SHORT COURSE MANUAL

ICAR sponsored short Course on 'Recent advances in adaptation and management strategies for sustainable oilseeds production under climate change scenario'

(03 - 12 Oct 2018)

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Hyderabad (TS)

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Preface

Oilseeds constitute a very important group of commercial crops in India. The oil extracted from oilseeds form an important item of our diet and are used as raw materials for manufacturing large number of items like paints, varnishes, hydrogenated oil, soaps, perfumery, lubricants, etc. Oil-cake which is the residue after the oil is extracted from the oilseeds, forms an important cattle-feed and manure. India has the largest area and production of oilseeds in the world. Majority of oilseeds grown in rainfed ecosystem are, groundnut, sesame, rapeseed, mustard, linseed, sunflower, safflower, soybean, cotton seed and castor. It is to be noted that the production of these oilseeds has always fallen short of our demand due to abiotic stresses especially shortage of rainfall, thermo and photosensitivity, change in pest and deseases due to climatic conditions and there has always been a need to import oil and oilseeds or their products for meeting the demand of our ever-growing population

The knowledge generated in the past have great potential to manage abiotic stresses on oilseeds production under climate change scenario and also curtailing huge import cost for oils. The training would act as contrivance for bringing change in livelihood of millions of dryland farmers, gambling with uncertain rains and rare opportunity to revive from harsh environments. Being leading national institute in oilseeds research, the institute has undertaken several farmer centric research projects, basic work on oils & oilseeds and evolved farmer oriented technologies and the same is disseminated to the researchers with the objective of sustaining oilseeds production.

It is assumed that this compilation will provide a basic platform on our knowledge for improving management of abiotic stresses for sustainable oilseeds production under changing climatic scenario. This manual will be useful for different stakholders including scientistd, students, farmers and policy makers. We are extremely thankful to the HRD division of ICAR and all the contributors for their efforts in providing comprehensive and cogent information.

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ICAR short course on

"*Recent advances in adaptation and management strategies for sustainable oilseeds production under climate change scenario*"

03-12, October 2018

Course Director: Dr. Ratna Kumar Pasala
Course Coordinators: Dr. K Ramesh and Dr. Praduman Yadav

Schedule of daily lectures/practical and name of the faculty to be engaged for ICAR short course

S. No.	Date/Day	Topic of lecture/Practicals	Name of Faculty
	03/10/18; Day 1 9.00 to 10.00 hrs	Registration & Pre-Training Assessment	Dr. Praduman Yadav & Mr. Giri
1	03/10/18; Day 1 10.00 to 11.00 hrs	Inauguration	Chief guest, Director - IIOR, Course Director, Participants & Staff
2	03/10/18; Day 1 11.30 to 13.00 hrs	Oilseeds production under changing climate	Dr. A. Vishnuvardhan Reddy, Director ICAR-IIOR Hyderabad
3	03/10/18; Day 1 14.00 to 15.00 hrs	Oilseed crop adaptations under abiotic stresses	Dr. P. Ratna Kumar, ICAR-IIOR, Hyderabad
4	03/10/18; Day 1 15.15 to 16.15 hrs	PoPs for soybean in the changing climate scenario	Dr. K. Ramesh, ICAR-IIOR, Hyderabad
5	04/10/18; Day 2 9.00 to 11.30 hrs	Visit to Narkhoda farm	Dr Ratna Kumar and Dr K Ramesh
6	04/10/18; Day 2 12.00 to 13.00 hrs	Seasonal impact on root phenotype, harvest index in castor under terminal drought	Dr. Lakshmamma, ICAR-IIOR, Hyderabad
7	04/10/18; Day 2 14.00 to 15.00 hrs	Quality profile of major edible oils from cultivated oilseed crops (theory)	Dr. Praduman Yadav, ICAR-IIOR, Hyderabad
8	04/10/18; Day 2 15.15 to 16.30 hrs	IIOR Central Lab Facility Visit and hands on training on biochemical analysis (Practical)	
9	05/10/18; Day 3 10.00 to 11.30 hrs	Genomics advancements in oilseeds	Dr. P. Kadirvel, ICAR-IIOR, Hyderabad
10	05/10/18; Day 3 11.45 to 13.15 hrs	Management of stored grain pest for oilseeds	Dr. A. Mariadoss, Asst. Director, NIPHM, Hyderabad
11	05/10/18; Day 3 14.15 to 16.00 hrs	Soil micronutrient and phosphorus management for oilseeds production in the shifting weather scenario	Dr. MAA Qureshi, ICAR-IIOR, Hyderabad

12	06/10/18; Day 4 10.00 to 11.30 hrs	Diversity in oilseeds and their importance in climate change	Dr Veeraragavaiah, ARS, ANGRAU
13	06/10/18; Day 4 11.45 to 13.15 hrs	Climate aberrations in rainfed oilseed ecosystems in India -An analysis	Dr. Vijaya Kumar, PC-ACRIPAM, ICAR-CRIDA, Hyderabad
14	06/10/18; Day 4 14.15 to 16.00 hrs	High-through-put phenomic technologies to assess the oilseed adaptations to drought	Dr. M. Maheswari, ICAR-CRIDA, Hyderabad
15	08/10/18; Day 6 10.00 to 11.30 hrs	Management of castor and groundnut under aberrant weather conditions	Dr. AV Ramanjaneyulu, RARS, Tornala , PJTSAU
16	08/10/18; Day 6 11.45 to 13.15 hrs	Dynamics of pathogenic microflora in the changing climate with special reference to oilseeds	Dr. C. Kannan, ICAR-IIRR, Hyderabad
17	08/10/18; Day 6 14.15 to 16.00 hrs	Competency enchantment for technology transfer in oilseed - soybean	Dr. S. Senthil Vinayagam, ICAR-NAARM, Hyderabad
18	09/10/18; Day 7 10.00 to 11.15 hrs	Recent advances of oilseed crop production under rainfed ecosystems	Dr. K. Sammi Reddy, Director, ICAR-CRIDA, Hyderabad
19	09/10/18; Day 7 11.30 to 13.00 hrs	Strategies for sustaining oilseeds production under dryland conditions	Dr. K.A. Gopinath, ACRPDA, ICAR-CRIDA, Hyderabad
20	09/10/18; Day 7 13.30 to 14.45	Oilseeds *visa-vis*. climate change-an analysis	Dr. M Vanaja, ICAR-CRIDA, Hyderabad
21	09/10/18; Day 7 14.45 to 16.45 hrs	CRIDA climate change facility visit	Dr K.S. Reddy/Dr. M Vanaja, ICAR-CRIDA, Hyderabad
22	10/10/18; Day 8 10.00 to 11.30 hrs	Disease management strategies in oilseeds in the climate change scenario	Dr. Chander Rao, ICAR-IIOR, Hyderabad
23	10/10/18; Day 8 11.45 to 13.15 hrs	Biosynthetic pathways of oilseeds in the wake of climate change	Dr. S.K. Yadav, ICAR-CRIDA, Hyderabad
24	10/10/18; Day 8 14.15 to 16.30 hrs	Breeding strategies for oilseeds in climate change scenario	Dr. K. Anjani, ICAR-IIOR, Hyderabad
25	11/10/18; Day 9 10.00 to 11.30 hrs	Impact of drought and high temperature on sunflower yield and WUE	Dr. Laxmi Prayaga, ICAR-IIOR, Hyderabad
26	11/10/18; Day 9 11.45 to 13.15 hrs	Nutrient management strategies in the climate change scenario with special reference to oilseeds	Dr D Damodar Reddy Director, ICAR-CTRI, Rajamundry
27	11/10/18; Day 9 14.30 to 16.00 hrs	Biotechnological advances in oilseeds to cope up with climate change	Dr. Dinesh Kumar, ICAR-IIOR, Hyderabad

28	12/10/18; Day 10 10.00 to 11.00 hrs	Pest management strategies in oilseeds in the climate change scenario	Dr. P. Durai Murugan, ICAR-IIOR, Hyderabad
	12/10/18; Day 10 11.00 to 12.30 hrs	Post Training Evaluation	Dr. RK Pasala, Dr. K. Ramesh & Dr. P. Yadav
	12/10/18; Day 10 12.30 to 13.30 hrs	Valedictory function & certificate distribution	Director IIOR, Chief Guest, Course Directors, Participants & Staff

(Note: Authorized Medical Attendant will be available at Jyothi hostel of the IIOR Campus between 11.00 am to 12 noon every day except closed holidays)

1. Vegetable Oilseed Scenario in India - Status and Strategies

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India is one among the largest vegetable oil economies in the world next only to USA, China, Brazil and Argentina. In India, oilseeds are important next to food-grains in terms of acreage, production and value. The diverse agro-ecological conditions in the country fosters growing all the nine annual oilseeds, which include seven edible oilseeds *viz*., groundnut, rapeseed-mustard, soybean, sunflower, sesame, safflower and niger and two non-edible oilseeds *viz*., castor and linseed. Apart from this, a wide range of other minor oilseeds of horticultural and forest origin, including in particular coconut and oil palm are grown in the country. In addition, substantial quantities of vegetable oil are also obtained from rice bran and cotton seed.

Vegetable oils are critical for nutrition, energy, economy of the country and in global commodity supplies. India occupies a prominent place in global oilseeds scenario with 12-15 per cent of area, 6-7 per cent of vegetable oil production, and 9-10 per cent of the total edible oil consumption and 13.6 per cent of vegetable oil imports (FAO, 201). The oilseeds sector has remained vibrant globally with 4.1 per cent growth per annum in the last three decades. In India, oilseeds account for 13 per cent of the gross cropped area, 3 per cent of the gross national product and 10 per cent of the value of all agricultural products. India has rich diversity of annual oilseed crops on account of diverse agro-ecological conditions. Nine annual oilseeds, which include seven edible oilseeds, *viz*.,groundnut, rapeseed-mustard, soybean, sunflower, sesame, safflower and niger and two non-edible crops, *viz.,* castor and linseed are grown in the country. Despite having the largest area under oilseeds in the world (28 m ha during 2014-15), India currently imports about 58 per cent of total oil requirement (12 mt) at an exchequer of Rs.68,000 crores (2014-15) (SEA Databank, 2016). Theproportion ofimporthasincreasedfroma meagre3percentin1970-71 to as high as 58percentin2014-15 primarily due to changing life styles and increase in per capita income.

