pod length, breadth and number of seeds/pod were recorded.For each provenance, seeds were separately extracted from sun-dried pods and thereafter seed length, seed breadth and seed thickness (three replicates with 25 seed each) and seed weight was measured in five replicates (each with 100 seeds) as per ISTA (1999).Phenotypic, genotypic and environmental coefficients of variation were calculated (Burton and Devane, 1953):

Phenotypic coefficient of variation % (PCV) = $\sqrt{PV}/x \times 100$

Genotypic coefficient of variation % (GCV) = $\sqrt{GV}/x \times 100$

x = population mean for each trait

Heritability values and genetic advance were worked out following the methodology of Johnson *et al*. (1955). Genetic advance (GA) is the expected increase in the magnitude of a particular character when a selection pressure of chosen intensity (i) is applied. This was calculated as per Johanson *et al.* (1955).

$$GA = GV/PV \times i \times \sqrt{PV}$$

Where, i = selection intensity

RESULTS AND DISCUSSION

The significant ($P < 0.05$) variations were observed in seed weight and number of seeds per pod among seed sources (Table 1). However, average highest pod length was in Dausa (Rajasthan) and least in Firozpur (Punjab) populations. The pod breadth varied from 13.44 to 14.25 mm with general mean of 13.82 mm. The maximum number of seeds per pod was also in Dausa (Rajasthan)and the lowest in Nagaur (Rajasthan). Seeds collected from Dausa exhibited significantly highest values for seed length (8.01 mm), seed width (7.01 mm)and seed thickness (3.97 mm) whereas, Firozpur seed sources showed significantly least values for these seed characters as compared to general mean. Seed weight was significantly highest in Dausa (17.27 g) followed by Nagaur (16.59 g) whereas significantly lowest in Hanumangarh (13.89 g) as compared to general mean (15.40 g). Among various pod and seed traits, heritability values were highest for the seed weight (78.06 %), followed by pod length (71.82%) and number of seeds per pod (70.85%). Highest genetic advance was also for seed weight (19.67%), while the least for seed length (0.90%). The genotypic coefficient of variation ranged from 1.29percent (seed length) to 10.81percent (seed weight). The estimate of phenotypic coefficient of variation was more in magnitude than genotypic coefficient of variation(Table 2). Variations were random between the sources and these differences might have arisen due to the fact that genotypes grew under different environmental conditions in different provenances in India.

In general, the genotypic correlation coefficients were higher than the corresponding phenotypic values. The maximum genotypic correlation (0.90) was observed between seed width and pod length and minimum (0.19) between 100 seed weight and pod width. The maximum phenotypic correlation (0.48) was between number of seeds per pod and pod length and minimum (0.12) between seed length and pod width. Pod length showed the highly significant and positive correlation with seed length, seed width, seed thickness, seeds per pod and 100 seed weight. Phenotypic correlation between seed length and pod width was not significant. Seed length, width and thickness were having significant positive association with 100 seed weight (Table 3). Summing up, these relationships indicate that pod length, pod width, number of seed per pod, seed length, seed width, seed thickness, and 100-seed weight have significant positive correlations with each other. The result showed that the genotypic correlations are higher than the corresponding phenotypic correlations, which indicate the presence of strong inherent association among all the characters.

Table 2. Magnitude of variation for pod and seed characters of different provenances of *Acacia nilotica*

Characters	GCV	PCV	Heritability (%)	GA (% mean)
Pod length (cm)	6.14	7.24	71.82	10.71
Pod width (mm)	4.20	5.27	63.51	6.90
Seeds/Pod	6.85	8.14	70.85	11.88
Seed length (mm)	1.29	3.82	11.40	0.90
Seed width (mm)	1.89	3.17	35.56	2.33
Seed thickness (mm)	3.06	5.98	26.14	3.22
Seed weight (100 seeds)	10.81	12.23	78.06	19.67

Due to the wide geographical distribution there is considerable scope of genetic variation in *A. nilotica* seeds. Seed contain a lot of variation from one origin to another origin with regard to morphological variation and physiological differences which could be genetic in nature as a result of adaptation to diverse environmental condition prevailing throughout their distributional range. In present investigation four of characters (pod length, pod width, number of seeds per pod and seed weight) were influenced by genotypic variations and three characters (seed length, seed width and seed thickness) were under the influence of environmental variation. Almostsimilar trend was obtained in growth, physiological and biochemical parameters of

Table 1. Morphological characteristics of pods and seeds of *Acacia nilotica* provenances

Geographical location	Pod length (cm)	Pod width (mm)	Seeds per pod	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	100 Seed weight (g)
Firozepur	13.71	13.44	9.91	7.61	6.65	3.60	14.01
Roopnagar	14.44	13.91	10.95	7.62	6.80	3.66	15.27
Sonipat	14.87	14.25	10.63	7.80	6.95	3.85	15.37
Dausa	15.08	14.19	11.21	8.01	7.01	3.97	17.27
Nagaur	14.04	13.46	9.76	7.82	6.84	3.86	16.59
Hanumangarh	13.87	13.65	9.99	7.67	6.72	3.63	13.89
Mean	14.34	13.82	10.41	7.76	6.83	3.76	15.40
CD (p=0.05)	0.42	0.21	0.32	0.23	0.18	0.19	0.57
CV	3.14	3.35	5.24	1.34	1.60	2.15	7.18

Table 3. Phenotypic and genotypic correlations among different pod and seed characters of selected seed sources of *A. nilotica*

Characters		Pod length	Pod width	Seeds/pod	Seed length	Seed width	Seed thickness
Pod width	rp	0.34**					
Seeds/pod	rp	0.48**	0.38**				
Seed length	rp	0.34**	0.12	0.15*			
Seed width	rp	0.47**	0.15*	0.27**	0.41**		
Seed thickness	rp	0.44**	0.20**	0.20**	0.40**	0.36**	
Seed weight(100 seeds)	rp	0.44**	0.15*	0.22**	0.37**	0.31**	0.41**

rp= phenotypic and rg= genotypic correlation; *,** significant at 5 and 1%, respectively

Dalbergia sissoo Roxb. (Rawat and Nautiyal, 2007).

The present observations indicate that considerable genetic differences exist in all the seed characteristics among the different provenances of *A. nilotica*, Dausa (Rajasthan) was found as a superior seed source on the basis of pod and seed morphological characters such as pod length, pod width, number of seeds per pod, seed weight, seed length, seed width and seed thickness. There was clear difference in seed characteristics among the provenances. The variations in most studied parameters are under genotypic control among provenances. It is suggested that the seed weight was superior character for selection of elite seed source for tree improvement program on the basis of heritability value.

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Multifunctional Actinomycetes as Natural Resource Management for Saline Soil Amelioration and Growth Promotion in Maize (*Zea mays*)

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Abstract:. In the present study attempts were made to overcome the salinity issue by isolating the halotolerant actinomycetes from saline soil and to evaluate the growth promotion in maize by ameliorating the salinity. Halotolerant isolates were further inoculated on corresponding plate to study their biochemical and plant growth promoting activities. Potent isolates were taken for preparing consortia following their compatibility with each other. A significant increase in height, fresh and dry weight, root and shoot length and the number of leaves in maize plant compared to the control was observed. On the other hand, increased concentration of proline and total chlorophyll content (TCC) was also observed. This investigation revealed the multifunctional properties of halotolerant actinomycetes isolates showing promising results for growth and yield in maize under saline condition.

Kewords: Saline soil, Actinomycetes Consortia, Proline and TCC

Soil salinity is one of the most serious abiotic threats throughout the world impairing the productivity of crop. Soil having electrical conductivity (EC) of saturation extract (ECe) in root zone exceeds 4dSm^{-1} at 25°C and has exchangeable sodium of 15% is referred as saline soil. Nearly 20% of the world′s cultivated land and nearly half of all irrigated lands are affected by salinity (Siddikee *et al*., 2010). According to the estimates of Martinez and Manzur (2005), every year 0.25–0.50 million hectares of irrigated lands are gone out of production in the world due to salts build up in the soil. It also results in losses of hundreds of millions of dollars (US$ 12.6 billion) per year to agriculture (Ghassemi *et al*., 1995). It has been estimated that more than 50% of the arable land would be salinized by the year 2050 (Jamil *et al*., 2011).

The biotic approach ′plant-microbe interaction′ to overcome salinity problems is a considerable attention throughout the world. Therefore, microbial application is a beneficial approach for the amelioration of saline soil, enhancing the fertility and ultimately crop yields. Actinomycetes are considerable group of microorganisms to ameliorate the saline soil because they have the properties of promoting plant growth by direct or indirect mechanisms and these are a dominant group of microorganisms occurred in the saline soil specially the genus *Streptomyces.* Sadeghi *et al*. (2012) studied the plant growth promoting activity of an auxin and siderophore producing isolate of *Streptomyces* under saline soil conditions and reported increase in growth and development of wheat plant. They observed significant increases in germination rate, percentage and uniformity, shoot length and dry weight compared to the control. Applying the microbial inoculum increased the concentration of N, P, Fe and Mn in wheat shoots grown in normal and saline soil and thus concluded that *Streptomyces* isolate has potential to be utilized as biofertilizers in saline soils. A lot of research is being carried out for sustainable approaches for addressing the salinity issue using microbes but most of them are concentrated on bacteria and fungi. In addition, few reports are there about halotolerant actinomycetes and their role in salinity amelioration and growth promotion in maize plant. Therefore, the present study was undertaken to overcome the salinity issue by making the consortia of potent halotolerant actinomycetes isolates and to evaluate the growth promotion in maize by estimating proline and chlorophyll contents after treatment.

MATERIAL AND METHODS

Collection of soil samples: Soil samples were collected from the different sites of saline soil from the campus of Babasaheb Bhimrao Ambedkar University, Lucknow and were kept in clean polythene bags.

Isolation of Actinomycetes: Actinomycetes were isolated by spread plate technique following serial dilution of soil samples on starch casein agar medium (SCA) (starch 5gm, casein 0.5gm, K_2HPO_4 0.25gm, agar 20gm, distilled water 1000ml at pH 8). Plates were incubated at 28°C for five to seven days and were observed intermittently during incubation.

Halotolerant Actinomycetes: To characterize the halotolerant capacity actinomycetes colonies were picked and spot inoculated on starch casein agar (SCA) medium containing different concentration of sodium chloride (NaCl) (3–11%). Plates were incubated at 28 ˚C for five to seven days.

Biochemical Characterization

Amylase test: Starch agar medium (starch 20gm, agar 15gm, distilled water 1000ml) was spot inoculated with different cultures of actinomycetes and the plates were incubated at 37˚C. For the visualization of clear zone around the colonies plates were flooded with Gram′s iodine and the presence of bluish black color of medium was observed for the hydrolysis of starch.

Urease test: Actinomycetes cultures were used to spot inoculate the urea agar medium (peptone 1gm, NaCl 5gm, K_2HPO_4 2gm, glucose 1gm, urea 20gm, agar 20gm, phenol red 0.0006ml to adjust pH 6.8, distilled water 1000ml) and plates were incubated at 37˚C. Color change of the medium from yellow to red or dark pink was observed as Urease production by the isolates.

Caseinase test: Skim milk agar medium (glucose 10gm, skim milk powder 50gm, K_2HPO_4 0.5gm, $MgSO_4.7H_2O$ 0.5gm, $FeSO_4$ 1gm, agar 20gm, distilled water 1000ml at pH 7.2) was spot inoculated with actinomycetes isolates and incubated at 30˚C to observe the clear zone around the visible colonies showing positive result for the production of Caseinase enzyme.

Catalase test: Using aseptic technique a small amount of different actinomycetes cultures was picked and smears were made on the clean glass slides and flooded with H_2O_2 to examine the rapid evolution of O_2 as evidence by bubbling indicated the positive result.

Plant Growth Promoting Attributes of Actinomycetes Isolates

Detection of IAA production: In order to characterize Indole acetic acid (IAA) production by actinomycetes isolates method given by Gordon and Weber (1951) was followed. Luria–Bertani broth amended with tryptophan (5mM) was inoculated with the isolates and incubated for 3 to 4 days. After incubation cultures were centrifuged at 10,000rpm for 20 minutes. 2ml of supernatant was mixed with two drops of orthophosphoric acid and 4ml of Salkowski reagent (1ml of 0.5 M $FeCl_3$ in 50 ml of 35% perchloric acid). Tubes were incubated at room temperature for 25 minutes. The intensity of pink color was observed as positive result for the production of IAA.

Characterization of HCN: Following methodology described by Castric (1975) actinomycetes cultures were spot inoculated on starch casein agar medium containing 4.4 g per liter of glycine. A Whatman filter paper No.1 soaked in 0.5% picric acid solution (in 2% sodium carbonate) was placed inside the lid of a plate. Plates were sealed with parafilm and incubated at 30˚C for 4 days. Development of light brown to dark brown color on the filter paper indicated hydrogen cyanide (HCN) production.

Phosphate solubilization by Actinomycetes: Pikovskaya agar medium (yeast extract 0.5gm, dextrose 10gm, $CaSO_4$ 5gm, NH_4SO_4 0.5gm, KCl 0.2gm, $MgSO_4$ 0.1gm, manganese sulfate 0.0001gm, ferrous sulfate 0.0001gm, agar 15gm, distilled water 1000ml at pH 7.2) was spot inoculated by the isolates to detect their phosphate solubilizing ability and plates were incubated at 30˚C for 5–7 days. Clear halo zone around colonial growth was observed as positive result.

Detection of siderophore production: Following the protocol of Schywn and Neiland, 1987 CAS–HDTMA solution was prepared by dissolving 121mg of CAS in 100ml of distilled water and to this 20ml of 1mM $FeCl_3.6H_2O$ solution was added. It was slowly added to 20ml HDTMA solution. 100ml of CAS–HDTMA solution was added to 900ml of the sterilized King′s B medium and plates were made. Now plates were inoculated with all the isolates and incubated at 35˚C for 5 to 7 days for the observation of orange zone around the colonial growth as positive result.

Actinomycetes Consortia

Although, the combination of two or more strains may perform better than single inuculum compatible actinomycetes cultures were used to prepare consortia (C_1 and C_2) following the protocol of Baker (1990). On the basis of biochemical and plant growth promoting attributes potent compatible isolates were streaked on SCA plates (one with two and other with three actinomycetes isolates) in such a manner that they overlap each other and incubated at 35˚C for 5 to 7 days.

Pot experiment: Saline soil from the campus of Babasaheb Bhimrao Ambedkar University, Lucknow was taken followed by the detection of electrical conductivity (EC) and pH. Soil (autoclaved) was filled in sterilized pots. Now, maize (*Zea mays*) seeds (sterilized with 1% $HgCl_2$) were sown in each of three pots and required amount of water was added for providing the moisture content. Actinomycetes consortia were influenced in each of two pots (one with C_1 and other with C_2), whereas, one leaving as control.

Proline and total chlorophyll estimation: According to protocol of Bates *et al*. (1973) 200 mg of treated fresh maize leaf samples were homogenized with 5ml of 3% salphosalicylic acid and extract was centrifuged at 3000 rpm for 10 minutes. Transferring 1ml of supernatant into a fresh tube 1ml of orthophosphoric acid, ninhydrin and glacial acetic acid were added. The tubes were kept in water bath at 100˚C for an hour and then in ice bath for 30 minutes. Now, 4ml of toluene was added in the tubes and were vertex for the development of two layers. The upper pink layer was collected as developed proline. Optical density (OD) was taken by spectrophotometer at 520 nm.

For the estimation of chlorophyll content 0.25 gm of treated fresh maize leaf samples were dipped in distilled water and kept in water bath at 100°C for 30 minutes. Leaves were homogenized with 5ml of 80% acetone and centrifuged at 3000 rpm for 10 minutes. OD was taken at 652 nm and total chlorophyll contents (TCC) was calculated as follows:

$$TCC = \frac{OD \times 1000 \times V}{34.5 \times 1000}$$

Where,
TCC= total chlorophyll content
OD= optical density at 652nm
V= volume of leaf extract

RESULTS AND DISCUSSION

The halotolerant actinomycetes played a key role in the alleviation of soil salinity and improving the crop productivity. Out of total seven isolates only V8, V20, V29 and V34 grew well at 9% of salt concentration and hence were more halotolerant than others. In addition, isolates V5, V8, V20, V29 gave positive result for amylase test and V20, V29, V34 for urease test. On the other hand, all the seven strains showed positive result for catalase test but only V8 was positive for caseinase test. Further, isolates V5, V8, V20 were positive for IAA production and V2, V5, V8, V29, V34 for phosphate solubilizing activities. Interestingly, all the seven isolates gave promising result for HCN production but only V29 was positive for siderophore production (Table 1). On the basis of performance for biochemical and PGP attributes of total seven actinomycetes isolates only V5, V8, V20, V29 and V34 were as potent strains but the isolates V8 and V20 were the best. The isolates V5 and V8 and V20, V29 and V34 were compatible with each other, therefore considered as potent isolates for making their consortia C_1 and C_2 respectively to promote growth promotion in maize plant by ameliorating the saline soil. Consortium C_1 is the combination of two isolates V5 and V8 both of which were most promising for biochemical and plant growth promoting attributes as compared to the isolates V20, V29, V34 (C_2). Although, both the consortia C_1 and C_2 promoted the growth in maize plant as there was increase in height, root and shoot length as well as proline and TCC concentration compared to non treated plant (control). Further, C_1 was more potent consortium than C_2 observed on the basis of yield parameters of maize plant treated with C_1 and C_2 (Table 2).