India grows oilseeds on an area of 26.73 mha, with a production of 30.70 mt and productivity of 1148 kg per hectare (quinquennium ending 2014-15) (*agricoop.nic.in*).Oils and fats, apart from forming an essential part of human diet, serve as important raw material for the manufacture of soaps, paints and varnishes, hair oils, lubricants, textiles, auxiliaries, pharmaceuticals, etc. India imports over 12 mt of edible oils annually accounting for more than half of total consumption in the country (SEA Databank, 2016). Vegetable oils provide the much-needed food security measured as meeting calorie requirements in poverty assessments. Rapid growth of food demand in the developing countries, in conjunction with the high calorie content of oil products, has contributed to the increases achieved in calorie consumption in these countries. One out of every four calories added to the consumption of the developing countries over this period originated in this group of products. In future, vegetable oils are likely to retain, and indeed strengthen, their primacy as major contributors to increases in food consumption of the developing countries. The *per capita* food consumption (kcal/person/day) is estimated to be 2980 by 2050 with 38% contribution from oil products**.** ***This reflects the prospects of increased demand for vegetable oils in the dietary composition which calls for increased productivity of edible oils on the global platform that include India as well.***

There has been continuous improvement in the production and productivity of oilseeds in India in the past six decades, despite wild fluctuations from year to year in response to mainly weather conditions

There have been dramatic changes in the oilseeds scenario of the country since 1986. India changed from net importer status in the 1980's to a net exporter status during 1989-90 which was again reversed later during 1997-98 where the country had to spend huge foreign exchange to meet the domestic needs of edible oils. The gap between export earnings and import cost has been narrowing down during the last couple of years and again the oilseed sector has become a net foreign exchange earner during 2007-08. The main contributors to large success of oilseed sector in the late eighties and early nineties were (i) availability of improved oilseeds production technology and its adoption, (ii) expansion in cultivated area (iii) price support policy and (iv) institutional support particularly the establishment of Technology Mission on Oilseeds (TMO) in 1986. The remarkable success of TMO in the initial period was facilitated by a relatively protectionist umbrella of higher import duties on the import of edible oil of the order of 65% on palmolein, the commonly imported oil. The so called 'Yellow revolution' when the oilseed sector became a net earner of foreign exchange, symbolized the will of the country to solve a problem which evaded solution for a long time. It also symbolized the teamwork of a number of scientific and developmental institutions, industries, departments, farmers and policy makers. There has also been large regional variation in area, production and productivity changes in oilseeds during the last two decades. Only a few states like Haryana, Madhya Pradesh, Maharashtra, Rajasthan, West Bengal and North-eastern states increased their oilseeds production both through area expansion and productivity improvement. State like Gujarat increased its oilseeds production mainly through productivity improvement. In state like Punjab, oilseeds production declined mainly in response to sharp decline in area while in state like Orissa, both area and productivity declined sharply leading to large decline in oilseeds production. Among different oilseeds, groundnut, rapeseed-mustard and soybean accounts for more than 80% of area and 90% of production in the country.

Vegetable oil consumption is both income and price-elastic. As per the recent projections by DAC-Rabo Bank, the *per capita* consumption of vegetable oils is likely to rise to 12.60, 14.57 and 16.38 kg/year by 2010, 2015 and 2020 respectively. Considering that *per capita* vegetable oil consumption has already reached 12 kg/year by 2007-08, the projected increase in consumption by 2020 is likely to become a reality. This amounts to vegetable oil requirement of 14.8, 18.3 and 21.8 mt, respectively by 2010, 2015 and 2020. Assuming an average oil recovery of about 30% from major oilseeds and proportion of different oilseeds constant in the coming years, the country needs to produce at least 44.8, 55.5 and 66.0 mt of oilseeds by 2020, 2015 and 2020 respectively. If one assumes 20% of vegetable oils from crops other than annual oilseeds, then country needs to produce about 55 mt of oilseeds by 2020 to achieve near self-sufficiency in vegetable oils production. Given that oilseeds output in 2008-09 amounted to about 28.05 mt, the country needs to almost double the oilseeds production in the next 11 years requiring an annual growth rate of nearly 6% which will indeed be a tall order, requiring efforts much beyond what is being ostensibly pursued until now. A multipronged approach including, area expansion in traditional and non-traditional niches, ensuring quality seed availability, enhancing productivity through appropriate nutrient and crop health management, value addition and price support and policy support from government is required to achieve such a tall order.

Meeting the challenges

To meet the challenges of oilseed production in the post-WTO regime, there is need to adopt multi-pronged strategy which involves enhancing oilseeds production through area expansion and productivity improvement through better adoption of improved technology, value addition to oilseeds and oils to increase their competitiveness, higher recovery of oil through efficient processing of oilseeds and oils, overcoming the constraints of domestic marketing of oilseeds and its products and finally liberalising trade in India's oilseed economy.

Expansion in oilseeds area

Besides exploiting limited opportunities for expansion of area under oilseeds as sole crops, large potential exists to introduce oilseeds as intercrops in several major crops. In India, about 45 million hectares of land is available with widely spaced crops, where introduction of oilseeds as intercrop is possible. Even in crops like wheat, introducing a row of mustard after 8 or 9 rows of wheat has proved more profitable than sole wheat in most of the irrigated wheat-growing regions. Even in high rainfall regions of Eastern India, intercropping groundnut and soybean in rice in uplands, during *kharif* season, has proved highly remunerative. In addition, oilseeds can also be introduced as intercrop in less remunerative, traditional staple food crops like rainfed wheat, chickpea, etc. whose complete replacement is not possible.

The expansion in area under oilseeds was hither to a major source of growth in oilseeds production. Since 1986, nearly 38% of the increase was contributed by area expansion and 62% by productivity improvement. The area increase came where the oilseed crops were superior options to traditional crops. Farmers always searched for technological options and practices which brought them higher returns and readily responded to various economic incentives. The expansion in area has occurred in those oilseed crops which have either shown a higher growth rate of productivity due to technological development or whose relative prices with competing crops have moved in their favour or higher growth rates in yields were combined with higher prices resulting in sharp increase in total productivity.

Identifying newer areas and seasons for cultivation of oilseeds can help increase oilseeds production. Rice-fallows, especially in Eastern India, are the potential general areas for many oilseed crops like sunflower, rapeseed-mustard, groundnut and sesame. Oilseeds, being more salt tolerant than pulses and many cereals, have better chances of success in large tracts of saline areas. Likewise, under situations of limited water availability for the second crops of rice or in tail-end areas of canals, oilseed crops are better options; with less than a third of water needs of rice, a good crop of oilseeds like sunflower, sesame and groundnut can be harvested.

In general, there is hardly any scope to bring additional area exclusively under oilseeds as the demand for land for producing other remunerative crops will continue to rise. However, it becomes imperative to search for newer approaches to expand their cultivation under different cropping/farming situations. Extending cultivation to underutilized farming situations such as in rice fallows of eastern India where 15 million hectares are under low land rice is one such possibility. Oilseeds like sunflower and sesame may also be better options under contingency planning where season for regular crops is not conducive or when these have failed. Value addition to some of the main and byproducts of oilseed crops will further increase their profitability and help expand the area. This will also arrest constant decline in area observed in some minor oilseed crops in recent years. It must be possible to reach 33 to 35 million hectares under oilseeds by 2015 if efforts are made for their promotion in all potential areas with appropriate policy and institutional back up.

Improving oilseeds productivity

With limited scope to bring additional area under oilseeds, bulk of the future increases in oilseed production have to come primarily from land saving technologies, highlighting a combination of high yielding plant types, standard crop management practices, protective irrigation to insure against, weather aberrations, balanced nutrition attained through integrated nutrient supply and management system. In this, crop ecological zoning, quality seed supply and effective technology transfer can also play a major role in enhancing oilseed productivity. The country must aim to increase oilseed productivity to at least 1.5 t/ha by 2015 through a combination of multi-pronged strategies and policy support. Considering the results of large number of frontline demonstrations conducted in different crops in farmers’ fields in various agro-ecological and crop growing situations, the productivity level of 1.5 t by 2015 from the current level of about 1 t/ha is certainly achievable.

Value addition to oilseeds and oils

Oilseeds are sources of oil, protein, sugar, minerals and even vitamins. Although oilseeds in general have good composition and quality, their domestic utilization as well as larger exports are hindered due to certain limitations and toxic factors. There is need to overcome these limitations for better value realization in oilseeds. Instead of exporting direct items like oilseeds, oil and oil cakes, India should strive to export value-added products. Full value addition to castor oil before exports alone can fetch additional earnings of about Rs. 20000 crores from the present level of Rs. 1000 to 1200 crores annually. There are uncommon opportunities to add value to different oilseeds and oils which must be fully exploited which will eventually enhance the competitiveness of these crops.

Cost effective production technologies

Oilseeds are cultivated for commercial purpose and the by-products of these crops are of little value, with the exception of groundnut. An oilseed grower is supposed to make arrangements for his food requirements by either producing them in a separate area, or purchasing them out of earnings from oilseed production. In either case, profit maximization is the prime motive for oilseed production. Profitable oilseed production lies in efficient crop management practices, many of which involve non-cash or low-cost inputs.

Efficient crops management practices, starting from adoption of proper crops rotation, timely planting, adequate plant stand through adjustment in seed rate and thinning, timely weed management, life saving irrigation, balanced plant nutrition and need-based plant protection : all these have great influence on the cost of cultivation of oilseed crops. Oilseed crops are far more susceptible to pests and diseases than cereals. Thus plant protection measures are also very essential for ensuring a good harvest of oilseed crops.

- Annual oilseeds support the livelihood earnings of small and marginal farmers of arid and semi-arid eco-systems of the country. It is estimated that 14 million farmers are involved in oilseed cultivation, while one million persons are involved in processing of oilseeds and oils (Hegde and Venkattakumar, 2007).
- The annual oilseed production of the country is faced with high degree of variation, as nearly 76% of the oilseeds area is under rainfed conditions and therefore subjected to uncertainties of moisture availability.
- The country's minimum support price (MSP) programme that has often favoured production of crops that compete with oilseeds for area. Hence, only by popularizing non-monetary, low-cost and cost-effective oilseeds production technologies among the resource-poor farmers, oilseeds can sustain their competition with the competing crops.
- The continuous cultivation of oilseed crops without proper crop rotation has led to depletion of soil nutrients as well as increase in pest and disease incidence causing upto

40% yield loss. This implies the need for use of cost-effective oilseeds-based cropping sequences and intercropping systems.

- Oilseed crops are prone to damage by more than 64 major diseases. For as many as 26 pests in different crops, no resistant source is available, vulnerability of majority of the cultivars of oilseed crops to insect pests and diseases continues to be one of the major factors responsible for the lower productivity and wider fluctuations in production. Thus, the need for use of low-cost and cost-effective integrated pest management practices in oilseeds cultivation is significantly important.
- Specific attention needs to be given to harness the residual effects of fertilizers containing P, K and S. Sound fertilizer management for intercropping systems involving oilseeds which can meet the nutrient needs of both main and intercrop will go a long way in enhancing the productivity of the system.
- Population growth, rising standard of living, aberrant weather for few years in succession and liberalization of export-import policy are the causes for rapid surge in imports. Over the last one decade, the irrigation coverage merely increased by 4% from 23 to 27%.

Some of the cost effective no cost /low cost production technologies are:

- Use of healthy and disease-tolerant seed.
- Seed treatment to prevent seed-borne diseases.
- Pest surveillance and monitoring in endemic areas.
- Integrated pest control campaign.
- Arrangements for timely supply of pesticides, sprayers and dusting machines.
- Training of extension field functionaries on pest behaviour in endemic areas.

Several anecdotal evidences particularly from the frontline demonstrations in oilseeds conducted across varied agro ecological situations across the annual oilseed crops suggest that with minimal adjustments within the management practices, there exists a huge potential to enhance the productivity of oilseeds. A few such management interventions are indicated below:

Adoption of recommended spacing: Adoption of recommended spacing between plants and rows, resulted in 5 and 15% seed yield increase under irrigated and rainfed conditions of castor respectively, with corresponding additional net returns.

Adoption of right method of sowing: Adoption of the recommended method of sowing gave an yield increase of 51% in sunflower, four times in safflower, 2.5 times in groundnut, 90% in sesame, 76% in niger and 36% in rapeseed-mustard.

Adoption of timely sowing: Right time of sowing resulted in 44 and 55% seed yield increase for sunflower and rapeseed-mustard respectively under irrigated conditions. Under rainfed conditions, the same technology resulted in 182 and 13% seed/ pod yield increase for niger and groundnut with Rs.3150 and 2889/ha additional net returns.

Adoption of right method of fertilizer application: Proper method of fertilizer application, under rainfed conditions, gave 42% seed yield increase with Rs.2771/ ha additional net returns for rapeseed-mustard.

Adoption of timely weeding: Considerable yield increase to the extent of 39% was observed in many of the oilseed crops when timely weeding was adopted under real farm conditions.

Selecting oilseed crops to competing crops: Selecting castor instead of maize, cotton and sorghum gave 104, 87 and 5% seed yield increase under rainfed conditions. Though tomato gave 21% seed yield equivalent increase than castor, there was Rs.675/ha additional net returns from castor, sine the labour requirement of castor is lower than that of tomato. Under irrigated conditions, sunflower was proved to be superior to finger millet by 86% in seed yield.

Improving varietal replacement rate: Choice of improved varieties of groundnut to locals and existing ones, gave 25% pod yield increase both under rainfed and irrigated conditions. In rapeseed-mustard, the technology gave seed yield increase to the tune of 58% under irrigated conditions. Improved dual-purpose linseed variety gave 68% seed yield, whereas, niger variety resulted in 120% seed yield increase. Similarly, improved varieties gave seed yield increase to the tune of 27 and 45% under rainfed conditions in soybean and castor, respectively

Adoption of recommended crop sequence: Adoption of recommended crop sequence has also resulted considerable yield increase in oilseed crops. In castor, it resulted in 33% seed yield increase under rainfed conditions and 11% seed yield increase under irrigated conditions.

In case of rapeseed-mustard, the seed yield increase as result of adoption of recommended crop sequence was 46 and 87% in irrigated and rainfed conditions respectively. In sunflower also, under irrigated conditions, the technology resulted in 19% seed yield increase.

Adoption of seed treatment practice: Proper seed treatment with chemicals and/or biofertilizers for pest management and nutrient supplement, resulted in 10% seed yield increase both under rainfed and irrigated conditions in sunflower, 12% increase in safflower, 24% in rapeseed-mustard, 44% pod yield increase in groundnut.

Adoption of thinning: Thinning excess plant population to maintain the recommended plant stand, resulted in seed yield increase to the tune of 26 and 32% in sunflower and safflower, 16% in rapeseed-mustard.

Use of biofertilizers: Application of biofertilizers, as a nutrient supplement, resulted in 9, 24 and 40% seed yield increase in sunflower, safflower and niger. Under irrigated conditions, this technology gave seed/pod yield increase to the tune of 44% for groundnut and 6% for rapeseed-mustard.

Application of gypsum: Application of gypsum in groundnut to increase pod yield and oil content of the crop and physio-chemical properties of the soil, resulted in 25% pod yield increase under rainfed conditions.

Application of sulphur: Application of sulphur to increase oil content in rapeseed-mustard resulted in 11% seed yield increase under rainfed conditions. Sulphur+boron application increased the oil content in sunflower to the tune of 34%.

Spraying of cycocel: Spraying cycocel as a growth regulator for safflower resulted in seed yield increase to the tune of 33% under irrigated conditions.

Integrated nutrient management (INM): Adoption of INM practices to improve the productivity of the crop as well as soil fertility in a sustained manner resulted in seed/ pod yield increase to the tune of 22 and 19% in groundnut and rapeseed-mustard under irrigated conditions.

Integrated weed management (IWM): IWM practices to manage the weeds in a sustained and cost-effective manner resulted in pod yield increase of 10% in groundnut under irrigated conditions.

Integrated water management: Integrated water management practices to meet the minimal water requirement of the crop with higher use efficiency and ensuring the sustained availability of water to the crop eco-system gave 9% pod yield increase.

Integrated pest management (IPM): IPM practices to ensure the arrest of resilience of insect pests of crops through integrated management practices and ecological balance in pest management in groundnut gave pod yield increase to the tune of 18% under rainfed conditions, whereas, 19% seed yield increase for rapeseed-mustard under irrigated conditions.

Technology transfer for Good agricultural practices: It is proven that the oilseeds production system in the country is operating on low levels of efficiency primarily due to non-adoption of technology practices. The farm level productivity of oilseed crops can be substantially enhanced by resorting to adoption of the Good agricultural Practices. It is important that networking of ICAR/NARS/SAU’s with the line departments especially ATMA,KVK’s need to be established in this direction for enhancing the farm level technical efficiency so that the productivity can be increase manifold.

Establishment of seed banks: It is an established fact that for the oilseed crops in general, the seed replacement rate is pretty dismal. Making available the quality seed at the right time to the farmer can enhance the productivity. To make available the quality HYV/Hybrid seeds of oilseed crops, it is important that creation of seed banks on cluster approach through KVK/NGO/private seed industry can pave way for increasing the productivity. This requires the establishment of linkages between ICAR/NARS with the stakeholders to translate the outcomes on the farmers’ fields. The crops that need immediate attention is groundnut, soybean and sesame.

Public Private Partnerships: There is enormous potential for PPP in oilseeds on the production and marketing aspects. On the production front, the industry can play a role in providing technical backstopping besides input marketing while on the other-hand, the direct linkage between the oilseed farmer and the industry on the output marketing is a WIN WIN situation.

Digital Agriculture for information dissemination: The role of ICT has not been explored in agriculture. Several anecdotal evidences suggest that there exists a huge asymmetry in information that has a direct bearing on the production and disposal of produce. The tools of ICT are to be explored on POP's / price information to the farmers or through KVK's for making available the pertinent information. The already available tools of ICT operational by a few private industries to the farming community can be readily used.

An important ICT technology that holds high promise is the weather based advisory service to the farming community. This can help the farmers in taking appropriate decisions on the management of oilseed crops

Crop ecological Zoning for enhancing exports: A few of the oilseed crops *viz.,* Sesame, HPS Groundnut have immense export potential. The country has a comparative advantage for export of the above commodities. It is important to carve out niche areas in select agro-ecological regions between farmers on a cluster mode with industry on "tie up" mode for increasing the volume of exports. This holds high promise for bold seeded pesticide free sesame, hand-picked selection (HPS) table purpose aflatoxin free groundnut and high oleic sunflower and safflower. This can ensure enhanced profitability both to the farmers and the industry.

Focused approach in select agro-ecological regions: It is pertinent to note that a few districts contribute to majority of the area under the respective oilseed crops. It is important to dovetail all the potentially viable technologies in these areas for enhancing the oilseeds productivity. The frontline demonstrations conducted across the nine annual oilseed crops have indicated the potential for increased productivity. Special emphasis has to be laid in these areas for harnessing the potentially viable technologies.

Technology access in non-traditional areas: Focus on spread of oilseed technologies to non-traditional area *viz.,* Orissa, West Bengal and Chhattisgarh in the Eastern Grid and in Indo-Gangetic Region of Punjab, Haryana, Western Uttar Pradesh and Bihar ably supported with buy back arrangements can play a vital role for increasing the productivity of oilseeds in the country. The agro ecological situations in the above regions provide a highly conducive environment for oilseeds. Hence, providing necessary input supply, technology, market and processing facilities in these areas can help realise quantum jump in productivity with ease.

Crop Diversification in select target domains: An important intervention is introducing oilseeds technology in *rabi* season under the tail end canal irrigation system. I am happy to cite that the pilot initiative on farm studies undertaken on sunflower and safflower crop in Nizamabad district of Telangana state is paying dividends on the economic and ecological front. The potential economic and ecological benefits are tremendous to the oilseed farmers since the management of oilseeds in these regions hold high promise.

Focus on Natural Resource Management: With the current practices of crop cultivation under sub-optimal management, especially without balanced nutrient replenishment, significant soil nutrient mining is perpetual. Addressing the imbalance in soil nutrients can provide rich dividends.Declining *per capita* arable land and extending oilseeds cultivation to poor and marginal soils result in low productivity. Moreover, productivity of oilseed crops is limited owing to their cultivation under rainfed conditions. Currently only 28 per cent of area is irrigated under oilseeds. Water requirement in oilseeds is, therefore, a key factor for ensuring higher yields. With dwindling water resources both in quantity and quality, water for irrigation will be costly and face severe competition from different enterprises within agriculture sector. Watershed management with appropriate rainwater harvesting both *in situ* with proper disposal and storage farm ponds provide excellent opportunity to mitigate the expected dual problems of long droughts and floods with advantage. Site specific land configuration and management for effective soil and moisture conservation and its economic use can operationalize the drought mitigation strategy. Enhancing drought tolerance in oilseed crops is therefore, a priority with associated practices to improve profitability through achieving ‘more crop (oil) per drop’ of water, Resource use efficiency and preferential edge over other competing crops.

Besides, due to the low fertilizer use efficiency, the investments are not remunerative. Improving nutrient use efficiency of fertilizers through better product development and method of application should now be a priority for achieving profitable oilseeds production. Improving soil fertility to reduce external applications is an achievable solution through site specific management. Exploiting nutrient interactions as per the soil test and crop response results in higher efficiency and reduced cost. Organic manures are central in the integrated nutrient management (INM) of oilseeds under rainfed situation along with other components such as secondary and micronutrients, like use of sulphur bio-inoculants, crop residues, etc. Precision crop management with conservation agricultural practices and customized fertilizer application schedules would usher higher efficiency and profitability. Emphasis on integrated natural resource management in oilseeds should, therefore, be our high priority.

Transfer of Technology

Concerted efforts are urgently needed for the dissemination of technologies and new approaches on a participatory mode are to be strengthened for effective delivery mechanism by show-casing the potential technologies/products. The Farmer-Institution-Industry linkage mechanism should be strengthened besides the existing formal delivery mechanisms so that the gap between the potentially attainable yield and the yield realized on the farmers' fields is reduced and it makes the industry more vibrant and profitable on account of assured quality supply, reduced obstacles in supply chain, enhanced capacity utilization and increased economic surplus with benefits to both the producer and the consumer. The potential Information and Communication Technology (ICT) tools should be harnessed on a dynamic and interactive mode. This can minimize the dissemination loss while sharing information and provide benefits to all the stakeholders involved in oilseeds. Also a dedicated TV channel on agriculture will help in faster dissemination of knowledge. Creation of agri-clinics with provision of outsourcing through involvement of new breed of young well trained technology agents would go a long way in upscaling innovation for a greater impact.