The above results revealed the multifunctional properties of halotolerant actinomycetes isolates as natural resource management for sustainable agriculture by saline soil amelioration and enhancing the growth and development of the plants. The application of actinomycetes consortia over single inoculation could be an effective approach for reducing the harmful impact of salt stress on plant growth. Plant growth promotion activity is one of the important attribute responsible for salinity stress remediation in plants. The attribution of diverse metabolite production by the isolates such as Indole acetic acid (IAA), siderophores, HCN and activities such as phosphate solubilization could be beneficial for the maize plant growth. Under salt stress compatible solute such as proline could be synthesized by the isolates as osmo-protectants that help the organisms in order to survive and protect the plant from osmotic stress. In this investigation both halotolerant actinomycetes consortia

Table 1. Yield parameters of maize (*Zea mays*) treated with actinomycetes consortia

Isolates	Amylase	Urease	Caseinase	Catalase	IAA	HCN	PSB	Siderophore
V2	−	+	−	+	−	+	+	−
V5	+	−	−	+	+	+	+	−
V8	+	−	+	+	+	+	+	−
V20	+	+	−	+	+	+	−	−
V29	+	+	−	+	−	+	+	+
V34	−	+	−	+	−	+	+	−
V36	−	−	−	+	−	+	−	−

Table 2. Biochemical and plant growth promoting attributes

	Height (cm)	Root length (cm)	Shoot length (cm)	Fresh weight (gm)	Dry weight (cm)	Proline (mg/ml)	TCC (mg/ml)
Control	18.4	6.6	3.5	0.8	0.28	0	0
C1	44	10.15	9.75	0.695	0.2575	0.001	0.0323
C2	40	10.95	11.5	1.19	0.228	0.0006	0.0121

(C_1 and C_2) gave promising results for growth and yield in maize (*Zea mays*) under saline condition. Furthermore, treatment with C_1 enhanced the high concentration of proline and chlorophyll contents than C_2 under saline condition and hence the application of isolates V5 and V8 as consortium had been the best producers under stressed conditions. Thus use of multi strain inoculums could be more effective for enhancing plant growth and development due to the presence of more growth‒promoting traits which might not be possible in single strain. Therefore, actinomycetes can be utilized in the field as biofertilizers for sustainable agricultural practices and management of the saline soil.

CONCLUSION

The study contributes to the acquaintance of saline soil associated actinobacteria and further augments the array of plant growth promoting actinobacteria isolates available for sustainable agricultural practices. Further, the results of the current study may serve as baseline data for selecting the actinobacteria strains as natural resource management for sustainable agricultural practices and improvement of the saline soil with great ease.

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Influence of Nitrogen and FYM application on Quality of Pear (*Pyrus pyrifolia* Nakai)

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Abstract: Field experiment was conducted to assess the effect of nitrogen and farmyard manure (FYM) on quality of pear cv. Punjab Beauty. The fruit quality in terms of juice content, total soluble solids (TSS), TSS to acid ratio, total sugar, reducing and non-reducing sugars improved with the application 600 g nitrogen and 90 kg FYM per plant. However, minimum acidity in fruits was with nitrogen 800 g per plant and FYM 90 kg per plant. Therefore, the application of 600 g nitrogen and 90 kg FYM plant^{-1} is the best combination for realizing higher quality under subtropical conditions of Haryana.

Keywords: *Pyrus pyrifolia Nakai*, Farmyard manure, Nitrogen, Fruit quality

Pear is the most important pome fruit after apple and belongs to family *Rosaceae*, sub family *Pomoideae* (Mirabdulbaghi, 2014) and is considered as the third deciduous fruit and fourth fruit among all fruit crops in distribution throughout the global market (FAO, 2011; Sheren *et al*., 2015). The nutrition management in crops is a complex subject involving interplay of many factors, which contribute to growth and quality of fruit crops. The continuous growth of the trees, changing root zone and its nutrient absorbing efficiency with the advancing age, varying nutrient needs during seasons and age of plant and the dynamic nutrients status of soil are to be satisfied through a regulated supply of the nutrients to meet the demand of plants at a particular stage. The precise manipulation to achieve the desired response is, of course, difficult. Application of fertilizers is a common practice to ameliorate the level of particular nutrient element in the soil to get favorable response on growth, yield and fruit quality.

The yield and quality of pear primarily depend on cultivar, pollination, fertilization and water relations (Song *et al.,* 2013). Presently, most of the growers choose high yield than quality thereby prefer chemical fertilizers to organic manures that result in problems like soil hardening, decreasing organic matter, nutrient disequilibrium and diminishing fruit quality. Therefore, application of organic matter can mitigate some negative effects engendered by chemical fertilizers; since it has prospective benefits in stabilizing the soil structure, maintaining its moisture content, increasing permeability and biological activity (Song *et al*., 2013).

Therefore, there is a need to determine the precise fertilizer requirements of the fruits vis-à-vis nutritional quality. Hence, the study was undertaken to evaluate the effect of Nitrogen and FYM on biochemical content of pear.

MATERIAL AND METHODS

The present investigation was carried out at CCS Haryana Agricultural University, Hisar, India on Pear *cv.* Punjab Beauty. The study was conducted on 11 years old pear plants, uniformly grown with all cultural practices. The study area is located at 29º 10′N latitude and 75º 46′E longitude with an elevation of 215.2 metres above mean sea level. The climate of the region is semi-arid and sub-tropical having cold winter and hot summer; maximum temperature is about 47˚C during hot summer while in winter the minimum temperature may be sub zero. The average annual rainfall of the area is around 450 mm with maximum rain during the monsoon *i.e.*, July to September. The soil of the orchard was sandy loam in texture with organic carbon 0.37 per cent, pH 7.8, electrical conductivity 0.48 dSm^{-1}, nitrogen 83 kg ha^{-1}, phosphorus 17 kg ha^{-1} and potassium 348 kg ha^{-1}. The soil fertility status of experimental orchard field was determined before the initiation of the experiment. Urea as a source of nitrogen was applied to the plants in five treatments (0, 200, 400, 600 and 800 g) while three treatments were setup for the addition of farmyard manure (FYM). Basal dose of 2 kg single super phosphate and 1.5 kg murate of potash per tree was also applied in December. Different quality parameters were estimated by extracting juice of fruits in the juice extractor. Total soluble solids were determined using a hand refractometer and expressed as ºBrix. The acidity was determined by titrating 5 ml of juice against 0.1 N NaOH solution using phenolphthalein as an indicator (A.O.A.C 1990). Total soluble solids to acid ratio were calculated by dividing the value of TSS with that of the corresponding acidity. Total sugar and reducing sugar were estimated by Hulme and Narain method (1931). Subtraction of reducing sugars from the total sugars gave the values of non-reducing sugar after multiplying the value with the factor (0.95) as suggested by A.O.A.C. (1990) method. The obtained results were statistically analyzed by analysis of variance for RBD using IRRISTAT data analysis package (IRRI 2000).

RESULTS AND DISCUSSION

The percent fruit juice content increased with increasing doses of nitrogen and FYM. Maximum juice content (56.71%) was recorded when plant was supplemented with 800 g nitrogen/plant, which was at par with 600 g/plant (56.07%). The maximum (56.79%) juice content was extracted significantly with application of 90 kg FYM/plant and minimum with 30 kg FYM/plant. The interaction between nitrogen and FYM was significant (Table 1). Dudi *et al*. (2005) also observed that application of nitrogen 750 g and FYM 100-150 kg/plant effectively increased the juice content in Kinnow mandarin. Similar results were obtained by Patel *et al*. (2009) in sweet orange *cv.* Mosambi and Ghosh *et al*. (2012) in pomegranate *cv.* Ruby. Total soluble solids of fruits also increased with increasing nitrogen and FYM level (Table 1) and were recorded maximum (12.98) with application @ 800 g nitrogen/plant, which was at par with 600 g/plant. Similarly, application of 90 kg FYM/plant also enhanced the quality, the maximum total soluble solids (12.88) were in with 90 kg FYM/plant followed FYM 60 kg/plant whereas, the minimum total soluble solids were observed in fruit with 30 kg FYM/plant. The interaction between nitrogen and FYM was non-significant. Results with respect to total soluble solids in this study have also been supported by several workers Singh and Chauhan (1998) in peach, El-Mahmoudi *et al*. (1960) in Egyptian Balady mandarin and Prasad (2005) in *Zizyphus mauritiana*. This is due to conversion of complex polysaccharides into simple sugars Mitra *et al*. (2007). Acidity of pear fruits indicated decreasing trend with increasing levels of nitrogen and FYM. The minimum (0.311%) acidity was obtained with application @ 800 g nitrogen/plant followed by 600 g/plant (Table 1). Moreover, acidity was significantly affected by different doses of FYM, minimum acidity (0.329%) was recorded with 90 kg FYM/plant followed by FYM 60 kg/plant whereas, the maximum acidity (0.406%) was in fruit with the application of 30 kg FYM/plant. The interaction between nitrogen and FYM was non-significant. Earlier studies by several researchers strengthen the results of present study (Yadav and Bist, 2003 in Pear *cv.* Bagugosha and Gautam *et al*. (2012) in mango. The maximum acidity in control might be due to minimum total soluble solid and sugars content present in control as cited by Bhatia *et al*. (2001) in guava.

Table 1. Effect of Nitrogen and FYM application on juice (%), TSS (˚Brix), Acidity (%) and TSS Acid ratio of pear *cv.* Punjab Beauty

FYM	Nitrogen (g/plant)					Mean
	0	200	400	600	800	
Juice						
30	50.53	51.77	53.00	54.29	55.21	52.96
60	52.27	53.79	54.46	55.82	56.76	54.62
90	54.79	55.77	57.12	58.10	58.16	56.79
Mean	52.53	53.78	54.86	56.07	56.71	
CD (p=0.05)	N=1.27, FYM=1.21			N X FYM=1.48		
TSS						
30	10.63	11.03	11.43	11.93	12.37	11.48
60	11.23	11.67	12.13	12.63	13.03	12.14
90	11.87	12.43	13.13	13.43	13.53	12.88
Mean	11.24	11.71	12.23	12.66	12.98	
CD (p=0.05)	N= 1.02, FYM = 0.52			N X FYM = Non significant		
Acidity						
30	0.460	200	400	600	800	
60	0.420	0.433	0.400	0.383	0.353	0.406
90	0.390	0.390	0.370	0.340	0.307	0.365
Mean	0.423	0.363	0.330	0.287	0.273	0.329
CD (p=0.05)	N= 0.007, FYM = 0.005			N X FYM = Non		
TSS Acid ratio						
30	23.14	25.65	28.63	31.47	35.44	28.87
60	26.74	29.96	32.87	37.20	42.16	33.79
90	30.53	34.62	39.86	46.48	50.37	40.37
Mean	26.80	30.08	33.79	38.38	42.66	

TSS to acid ratio increased with increasing nitrogen and FYM levels. The maximum (42.66) with application @ 800 g nitrogen/plant followed by 600 g/plant and minimum with 30 kg FYM/plant (Table 1). The FYM dose also improved the quality of TSS acid ratio. The interaction between nitrogen and FYM was significant. Similar result, were observed by Monga *et al*. (2004) in Kinnow mandarin and Dutta *et al*. (2010) in litchi *cv.* Bombai. These variations in TSS acid ratio might be due to the treatments, which either increased TSS or decreased the acidity resulted in higher TSS acid ratio. The total sugar also showed the same trend. The maximum total sugar was obtained with the application of 800 g nitrogen and 90 kg FYM/plant and minimum without application of nitrogen and 30 kg FYM/plant (Table 2), the interaction was significant. The reducing sugar was maximum (4.30%) with application @ 800 g nitrogen/plant, which was at par with 600 g/plant. For FYM doses, the maximum reducing sugar (4.26%) was with 90 kg FYM/plant followed by FYM 60 kg/plant (4.19%), (Table 2). The interaction between nitrogen and FYM was found significant.

Table 2. Effect of nitrogen and FYM on total sugars (%), reducing sugars (%) and non-reducing sugar (%) of pear *cv.* Punjab Beauty

FYM	Nitrogen (g/plant)					Mean
	0	200	400	600	800	
Total sugars						
30	7.15	7.31	7.46	7.64	7.77	7.47
60	7.40	7.53	7.73	7.92	8.00	7.72
90	7.59	7.76	7.97	8.16	8.21	7.94
Mean	7.38	7.53	7.72	7.91	7.99	
CD (p=0.05)	N=0.11, FYM=0.12 N X FYM =0.12					
Reducing sugars						
30	3.94	4.01	3.37	4.15	4.23	4.08
60	4.05	4.12	3.54	4.26	4.31	4.19
90	4.14	4.21	3.72	4.34	4.36	4.26
Mean	4.04	4.11	3.54	4.25	4.30	
CD (p=0.05)	N= 0.05, FYM = 0.04 N X FYM = 0.09					
Non-reducing sugar						
30	3.21	3.30	3.37	3.49	3.54	3.39
60	3.35	3.41	3.54	3.66	3.69	3.53
90	3.45	3.55	3.72	3.82	3.85	3.68
Mean	3.34	3.42	3.54	3.66	3.69	
CD (p=0.05)	N= 0.02, FYM = 0.01 N X FYM = 0.05					

The reducing, non reducing sugars were maximum in fruit supplied with 800 g nitrogen and FYM 90 kg/plant. The interaction between nitrogen and FYM was significant, whereas, minimum (3.94%) without nitrogen and 30 kg FYM/plant. The total, reducing, and non-reducing sugars increased significantly with increase in nitrogen and FYM levels. These results were in conformity with earlier reports of Dudi *et al*. (2005) in Kinnow mandarin, Ghosh *et al.,* (2012) and Kashyap *et al*. (2012) in pomegranate *cv.* Ganesh. The possible reason for increase may be conversion of complex polysaccride into simple sugar. The content of fruit could easily be explained by the fact that urea is helpful in process of photosynthesis which ultimately led to accumulation of carbohydrates and helped to increase the sugar content of fruits. Hence, it can be concluded from various parameters studied that optimum dose of nitrogen 600 g per plant in combination with FYM 90 kg per plant was economical with respect to quality of pear cv. Punjab Beauty.

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Nutrient Uptake and Tuber Yield Influenced by Nitrogen Levels and Fertigation Frequency in Potato (*Solanum tuberosum* L)

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Abstract: The experiment comprising of four levels of nitrogen, *i.e.,* 90, 120, 150 and 180 kg ha^{-1} and three fertigation frequencies, *i.e.,* every 3rd, 6th and 9th day, was carried out at CCS H.A.U., Hisar during r*abi* season of 2014–15. Nitrogen levels exhibited significant difference for growth and yield of potato. The maximum removal of nitrogen, phosphorus and potassium and nitrogen use efficiency were with the application of nitrogen @120 kg ha^{-1}. Fertigation frequency were significantly higher when fertigation applied at every 3rd day. Interaction effect of fertigation frequency and nitrogen levels showed variation. The highest nutrient use efficiency was with application of 120 kg/ha at every 3rd day. The fertigation at every 3rd day with the nitrogen @120 kg ha^{-1} was significantly superior to all other treatments .

Keywords: Drip irrigation, Fertigation frequency, NUE, Nutrient uptake, Tuber yield

Potato (*Solanum tuberosum* L.), a member of Solanaceae family, is believed to be the native of South America. Its production in many part of the world is highly dependent on inputs of irrigation water and N fertilizer to achieve optimum yield and quality. These inputs must be carefully managed to ensure optimum profits and minimal environmental impacts. Escalating water costs and declining water availability are causing growers to adopt production practices which allow them to significantly improve water and N use efficiency and decrease labor costs. Frequent application of water and nutrients ensure that the root systems well supplied with nutrient solution and prevents the formation of depletion zone resulted from uptake of nutrient between successive fertigation. N rate and fertigation frequency resulted in significant differences in total N uptake, N recovery and apparent N use efficiency. Total N uptake was appreciable higher with increasing N rate and with more frequent than with less frequent fertigation (Badr *et al.,* 2011). As critical as irrigation management, both the timing and amount of N applied to the crop must be managed in a way that supplies sufficient N for crop yield without leaching N of the groundwater. This greatly improves the potential for excellent N use efficiency due to decreased amount of applied N and leaching losses. Drip irrigation also provides application of soluble fertilizers and other chemicals along with irrigation water. Among modern irrigation techniques, drip irrigation has been shown to be a more water effcient alternative than furrow irrigation for potato (Wang *et al.,* 2011). In fertigation Nutrient use efficiency could be as high as 90% compared to 40 – 60% in conventional methods. Keeping in view of the importance of crop problems and scope the present investigation has been planned to find out the effect of frequency and dose of nitrogen fertigation on yield of potato.

MATERIAL AND METHODS

The experiment was carried out at Chaudhary Charan Singh Agricultural University, Hisar during *Rabi* season 2014–15. Hisar is situated at latitude of 29º10′ N, longitude of 75º 46′ E and height of 215.2 meters above mean sea level and falls in semi–arid and sub–tropical region with hot and dry summer and sever cold in winter. The soil was sandy loam in available organic carbon (0.66%), available nitrogen (105 kg/ha), available phosphorus (8.0 kg/ha) and available potash (225 kg/ha) with pH of 8.3. The experiment was laid out with three replication of each of the twelve treatments in randomized block design. The net plot size was two rows of eight–meter length each (8.0 x 1.2 m). Farm yard manure (FYM) @ 50 t/ha was applied prior to field preparation and full dose of phosphorus and potash were applied as basal dose. Potato tubers of *cv.* Kufri Bahar were planted with spacing of 60×20 cm during the last week of October. A common irrigation was applied immediately after planting in all the treatments through conventional furrow method for uniform and rapid germination. The differential drip fertigation treatments were started 20 days after planting. The crop was subjected to four levels of nitrogen i.e., 90(N_1), 120(N_2), 150(N_3) and 180(N_4) kg ha^{-1}. Each nitrogen level was coupled with three fertigation frequencies, *i.e.,* every 3rd day in 30 split doses (F_1), every 6th day in 12 split doses (F_2) and every 9th day in 8 split doses (F_3). Hence, twelve treatment combinations were used for conducting present study. The irrigation was applied at every 3rd day though drip.

Nutrients uptake by potato foliage/haulm = [Nutrient contents in haulm (%) ×Dry Weight of haulm (kg/ha)] / 100

Nutrients uptake by tuber = [Nutrient contents in tubers (%) ×Dry weight of tuber (kg/ha)] / 100

RESULTS AND DISCUSSION

Nutrient (NPK) uptake: The uptake of N, P and K by potato crop indicated significant differences due to nitrogen levels and fertigation frequency. The uptake of N, P and K by potato crop was significantly higher in F_1 (fertigation frequency at every 3rd day) and N_2 (nitrogen 120 kg ha^{-1}) as compare to other treatments. Among the fertigation frequency, F_1 had significantly higher nitrogen uptake by the foliage and tuber (4.74 and 135.07 kg ha^{-1}), which was followed by the F_2, whereas, the minimum nitrogen removal was with F_3. Among the nitrogen levels, the maximum nitrogen uptake by the foliage and tuber of potato (5.12 and 142 kg ha^{-1}) was with application of N_2. This value of nitrogen uptake was significantly higher than the other levels of nitrogen. The higher values of nitrogen uptake with drip irrigation might be due to increase in solubility of nutrients with increasing water content in soil. Both nitrogen rate and fertigation frequency at shorter durations (daily, alternate and weekly) intended to stimulate the pattern of potato N uptake more than longest duration. The total nitrogen uptake was significantly higher with daily fertigation (180 kg N ha^{-1}) than with weekly (165 kg N/ha) and biweekly fertigation (139 kg N ha^{-1}) (Badr *et al.,* 2011). The lowest N uptake in the longest duration was mostly likely due to a lack of NO_3–N in the root zone when plant demand was high. This may be because of a better synchrony between N supply and demand. The significantly maximum phosphorus uptake by the foliage and tuber of potato (12.27 and 26.27 kg ha^{-1}) was by F_1 followed by F_2. Among the various nitrogen levels, the maximum phosphorus uptake by the foliage and tuber of potato (14.14 and 28.71 kg ha^{-1}) was in N_2. The higher uptake of phosphorus under drip irrigation might be due to sound root–soil relation, which provides rapid diffusion of ions by reducing the path length of ion movement on one hand and other hand increase in elongation, turgidity and number of root hairs, which ultimately boost the uptake. Among the fertigation frequency, F_1 removed maximum potassium uptake by foliage and tuber of potato (46.49 and 193.65

Table 1. Effect of nitrogen levels and fertigation frequency on nutrient uptake and total tuber yield of potato

N rate Kg ha^{-1}	Fertigation	Nutrient uptake by foliage			Nutrient uptake by tuber			Total tuber yield (q ha^{-1})
		N	P	K	N	P	K	
90(N_1)	F_1	4.51	10.40	44.79	131.84	24.71	191.17	296.95
	F_2	4.15	9.74	34.71	129.05	25.63	171.95	275.13
	F_3	4.12	9.18	33.29	116.94	24.86	179.51	269.93
120(N_2)	F_1	5.35	15.38	48.42	146.59	29.43	205.74	307.78
	F_2	5.14	13.77	47.19	142.63	29.16	202.45	294.34
	F_3	4.87	13.28	42.77	136.79	27.55	191.71	274.88
150(N_3)	F_1	4.84	13.04	48.15	141.91	27.46	197.36	299.06
	F_2	4.53	12.40	41.99	135.33	26.22	194.16	292.01
	F_3	4.53	11.52	39.37	130.37	24.92	180.97	274.38
180(N_4)	F_1	4.29	10.25	44.61	119.93	23.49	180.34	282.22
	F_2	4.06	8.66	33.24	119.54	20.11	167.44	259.04
	F_3	4.00	8.05	32.99	110.20	18.00	167.36	252.80
Mean	N_1	4.26	9.77	37.60	125.94	25.06	180.87	280.33
	N_2	5.12	14.14	46.12	142.00	28.71	199.96	292.33
	N_3	4.63	12.32	43.17	135.87	26.20	190.83	288.48
	N_4	4.11	8.99	36.94	116.56	20.53	171.71	264.69
	F_1	4.74	12.27	46.49	135.07	26.27	193.65	296.50
	F_2	4.47	11.14	39.28	131.64	25.28	184.00	280.13
	F_3	4.38	10.51	37.10	123.57	23.83	179.89	268.00
CD (p=0.05)	Frequency	NS	0.90	1.74	3.04	1.03	3.91	2.85
	Nitrogen	0.55	1.04	2.01	3.51	1.92	4.52	3.29
	F × N	NS	NS	3.48	NS	2.06	7.83	5.71

kg/ha) whereas, the minimum potassium uptake was found with F_3. The interaction treatments nitrogen levels and fertigation frequency also differed significantly with respect to potassium uptake by potato crop. The maximum (48.42 and 205.74 kg ha^{-1}) potassium uptake by foliage and tuber of potato was found in F_1N_2.

Total tuber yield; The total tuber yield (q ha^{-1}) varied significantly due to the interaction of nitrogen levels and fertigation frequency. The maximum total tuber yield (307.78 q ha^{-1}) in F_1N_2 followed by F_1N_3 (299.06 q ha^{-1}). Behnam Etemad and Mansour Sarajuoghi (2012) showed that the interaction of different levels of N fertilizer × different of application times significantly affected the tuber yield. A distinct increase in tubers yield with ha with drip each row and drip each pair was observed by Kapadiya *et. al.* (2013). Kumar *et. al.* (2006) reported that crop responded to nutrient application rate under drip fertigation with fertilizer level F_1 (N 187: P_2O_5 63: K_2O: 125 kg ha^{-1}) producing higher tuber yield, followed by F_2 (141:47:93kg ha^{-1}) and F_1 (93:32:63 kg ha^{-1}).

Nutrient use efficiency: There were significant differences among the fertigation frequency, nitrogen levels and interaction between the treatments with respect to nutrient use efficiency. The maximum nutrient use efficiency (70.70 kg kg^{-1}) was with F_1N_2, which was statistically at par with F_1N_3 (70.67 kg/kg) and minimum nutrient use efficiency (51.48 kg/kg) with F_3N_4 (Figure 1). The N rate and fertigation frequency caused significant differences in nitrogen use efficiency. It was significantly higher at low nitrogen rate as compared with the high N rate. The NUE *i.e.* 151 kg yield kg^{-1} N^{-1} was with the application of lower doses of nitrogen *i.e.* 200 kg ha^{-1} by Badr *et.al.,* 2011, which is higher than the 142 kg yield kg^{-1} N^{-1} with the application of higher dose of nitrogen (300 kg ha^{-1}). Similar results were also reported by Kumar *et. al.,* 2006, where the NUE was higher with lower rate of nutrient application *i.e.* fertigation level F_3 (N 93: P_2O_5 32: K_2O: 63 kg ha^{-1}) followed by F_2 and F_1 (N 187: P_2O_5 63: K_2O: 125 kg ha^{-1}).

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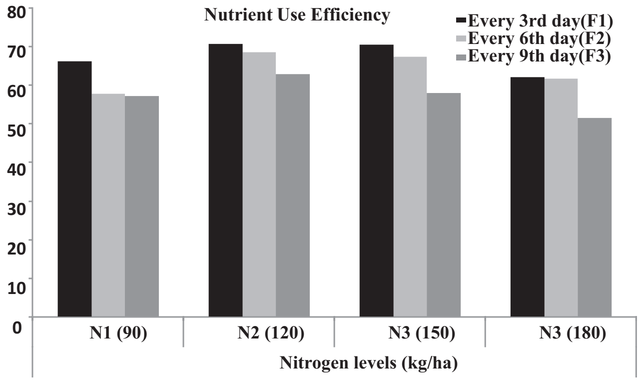

Fig. 1. Effect of fertigation frequency and nitrogen levels on nutrient use efficiency (kg/kg) in Potato cv. Kufri Bahar

CONCLUSION

It is concluded that the nutrient uptake, nutrient use efficiency and yield of potato were maximum when nitrogen 120 kg/ha was supplied every 3rd day in split doses through drip in potato.

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Analytical Study on Fabrication of Family Size Biomass Cooking Gas Stove Using Natural Biomass as Fuel

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Abstract: In this study biomass has been used as a natural fuel for testing of fabricated family size biomass cooking gas stove and to get their efficiency in respect of traditional chulha. Mild steel sheet and mild steel rod were used in fabrication; whereas rice husk, saw dust and coal were taken for it's testing and finding for the efficiency. An aluminium pot of capacity of 22 litres and boiling of 20 litres of water was used for performance and testing purpose. The thermal efficiency of biomass cooking gas stove for rice husk and saw dust was found 26.81 and 28.64 percent respectively. The biomass cooking gas stove has high rate of cooking and can achieve higher temperature than the traditional chulha, due to concentric flame and smokeless burn. In actual, the thermal efficiency of biomass cooking gas stove found to be more efficient than the traditional chulha but less than the thermal efficiency of LPG stove as reported.

***Keywords*:** Biomass, Biomass cooking gas stove, Fabrication, Traditional chulha

Since the beginning of civilization wood and biomass have been used for cooking. Over 2 billion people cook on inefficient wood stoves causing wastage of wood, health hazard and deforestation. Inefficient wood stoves and traditional chulha causes health related problem due to the production of smoke like respiratory system, eye and skin diseases and pollution of the environment. Biomass, in the form of agricultural forestry and industrial waste is good source of solid, liquid and gaseous fuel. Exposure to smoke from indoor biomass burning is to cause acute respiratory infection, incidence of eye, low birth weight, cancer and chronic lung disease (Kammen, 1999). Sawdust stove, the poor ignition characteristics and smoky start up are related to improper geometric dimensions. Based on a parametric study, the startup procedure and the dimensions of the stove can be modifying to achieve a smooth start up (Mukunda *et al.,* 1993). The biomass gas stove installation under operational research demonstration programme at the selected dhabas/hotels/tea shops to evaluate its performance (Kamble *et al.* 2008). The evaluation of fuel consumption and/or fuel efficiency is likely to be an essential element is needed to design more efficient stoves and to compare and determine fuel-wood savings under particular operating conditions (Geller *et al*., 1979). The gaseous products are largely carbon dioxide, carbon monoxide, methane and hydrogen with overall heat content in the range of 10,500–15,000 KJ per cubic meters as compared with 37500 KJ per cubic meters for natural gas (Geller *et al*., 1979). Keeping into view the availability of the biomass cooking gas stove chulha it was felt that a family size cooking stove was required to meet the requirement of nuclear families of villagers. Hence this work has been selected to complete the objective of fabrication and testing of biomass cooking gas stove, comparison with others traditional cooking systems and to find the economics over other available chulha. It was also kept in mind that it may require using as a community size cooking gas stove.

MATERIAL AND METHODS

Mild steel sheet and mild steel rod were used in fabrication, whereas rice husk, saw dust and coal were taken for it testing and finding for the efficiency. An aluminium pot of capacity of 22 litres and boiling of 20 litres of water was used for performance and testing purpose. It was also taken with the traditional chulha and LPG stove from the water boiling operation.

Components of Biomass Fabricated Cooking Gas Stove: Various components of biomass cooking gas stove such as circular outer jacket, inner jacket, cylindrical inner chamber, heat transfer fins, gas inlet port, stand, grating, top and bottom cover and bottom air inlet chamber were made by mild steel sheet and rod, because it was more durable and heat resisting material. Each components of stove has been design according to their suitable dimensions, which permits to enhancing the thermal efficiency of stove.

Instruments Used for Measurement: Oven thermometer was used for the measurement of temperature of biomass cooking gas stove with the maximum scale of 600 ^{0}C, whereas the simple thermometer of glass rod was used to measure the boiling temperature of water. Weighing machine was used for weighing materials like saw dust, rice husk, dry wood, coal etc. For the purpose of boiling water an aluminium pot with the capacity of 22 litres was used throughout the experiment.

Input Materials: The low moisture centrally produced rice husk from rice mill was used and saw dust was a by-product of saw-mill. Dry wood and coal was used for production of heat.

Methodology, Performance and Testing: After removing top cover jacket saw dust (or rice husk) was filled in the circular jacket without any ramming and fixed tightly. Solid fuel (coal or cock) added into the central portion above the grating was ignited. The horizontal portion of the heat thus produced help in heating by dry biomass placed in the jacket. Heating fins provided in the jacket help in extending the heat to the farthest part of the biomass. This result in partial pyrolysis and the volatile matters in the form of gases were released which contend of hydrocarbon and oxygenated hydrocarbons. There were holes at the bottom of the inner side of the jacket, these gases entered the central chamber from these holes and further subjected to high temperature contributed by the vertical portion of the heat produced by the solid fuel. The gases were getting thermally cracked into gaseous compound having 1-4 carbon atoms and burn without smoke at the top of the stove. An aluminium pot of 22 litres capacity was selected for the performance and testing of the biomass cooking gas stove. 20 litres of water was taken for boiling purpose initially on improved biomass cooking gas stove. Initially temperature were taken 27 ^{0}C (ambient temperature) up to boiling temperature at 100 ^{0}C and corresponding observations were measured for the determination of thermal efficiency and other parameters. Similar observations were made on LPG stove and traditional Chulha with same quantity of water in same pot.

Thermal efficiency of biomass cooking gas stove for rice husk: Geller et al. (1979)[*] gave the following formula to determine the thermal efficiency of biomass cooking gas stove;

$$\text{Thermal efficiency} = \frac{M_p C_p + M_m C_m}{(M_c E_c - M_{rc} E_{rc}) + (M_r - M_{rr}) \times E_r} \times (T_f - T_i)$$

Where, M_p= Mass of aluminium pot (kg), C_p = Specific heat capacity of aluminium pot (kJ/kg^{0}C), M_m= Mass of cooking medium (water) (kg), C_m= Specific heat capacity of medium (water) (kJ/kg^{0}C), M_c= Mass of coal (kg), E_c= Calorific value of coal (kJ/kg^{0}C), M_{rc} = Remaining mass of coal (kg), E_{rc} = Remaining calorific value of coal (kJ/kg^{0}C), M_r = Mass of rice husk used (kg), M_{rr} = Remaining mass of rice husk (kg), E_r = Calorific value of rice husk used (kJ/kg^{0}C), T_i = Initial temperature (^{0}C), T_f = Final temperature (^{0}C).

Thermal efficiency of biomass cooking gas stove for saw dust:

$$\text{Thermal efficiency} = \frac{M_p C_p + M_m C_m}{(M_c E_c - M_{rc} E_{rc}) + (M_s - M_{rs}) \times E_s} \times (T_f - T_i)$$

Where, M_s = Mass of saw dust used (kg), M_{rs} = Remaining mass of saw dust (kg), E_s = Calorific value of saw dust used (kJ/kg^{0}C).

RESULTS AND DISCUSSIONS

Study of temperature vs. time graph for saw dust: It was observed that with use of saw dust the temperature of cooking gas stove increases with respect to time and taken 3.50, 3.45 and 1.30 min attain the 100-150°C, 300-350^{0}C and 550-600^{0}C respectively. This variation of time showed that the temperature interval of biomass cooking gas stove increases with respect to increase in time. Total time taken to attain 600°C temperature was 24.03 min.