Access to stakeholders especially between ICAR /NARS and private industry on PPP mode in identified areas hold high promise. However there is a gestation period involved in the above endeavour. The potential of public-private partnership (PPP) through linkages in all aspects of oilseeds production and marketing needs to be harnessed for a win-win situation. The grey areas for PPP in oilseeds include value addition, contract research in niche areas, contract farming, joint ventures for higher order derivatives and speciality products, etc. The edible oil industry is largely dominated by the bulk segment which creates an opportunity for the Agri-Business sector. The unbranded segment accounts for anywhere between 80 and 90 per cent of the total consumption which can be targeted for better value addition and thus, minimize health hazards that otherwise occur on account of adulteration of edible oils. The share of raw oil, refined oil and vanaspati in the total edible oil market is estimated at 35 per cent, 55 per cent and 10 per cent, respectively. The former group is a viable Agri-Business venture. The shift in consumer preference for branded edible oils has resulted in the corporate sector targeting on packaged edible oil segment in the last few years. Hence, PPP mode for R&D efforts towards value addition emerges as a new priority to move forward.

PPP for value addition: Profitability of oilseeds solely from the primary products like seed and oil will not be sustainable. Besides the primary product oil, oilseed crops provide immense scope for diversified uses with high value specialty products and derivatives. From the vegetable oil consumption point of view either for edible or for fuel purpose, the situation is envisaged towards valuing oil for its intrinsic value for calorie or for desired fatty acid that is beyond the realm of individual crop as perceived now. Designer oils with requisite blends can meet the expectation and to that extent individual oilseed crop's potential would be seen for the yield of oil or the desired fatty acid and not as oil from specific crop. Thus, the present wide diversity of oilseeds crops may narrow down to a few high oil yielding crops. As for unique non-oil value aspects for specific aroma or non-oil uses (medicinal, ornamental or other uses), individual oilseed crops would be grown for specialty purpose irrespective of productivity level.

The value addition in oilseeds is not realised as of now. Harnessing the omega 3 in linseed for enriched eggs through feed mechanisms, quality linseed fiber production, zero ricin castor and higher order derivates in castor are a few possibilities that come to my mind. This is a huge agribusiness opportunity especially in castor on higher order derivatives since these have enormous global absorption capacity. Hence, JV's between ICAR/NARS and the industry can go a big way for realising the benefits of value addition

PPP for high oleics: High oleic acid oils have a premium market globally. On this front, collaborative research programmes on specific oilseed crops for high oleic varieties / hybrids can enable the country to enhance the exports.

PPP on crop production/improvement: Many stakeholders are not aware of the possibilities of technology(s) that can be accessed to them from ICAR / NARS through technology licensing that can play a key role in enhancing the productivity of oilseeds.

Future Direction

The vegetable oils are indispensable in the human food as also in several industrial uses. The oilseed sector constitutes an important determinant of agricultural economy in India. The country may have to almost double the vegetable oils production by 2020 if it has to achieve near self-sufficiency. This is indeed a tall order requiring a growth rate in excess of 6% per annum. There is also a high degree of variation in production of annual oilseeds due to their cultivation predominantly under low and uncertain rainfall conditions in soils which are hungry coupled with poor input supply and crop management. Sustainability of the enhanced oilseeds production is as important as enhancing production. Favourable policy framework for the oilseed sector with respect to processing, marketing and trade is the basic and overarching requirement to achieve self-reliance in vegetable oils. Given a desired policy frame work in place, oilseeds production can be increased to a limited extent by area expansion through replacement of non-remunerative crops, extension in rice fallows and problem areas, intercropping in widely spaced crops, as options in contingency planning, introduction in water scarce areas, diversification of rice-rice and rice-wheat systems and by increasing competitiveness of oilseeds through value addition. There is limited scope to bring additional area under oilseeds and bulk of the future increases in oilseed production has to come primarily from land saving technologies. This calls for giving new thrust for improving the productivity of oilseed crops by use of quality seed, providing protective irrigation, resorting to efficient crop zoning, enhanced and integrated nutrient use, farm mechanization, efficient crop management, overcoming biotic and abiotic stresses through novel approaches and effective technology transfer to bridge yield gap to harness the exploitable yield reservoir. This calls for effective contribution by all those concerned with oilseed sector to the best advantage of oilseed farmers to achieve self-reliance in vegetable oils.

References

Acharya, S.S. (1993). Oilseeds and Pulses – Price Policy and Production Performance, Indian Journal of Agricultural Economics, 48(3): 317-333.

Anonymous. 2010. Oilseeds Situation in India: A Statistical Compendium. Directorate of Oilseeds Research, Hyderabad pp.296.

Anonymous. 2011. Vision 2030. Directorate of Oilseeds Research, Hyderabad.pp.29.

FAOSTAT,2014

Gulati, A. (1990). Incentives for Oilseeds Cultivars–Implication and Efficiency, Journal of the Indian School of Political Economy, 2 (2).

Jha, G.K.2012. Edible Oilseeds Supply and Demand Scenario in India: Implications for Policy, IARI, New Delhi

SEA HANDBOOK,2015,2016

Hegde, D.M. 2010. Oilseed Scenario in India: Strategies to Improve Production and Productivity. *Journal of Oilseeds Research (Spl.) Issue, 2010*, pp.1-8.

Mruthyunjaya, Kumar, S., Rajaksherappa, M.T., Pandey, L.M., Ramanarao, S.V. and Narayan, P. (2005). Efficiency in Indian Edible Oilseed Sector: Analysis and Implications, Agricultural Economics Research Review, 18:153-166.

Venkattakumar, R., Ramana Rao, S.V., Padmaiah, M. and Hegde, D.M. 2009. Productivity potentials and profitability of non-monetary, low-cost and cost-effective oilseeds production technologies. Journal of Oilseeds Research, 26(2) : 140-147.

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2. Diversity in Oilseeds and Their Importance in Climate Change

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Oilseed crops have a unique place in Indian Agriculture apart from Cereals from time immemorial. India is the largest producer of Oilseeds in the World by devoting 14% of its area under major crops. The climatic conditions prevailing in length and breadth of India are supporting production of all the nine Oilseed crops such as groundnut, castor, sesame, rapeseed and mustard, linseed, soybean, sunflower, niger seed and safflower. At present, India’s largest oilseed producing state is Gujarat, thanks to its position as top groundnut producing state of India. Rajasthan is India’s top rapeseed and mustard producing state, followed by Madhya Pradesh and Haryana. Almost half (48.12%) of Rapeseed and Mustard is produced by only Rajasthan. India’s top soybean producing state is Madhya Pradesh with a share of 44% in India’s total production of this protein rich crop. Karnataka is the largest producer of sunflower.

India’s Oilseed production went up from a meagre 5 million tonnes in 1951 to 31.30 million tonnes in 2017-18. The major leap in production, however, occurred with launching of Technology Mission on Oilseeds in 1986 and thereafter there has been a slow pace of growth. Since 2010-11, the area under oilseeds in India has been moving between 25 m ha and 29 m ha while production between 25 m tonnes and 33 m tonnes (Table-1).

Today, a huge gap in demand-supply of vegetable oils exists in India, which keeps the country as number one in edible oil importer in the world. The reason is that domestic demand for vegetable oils and fats has been rising rapidly at the rate of 6% per year but domestic output has been increasing at just about 2 % per annum. In India, the average yields of most oilseeds are extremely low as compared to those of other countries of the World.

The cultivation of Oilseeds in India is in high risk regions where there are uncertain returns on the investments and such a situation is becoming worse with the recent weird weather variations under the growing threat of climate change. In general, productionof a crop is sensitive to short-term changes in weather and to seasonal, annual and longer-term variations in climate. For the long-term changes, crops can tolerate moderate variations in the climatic mean. Changes beyond these bands of tolerance may require shifts in cultivars and crops, new technologies and infrastructure or ultimately conversion to different land uses. Therefore, a proper planning to match Oilseed crops and their varieties/hybrids to suit to the weather conditions expected for a place/region, duly understanding these crops'diversity in adaptation to climate and its change, certainly keep up the place of India in Oilseed production and their importance in Indian economy in spite of expected climate change.

Diversity Among Oilseed Crops

Among different crop groups, Oilseeds are more diverse in many ways (Table -2) compared to other major crop groups such as Cereals and Millets and Pulses. All the Cereals and Millets belong to one family namely Poaceae and similarly, all Pulses belong to one family, namely Fabaceae as against the Oilseeds, which belong to five different families. They also vary in chromosome number (from 2n=20 in castor to 2n=40 in soybean), chromosome sizes, ploidy level (diploids to allotetraploids), pollination mechanism (self, often cross and cross pollination), position of economic part/ inflorescence, type of inflorescence, seed size (with 100 seed weight of 0.2 g in sesame to 50 g in sastor and groundnut) and oil content (from 18% to 55%). The origin and climatic adaptation of Oilseeds also so diverse in their adaptation from highly temperate to hot tropical climates with varied cardinal temperature requirements (Table -3). Adaptation ranges from a crop very much adapted to cool climate (rape seed and mustard) to that of a dry hot climate (groundnut). Existence of such diversified adaptation to climate certainly be helpful to match with any change in climate in a country like India, where exists all type of world climates in length and breadth. Therefore, India can utilize this diversity among the Oilseed crops even under changing climate to sustain their production, however, with change in sowing windows and with slight shifts in cropping zones.

Table 1: Area and Production of Oilseed Crops in India

Year	Area (m. ha)	Production (m. tonnes)
2010-11	27.22	32.48
2011-12	26.31	29.80
2012-13	26.48	30.94
2013-14	28.05	32.75
2014-15	25.59	27.51
2015-16	26.13	25.30
2016-17	26.20	31.26
2017-18	24.69	31.30

Influence of Climate Change on Crop Management

Depending upon the location on the globe, the plant growth and yield of crops will be negatively or positively affected by the climate change (Howden *et al*., 2007). Increasing carbon dioxide concentration in air and temperatures affect growth and development of crops, thus influencing potential yields, especially oil accumulation in Oilseed crops.

- Climate change impacts on crop yield depend on the latitude of the area and precipitation.
- The crop yield can be increased with increase in precipitation during the crop growth.
- Crop yield is more sensitive to the precipitation than temperature, especially under rainfed conditions.
- Expected reduction or ill-distribution of rainfall need to be tackled through proper *ex-situ* or *in-situ* water harvesting and conservation strategies.
- If water availability is reduced in the future, soil of high water holding capacity will be better to tide over ill-effects of frequent drought proneness and maintain crop productivity.
- With climate change, the growing period of a crop may be reduced, and the sowing window mayneed readjustment accordingly.

- Climate change can decrease the crop rotation period, so farmers need to consider duration of crop varieties to fit in.
- Expected yield reduction needs to be managed through enhancing crop densities and fertilization levels.

Table 2: Diversity for Various Characters Among the Major Oilseed Crops in India

Character	Oilseed Crops								
	Groundnut	**Rapeseed and**	**Soybean**	**Sunflower**	**Safflower**	**Sesame**	**Linseed**	**Niger**	**Castor**
Family	Papilionaceae	Brassicasese	Papilionaceae	Asteraceae	Asteraceae	Pedaliaceae	Linaceae	Asteraceae	Euphorbiaceae
Chromosome Number	2 n = 40	2 n = 38; 2 n = 36	2 n = 40	2 n = 34	2 n = 24	2 n = 26	2 n = 30	2 n = 30	2 n = 20
Mode of Pollination	Self	Self	Self	Cross	Often Cross	Self	Self	Cross	Cross
Center of origin	Brazil	Western and Central Asia	China	North America	India	Africa - PSO, India and Japan -	Medi-terranean Centre	Ethiopian highlands	Ethiopia
Climatic requirement	Tropical Sub-Tropical	Tropical &Temperate	Temperate	Temperate	Tropical &Sub-	Tropical	Tropical &Sub-	Tropical Sub-	Tropical Sub-Tropical
Position of economic part	Flowers in axillary clusters and pods below	Terminal racemose inflorescence	Axillary receme all along the stem	Terminal Head	Many branches, each terminating	Solitary, Axillary, pedicillate flowers all	Terminal cymose flowers	Terminal flower heads	Main axis and the branches terminate in inflorescence
100 seed weight (g)	25-45	0.35 - 0.6	12-14	3 -6	4-5	0.2-0.3	0.4-0.5	10-13	30-70
Oil content (%)	40–54	37–46	18–23	39–48	28-32	45–52	28–30	40	40–55

The positive effects of climate change on crop production are concerned with the CO_2 concentration enhancement and increase in growth period in higher latitudes. The negative effects include the increasing incidence of pests and diseases, and soil degradation owing to temperature change. This has urged Scientists to develop suitable strategies or technologies, which are more climate resilient. Quantification of climate uncertainty, however, is an important indicator for crop yield variation in future climate scenarios.

Table 3: Cardinal Temperatures and Day Length Sensitivity of Oilseed Crops

Crop	Max. Temp (°C)	Min. Temp (°C)	Opt. Temp. (°C)	Day length sensitivity
Groundnut	35 – 42	15 – 20	25 – 35	Short day
Castor	35 – 38	15 – 17	20 – 26	Long day
Soybean	24 – 36	20 – 26	26 – 30	Short day
Sunflower	35 – 38	15	20 – 25	Day neutral
Rapeseed/ Mustard	27 – 35	7 – 15	15 – 25	Long day
Sesame	40	12 – 20	25 – 35	Short day
Linseed	25 – 32	15 – 20	21 – 27	Long day
Niger	30	10	15 – 23	Short day
Safflower	--	32	24 – 28	Day neutral

Oilseed Crops Adaptation to Climate and Climate Change

1. Groundnut

(a) Adaptation to Climate

Groundnut is predominantly a crop of the tropics. The approximate limits of present commercial production are between latitudes 40^0 N and 40^0 S and up to an attitude of 1065 m. **Rainfall:** The crop can be grown successfully in places receiving a rainfall of as less as 300 mm to 400 mm to as high as of 1250 mm. In semi – arid and arid regions, a rainfall of 500 mm to 700 mm during crop period is very ideal for groundnut production. In fact, groundnut can withstand up to 25 days to 30 days of sowing once established. Rainfall should be adequate during flowering and pegging stages. Continuous rains leads to excessive vegetative growth resulting in poor pod yield. It can also withstand flooding up to one week.

Temperature: Soil temperature <18^0 C delays emergence of seedlings. The embryo is killed above 54^0 C. Groundnut performs well in dry temperature range between 24^0 C and 33^0 C. But it can survive up to 45^0 C. Ideal temperature for reproductive stage is between 24^0 C and 27^0 C. Rate of pod growth will be at its maximum between 30^0 C and 34^0 C. In general, one month of clear, warm and dry weather during ripening is very much useful for increased productivity

Light: Groundnut is a day length insensitive plant. About 60% solar radiation for 60 days after emergence appears to be critical. Low light intensity prior to flowering slows down the vegetative growth and increases the plant height. Flowering phase is more sensitive to low light intensities. In the absence of soil moisture stress, clear bright sunny days have the greatest potential for optimum growth and development leading to high pod yield.

Overall, groundnut adaptation to climate is wider and hence, a narrow range in climate change would probably not affect much of its productivity. In general, bunchy types are more sensitive to climate variability than that of runner types.

(b) Impact of Climate Change

Climate change is projected to alter the growing conditions of groundnut crop differently in different regions of India (Singh *et al.*, 2014). Quantification of the impact of climate change on the productivity of groundnut by the use of CROPGRO-Groundnut by them at three sites (Anantapuramu Mahbubnagar and Junagadh) in India, has indicated a significant decrease in pod yield by increase in temperature at all the sites by 2050. But the net effect of changes in temperature, rainfall and CO_2 showed a 4% decrease in yield at Anantapuramu and 11% increase at both Mahbubnagar and Junagadh. A number of agronomic practices evaluated under climate change at Anantapuramu showed that the maximum increase in yield was simulated with supplemental irrigation, followed by delay in sowing and growing a longer maturity variety. At Mahbubnagar, the maximum yield gain showed with delayed sowing, followed by growing a longer maturity variety, supplemental irrigation and application of crop residues. At Junagadh, the yield increase showed the maximum with supplemental irrigation, followed by application of crop residues. It is concluded that the relative contribution and prioritization of agronomic practices to increase groundnut yield under climate change varied with the region.

2. Castor

(a) Adaptation to Climate

Castor is essentially a warm season crop grown mostly during *kharif* season under rainfed conditions in temperate and tropical regions throughout the world. It can be successfully grown from 300 m to1800 m (occasionally to 3000 m) above sea mean level .Castor production lies between 40^{o} N and 40^{o} S. With the availability of early maturing varieties and hybrids and improved agronomic practices, the crop is being grown during *rabi* as well as during summer season under irrigation.

Rainfall: Castor crop can be grown successfully under 600 mm to 760 mm rainfall. It can tolerate long dry spells as well as heavy rains, but is highly susceptible to water logged conditions.

Temperature: At the time of germination, high soil temperature reduces the period of seedling emergence, while at low temperature this period increases. However, during the period of crop growth, it requires moderate, temperatures ranging from 20^{0} C to 30^{0} C with low humidity. Temperatures above 35^{0} C reduce oil and protein contents, those below 15^{0} C reduce oil content and alter oil characteristics. High temperature 41^{0} C results in blasting of flowers and poor seed set. A frost free growing period between 130 days and 190 days depending on cultivar is necessary for satisfactory yields

Light: Basically it is a long day plant, fairly adaptable to day length from 13 h to 18 h. normally, long clear and sunny days are preferable, but severe summer with high temperature and low humidity leads of blasting of flowers.

(b) Impact of Climate Change

All growth parameters of castor showed maximum response under elevated CO_2 of 700 ppm followed by 550 ppm. Elevated CO_2 also showed a decrease in the days to initiation of flowering by three days and days to 50% flowering by 15 days. Improvement in bean yield and yield components as well as oil yield showed at elevated CO_2 levels. Overall, elevated CO_2 attributable to climate change showed a positive effect on castor. Under irrigated conditions where water is not a limitation, it is possible to realize higher yields in castor due to elevation of CO_2.

3. Sunflower

(a) Adaptation to Climate

Basically sunflower is a temperate oilseed crop but it is adapted to tropical and subtropical climate. Generally, it is grown between 40^0 S to 55^0 N latitudes but most of the production is concentrated between 20^0 S to 50^0 N latitude. The crop can be cultivated up to an altitude of 2500 m but the highest yield of oil is obtained below 1500 m.

Rainfall: Fairly drought tolerant with deep root system and comes up well in areas receiving a minimum rainfall of 500 mm to 700 mm.

Temperature: Sunflower can tolerate temperature range of 8 to 30^0 C but the temperature below 16^0 C and above 40^0 C reduces yield and oil content. The optimum temperature for best performance under controlled conditions is 27^0 C-28^0 C.

a) Minimum temperature for germination is 8^o C-10^o C but it can germinate even up to 40^0 C. (Germination begins at 3^0 C-5^0 C and can withstand frost to -6^0 C.) Night temperature of 18^0 C-20^0 C and day temperature of 24^0 C-26^0 C are ideal for growth, yield and higher oil content.

b) During flowering temperature should be between18^0 C-20^0C. Goods yields are obtained where the ruling temperature is 18^0 C-22^0 C showing that generally speaking the crop needs a warm climate. Average minimum temperature below 17^0 C between flowering and maturity is necessary to ensure best oil quality.

Light: The crop is photo insensitive as it flowers at wide range of photoperiods. Optimum day length for better yield should be >12 h to 14 h. The crop requires a cool climate during germination seedling growth and warm weather from seedling to flowering. Warm and sunny (high light intensity) days during flowering to maturity are most favourable.

(b) Impact of Climate Change

A study conducted by Vanaja *et.al*. (2006) to study the impact of elevated CO_2 (600 ppm) from the ambient level (365 ppm) showed significant in all the growth parameters. Similar impact has also shown by other researchers (Table – 4).

Table 4: Influence of elevated CO_2 levels on growth and yield of Sunflower

Reference	**CO_2 conditions (ppm)**	**Shoot biomass variation with eCO_2**	**Yield variation with increase CO_2**
Vanaja *et al.* (2011)	380–700	+ 24% (well-watered)	NA
		+ 49% (water stressed)	+ 35% to + 46% (2 varieties)
Pal et al. (2014)	370–550	+ 61% to + 68% (2 varieties)	-
Srinivasarao *et al.* (2016)	380–550–700	+ 32%(700 ppm)	NA
		+ 42%(550 ppm)	-
Nasim et al. (2016)	360 - 550	-	+ 4 % (Sub-humid) to +2 % (Arid)

4. Sesame

(a) Adaptation to Climate

Sesame is essentially a tropical crop grown in arid and semi-arid areas. It is generally cultivated in tropical and sub-tropical countries. Its main distribution is between 25^0 S and 25^0 N Latitudes. Its altitude range is normally below 1250 m although some varieties locally adapted up to 1500 m.

Temperature: Generally, it requires fairly hot conditions during growth for optimum yield. Ideal optimum temperature for growth is 25^0 C-27^0 C. Extremely low temperatures of 10^0 C ceases growth completely. Temperatures >40^0 C seriously affect the pollination when there is less number of capsules.

Light: Sesame is a short day plant. High light intensity increase number of capsules / plant.

(b) Impact of Climate Change

Impact of change in climate may not be seen as it known to be grown from early *kharif* to summer seasons, however, no information is available from structured studies.

5. Rapeseed and Mustard

The rapeseed and mustard crops are of the tropical as well as of the temperate zones and require relatively cool temperatures for satisfactory growth. In India, they are grown in the rabi season from September-October to February-March.

Rainfall: The rapeseed and mustard crops grow well in areas having 250 mm to 400 mm of rainfall. Sarson and toria are preferred in low-rainfall areas, whereas raya and toria are grown in medium and high-rainfall areas respectively. Sarson and Taramira are preferred in low rainfall areas where as raya and toria are grown in medium to high rainfall areas respectively.

Temperature: It requires relatively cool temperature and a dry harvest period. Cool temperature, clear dry weather with a plentiful of bright sunshine accompanied with adequate soil moisture increases the yield. These favourable conditions are existing in northern India. It is grown in *rabi* season from September-October to February –March. They prefer moderate temperature of 24 ^{o} C-28 ^{o} C with an optimum of 20 ^{o} C.