Study of temperature vs. time graph for rice husk: Same process has been used with rice husk. It was observed that with use of rice husk the temperature of cooking gas stove increases with respect to time and take 3.56, 2.42 and 1.21 min attain the 100-150°C, 300-350^{0}C and 550-600^{0}C respectively. Total time taken to attain 600°C temperature was 24.33 min. From above Figure and Table it was observed that rice husk taken more time in comparison to saw dust and the difference of time to attain 600 °C was 0.30 minute, because rice husk was less calorific value than saw dust. So, it showed that the efficiency of saw dust was more than rice husk.

Thermal efficiency of biomass cooking gas stove: The thermal efficiency of biomass cooking gas stove was 26.81 and 28.64 percent for rice husk and saw dust respectively.

Economic Comparison: The biomass cooking stove was more economic than traditional chulha and LPG gas stove but their working ability is more efficient than traditional chulha and less than LPG stove, whereas the fuel cost per kg was less than LPG but more than traditional chulha (Table 1). Total cost of fuel saved by biomass cooking gas stove was Rs. 2590 in one year. The payback period of biomass cooking gas stove was found eight months.

The biomass cooking gas stove has high rate of cooking and can achieve higher temperature than the traditional chulha. The resistance of temperature capacity of mild still material was good and it was efficient at more than 600 °C temperatures. The use of biomass fuel as rice husk and saw dust has been taken 24.33 and 24.03 min time to attained temperature 550-600 °C respectively. Saw dust had taken less time (0.30 minutes) in comparison to rice husk and taken

Table 1. Temperature and time variation for saw dust and rice husk

Temperature (°C)	27	100	150	200	250	300	350	400	450	500	550	600
Saw Dust Time (min)	0	14	17.50	20.92	24.17	27.28	29.68	32.01	34.04	35.47	36.85	38.03
Rice Husk Time (min)	0	14	17.56	21.01	24.29	27.46	29.88	32.22	34.27	35.73	37.12	38.33

Table 2. Economic comparison of biomass cooking gas stove with two others types of chulha

Treatment	Types of fuel used in chulha	Boiling time (hrs) for 20 litres of water	Cost of fuel per kg (Rs.)	Fuel consumption (kg)	Economics (Rs.)
Biomass cooking gas stove	Coal and Biomass	1.26	20	1.400	28.00
Traditional chulha	Wood	1.53	06	4.250	25.50
LPG stove	LPG	1.15	30.98	0.300	09.30

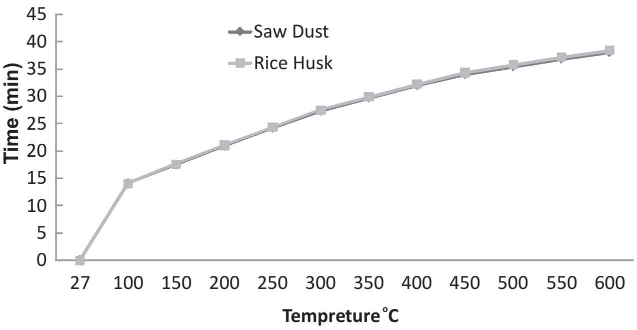

Fig. 1. Combined temperatures vs. time graph of saw dust and rice husk

1 hrs and 26 minutes for boiling of 20 litres water at 100°C, 1 hrs and 53 minutes by traditional chulha, whereas 1 hrs and 14 minutes time taken by LPG stove. The biomass cooking gas stove is more helpful and efficient in use to complete the mid day meal programme in the school and Aangan Bari Kendra.

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Impacts of Land use on Selected Chemical Properties of Soils of Temperate Himalayas

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Abstract: The aim of this study was to examine the impacts of land use on soilpH, SOC,N, P and K. Cereal farms, vegetable farm, horticulture and*floriculture fields were the land use for evaluation*. The impact of land use was significant on soil properties as reflected by the significant differences in pH, OC, and K contents among different landuses. The soils in the vegetable farms had significantly ($p<0.05$) higher pH (7.15) and OC (1.27%) and non-significantly higher N content (358.41 $kgha^{-1}$). Lower pH (6.41), OC (1.18%), N, P and K (313.40, 29.45 and 145.17 $kgha^{-1}$, respectively) in cereal lands in comparison to other land uses showed the severity of land degradation under this land use utilization. Therefore, future land managementof soil shouldfocus on strategies that improving the soil nutrient and carbon storage under cereal land for enhancing sustainableagricultural landscape management.

Keywords: Land use, Physicochemical Properties, Temperate region

Land is one of the important factors of production. In developing country like India, land is not only an important factor of production, but also the basic means of subsistence for majority of the population (Maqbool, 2015). Successful agriculture expects the sustainable use of soil resources, therefore, agricultural practices require basic knowledge for prolonged use of land. The inherent characteristics of soil, which are mainly the resultant of parent material and climate undergo subtle change due to different land management practices. Researchers have showed the linkage between land uses and soil properties, particularly in relation to soil nutrients and carbon sequestrations (Solomon *et al.,* 2002; Nega and Heluf, 2013). Soil characteristics such as soil organic matter (SOM), aggregation and aggregate stability (Shrestha *et al.,* 2007), bulk density, and water retention (Lal, 2003), pH and nutrient status (Benbi and Brar, 2003), and soil biota (Islam and Weil, 2000) tend to change because of different natural anthropogenic activities, namely climate, planting, tillage, livestock trampling, harvesting, application of fertilizer etc. Adoption of appropriate land use management practices and land use planning would help to minimize the degradation in soil quality and would ensure sustainable crop production and productivity. Therefore, this study was conducted with specific objective to assess the status of soil physico-chemical characteristics of four different land use systems of research farm of SKUAST-K, Shalimar farm.

Study area: The present investigation was carried out in a Research farm of SKUAST-K, Shalimar (34º 8′42" and 34º 9′3" N latitudes and 74º 39′5" and 74º 53′5.6"E longitude) Srinagar (Figure 1). It has 1615 m average altitude above sea surface and covers an area of 23.8 ha. The climate is temperate and characterized by mild summers and chilling winters having normal annual maximum temperature of 19.53°C and minimum of 6.80°C with normal annual rainfall of 786.2 mm. Dominant vegetation are cereals (wheat, rice, maize, oats), vegetables, fruits and floriculture.

Soil Sampling and analysis: Soil samples were collected from Research farm of SKUAST-K Shalimar in the spring 2013. Sampling points were located using Geographical Positioning System (GPS) in order to improve accuracy and precision of sampling for field studies so that field can be re-visited any time for updation of results. Perimeter points were taken by firstly establishing the boundary of the field. Working inside the boundary of the field, perimeter readings were taken at specific distances to construct an outer layer. Data collected was transferred onto Arc GIS software, where a map of the perimeter points generates. A total of seventy seven (77) samples were selected in a systematic grid design using Arc GIS from four land uses (cereals, horticulture, vegetables and floriculture). Each grid was specified at a fixed distance of 50 × 50 m^2 grid from 0-22.5 cm depth. Samples were thoroughly mixed and ground to pass a 2mm sieve, then stored in plastic bags prior to chemical analysis. Standard procedures were followed to analyse the soil samples for pH, organic matter (OM),nitrogen (N),phosphorus (P) and exchangeable/available potassium (K).

Statistical analysis: The statistical analyses were conducted using SPSS 20.0 release software (SPSS,

Table 1. Summary statistics of soil properties for four land uses

Crop	pH	OC	N	P	K
Vegetables	(6.39–7.60)	(0.48–1.73)	(250.88–469.70)	(17.79–47.69)	(117.60–369.60)
	7.15, 0.11 [a]	1.27, 0.12 [a]	358.41, 24.38	34.16, 4.17	216.40, 4.79 [a]
Horticulture	(5.90–7.94)	(0.54–1.94)	(125.44–489.92)	(16.17–54.25)	(100.80–324.80)
	6.68, 0.06 [b]	1.23, 0.05 [a]	324.45,12.36	32.45, 1.70	186.00, 8.03 [b]
Cereals	(6.20–7.07)	(0.77–1.65)	(188.16–433.12)	(15.99–49.63)	(95.20–201.60)
	6.41, 0.06 [c]	1.18, 0.07 [b]	313.40, 19.08	29.45, 3.14	145.17, 7.90 [b]
Floriculture	(6.32–7.28)	(1.16–1.22)	(313.6–376.32)	(40.96–41.16)	(268.80–386.40)
	6.80, 0.48 [b]	1.20, 0.02 [c]	344.96, 31.36	41.06, 0.10	327.68, 38.80 [c]

2011).Significant influences of land use change on analyzed soil properties were tested using one-way analysis of variance (ANOVA) ($P<0.05$).

Soil pH: The pH of soils differ significantly ($p<0.05$) among four land uses (namely cereals, horticulture, vegetables and floriculture) (Table 1). Soil pH was higher in vegetables (7.15) while as lowest in cereals (6.41) and could be attributed to higher values of exchangeable bases in the vegetable soils due to the application of large amount of vermicompost, manures and wood and /or biomass ash (Haile *et al.,* 2014). On the other hand low pH under cereal lands may be attributed due to the long-term application of chemical fertilizer mainly urea which may rise the carbonate level of the soil.

Soil organic carbon: The vegetable lands had significantly higher OC while soils under cereal land recorded lower OC content. It can be concluded that, under the cereal land use, losses of soil organic matter were not fully compensated by organic matter input from the cereal crop residues(Woldeamlak and Stroosnijder, 2003;Genxu*et al*., 2004).Vegetable farming soils accounted highest content of organic C among the different land uses and could be attributed to their management. Large amount of manure, vermicompost, woodash and other decomposable materials areoften thrown to the vegetable fields, which in aggregate changes nutrient and carbon storage over long time (Bekunda, 1999; Elias, 2000).

Soil macronutrients: Among macronutrients (N, P and K) only the difference in potassium concentrations between the land uses were significant ($p<0.05$). However, there was no significant variation in available nitrogen and phosphorus between land use types. The highest content of nitrogen was observed in the vegetables and such result is expected since most soil nitrogen is bound in organic carbon and the content of OC was highest in vegetable crops and lowest in cereal lands. Tripathi and Singh (1992), and Yifru and Taye (2011) also reported a significant positive correlation of available nitrogen with organic carbon. On other hand, the relatively higher available phosphorus and potassium under floricultural land as compared to other land uses may be attributed due to the continuous application of phosphorus and potassium fertilizers coupled with less feeding of nutrients by floricultural crops. Many workers observed higher available P in surface layers owing to annual leftover of P from fertilizer application (Wakene and Elufe, 2004; Alemayehu and Sheleme, 2013). Sarno *et al*. (2004) revealed that available P increases with cultivation due to fertilizer application.

Nevertheless, the lower contents of nitrogen, phosphorus and potassium content under cereal farms may be attributed due to the frequent and intensive traditional tillage practice carried in paddy growing soils. It is obvious that intensive tillage enhance oxidation of organic carbon thereby lead into depletion of nutrient.

CONCLUSION

The variation in soil chemical properties among different landuses could be related to frequent tillage practice, crop residue harvest and application of variable amounts of fertilizers. Therefore, future land management of soil should focus on strategies that improving the soil nutrient and carbon storage under cereal land for enhancing sustainable agricultural landscape management, thereby improving the livelihood of agrarian community.

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Litter fall and Leaf Litter Decomposition in a *Dalbergia Sissoo* Roxb. Plantation in Sodic Soil

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Abstract: Total annual litter fall in shisham was recorded 229.64g m^{-2} $year^{-1}$ with highest litter fall (187.94g m^{-2} $year^{-1}$) recorded during winter months of the year. Decomposition rate was found higher between the month of June–July and April–May. During the month of June–July maximum weight loss of 15.42% was recorded followed by 13.60% in the month of April–May. The decomposition rate is stimulated with the high temperature, high humidity during rainy season.

***Key Words*:** Litter fall and decomposition, Shisham, Silvicultural system

Dalbergiasissoo Roxb.(shisham, sissoo) is widely distributed in many part of India up to 900 m in the sub Himalayan tract, occasionally ascending to 1500 m. It grows abundantly and forms a forest either pure or mixed with other species on the new alluvium formed of deposits of sand boulders etc. in the river beds of their regions. The rotation of the natural trees in Uttar Pradesh is about 60 years though in irrigated plantations of west Punjab, it is much shorter being about 20–25 years. It thrives well in sandy loam soil with good drainage. It grows on land slips and other places where fresh soil is exposed but not on stiff clay. Sissoo is a primary coloniser on the new alluvial soils along the riverbanks. Sissoo trees from different localities have varied characteristics, including growth, form, colour, grain, working, strength properties, etc.

Sissoo can successfully be grown in combination with a variety of other crops viz., grasses, and agricultural and fruit crops. This also can be grown as part of farm forestry, agroforestry, alley cropping, silvi–pasture and social forestry. Cultivation of agricultural crops between the lines of *sissoo* can be carried out without any difficulty for at least initial two years. Over the years, *D. sissoo* has been grown as scattered trees on field boundaries and also as windbreaks around fruit orchards. Sissoo produces one of the finest all round timbers, and is one of the best quality fuels.

Litter fall and decomposition are two primary mechanisms by which the nutrient pool of forest ecosystem is maintained. Litter enters the system and is broken down by various decomposing organisms under the influence of abiotic attributes of particular system.Litterfall inputs and litter decomposition represents a dynamic portion of the nutrient cycling in forest ecosystem. In addition, the turnover of litter is a major pathway of the nutrient and carbon inputs to forest soils. Significant amounts of organic matter and nutrients in the soils can be transferred during litter decomposition processes. The present study was conducted to provide base line information on litter dynamics and to fill in the blank of knowledge about pattern of litter fall and leaf dry weight loss under sodic land condition.

The present study was conducted at the Main Experiment Station (MES) of Department of Forestry, Narendra Deva University of Agriculture and Technology, Faizabad (U.P.) located at 26^0 27′N latitude and 82^0 12′ E longitude and about 113 meter above the mean sea level during the year 2011–12. Twenty 0.5 x 0.5 m litter traps made of steel mesh with wooden frame were arranged in each stand and were raised 25 cm above the ground, and litter fall was collected at 15 days intervals every month during the year 2011–12. The collected litter at each time was oven–dried at 60°C to constant weight. At the end of each month, the oven–dried litter was combined and sorted into leaves, small branches, flowers, fruits and miscellaneous material.

The litter bag technique was used to quantify litter decomposition rate. The leaves collected from the steel mesh were used for the determination of the decomposition rate. Sub–samples were retained for the determination of initial chemical composition. A known amount of air–dried leaf litter (20g) of each was put into a 10 x 10 cm, 0.5 mm mesh size nylon bag. A total of 60 bags were prepared and randomly placed at sub–surface under soil. The decomposed material was taken after 1 month and the process continued for 12 months. The retrieved bags were brought to laboratory and was washed carefully to remove foreign material from it and dried at 60°C in over until the constant weight was observed. The percentage of leaf litter decomposition and the rate of decomposition was determined using the desirable statistical tools.

The rate of leaf fall on per day basis was greatest in winter followed by summer and rainy seasons (Table 1). *D. sissoo* is a deciduous species and the leaf fall was concentrated only for a few months. However, higher values were recorded during winter and summer than in rainy season. Litter fall production in forest ecosystem is determined by climatic condition, species composition and succession stage in its development (Hasse, 1999).

Table 1. Seasonal and annual estimates if litter fall (g m^{-2}) under 12 year old *D. sissoo*

Season	Litter components			Total	Mean
	Leaf	Wood	Miscellaneous		
Winter	181.0	4.73	2.21	187.94	62.64
Summer	16.01	7.46	2.83	26.3	8.77
Rainy	5.36	9.60	0.46	15.42	5.14
Total	202.3	21.79	5.50	229.66	76.55
Mean	67.46	7.26	1.83		25.52
Annual (g m^{-2} $year^{-1}$)	202.3	21.79	5.50	229.64	

The bulk of leaf fall (81% of the total litter fall) in *D. sissoo* was recorded highest during the period of winter season while summer and rainy season litter fall restricted to the 11 and 6%, respectively of the total litter fall (Fig. 1). Among litter component, wood litter fall and miscellaneous accounted for 9.5 and 2.4%, respectively of total litter fall. Contribution of leaf litter fall was 88%. The leaf fall accounted for 90.8% in *D. sissoo* of the total annual litterfall, which is within the range of

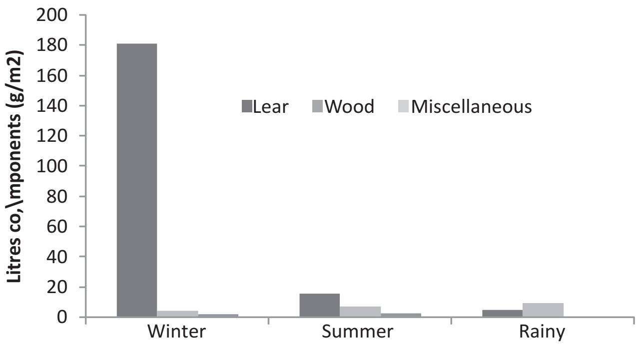

Fig. 1. Seasonal pattern of litterfall under *D.sissoo*

37.7−96.3% reported for different other plantations (Joshi *et al.,* 1997; Panda and Mohanty, 1998).