Light: Rape seed and mustard are long day plants. These crops neither tolerant to drought nor water logging. Cloudy weather with high humidity affect very badly during crop period.

(c) Impact of Climate Change

Boomiraj et al. (2009) studied various scenarios of impact of climate change on mustard production came out with a overall negative impact on India’s mustard production with a special variation in terms of yield loss with Westerns and Northern India being more vulnerable.

6. Safflower

(a) Adaptation to Climate

Safflower is well adapted to wide range of climatic condition. However, the maximum production is confined up to 1000 m mean sea level in semi-arid tropics and arid areas. Important production factors are soil temperature and soil moisture.

Rainfall: It is a drought resistant and susceptible to water logging. It comes up well with a rainfall of 500 mm - 600 mm. It cannot withstand excessive soil moisture/ humidity at any stage due to damage from fungal diseases.

Temperature: Temperature is the most important climatic parameter as it is thermo sensitive and it is mainly grown as *rabi* oil seed crop. Optimum temperature of soil for seed germination 15 ^{o} C-16° C. It may tolerate to temperature of 49° C, if sufficient soil moisture is available. Temperature more than 40° C reduced the plant height, dry matter production and seed set and test weight. A Day temperature in the range of 24 ^{o} C-32° C at flowering is the optimum. Higher temperature at flowering is harmful to crop resulting in sterile heads. Crop is tolerant to frost at seedling stage but sensitive at later stages.

Light: It is a day neutral plant, but a day length of 12-14 hour is essential for flowering and seed set. When compared to day length, temperature is more important.

(b) Impact of Climate Change

Several studies (Anten et al., 2004; Anisworth and Rogers, 2007; Mohamed et al., 2013): reported a positive impact of elevated CO_2 levels on growth and yield of Safflower.

7. Niger

(a) Adaptation to Climate

Niger is grown as a *kharif* crop under rainfed conditions. It is a short day plant. A moderate rainfall of 1,000-1,250 mm suits this crop and, as such, it is not cultivated in regions of heavy rainfall.

Rainfall: Rainfall of 1000-1300 mm is optimum although 800 mm will produce reasonable yield. The peak flowering period of crop should not coincide with rainy periods as the honey bees, which are main pollinators, are disturbed, resulting in poor seed setting. High wind or rain at seed maturity will cause severe maturity.

Temperature: It is a temperate region crop and also adapted to semi-tropical environment. Niger is a short day plant. It requires moderate temperature of 18^o C-23^o C for its growth. Temperature above 30^o C growth rate and flowering are adversely affected and hastens maturity. Frost will kill the young seedlings. Temperature below 10^o C; emergence is restricted – leading to in adequate stand establishment.

8. Lin Seed

(a) Adaptation to Climate

Linseed is grown in the range of latitudes between the 10_{th} and 65_{th} parallels, both north and south. Its cultivation is confined to low elevations, but it can be successfully grown up to 770 metres. In lndia, the crop is grown in the rabi season from September-October to February-March.

Rainfall: Areas with the annual rainfall ranging from 450 mm -750 mm are best suited for its cultivation. The seed crop does well under moderate cold, but the fibre crop grows best in cool moist climates.

Temperature: Requires temperature of 25^{o} C-30^{0} C during germination, 15^{o} C-20^{0} C during seed formation. It requires high humidity. Temperature above 32^{0} C along with the drought during flowering reduces yield, oil content and oil quality of linseed. Plants are susceptible to frost and cause injury to blossom. It is resistant to drought and grows well in areas receiving an annual rainfall of 450 mm -750 mm.

(b) Impact of Climate Change

A study by Li et al. (2014) reported a negative influence of increase in temperature and decrease in precipitation, that are contemplated with change in climate, on linseed vegetative and reproductive stages and ultimately on yield.

9. Soybean

(a) Adaptation to Climate

Soybean is cultivated in temperate, tropical and subtropical climates. It can be grown almost anywhere with a warm growing season, ample water and sunlight. It is predominantly grown as rainfed crop on Vertisols and associated soils. □In India, the area under soybean is mainly spread in latitudinal belt of about 15^{o} N to 25^{o} N comprising the states of Madhya Pradesh, Maharashtra, Rajasthan, Chhattisgarh, Andhra Pradesh and Karnataka.

Rainfall: The crop can be grown in areas receiving crop seasonal rainfall of 600 mm – 900 mm; however, higher rainfall is equally harmful than lower one as high moisture at germination causes rotting of seeds and seedlings, poor nodulation and growth. Rainfall during maturity deteriorates the grain quality.

Temperature: Soybean requires 15^{o} C to 32^{o} C temperature for germination. Optimum temperature required for its growth and yield is 26^{o} C – 30° C. If temperature is below 10° C, crop growth is retarded. Similarly, temperatures above 36° C affects growth, flowering, seed formation and seed quality. Day temperatures of 25° C are good for flowering. It is reported that cold temperatures lower the oil content and high temperatures during seed formation increases oil content in the seed.

Light: Soybean is a short day plant and is highly sensitive to day length. Most of the varieties flower and mature quickly if grown under conditions where the day length is less than 14 hours provided that temperatures are also favorable. Cloudy weather prolongs the vegetative phase.

(b) Impact of Climate Change

Mall et al. (2004) reported from their simulation models that increasing temperatures pose a serious threat in decreasing growth of soybean and hence yields. They, however, suggested that the negative impact of temperature increases can be reduced by delaying sowing dates or switching over to the next season.

Conclusions

The group of Oilseed crops is having very distinctive differences among themselves compared to those of other groups of crops such as Cereal, Millets and Pulses. Oilseed crops adaptation to climate is highly varied, which favored their cultivation throughout India in different seasons owing to the country’s diversified climate. Hence, they have a unique place in Indian Agriculture and its economy. Further, they continue to play an important role even in the projected climate change due their adaptation to wider range of climatic conditions and availability of such a variety of climatic conditions in India. The expected range in change in climate is much less than that of the diversity of Oilseeds adaptation to climate in general. The change expected in climate also shown both positive and negative effects on these crops with a wider range from place to place. An overall negative effect of increase in temperature may be countered by increase in CO_2 level wherein the ambient CO_2 level found to be less for optimum photosynthesis in many crops. Therefore, a proper planning to match Oilseed crops and their varieties/hybrids to suit to the weather conditions expected for a place/region, duly understanding these crops’ diversity in adaptation to climate and its change, certainly keep up the place of India in Oilseed production and their importance in Indian economy in spite of expected climate change.

Literature Cited

Ainsworth, E. A and Rogers.A.2007. Theresponseofphotosynthesisand stomatalconductance torisingCO$_2$mechanisms andenvironmentalinteractions.PlantCellEnvironment.30:258–270.

AntenN, HiroseT,OnodaY, KinugasaT, KimH, Okada,M and KobayashiK. 2004. Elevated CO$_2$ and nitrogen availability have interactive effects on canopy carbon gain in rice.NewPhytologist.161:459–471.

Boomiraj, K, B. Chakrabarti, P.K. Aggarwal R., Choudharyand, S. Chander. 2009. Impact of Climate Change on Indian Mustard (*Brasssica juncea*) in Contrasting Agro-Environments of the Tropics. Climate change. ICAR Annual Report.2008–2009, DARE, New Delhi.

Li SZ, Sun LL, Ma YP, Ma YP, Xu YD, E YH. 2014. Effects of climate change on flax development and yield in Guyana of Ningxia, Northwest China. The Journal of Applied ecology. 2014.25(10):2892-900.

Mohamed, S., Anita Jellings. 2013. Michael Fuller. Positive effects of elevated CO$_2$ and its interaction with nitrogen on safflower physiology and growth. Agronomy for Sustainable Development, EDP Sciences: 33 (3):497-505.

Mall,Lal,V.S. Bhatia ,L. S.R Rathore,Ranjeet Singh. 2004.. Mitigating climate change impact on soybean productivity in India, Agricultural and Forest Meteorology.121(2004):113–125.

PalM,Chaturvedi AK,PandeySK,Bahuguna RN,Khetarpal S, AnandA.2014.RisingatmosphericCO$_2$mayaffectoilquality andseed yieldofsunflower(*Helianthusannuus*L).ActaPhysiology Plant36:2853–2861.

Singh, N. P. Singh, K. J. Boote, S. Nedumaran, K. Srinivas and M. C. Bantilan. 2014. Management options to increase groundnut productivity under climate change at selected sites in India. Journal of Agrometeorology 16 (1): 52-59 (June 2014).

SrinivasaraoC, KunduS, ShankerAK, etal. 2016. Continuous cropping under elevated CO$_2$: differential effects on C$_4$ and C$_3$ crops, soil properties and carbon dynamics in semi-arid *alfisols*. AgricultureEcosystemEnvironment.218:73–86.

Vanaja. M, Jyothi, Ratnakumar, Vagheera. P, RaghuramReddy, N.JyothiLakshmi, S.K.Yadav, M.Maheshwari, Venkateswarlu.B. 2008. Growth and yield responses of castor bean

(*RicinuscommunisL.*) to two enhanced CO_2levels. Plant Soil Environment.54 (1):38-46.

Vanaja. M, P. Vagheera, P. Ratnakumar, N. Jyothi Lakshmi, P. Raghuram Reddy, S.K. Yadav, M. Maheshwari, B. Venkateswarlu. 2006. Evaluation of certain rainfed food and oil seed crops for their response to elevated CO_2 at vegetative stage. Plant Soil Environ. 52, 2006 (4): 162–168

VanajaM, YadavSK, Archana G. 2011. Response of C_4 (maize) and C_3(sunflower) cropplantstodroughtstressand enhanced carbondioxide concentration. Plant Soil Environment.57:207–215.

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3. Climate Aberrations in Rainfed Oilseed Ecosystems in India – An Analysis

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1. Introduction

Rainfed agriculture constitutes 80% of global agriculture, and plays a critical role in achieving global food security. The importance of rainfed agriculture varies regionally, but it produces most food for poor communities in developing countries. The proportion of rainfed agriculture is 95% in Sub-Saharan Africa (SSA), 90% in Latin America, 60% in South Asia (SA), 65% in East Asia, and 75% in Near East and North Africa (FAO, 2003). India ranks first in rainfed agriculture globally in both area (86 Mha) and the value of produce. Overall, the rainfed areas produce 40% of the food grains, support two-thirds of the livestock population, and are critical to food security, equity, and sustainability. Rainfed regions in India contribute substantially towards food grain production including 90% of minor millets, 87% of coarse cereals, 85% of food legumes, 72% of oilseeds, 65% of cotton, and 44% of rice. Production potential of crops, particularly under rainfed conditions, depends on the resource endowments of the region and the management practices adopted.

On the basis of climate, soils, topography and effective growing seasons, the country is divided into 20 homogenous agro-ecological regions. With diverse climate, India has a high spatial and temporal variability in rainfall and temperature. Rainfed agriculture supports 40% of the national food basket and is practiced in two-thirds of the total cropped area of 162 million hectares (66%) (**Fig. 1**). These areas receive an annual rainfall between 400 mm to 1000 mm, which is unevenly distributed, highly uncertain and erratic. Thus, rainfed farming systems are practiced in regions of strong climate contrast (Rao *et al.*, 2010). The major problems in rainfed areas of the country are as follows

- Low and erratic rainfall
- Frequent droughts leading to land degradation
- Low level of input use and technology adoption
- Resource poor farmers
- Fodder scarcity leading to low livestock productivity
- Reduction in the size of holdings

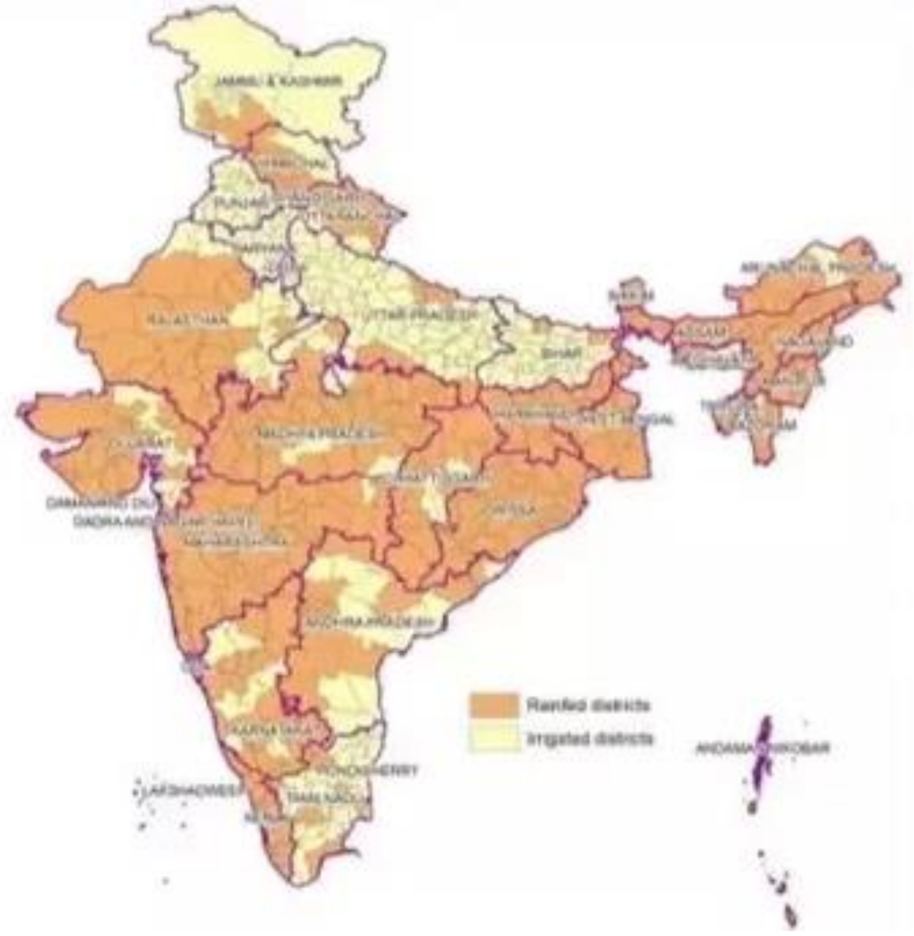

Fig. 1: Rainfed and irrigated districts of India

2. Climatic Aberrations

Throughout the world there is significant concern about the effects of climate change and its variability on agricultural production. Climate change is any change in climate over time that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere in addition to natural climate variability observed over comparable time periods (IPCC, 2007). Within agriculture, it is the rainfed agriculture that will be most impacted by climatic aberrations. Reduction in crop yields were reported due to rising temperature and erratic rainfall. The trends in maximum temperature shows a positive value both annually as well as during the two major crop growing seasons of the country (**Fig. 2**). Though most rainfed crops tolerate high temperatures, rainfed crops grown during *rabi* are vulnerable to changes in minimum temperatures. Annual minimum temperatures are increasing over most parts of India @ 0.24 °C10 yr^{-1}, and the warming was more during *rabi* compared to *kharif* (Bapuji Rao *et al.*, 2014). This will have serious implications for production of *rabi* crops like wheat, mustard and chickpea in the Indo-Gangetic Plains (**Fig. 3**). In the case of rainfall, significant decreasing trend of monsoon season rainfall was noticed in the eastern part of India, Kerala, Himachal Pradesh and Uttarakhand, whereas significant increase has been noticed in some parts of Southern Peninsula, Western Uttar Pradesh, West Bengal and Jammu & Kashmir (**Fig. 4**). The increasing frequency of droughts is the other important climatic aberrations in rainfed agriculture. Extreme weather events, due to climate change, will be more in number. Interannual precipitation variability over the growing season will have greater impact on crop yield and yield quality in rainfed agriculture.

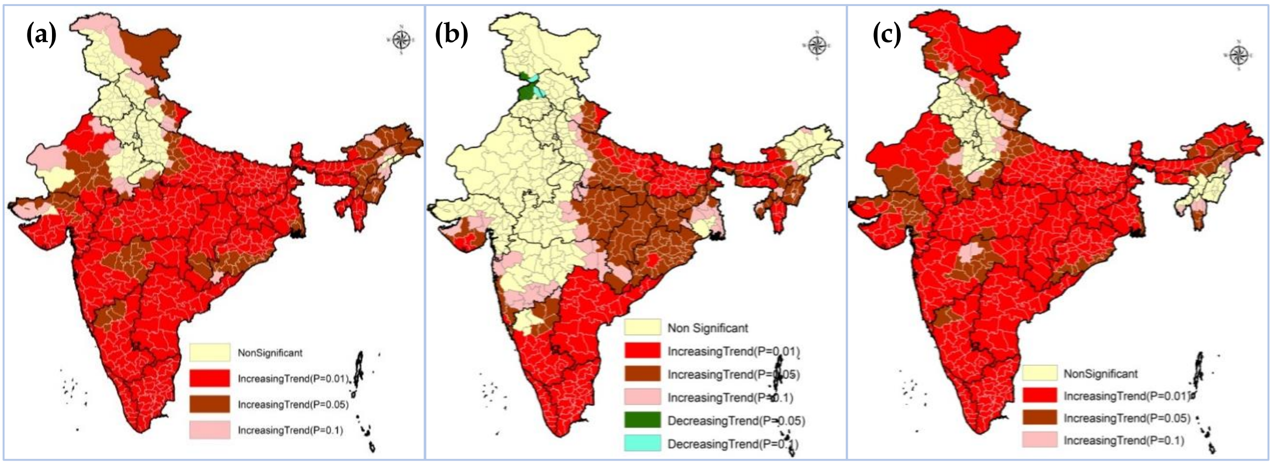

Fig. 2: Trends in maximum temperature over India (1971-2009) on (a) annual (b) *kharif* and (c) *rabi*

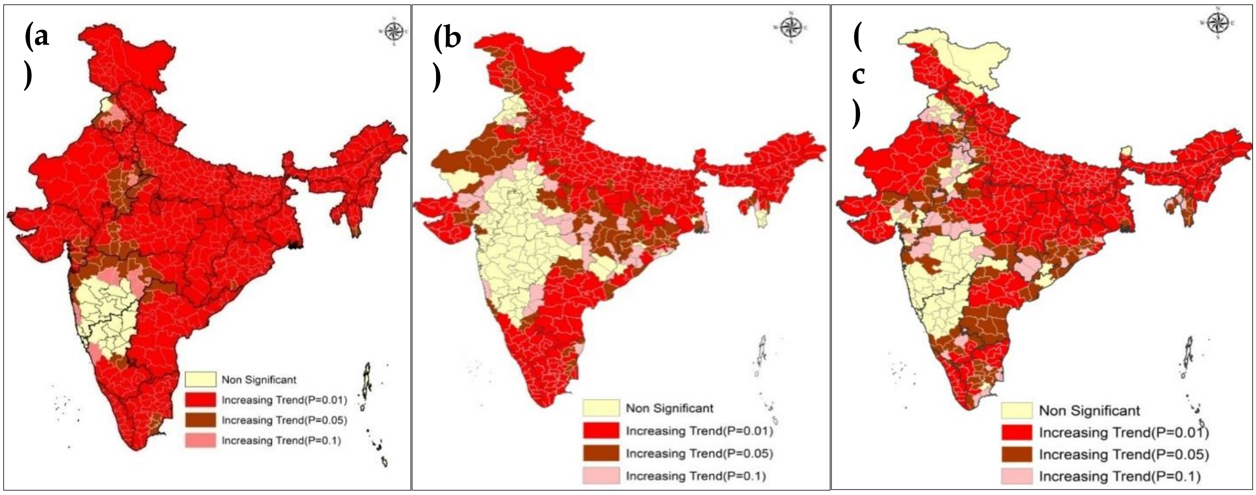

Fig. 3: Trends in minimum temperature over India (1971-2009) on (a) annual (b) *kharif* and (c) *rabi*

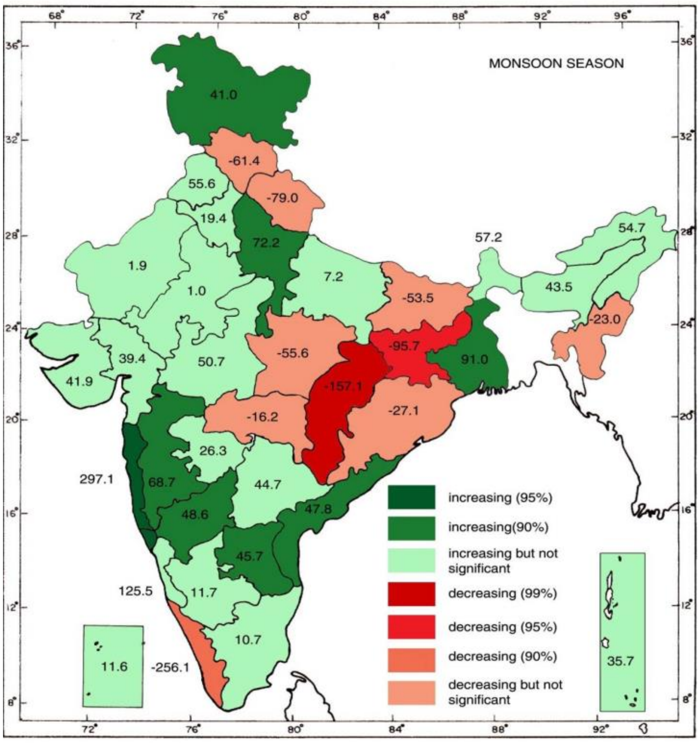

Fig. 4: Trends of southwest monsoon in 100 years

3. Impacts of Climatic Aberrations on Oilseed Crops

In India, area of oil seed crops occupies 27.22 millon hectare (Mha) with a production of 30.53 million tonnes (MT). Groundnut, Mustard, Soybean and Sunflower are the major oil seed crops, which play important role in economy of Indian agriculture. Current variation in crop productivity and yield among different regions, are likely to become greater due to impact of climate change. Crop production is affected by meteorological variables including rising temperatures, changing precipitation regimes and increased atmospheric carbon dioxide levels. The climate changes involve in the next century are mostly attributed to the increasing concentration of CO_2 and other "greenhouse gases". The effects of climate change on agricultural production will be positive in some agricultural systems and regions and negative in others and these effects will vary through time. There are very limited studies to assess the impact of climate change on oilseed crops as compared to cereals. Let us analyze how the impacts of change in climate affects the major oilseed crops of India.