Decomposition rate was recorded higher in between the month of June-July. Litter decomposed more during the wet season than the dry season. Oldaye *et al.* (2005) similarly reported that under the influence of the prevailing climatic environment, different litter species have their own specific rate of decomposition which governs the rate at which nutrients are released from the litter. The complete disappearance (approx. 90%) of litter was recorded within the 10 months from date of collection (Table 2). It can be concluded from the study that a considerable variation exists between months for decomposition rate hence it can be stated that the high temperature and high humidity causes a high decomposition rate.

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Table 2. Weight remaining in leaf litter after decomposition under *D. sissoo* plantation sites during different months

Initial leaf weight (4.41 g) Month	I	II	III	IV	V	Mean	Decomposition rate (%)
	4.39	4.47	4.39	4.43	4.37	4.41	
February	4.30	4.24	4.25	4.35	4.33	4.31	2.727
March	4.15	3.90	3.95	4.00	3.95	3.325	9.29
April	4.15	3.85	3.93	3.91	4.10	3.323	9.52
May	4.00	3.82	4.10	3.92	3.91	3.29	23.12
June	3.45	3.35	3.70	3.60	3.50	2.93	23.56
July	2.60	2.10	2.20	2.20	2.15	2.25	48.97
August	1.85	1.10	1.83	1.85	1.89	1.86	57.82
September	1.41	1.43	1.45	1.45	1.46	1.44	67.34
October	0.90	0.88	0.89	0.87	0.91	0.89	79.81
November	0.71	0.73	0.69	0.74	0.71	0.71	83.90
December	0.70	0.69	0.67	0.70	0.66	0.69	84.35
January	0.52	0.51	0.55	0.49	0.45	0.42	90.47
SEm±						0.041	
CD (p=0.05)						0.117	

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Diversity and Abundance of Insect Visitors and Pollinators on Pumpkin, *Cucurbita moschata* (Duch.ex Lam)

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Abstract: Study was conducted at CCS Haryana Agricultural University, Hisar. A total of 42 insect species visited pumpkin flowers, out of these, 8 were hymenopterans, 7 lepidopterans, 7 dipterans, 3 hemipterans, 2 orthopterans, 14 coleopterans and one belonged to order odonata. Among these, *Apis dorsata* Fab., *A. mellifera* L., *A. cerana* Fab. and *A. florea* Fab. were the most abundant pollinators. Abundance of four honey bee species on flowers at different hours of the day, differed significantly. *A. dorsata* was the most abundant visitor followed by *A. mellifera* , *A. cerana* and *A. florea* .

Keywords:

Pumpkin is a cross-pollinated crop and requires small bees for effective transfer of pollens from male to the female flowers. The insect pollinators of pumpkins include bees, butterflies, ants and even beetles which while damaging the flower parts, incidentally, caused pollination. Out of all the insects, honey bees were the main contributor for the pollination in *Cucurbita moschata*. Pinkus-Rendon *et al.* (2005) in Mexico reported that *Peponapis limitaris, Augochlora nigrocyana, Apis mellifera* and *Partamona biteanata* were the most abundant bee species on staminate flowers of squash, (*Cucurbita moschata)* while on pistillate flowers, *Peponapis limitaris, P. bileanata, A. nigrocyana* and *A. mellifera* were the most abundant bee species. Lot of work on its nutritional value, processing and role of insect pollinators have been done abroad in India but the lack of information on the diversity, abundance , role of insect pollinators and their efficiency in fruit production of pumpkin is lacking in agro climatic condition of Haryana. So study was undertaken to record the diversity and abundance of insect visitors and pollinators especially honey bees on pumpkin, *Cucurbita moschata.*

MATERIAL AND METHODS

The studies were carried out at Chaudhary Charan Singh Haryana Agricultural University, Hisar from June to December, 2013. Pumpkin cultivar C-1076 was *selected for study. Flowering began in August -September.* Flower visiting insects and pollinators of pumpkin were collected by a cone type hand net of 30cm ring. For this purpose, sweeps were made throughout the blooming period of the crop from morning to the evening. The collected insects were preserved as dry specimen and were got identified from Division of Entomology, Indian Agricultural Research Institute, New Delhi. Abundance of major insect visitors/pollinators on pumpkin flowers was recorded during the blooming period of the crop. For recording these observations, count of major insect visitors or pollinators (*Apis dorsata, A. mellifera, A.cerana* and *A. florea)* were made on flowers of *C. moschata* per 5 flowers per 5 minutes using a hand tally counter at hourly interval starting from 0530h till 1030h. Observations on abundance of insect pollinators were recorded at 10 per cent flowering initiation stage in the crop, at peak flowering period and before the cessation of flowering in the crop.

RESULTS AND DISCUSSION

Forty two insect species belonging to twenty four families under seven orders were observed visiting the flowers of pumpkin under agro-ecological conditions of Hisar (Table 1). The *pumpkin flowers* were visited by 8 hymenopterans, 7 lepidopterans, 7 dipterans, one species from odonata 3 hemipterans, 2 orthopteran and 14 coleopterans.

Among the insects visitors and pollinators, *A. dorsata, A. mellifera, A. cerana* and *A. florea* were the most frequent visitors. In general, diversity of pollinating insects varies from region to region and locality to locality. Deyto and Cervancia (2009) grouped insect visitors of *Cucurbita moschata* (Duch.ex Lam) flowers into four different orders: Hymenoptera (*Apis dorsata*, *A. mellifera*, *Trigona* spp., *Halictus* spp., *Xylocopa* spp. and Formicidae), Lepidoptera (butterflies), Coleoptera (Chrysomelidae) and Diptera (*Calliphora* spp., Sarcophagidae and Syrphidae). Out of these, *Trigona* spp., *Halictus* spp. and lepidopterans were the most frequent visitors. Honey bees were reported as

Table 1. Insect visitors/pollinators of *Cucurbita moschata* (Duch. ex Lam) flowers

Scientific name	Family	Behaviour of insects
Lepidoptera		
Hypolimnes misipusus Linnaeus	Nymphalidae	Visitors
Calotis etrida Boisduval	Pieridae	
Ixias marianne cumballa (Swinhoe)	Pieridae	
Terias libythea Linnaeus	Pieridae	
Herse convolvuli Linnaeus	Sphingidae	
Diathania indica Saunders	Crambidae	
Lampides boeticus Linnaeus	Lycaenidae	
Odonata		
Anisoptera (species unidentified)	Gomphidae	Visitors
Hymenoptera		
Apis dorsata Fabricius	Apidae	Pollinators
Apis mellifera Linnaeus	Apidae	
Apis cerana Fabricius	Apidae	
A. florea Fabricius	Apidae	
Polistes habraeus De Geer	Vespidae	
Nomia melanderi	Halictidae	
Ceratina viridissima Dalla Torre	Apidae	
Vespa orientalis Linnaeus	Vespidae	
Diptera		
Eristalinus tabanoides Jaennicke	Syrphidae	Pollinators
Eristalinus aeneus Scopoli	Syrphidae	
Ischiodon scuttellaris Fabricius	Syrphidae	
Sarsophaga sp.	Sarcophagidae	Visitors
Tabanid fly (species unidentified)	Tabanidae	
Musca domestica	Muscidae	
Bactocera cucurbitae Coquillett	Tephritidae	
Hemiptera		
Aspongopus janus	Coreidae	Visitors
*Dysdercus koenigi*i Fabricious	Pyrrhocoridae	
Clavigralla gibbosa Spinola	Coreidae	
Orthoptera		
Schistocera gregaria Forskal	Acrididae	Visitors
Oxya nitidula Walker	Acrididae	
Coleopteran		
Pseudoblaps mellyi Mulsant	Tenebrionidae	Visitors
Lycostomus praeustus Fabricious	Lycidae	
Mylabris pustulata Thumb	Meloidae	Pollinators
Aulacophora foveicollis Lucas	Chrysomelidae	Visitors
Diplocheila polita Fabricious	Carabidae	
Scarites indicus Olivier	Carabidae	
Chlaenius pretiosus Chaudoir	Carabidae	
Oxycetonia versicolor Fabricius	Scarabaeidae	
Chlaenius vulneratus Dejean	Carabidae	
Coccinella septumpunctata L.	Coccinellidae	
Epilachana dodecastigma L.	Coccinellidae	
Chilonemus sexmaculata chevrolat	Coccinellidae	
Aulacophora lewissi Lucas	Chrysomelidae	
Serangium sp.	Coccinellidae	

important pollinators of pumpkin (Nicodemo *et al*., 2009; Vidal *et al*., 2010). In Kenya, honey bees are the most utilized for commercial pollination of squash (Vidal *et al*., 2010).

Diurnal abundance honey bee species at initiation of flowering stage (August, 2013): The result revealed that A**pis** *dorsata* (2.25) was most abundant visitors followed by *Apis mellilfera* (2.09), *Apis cerana* (1.63) and *A. florea* (1.24). Deyto and Cervancia (2009) stated that *Trigona* spp., *Halictus* sp. and lepidopterans were the most frequent visitors among the different insect pollinators on *M. charantia* flowers in Philippines. Mean diurnal abundance of *A. dorsata* on blossoms of pumpkin cultivar (C–1106) irrespective of day time at initiation of the flowering period was the highest (2.25/5flowers/5minutes) followed by *A. mellifera*), *A. cerana* and *A. florea*. Mean abundance irrespective of the honey bee species was the maximum between 0730–0830 h (2.58/5flowers /5minute) followed by 0830–0930, 0630–0730 and 0930–1030 h. *Apis dorsata* was most abundant between 0530 to 0630 h (67.71%) followed by *Apis mellifera* (30.78%), *A. cerana* (27.57%) and *A. florea* (20.44%). Pateel and Sattagi (2007) recorded that *A. florea*, *A. cerana* and *A. dorsata* were the most frequent insect pollinators visiting the *Rabi* cucumber flowers in Karnataka with abundance of 8.03, 6.03 and 3.43 bees/m^2/5 minutes, respectively.

Diurnal abundance of four honey bee species on *C. moschata* cultivar (C-1106) flowers at peak flowering stage during September, 2013

Mean diurnal abundance of *A. dorsata* on blossoms of cultivar (C–1106) irrespective of day time (day hours) at peak of the flowering period was the maximum (4.42/5flowers/5minutes) followed by *A. mellifera* , *A. cerana* and *A. florea*. Mean abundance irrespective of the honey bee species was highest between 0730–0830 h (5.01/5flowers/5minute) followed by 0630–0730 h. The data reveal that Irrespective of the day time, *Apis dorsata* was the most dominant and highly significant species constituting (34.72%) followed by *A. mellifera* (31.10 %), *A. cerana* (18.69%) and *A. florea* was the least dominant (15.39 %). A**pis** *dorsata* was most abundant between 0530 to 0630 h (44.86%) followed by A**pis** *mellifera* between 0830 to 0930 h (35.42%) . Gahlawat *et al.* (2002) reported that *A. mellifera* was the most abundant insect pollinator on cucumber flowers with 0.08, 2.58, 1.75 and 0.83 bee/m2/5 minutes at 0600, 0800, 1000 and 1200 h of the day, respectively and peak foraging activity was observed at 1000 h of the day.

Diurnal abundance of four honey bee species on *C. moschata* cultivar (C-1106) at cessation of flowering stage during September, 2013

The mean population of four honey bee species ranged from 0.32 to 2.89/5flowers/5minutes. Irrespective of day time (day hours) at cessation of the flowering period **mean** diurnal abundance of A**pis** *dorsata* (2.79/5flowers/5minutes) was the dominant species followed by *Apis mellifera, A. cerana* and *A. florea*. Mean abundance irrespective of the honey bee species was significantly highest between 0630–0730 h (2.89/5flowers/5minute) followed by 0730–0830 h, 0930–1030 h, 0830–0930 h. Irrespective of the day time, *Apis*

Table 2. Diurnal abundance of four honey bee species on *C. moschata* cultivar during initiation of flowering stage (August, 2013)

Honey bee species	Number of honey bees/5 flowers /5 minutes during different day hours					
	0530–0630	0630–0730	0730–0830	0830–0930	0930–1030	Mean
Apis dorsata	0.86 (1.36)	2.61 (1.89)	2.88 (1.96)	2.85 (1.96)	2.08 (1.75)	2.25 (1.79)
Apis mellifera	0.28 (1.13)	2.52 (1.87)	3.08 (2.01)	2.91 (1.97)	1.72 (1.64)	2.09 (1.72)
Apis cerana	0.08 (1.03)	1.77 (1.16)	2.28 (1.80)	2.19 (1.78)	1.82 (1.67)	1.63 (1.59)
A. florea	0.05 (1.02)	1.25 (1.66)	2.11 (1.76)	1.77 (1.66)	1.02 (1.41)	1.24 (1.47)
Mean	0.32 (1.13)	2.03 (1.50)	2.58 (1.88)	2.44 (1.84)	1.65 (1.62)	
Factors (CD p=0.05)						
Bee species						(0.02)
Day hours						(0.03)
Bee species X day hours						(0.06)

Each value represents mean of 5 observations at each sampling time ; Figures in parentheses are $\sqrt{(n+1)}$ transformed value

Table 3. Diurnal abundance of honey bee species on *C. moschata* cultivar C–1106 at peak flowering stage (September, 2013)

Honey bee species	Number of honey bees/5 flowers /5 minutes during different day hours					
	0530–0630	0630–0730	0730–0830	0830–0930	0930–1030	Mean
Apis dorsata	1.31 (1.51)	5.71 (2.59)	7.12 (2.84)	5.42 (2.53)	2.63 (1.89)	4.42 (2.27)
Apis mellifera	0.62 (1.27)	5.57 (2.55)	5.88 (2.62)	5.42 (2.53)	2.31 (1.80)	3.96 (2.15)
Apis cerana	0.57 (1.25)	3.28 (2.05)	3.91 (2.21)	2.31 (1.81)	1.85 (1.68)	2.38 (1.80)
A. florea	0.42 (1.18)	2.57 (1.87)	3.11 (2.02)	2.17 (2.03)	1.54 (1.59)	1.96 (1.74)
Mean	0.73 (1.30)	4.28 (2.27)	5.01 (2.42)	3.83 (2.22)	2.08 (1.74)	
Factors (CD p=0.05)						
Bee species						(0.08)
Day hours						(0.09)
Bee species X day hours						(0.20)

Each value represents mean of 5 observations at each sampling time ; Figures in parentheses are $\sqrt{(n+1)}$ transformed value

dorsata was the most dominant species constituting (38.16%) followed by *A. mellifera* (30.77 %), *A. cerana* (18.87%) and *A. florea* was the least dominant (12.17 %).

Diurnal abundance on pumpkin cultivar C-1106 (August-September, 2013): Mean diurnal abundance throughout the flowering period of *A. dorsata* on blossoms of pumpkin cultivar (C–1106) irrespective of day time shiwed the same trend. Diurnal abundance irrespective of the honey bee species during different day hours was highest between 0730–0830 h (3.69/5flowers/5minutes) and lowest between 0530–0630 h (0.49/5flowers/ 5minutes). The mean per cent abundance of four honey bee species throughout the flowering period of the pumpkin's hybrid (C–1106) was observed highest for *A. dorsata* (34.71 %) followed by *A. mellifera* (30.30%), *A. cerana,* (20.06%), *A. florea* (14.88%). Nicodemo *et al*. (2009) in Brazil reported that *A. mellifera, Diabrotica speciosa* (Germ.) and *Trigona spinipes* (fab.) were the most frequent insect visitors on the flowers of pumpkin plant. Among bee visitors, *Apis mellifera* accounted for 73.44 per cent and *Trigona spinipes* represented 26.64 per cent of the total bee visitors. The peak activity for *A. mellifera* was noticed at 0800 h, for *T. spinipes* from 0900 to 1000 h and for *Diabrotica speciosa* from 1400 to 1700 h with no overlapping of these peaks.

CONCLUSION

The result shows that total of 42 insect species visited pumpkin flowers, out of these, 8 were hymenopterans, 7 lepidopterans, 7 dipterans, 3 hemipterans, 2 orthopterans, 14 coleopterans and one belonged to order odonata. Among these, *Apis dorsata* Fab.*, A. mellifera* L.*, A. cerana* Fab. and *A. florea* Fab. were the most abundant pollinators.

Table 4. Diurnal abundance honey bee species on *C. moschata* cultivar C–1106 at cessation of flowering stage (September, 2013)

Honey bee species	Number of honey bees/ 5 flowers/ 5 minutes during different day hours					
	0530–0630	0630–0730	0730–0830	0830–0930	0930–1030	Mean
Apis dorsata	0.65 (1.28)	4.22 (2.28)	4.62 (2.36)	2.94 (1.98)	1.54 (1.59)	2.79 (1.90)
Apis mellifera	0.31 (1.14)	3.37 (2.07)	3.34 (2.05)	2.50 (1.86)	1.71 (1.63)	2.25 (1.75)
Apis cerana	0.22 (1.10)	2.37 (1.83)	1.68 (1.64)	1.45 (1.56)	1.25 (1.49)	1.38 (1.52)
A. florea	0.11 (1.05)	1.64 (1.61)	1.02 (1.42)	0.88 (1.36)	0.81 (1.34)	0.89 (1.35)
Mean	0.32 (1.14)	2.66 (1.87)	2.89 (1.95)	0.88 (1.69)	1.32 (1.51)	
Factors (CD p=0.05)						
Bee species						(0.08)
Day hours						(0.09)
Bee species X day hours						(0.19)

Each value represents mean of 5 observations at each sampling time ; Figures in parentheses are $\sqrt{(n+1)}$ transformed value

Table 5. Diurnal abundance of honey bee species on pumpkin cultivar C–1106 (August–September, 2013)

Honey Bee species	Number of honey bees/5 flowers /5 minutes during different day hours					
	0530–0630	0630–0730	0730–0830	0830–0930	0930–1030	Mean
Apis dorsata	0.94 (1.38)	4.17 (2.25)	4.85 (2.39)	3.74 (2.16)	2.07 (1.74)	3.15 (1.98)
Apis mellifera	0.40 (1.18)	3.81 (2.16)	4.10 (2.23)	3.61 (2.12)	1.90 (1.69)	2.76 (1.87)
Apis cerana	0.32 (1.13)	2.80 (1.84)	3.17 (1.88)	2.33 (1.72)	1.79 (1.61)	2.08 (1.64)
A. florea	0.29 (1.08)	2.47 (1.66)	2.62 (1.73)	1.98 (1.68)	1.62 (1.45)	1.80 (1.52)
Mean	0.49 (1.19)	3.31 (1.97)	3.69 (2.05)	2.92 (1.92)	1.85 (1.62)	
Factors (CD p=0.05)						
Bee species						(0.08)
Day hours						(0.09)
Bee species X day hours						(0.19)

Each value represents mean of 5 observations at each sampling time ; Figures in parentheses are $\sqrt{(n+1)}$ transformed value

Abundance of four honey bee species was low at the initiation of flowering stage of the crop. It was maximum at peak flowering period of the crop and again was low at the cessation of flowering stage of the crop. These differences seem to be related with flower density in the crop. At peak flowering stage, *A. dorsata was more abundant* followed by *A. mellifera* , *A. cerana* and *A. florae.*

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Quantification of Relationship of Weather Parameters with Cotton Crop Productivity

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Abstract: Field investigation was undertaken to evaluate the performance of cotton cultivars (HD 123, H 1098 and RASI 134) under different sowing environments and changing microclimate during the *kharif* 2013–14. Radiation and thermal use efficiency (TUE) were computed at different phenophases in all the treatments. Crop sown during 2nd week of April consumed highest thermal and radiation indices. Weather parameters during 50 per cent flowering were better associated with crop parameters than those of other phenophases. Tmax, Tmin and Vapour pressure deficit showed a strong positive correlation with seed cotton, cotton seed, cotton lint and bolls per plant during boll opening stage, whereas morning and evening relative humidity showed negative correlation with seed cotton, cotton seed, cotton lint and bolls per plant during vegetative, flowering stage and boll opening stage. Among the agrometerological indices, heat use efficiency was highly correlated with seed cotton, cotton seed, cotton lint and bolls per plant followed by photothermal unit and heat unit. Maximum temperature, morning relative humidity, vapour pressure deficit during boll opening and sunshine hours during flowering stage were most significant weather parameters which influenced collectively the cotton yield up to 82 percent.

Keywords: Correlation, Thermal use efficiency, Regression, Yield attributes, Sowing environment, Cotton

Lint is most important economical product of cotton plant provides a source of high quality fiber for the textile industry and cotton seeds are primary by product of lint production or an important source of oil for human consumption, and high protein meal used as cattle/livestock feed. Cotton development rates are related to air temperature during the growing season and can be expressed as accumulated heat units or growing degree days (Roussoppoulos *et al.,*1998). A heat unit is a measure of the amount of heat energy a plant accumulates each day during the growing season and has been used to describe the development of crops). A cotton plant can produce one open boll and four more bolls that are 85% mature with 1000 heat unit, and crop termination through defoliation at this stage of plant development results in a loss of about 1% of total expected yield but does not reduce the fibre quality (Wrona *et al*.1996). Cotton developmental events occur much more rapidly as maximum temperature increases. Tripathi (2005) and Pouresia and Nabipour (2007) observed a negative correlation between air temperature and sunshine hours during seed development phase with leaf area index in mustard crop. The negative correlations of temperature and sunshine hours during reproductive phase with oil content were also reported by Omidi *et al*. (2007) and Liyong *et al*. (2007). Therefore this investigation was carried out to quantify the relationship of weather parameters with cotton crop parameters in north irrigated cotton zone of India.

MATERIAL AND METHODS

The experiment was conducted at the research farm of Department of Agricultural Meteorology CCS Haryana Agricultural University, Hisar (longitude 75^0 46 $'$ E and latitude $29^0 10'$ N, altitude 215.2 msl). The main plots treatments consisted of four date of sowing (2nd week of April (G1), 4th week of April (G2), 2nd week of May (G3) and 1st week of June (G4) and the sub–plots consisted of three varieties (HD 123, H 1098 and RASI 134). The forty eight treatment combinations were tested in split plot design to quantify the relationship weather with crop yield cotton cultivars under different growing environments. The cotton crop yield, its attributes and quality was recorded in all the treatment combinations at harvest time. Daily weather data recorded at agrimet observatory were used to compute the following agro–meteorological indices.

Cumulative heat units (HU) = $(T_{max.} + T_{min})/2 - T_b$ Where, T_{max}= Daily maximum temperature (^{0}C), T_{min}=Daily minimum temperature (^{0}C) & T_b=Minimum threshold/base temperature (10^{o}C, WMO, 1996).

HTU = (HU x n) Where, n = Actual sunshine hours

Photothermal units PTU = Σ (HU x N) Where, N = Maximum possible sunshine hours or day length.

Saturated vapour pressure SVP= [(Relative humidity/100)/AVP] where AVP is actual vapour pressure

Correlation and regression analysis were carried out for quantification of relationship between weather and crop parameters. Linear relationship was quantified using the linear trend analysis.

RESULTS AND DISCUSSION

Correlation coefficient: Maximum and minimum temperatures during boll opening stage had significant positive correlation with seed cotton, cotton seed, cotton lint and bolls per plant, whereas minimum temperature during vegetative and flowering stage showed significant negative correlation with the above said crop parameters (Table 1). This might be due to low minimum temperatures resulted in lower respiration losses. Tripathi (2005) and Pouresia and Nabipour (2007) also observed a negative correlation between air temperature and sunshine hours during seed development phase with leaf area index. Negative correlations between temperatures during two later phenophases and seed yield were due to higher temperatures during reproductive phase. Such results were also obtained by Sahoo *et al*. (2000), Singh (2005) and Liyong *et al*. (2007). Sunshine hours during flowering had highly significant positive correlation with seed cotton, cotton seed, cotton lint and bolls per plant with correlation coefficients of 0.86, 0.78, 0.96 and 0.89, respectively, but correlation coefficient was highly significant with cotton lint as compared to other crop parameters. The data reveals that a significant negative correlation exists between relative humidity at morning and evening hours with seed cotton, cotton seed, cotton lint and bolls per plant during vegetative, flowering and boll opening stage. Similarly, a significant positive correlation was observed between vapour pressure deficit versus seed cotton, cotton seed, cotton lint and bolls per plant during vegetative, flowering and boll opening stage. It was also derived that a positive correlation also exists among all the thermal units with seed cotton, cotton seed, cotton lint and bolls per plant during different growth stages, while it was observed that the heliothermal units were highly positively correlated during vegetative and flowering stage (Table 2). This show that bright sunshine hour in combination with heat unit is important for cotton crop growth and yield. Weather parameters were better associated with crop parameters than those of other phenophase during 50 percent flowering. Maximum temperature, minimum temperature and vapour pressure deficit showed a strong positive correlation with seed cotton, cotton seed, cotton lint and bolls per plant during boll opening stage, whereas morning and evening relative humidity showed negative correlation with these parameters during vegetative, flowering and boll opening stages.

Regression analysis: Simple linear equations were developed for the estimation of different crop parameters using significant weather parameters. A linear direct

Table 1. Correlation between weather and crop parameters at different phenological stages

Weather paramete	Seed cotton (q ha^{-1})	Cotton seed (q ha^{-1})	Cotton lint (q ha^{-1})	Bolls plant^{-1}
Vegetative phase				
T_{Max}	0.74*	0.67*	0.81**	0.80**
T_{Min}	-0.68*	-0.59*	-0.80**	-0.67*
RH_M	-0.76**	-0.67*	-0.89**	-0.81**
RH_E	-0.77**	-0.70*	-0.86**	-0.82**
SSH	0.73**	0.66*	0.81**	0.80**
VPD	0.75**	0.68*	0.84**	0.82**
Flowering stage				
T_{Max}	0.88**	0.79**	0.98**	0.89**
T_{Min}	-0.52	-0.44	-0.62*	-0.52
RH_M	-0.87**	-0.79**	-0.97**	-0.89**
RH_E	-0.85**	-0.76**	-0.96**	-0.87**
SSH	0.86**	0.78**	0.96**	0.89**
VPD	0.88**	0.80**	0.97**	0.91**
Boll opening stage				
T_{Max}	0.90**	0.81**	0.99**	0.91**
T_{Min}	0.71**	0.69*	0.71**	0.70*
RH_M	-0.87**	-0.78**	-0.97**	-0.89**
RH_E	-0.74**	-0.63*	-0.88**	-0.76**
SSH	0.44	0.33	0.64*	0.51
VPD	0.89**	0.81**	0.98**	0.91**

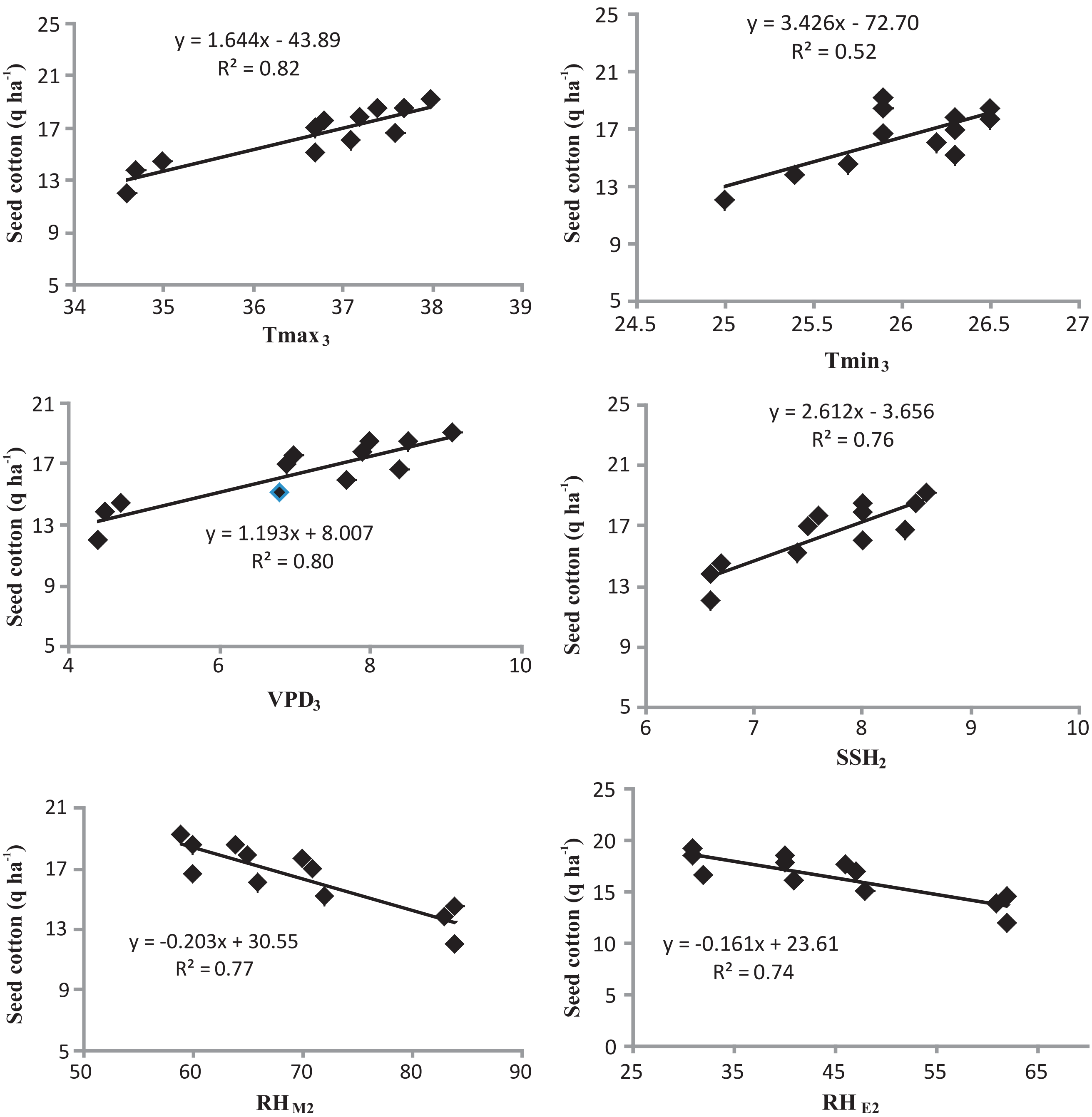
*and ** significant at 5 and 1% level of confidence

Table 2. Correlation between agrometeorological indices and yield and its attributing factors at different phenophases (Pooled data for cultivars and growing environments)

Thermal indices	Seed cotton (q ha^{-1})	Cotton seed (q ha^{-1})	Cotton lint (q ha^{-1})	Bolls plant^{-1}
Vegetative phase				
HU	0.57	0.02	0.16	0.08
HTU	0.69*	0.65*	0.72**	0.74**
PTU	0.05	0.01	0.14	0.06
Flowering stage				
HU	0.10	0.03	0.44	0.19
HTU	0.65*	0.61*	0.89**	0.76**
PTU	0.26	0.19	0.63	0.39
Boll opening stage				
HU	0.21	0.34	0.09	0.15
HTU	0.25	0.38	0.45	0.31
PTU	0.17	0.03	0.47	0.22

* and ** significant at 5 and 1% level of confidence
HU= Heat unit, HTU = Heliothermal unit & PTU = Photothermal unit

relationship was observed between maximum temperature and seed cotton yield explaining the variability up to 82 per cent during boll opening stage. A similar relationship was found between minimum temperature and seed cotton yield explaining the variability up to 52 per cent during boll opening stage (Figure 1). A vapour pressure deficit showed direct linear relationship with seed cotton yield explained the variability up to 80 per cent during boll opening stage. But sunshine hours during flowering stage showed linear and direct relationship with seed cotton yield explaining the variability up to 76 per cent. A direct linear relationship was between morning relative humidity and seed cotton yield explaining the variability up to 77 per cent and linear reverse relationship was between evening relative humidity and



$Tmax_3$, $Tmin_3$ and VPD_3= Boll opening stage. ; SSH_2, RH_{M2} and RH_{E2} = Flowering stage

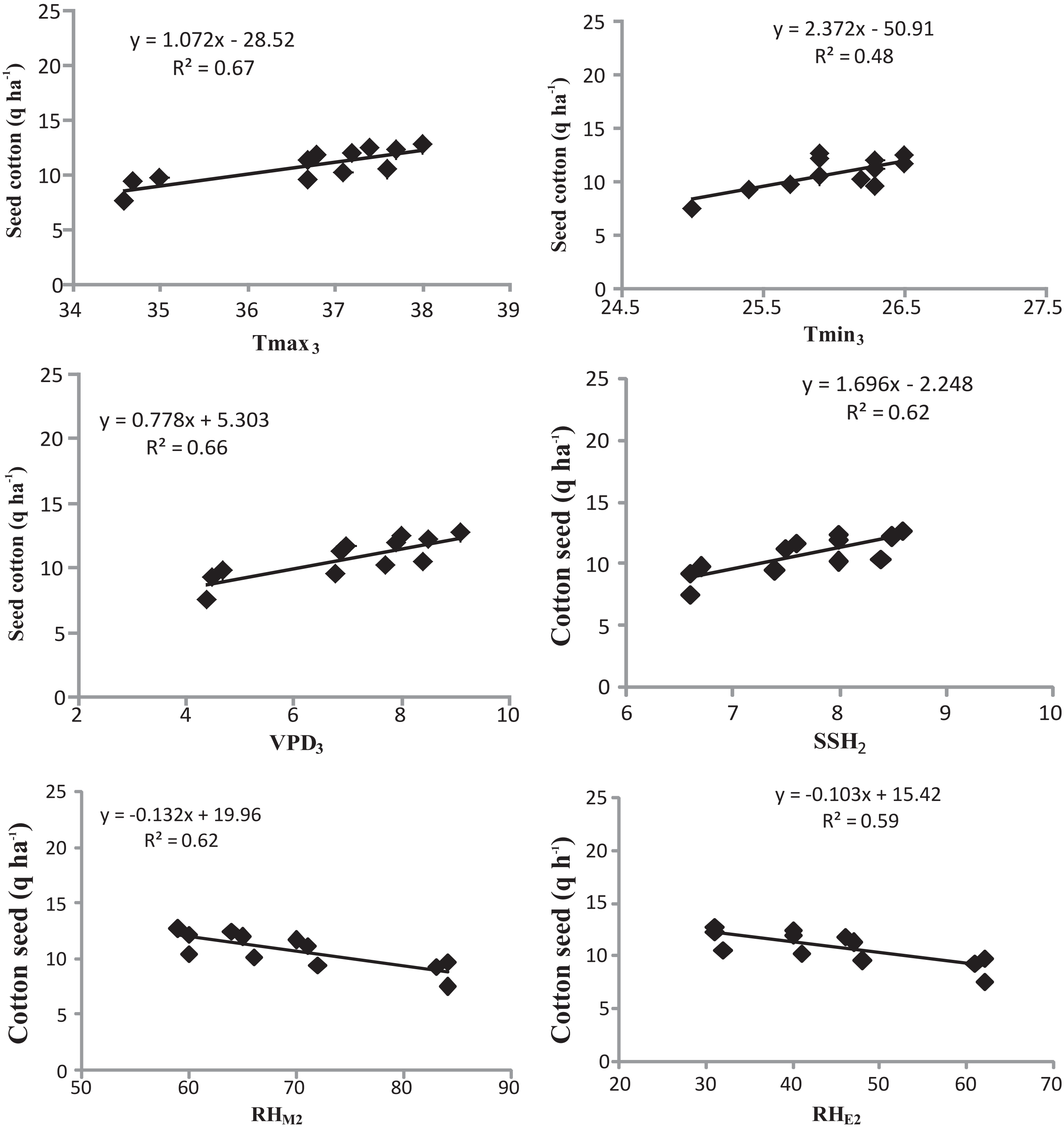
Fig. 1. Relationship of seed cotton with weather parameters

seed cotton yield explaining the variability up to 74 per cent during flowering stage.

Llinear relationship was positive obetween maximum and minimum temperature, vapour pressure deficit and cotton seed yield during boll opening stage explaining the variability up to 67, 48 and 66 per cent, respectively.

CONCLUSION

Tmax, Tmin and VPD strongly and directly correlated with seed cotton, cotton seed, cotton lint and bolls per plant



$Tmax_3$, $Tmin_3$ and VPD_3= Boll opening stage. ; SSH_2, RH_{M2} and RH_{E2} = Flowering stage

Fig. 2. Relationship of cotton seed with weather parameters

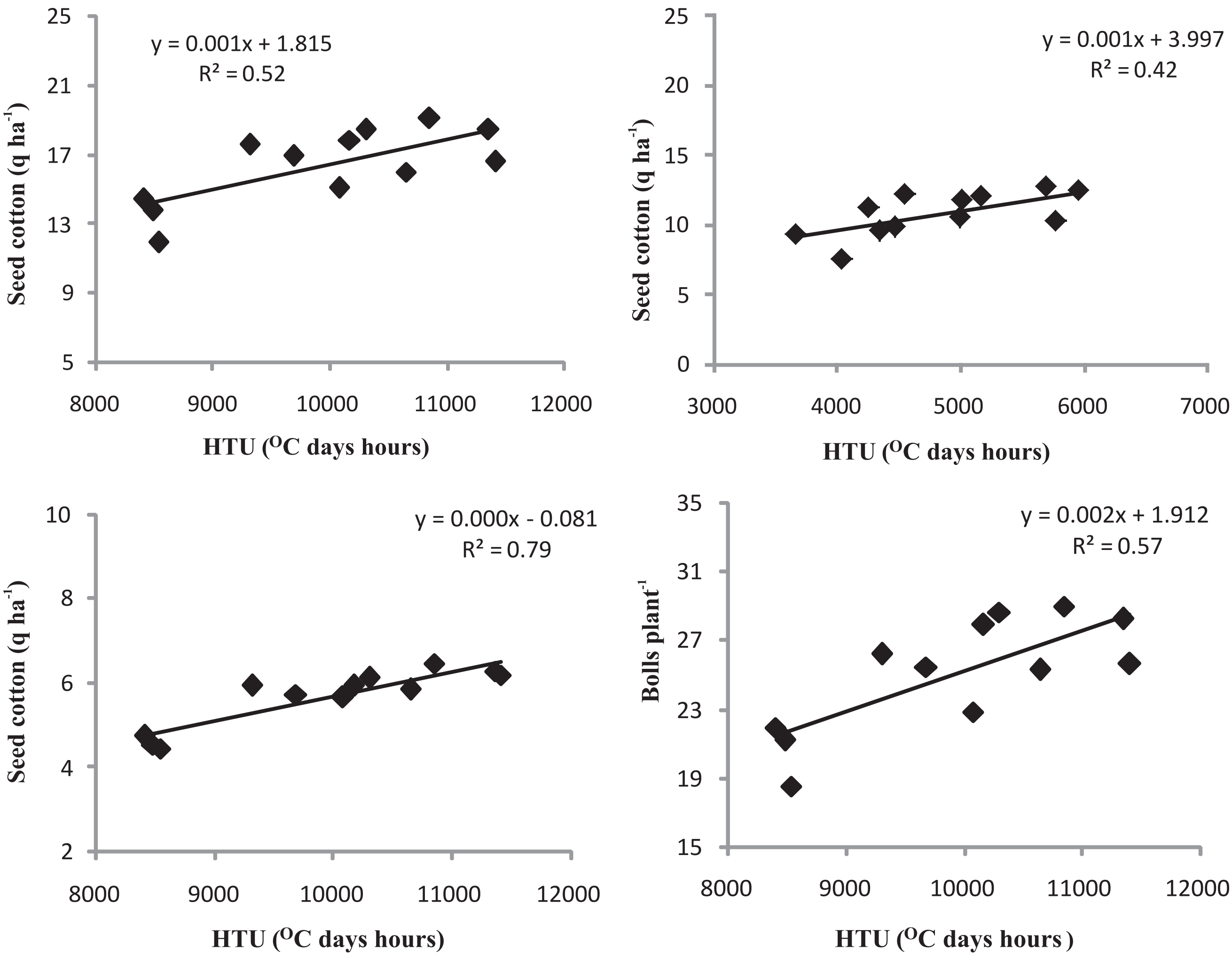


Fig. 3. Relationship of seed cotton, cotton seed, cotton lint and bolls/plant with HTU

during boll opening stage, whereas, morning and evening relative humidity showed negative correlation with seed cotton, cotton seed, cotton lint and bolls plant^{-1} during vegetative, flowering stage and boll opening stage. HTU were highly correlated with seed cotton, cotton seed, cotton lint and bolls plant^{-1}. Maximum temperature during boll opening stage individually explained 82 per cent variability in seed cotton yield and yield attributes

(Figure 2). A linear negative relationship was between morning and evening relative humidity and cotton seed yield during flowering stage explaining the variability up to 62 per cent. Heliothermal units showed positive linear relationship with seed cotton, cotton seed, cotton lint and bolls plant^{-1} (Figure 3). Heliothermal units explained the variability up to 52, 42, 79 and 57 per cent in seed cotton, cotton seed, cotton lint and bolls per plant, respectively. Simple and multiple regression equations were developed for the estimation of different crop parameters using significant weather parameters. A linear positive relationship was between maximum temperatures, minimum temperature, vapour pressure deficit and seed cotton yield during boll opening stage (Figure 3). However, linear negative relationship was found between maximum temperatures, minimum temperature, vapour pressure deficit and seed cotton yield during flowering stage.

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Short and Medium Duration Varieties of Cereals and Millets to Mitigate Monsoon Vagaries in Rainfed Agriculture

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Abstract: The improved short and medium duration varieties of cereals and millets were implemented through National Innovations in Climate Resilient Agriculture (NICRA), in select drought-prone villages through KVKs of ATARI, Bengaluru since 2011 in Karnataka and Tamil Nadu. A total of 680 demonstrations were implemented in Karnataka and Tamil Nadu in 288.2 ha area during 2011 to 2015. In Karnataka state, drought tolerant and short duration varieties gave higher yield and net returns as compared to local checks *viz.,*pearl millet Cv.ICTP-8203, foxtail millet Cv. PS-4 and wheat Cv.DWR-2006 have recorded 34.6 %, 19.5 % and 34.2 % respectively at Belgavi, finger millet Cv.GPU-28 recorded 22.3 % at Chikkaballapura, Cv. GPU-28 and GPU-48 recorded 51.9% and 8.2 to 13.5 % to at Davanagere and finger millet Cv.ML-365 and aerobic paddy Cv.MAS-26 gave 33.3 to 41.8 % and 12.4% to 25.8 % increased yield with better BCR ratio as compared to local varieties at Tumkur. In Tamil Nadu state, the short and medium duration sorghum Cv.K.8 and paddy Cv.ADT-49 gave 45.3 % in sorghum and 10% increase in yield in paddy at Namakkal, the flood tolerant rice Cv. Swarna sub1 recorded 15.2 %, saline tolerant rice Cv. TRY 3 gave 12.6 % andadvanced rice nursery in *kharif* for timely planting Cv.ADT-38 gave 8.0 % increase in yield at Nagapattinam. At Villupuram district higher yield ranging from 26.3 to 28.4% in Cv. Anna 4, 18.2% in Cv. Ponni and 23.4% in Cv. ADT-49 were recorded with better BCR as compared to local varieties.

Keywords:Cereals, Millets, Rainfall, Yield, BCR

Normal on set of monsoon is very crucial to rainfed agriculture, as it sets forth cropping season well in time. However, in the recent past, the monsoon onset is delayed by 2-3 weeks impairing the whole cropping season. Besides distribution of rainfall throughout the cropping seasons is equally important for good harvest in the rainfed lands. Data of the past decades shows that there is an increase in trend of 'breaking in monsoon'. This is depriving the crop moisture during critical growth phase, their by causing severe yield loss. The continued experiences of varying rainfall distribution and rainfall periods, has disrupted the normal crop production especially during water shortage in farms at critical crop development stages. Irregular rainfall in late vegetative crop growth stage has been credited to poor flowering and seed filling for maize resulting to dismal yields (Hastenrath *et al*., 2010). In such a scenario farmers need varieties that not only matures in a short duration but also tolerant to mid-season moisture stress. Keeping this in view, promoted available short and medium duration crop varieties among farmers under National Innovations in Climate Resilient Agriculture (NICRA) as a part of crop intervention module.

MATERIAL AND METHODS

The crop intervention module under National Innovations in Climate Resilient Agriculture (NICRA) promoted the available short and medium duration crop varieties with farmers' participatory research mode at select drought-prone districts of Karnataka and Tamil Nadu under ATARI, Zone VIII during 2011 to 2015 through KVKs. Farmers in the villages traditionally grow local varieties of different crops resulting in poor crop productivity due to heat, droughts or floods. Hence, improved early duration drought and heat tolerant varieties were introduced for achieving optimum levels yields despite climate stresses. These crop varieties were demonstrated for drought situations through 680 farmers' fields covering an area of 288.2 ha in the districts of Belgavi (rainfall received was 333.1 mm, 235.6 mm and 505.5 mm, during 2011-12, 2013-14 and 2014-15 respectively as against normal rainfall of 538.0 mm), Chikkaballapura (rainfall received was 107.5 mm during 2011-12 as against normal rainfall of 740.0 mm), Davanagere (rainfall received was 219.2 mm, 368.9 mm and 699.9 mm during 2011-12 to 2013-14 respectively as against normal rainfall of 648.0 mm), Tumkur (rainfall received was 779 mm, 824 mm, 1082 mm and 1132 mm during 2012-13 to 2015-16 respectively as against normal rainfall of 696.0 mm) of Karnataka and Namakkal (rainfall received was 405.6 mm and 548.3 mm against normal rainfall of 410.0 mm during 2011-12 and 2014-15), Nagapattinam (rainfall received was 957.84 mm and 1215.6 mm during 2011–12 and 2012–13 respectively as against normal rainfall of 1341.0 mm) and Villupuram (rainfall received was 936.5 mm, 957.5 mm, 1158.1 mm, 1095.7 mm during 2011–12 to 2014–15 respectively as against normal rainfall of 1058.0 mm) of Tamil Nadu as shown in Table.1. The crop varieties such as DWR-2006 in wheat (*Triticuma estivum*), MAS-26, Swarna sub1, TRY3, Anna 4, Ponni, ADT 38 and ADT49 in paddy (*Oryza sativa* L.), K.8 in sorghum(*Sorghum bicolor*), ICTP-8203 in pearl millet(*Pennisetum glaucum*), PS-4 in foxtail millet (*Setaria italic*) and GPU-28, GPU-48 and ML-365 in finger millet (*Eleusinecoracana*) were demonstrated for drought situations. These short duration and drought tolerant varieties that can withstand up to 2 weeks of exposure to dry spells in rainfed areas.

RESULTS AND DISCUSSION

The results have been very encouraging as the loss in yield due to late onset of monsoon or mid-season moisture stress in the varieties introduced by the project was much less compared to the local varieties cultivated by the farmers. This paper illustrates how under different locations short and medium duration varieties were able to limit the loss for farmers under adverse climate condition in the back drop of challenging rainfall situation (Table 2 and 3).

In Belgavi district of Karnataka, short and medium duration improved varieties of bajra, foxtail millet and *rabi* wheat were demonstrated in an area of 39.4 ha by 99 farmers. In the year 2011–12, demonstration of bajra Cv. ICTP-8203 which have the characteristic of short duration (70-80 days) and uniform ear head recorded 34.6 % higher yield with higher BCR (3.04) over local variety despite 38.08 % deficit rainfall with 3 dry spells of >10–15 days during crop growth period. In the year 2013–14, demonstration of short duration (80-85 days) and drought resistant foxtail millet Cv. PS-4 recorded 19.5 % increase in yield over local variety in spite of encountering a deficit rainfall of 49.25% with 3 dry spells (>10–15 days). The BCR realized with Cv. PS-4 was marginally better (1.60) as compared to farmers′ practice (1.45). In 2013–14 and 2014–15, demonstration of wheat Cv. DWR-2006 encountered a deficit rainfall of 49.25% and 6.04 % with 2 and 4 dry spells (> 10–15 days) respectively. In spite of this, an average higher yield of 1387 kg/ha was recorded as compared to 1030 kg/ha in local varieties registering an increase of 34.2 %. The BCR with Cv. DWR-2006 was 2.24 as compared to 1.90 in farmers practice. Rijsberman, (2014) pearl millet/bajrahasbeen selected as water saving, drought tolerant and climate change complaint crop. Finger millet Cv. GPU-28a medium duration (105–120 days) and blast resistant suitable under delayed onset of monsoon (about 4 weeks) and can be directly sown as a sole crop till end of August. This variety was demonstrated in 72 farmers′ fields(28.8 ha)in Chikkaballapura and Davanagere districts of Karnataka recorded 37.1 % increase in yield when compared to local varieties with a deficit rainfall of 85.47% and 2 dry spells of > 10–15 days in Chikkaballapura and with a deficit rainfall of 67.0 % and 3 dry spells of > 10–15 days in a in Davangere during 2011–12. The BCR was also higher (2.50) as compared to farmers′ variety (1.82). Hence, this variety performed better under adverse climatic condition compared to local varieties.

In the year 2012–13, the demonstration of finger millet Cv. GPU-48 encountered a deficit rainfall of 42.61% with 2 dry spells of >10–15 days and in 2013–14 with an excess rainfall of 7.40 % and 1dry spells of >10–15 days in Davanagere district has recorded an average increase of 10.85 % in yield when compared to local variety. The BCR was 2.05 with Cv. GPU-48 as compared to farmers′ variety. Ramachandrappa *et al.* (2010; 2013) reported that the yield and economics of medium duration variety were higher than long duration due to delayed monsoon and sowing.

`In Tumkur district, the farmers demonstrated short duration finger millet (ML-365) and medium duration aerobic paddy (MAS 26) variety in130.0 ha area by 337 farmers.

When the delay in monsoon is about 5 weeks, short duration variety like ML-365 (105 days) can be taken up for sustainable production. This variety is tolerant/resistant to blast disease and can be sown till August under rainfed conditions in medium to deep red soils. The rainfall was excess by 10.65 %, 15.53 %, 38.51 % and encountered 3, 4 and 1 dry spells of > 10–15 days respectively during 2011–12 to 2015–16.The demonstration of Cv. ML-365 during these years has led to an average increase of 37.6 % in yield when compared to local variety. The BCR was better with Cv. ML-365 (2.41) as compared to farmers′ variety (1.57).

Aerobic paddy Cv. MAS-26 is a short duration(115–120 days) and highly adapted to dry zone of Karnataka. Blast is common problem in aerobic system, however the new aerobic varieties are showing high level of tolerance to blast diseases and performing better under adverse climatic condition. This variety was demonstrated in 2012–13, 2013–14, 2014–15 and 2015–16 and achieved higher yield of 3387 kg/ha when compared to local variety (2850 kg/ha) registering an increase of 18.9 % besides better BCR (2.12). Aerobic rice could be successfully cultivated with 600 to 700 mm of total water in summer and entirely on rainfall in wet season (Shailaja Hittalmani, 2007a, 2007b).

In Namakkal district of Tamil Nadu, the farmers

Table 1. Rainfall in select KVKs of Karnataka and Tamil Nadu under NICRA

NICRA KVK District	Year	Normal rainfall (mm)	Total rainfall (mm) from Jan–Dec	No. of rainy days	No. of dry spells> 10–15 days	No. of dry spells> 15 days	No. of highest rainfall intensity events	Water inundation floods > 10 days (No. of events)	Rainfall (mm)		
									Khairf	*Rabi*	Summer
Belgavi	2011	538	333.1	29	3	2	0	0	185.3	136.2	11.6
	2012		235.6	21	3	2	1	0	139.4	93.51	2.75
	2013		273.0	31	2	2	1	0	127.2	136.8	9
	2014		505.5	42	4	2	0	0	301.1	178.42	23
Chikkaballapura	2011	740	107.5	12	2	1	0	0	52	55.5	0
Davanagere	2011	648	213.6	28	3	1	0	0	185.5	33.7	0
	2012		371.9	36	2	1	0	0	195.6	0	134.3
	2013		699.9	67	1	0	2	0	383.9	35	281
Tumkur	2012	696	779.0	49	3	1	1	0	310	193	276
	2013		824.0	50	4	0	1	0	500	169	155
	2014		1082.0	63	2	0	3	0	560	225	297
	2015		1132.0	67	1	1	3	0	335	460	337
Namakkal	2011 (Sep–Dec)	410	405.4	31	1	1	0	0	0	316	0
	2014		548.3	32	4	7	1	0	307	217.3	24
Nagapattinam	2011	1341	957.8	51	5	4	1	0	144.5	774.84	38.5
	2012		1215.6	41	3	7	7	0	120.1	1062.8	32.7
Villupuram	2011	1058	936.5	45	4	8	2	0	428	373.5	135
	2012		957.5	48	5	8	2	0	352	595	10.5
	2013		1158.1	53	3	6	2	0	731.8	362.75	63.5
	2014		1095.7	51	5	7	2	0	502	459.5	134.25

Table 2. Performance of short and medium duration varieties of cereals and millets in rainfed situation of Karnataka

Crop	NICRA KVK name	Year	Variety		Demo (No.)	Area (ha)	Yield (kg/ha)		% Yield increase	B:C ratio	
			Demo	FP*			Demo	FP		Demo	FP
Bajra	Belgavi	2011–12	ICTP-8203	Local	9	5.4	875	650	34.6	3.04	2.97
Foxtail millet	Belgavi	2013–14	PS-4	Local	10	2	950	795	19.5	1.60	1.45
Rabi Wheat	Belgavi	2013–14	DWR-2006	DWR-162	30	12	1625	1186	37.0	1.55	1.38
		2014–15	DWR-2006	DWR-162	50	20	1150	875	31.4	2.94	2.41
		Average of DWR −2006					1387.5	1030.5	34.2	2.25	1.90
Finger millet	Chikkaballapura	2011–12	GPU-28	Indaf	40	16	1944	1590	22.3	2.66	2.01
	Davanagere	2011–12	GPU-28	Local	32	12.8	2242	1476	51.9	2.34	1.62
		Average of GPU-28					2093	1533	37.1	2.50	1.82
Finger millet	Davanagere	2012–13	GPU-48	Local	15	6	2188	1927	13.5	2.00	1.84
		2013–14	GPU-48	Local	15	6	2225	2057	8.2	2.10	2.03
		Average of GPU −48					2206.5	1992	10.85	2.05	1.94
Finger millet	Tumkur	2011–12	ML-365	Local	70	20	2240	1580	41.8	2.29	1.36
		2012–13	ML-365	Local	65	25	2350	1750	34.3	2.74	1.78
		2013–14	ML-365	Local	110	50	2800	2100	33.3	2.74	1.78
		2015–16	ML-365	Local	70	25	2720	1930	40.9	1.85	1.37
		Average of ML −365					2527.5	1840	37.6	2.41	1.57
Aerobic paddy	Tumkur	2012–13	MAS 26	Local	5	2	3750	2980	25.8	2.13	1.87
		2013–14	MAS 26	Local	2	1	3350	2980	12.4	2.13	1.87
		2014–15	MAS 26	Local	5	2	3250	2840	14.4	2.20	1.90
		2015–16	MAS 26	Local	10	5	3200	2600	23.1	2.01	1.70
		Average of MAS-26					3387.5	2850	18.9	2.12	1.8
Total					538	210.2					

* −Farmers practice

Table 3. Performance of short and medium duration varieties of cereals and millets in rainfed situation of Tamil Nadu

Crop	NICRA KVK	Year	Variety		Demo	Area	Yield (kg/ha)		% Yield increase	B:C ratio	
			Demo	FP*			Demo	FP		Demo	FP
Paddy	Nagapattinam	2011–12	Swarna sub 1[€]	Local	36	14.4	5475	4750	15.26	1.83	1.58
		2012–13	TRY 3[β]	Local	39	15.6	5350	4750	12.63	1.78	1.58
		2011–12	ADT 38[Ω]	Local	2	3	5240	4850	8.0	1.60	1.58
	Namakkal	2014–15	ADT 49	ADT 45	10	5	6440	5855	10.0	2.91	2.18
	Villupuram	2014–15	ADT 49	ADT 39	5	2	5044	4088	23.4	3.07	2.51
Average of ADT 49							5742	4971.5	16.7	2.99	2.35
Paddy	Villupuram	2011–12	Anna 4	ADT 39	25	10	4037	3144	28.4	2.51	2.02
		2012–13	Anna 4	ADT 39	5	1	4120	3258	26.5	2.53	2.09
		2013–14	Anna 4	ADT 39	8	4	4104	3250	26.3	2.51	2.02
Average of Anna 4							4087	3217.3	27.1	2.52	2.04
Paddy	Villupuram	2013–14	Ponni	ADT 39	3	0.5	5650	4780	18.2	2.00	1.49
Sorghum	Namakkal	2011–12	K.8	Co.4	9	22.5	1780	1225	45.3	2.93	2.38
Total					142	78					

* –Farmers practice [€]–Flood tolerant rice [β] –Saline tolerant rice [Ω] –Advanced rice nursery in kharif for timely planting

demonstrated sorghum (K.8) and paddy (ADT.49) in 27.5 ha area in 19 farmers′ field (Table 3).

Short duration sorghum Cv. K.8 (85 days) was demonstrated in 2011–12 with 45.3% increase in yield in spite of deficit rainfall of 1.08 % with 1 dry spell of > 10–15 days. According to Rao *et al.* (1989), sorghum is one of the most important traditional cereal crops of the hotter and drier regions of the tropics and subtropics

Paddy Cv. ADT.49 is a medium duration(132 days) and is suitable for cultivation in late samba season. This variety was demonstrated in 2014–15 in Namakkal and Villupuram districts of Tamil Nadu has recorded 16.7 % increase in yield under excess rainfall of 25.22 % but encountering 4 dry spells (>10–15 days) in Namakkal and with excess rainfall of 3.44 % and 5 dry spells (> 10–15 days) in Villupuram during crop growth as compared to local varieties. The BCR was 2.99 in Cv. ADT-49 as compared to 2.35 in farmers′ varieties. Thiyagarajan *et al*., (2000), stated that when the monsoon fails, lowland rice also faces water scarcity leading to crop failure or farmers fail to plant their paddy.

In Nagapattinam district, demonstration of flood tolerant rice (Swarna sub 1), saline tolerant rice (TRY 3) and advanced rice nursery in *kharif* for timely planting (ADT-38) was taken in an area of 33.0 ha by77 farmers.

Flood tolerant paddy Cv. Swarna sub 1 is a late duration (143 days)variety and it can tolerate complete submergence for two weeks and shows tolerance against all major diseases and pests. This variety was demonstrated in 2011–12 with 15.2 % increase in yield with deficit rainfall of 40.0%and 5 dry spells (> 10–15 days)during crop growth period. Singh *et al.* (2011) subjected Swarna and Swarna–sub1 to 50 cm of stagnant flooding and observed a decline in survival by 16 and 17 %, whereas the taller breeding line IR49830 (with SUB1A) showed superior survival with only a 2 % reduction. Sarkar and Bhattacharjee (2011) reported that the lines with the Sub1 gene combined with intermediate elongation ability will be more adapted to stagnant flood affected areas.

Saline tolerant rice Cv. TRY 3 matures in 135 days and moderately tolerant to sodicity, suitable for samba/late samba season. This variety was demonstrated in 2012–13 with 12.6 % increase in yield with deficit rainfall of 10.31 % and 3 dry spells (> 10–15 days) during crop growth period. Paddy Cv. ADT-38is suitable for growing in late samba season. The duration of the crop is 130–135 days and suitable for cultivation as transplanted rice throughout rice growing areas of Tamil Nadu. This was demonstrated in 2011–12 with advancement of nursery in *kharif* for timely planting. The demonstration led to 8.0 % increase in yield with deficit rainfall of 40.0 % and 5 dry spells (> 10–15 days) during crop growth period when compared to local varieties. The BCR was also superior in all the improved paddy varieties at Nagapattinam district as compared to farmers check varieties.

In Villupuram district, 46 farmers demonstrated short and medium duration paddy (Anna 4, Ponni and ADT 49) varieties in 17.5 ha area.

Paddy Cv. Anna 4 is a short duration (100–105 days), drought tolerant, semi dwarf, erect, non–lodging and suitable for September-October sowing (North East Monsoon) in rainfed areas. This variety was demonstrated in 2011–12, 2012–13 and 2013–14 with an average increase of 27.1 % in yield against control with deficit rainfall of 11.48, 9.49% and excess rainfall of 8.64 % with 4,3 and 3 dry spells (> 10–15 days) respectively during crop growth period of 2011–12 to 2013–14.The BCR was 2.52 with Cv. Anna-4 as compared to only 2.04 in farmers′ varieties. Similarly, paddy Cv. Ponni is a medium duration(130–135 days), suitable for late samba season in Cauvery delta and resistant to leaf yellowing (tungro virus), blast and bacterial blight diseases was demonstrated in 2013–14 with 18.2 % increase in yield per hectare and higher BCR as compared to check under excess rainfall of 8.64 % and 3 dry spells (> 10–15 days) during crop growth period.

All the improved varieties recorded higher yield even in deficit rainfall when compared to local varieties. This varietal shift was carefully promoted by encouraging village level seed production and linking farmers′ decision-making to weather based agro advisories and contingency planning.

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Population Dynamics of Fruit Fly, *Bactrocera dorsalis* (Hendel) on Guava

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Abstract: The population dynamics studies were carried out in the orchard of CCS HAU, Hisar from June to August during 2013 on guava trees (var. Hisar Safeda). Four methyl eugenol traps per acre were installed on the guava trees for observing the fluctuation in adult fruit fly population The average population of fruit fly, *Bactrocera dorsalis* (Hendel) were varied from 5.3 to 28 / trap in 27 to 35 standard weeks. The average temperature varied from 38.6^{0}C–25.2^{0}C (maximum–minimum) whereas R.H (%) 96.1–55 (morning–evening) and a rainfall of 4.3–25.7 mm during the experimental period. The peak activity of fruit fly population was in 33th standard metrological week (28/trap) when average temperature was minimum and relative humidity maximum.

Keywords: *Bactrocera dorsalis*, Guava, Methyl eugenol trap, Population dynamics

Among the various tropical fruits, guava (*Psidium guajava* Linn.) is one of the most important fruit crops grown in India, with an area of 2.05 lac hectares, and production of 24.62 lac mt , respectively, (Anonymous, 2012). The oriental fruit fly, *Bactrocera dorsalis* (Hendel), is a serious pest of guava fruit crop in all the parts of India i.e. tropical, subtropical and temperate regions (Norrbom *et al*., 1998). Fruit flies have been recognised one of the most serious pests of agricultural crops causing an annual monetary losses to the tune of Rs. 7000 crores (Sardana *et al*., 2005). The pest is active throughout the rainy season in North India and hibernates during winter in pupal stage. In the event of climate change it becomes necessary to monitor the fruit fly population in order to manage the pest timely, effectively and in an environment friendly manner. The methyl eugenol traps serves as an important tool which has been used for the monitoring as well as for the management of fruit fly populations (Gupta and Bhatia, 2000; Suresh and Viraktamath, 2003 and Singh and Sharma, 2012). In the present investigation, therefore, the population fluctuations of fruit flies infesting guava was studied using methyl eugenol traps and effect of weather parameters on population build up was also studied.

Identification: Field collected guava fruits having egg punctures were placed on sand in pots, which were then covered with net cages. The fruit fly adults emerging from infested fruits were killed, pinned, labelled and sent for identification to IARI, New Delhi. It has been identified as *Bactrocera dorsalis* (Hendel).

Population dynamics of guava fruit fly: The monitoring was carried out with the help of methyl eugenol traps and observation on fruit fly population was taken at weekly interval. Each trap had only one hole for entry of fruit flies. An iron wire was inserted inside the box upto the level of holes by piercing through the lid of the trap and the tip of the wire was twisted to make a loop. The other end of the wire protruding out of the box was used for hanging the trap to the trees. A ply board block (1.5× 1.5× 1.5 cm) was impregnated by keeping it in methyl eugenol for about 48 hrs and placed inside the loop of the wire. Four traps spaced at 50 m were set up separately in guava orchards. The methyl eugenol impragneted blocks were replaced at monthly interval. The traps were installed at 2.0– 2.5 meter above from the ground surface in the shady condition within the canopy of guava trees. The male fruit flies were counted in the traps at weekly intervals during the July, August and September, 2013. Correlations were made between trap catches and mean weather parameter for every standard week.

The fruit fly mean population at first week (27th Standard week) of July was 11 per trap and increased to 20 / trap during 28th standard week when temperature decreased and relative humidity increased. Thereafter that fruit fly population was decreased to 17 / trap. It further fluctuated in the fourth week (30th Standard week) of July (21 / trap) at 35.3^{0}C max.–26.1^{0}C min, 85.4% – 59% relative humidity and 4.3 mm rainfall. The fruit fly population increased to 23 per trap in first week of August and 26 per trap in the second week or 32th Standard week when average temperature, relative humidity and rainfall were 34.5, 32.8^{0}C max. and 26.9, 26.1^{0}C min. whereas 86.8, 92.3% M to 67.1, 76.2% E and 9.8– 9.5 mm, respectively.

The fruit fly population was significantly positively correlated with morning and evening relative humidity (r =

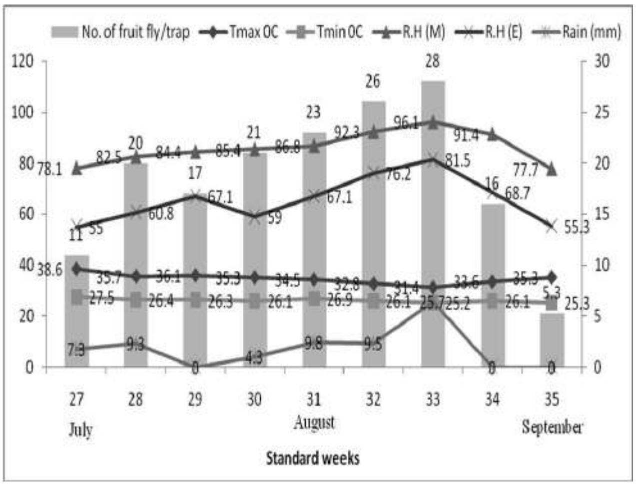

Fig. 1. Effect of abiotic factors on population of fruit fly

0.814 and 0.789) and rainfall (r = 0.695) whereas significantly negatively correlated with maximum temperature (r = –0.668). The population was high during ripening period of guava as the fruit flies got a suitable fruit stage for egg laying. Hence, the population of fruit fly is significantly negatively correlated with the maximum temperature and positively correlated with the RH and rainfall (Figure 1).

Sarada *et al*. (2001) reported that the fruit fly on guava population was positively correlated with relative humidity and rainfall whereas it was negatively correlated with maximum temperature . Similar observations were reported by Mishra *et al*. (2012) and Rajitha and Viraktamath (2006) on guava which is in conformity with the present studies.

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