3.1 Groundnut

Groundnut is a tropical plant which is mainly grown as a principal source of edible oil. The most favorable climatic conditions for groundnut are a well distributed rainfall of at least 500 mm during growing season, abundance of sunshine and relatively warm temperatures. Temperature is a major environmental factor that determines the rate of crop development. Well - drained, light - textured, loose, friable sandy - loam or sandy clay loam soil is most suitable for groundnut crop. In India, about 80% of area under groundnut cultivation is confined to five states, i.e., Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra, which account for 84% of the total production. Groundnut crop has been observed over time to be sensitive to short-term changes in weather, as well as to seasonal, annual and longer-term changes and variations in climate (Khanal and Mishra, 2017). As the concentrations of greenhouse gases increase, the overall temperature also increase resulting in differential precipitation leading to abrupt variation in crop productivity. Groundnut yield response to elevated rainfall variability, temperature and CO_2 was studied by Murthy *et al.,* (2002) using the sensitivity analysis for different climate change scenarios. These changes in climatic factors alters plant growth and development processes and most likely have negative impact on crop productivity (**Table 1**). It is projected that, even a small rise in temperature (0.5 °C) would decrease productivity. The effect of elevated temperature on yield attributes is also found to be adverse (**Fig. 5**).

Table 1: Groundnut yield response to elevated temperature, CO_2 and rainfall variability at Hyderabad

Temperature increase (°C)	(+20 % rainfall)		(-20 % rainfall)	
	330 ppm CO_2	555 ppm CO_2	330 ppm CO_2	555 ppm CO_2
0.0	1494	2140	1430	1948
1.0	1437	2060	1298	1873
1.5	1400	2018	1254	1821
2.0	1368	1990	1222	1780
2.5	1356	1980	1195	1762
3.0	1367	2005	1177	1742
3.5	1385	2035	1095	1628
4.0	1346	1871	1015	1518
4.5	1238	1795	700	1048
5.0	1000	1213	416	647

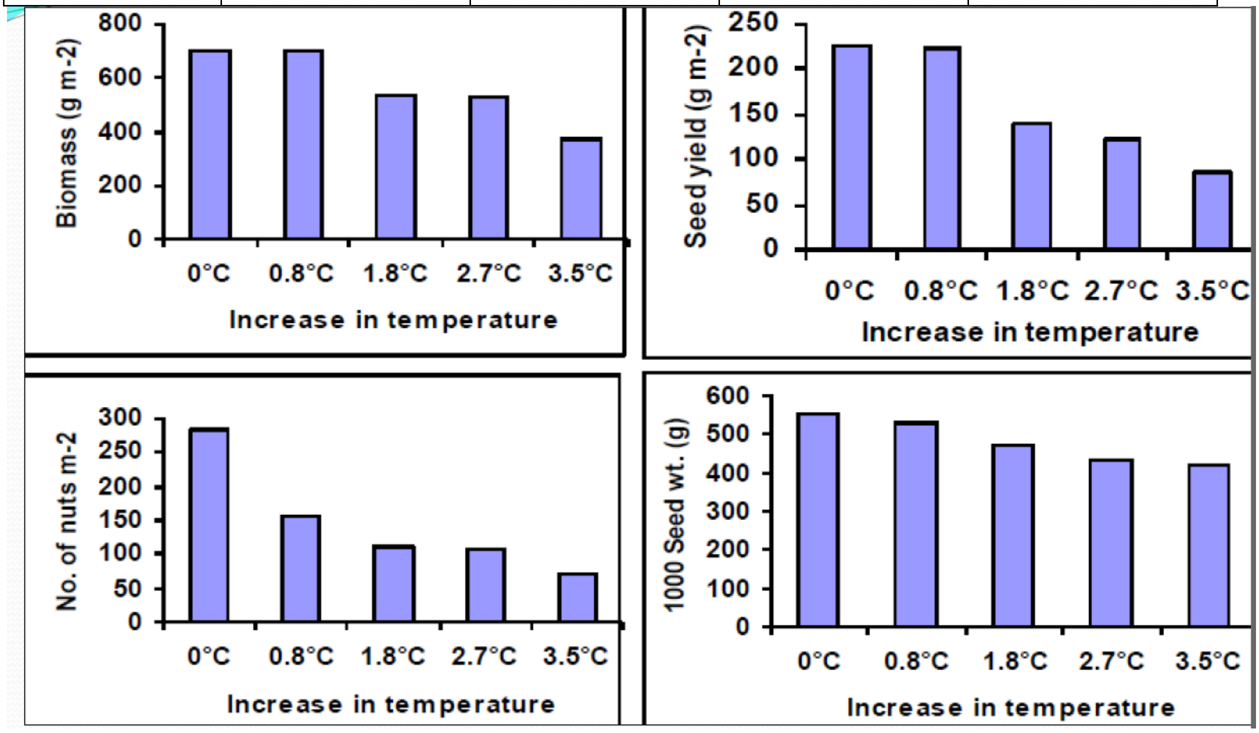

Fig. 5: Effect of elevated temperature on yield attributes (Location: IARI, New Delhi)

3.2 Mustard

Rapeseed and mustard are crops of temperate climates, but these can also be cultivated at higher elevations in the tropics. Crop requires about 18-25 °C temperature, low humidity, practically no rains especially at the time of flowering. The crop growth is optimum at < 25 °C, while it ceases at < 3 °C and > 35 °C. These crops thrive well on light to heavy loam soils. Mustard is much sensitive to climatic variables and hence climate change could have significant effect on its production. Hightemperature during mustard crop establishment (mid September to early November), cold spell, fog and intermittent rains during crop growth also affect the crop adversely and cause considerable yield losses by physiological disorder. There are almost no studies to assess the probable impact of climate change on mustard productivity in tropical regions. Future climate change scenario analysis showed that mustard yields are likely to reduce in both irrigated and rainfed conditions (Boomiraj *et al.*, 2010). Rise in CO_2 coupled with rise in temperature caused less yield reduction due to the beneficial effect of CO_2 on crop growth and yield. However, these reductions have spatial variation in different mustard growing region of India. Under rainfed condition, temperature increase caused substantial yield loss in eastern India with yield loss of 78.4% with 5 °C rise in temperature (**Fig. 6**). Substantial yield loss would also occur in central India with a loss of 40.2% yield. Rainfed mustard was less vulnerable to temperature rise in northern India as compared to other two locations.

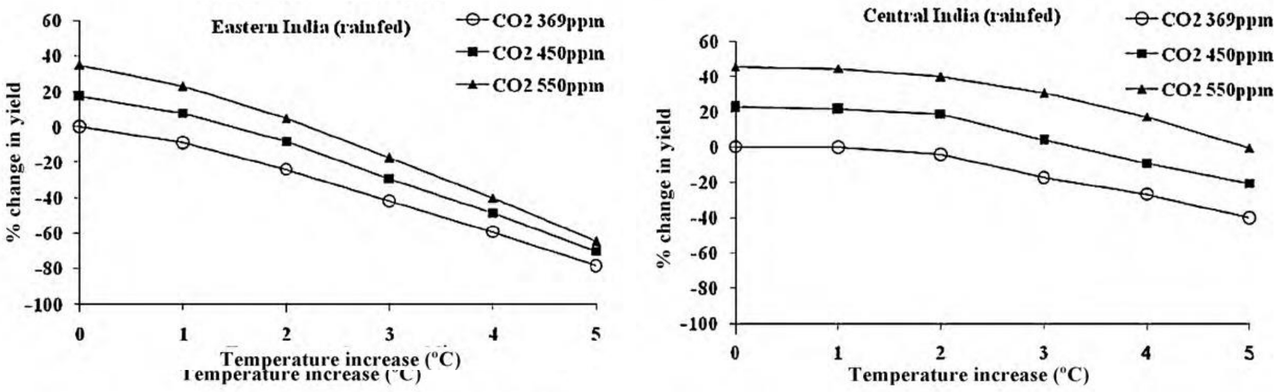

Fig. 6: Effectof CO_2 and temperature on simulated yield of rainfed mustard in different locations of India

3.3 Soybean

Among the oilseeds in the world, soybean ranks first and it is considered one of the most stable *kharif* crops of India. The temperature ranging from 26.5 to 30 °C is considered favorable for most of the soybean varieties. The minimum temperature for effective growth of soybean crop is 10 °C. Lesser than optimum temperature in soybean might result in delayed flowering. Its growth also depends on day length, as they are short-day plants. Depending upon the magnitude of variation in CO_2 and temperature, the aberrations in climatic variables is likely to have substantial impact on soybean production. Over the globe, several studies quantitatively examined the warming impacts on soybean grain yields and reported significantly decreased grain yield with rising temperature during growing season. Increased temperature significantly reduces the grain yield due to accelerated development and decreased time to accumulate grain weight. The crop yields was found to decrease by 350 and 250 kg for each 1 °C rise in maximum and diurnal temperature, respectively during pod formation to seed filling stage at Akola (**Fig. 7**). The state of Madhya Pradesh contributes 60% of the total area under soybean production in the country. The impact of projected climate change across the major crop growing districts of the state using the crop simulation models shows a decrease in yield in most of the locations (**Fig. 8**).

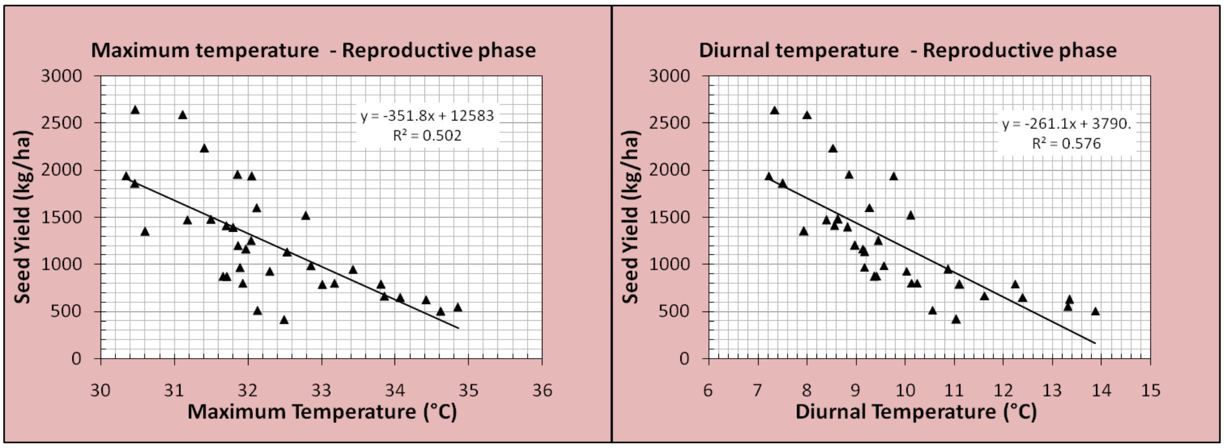

Fig. 7: Yield response to change in maximum and diurnal temperature.

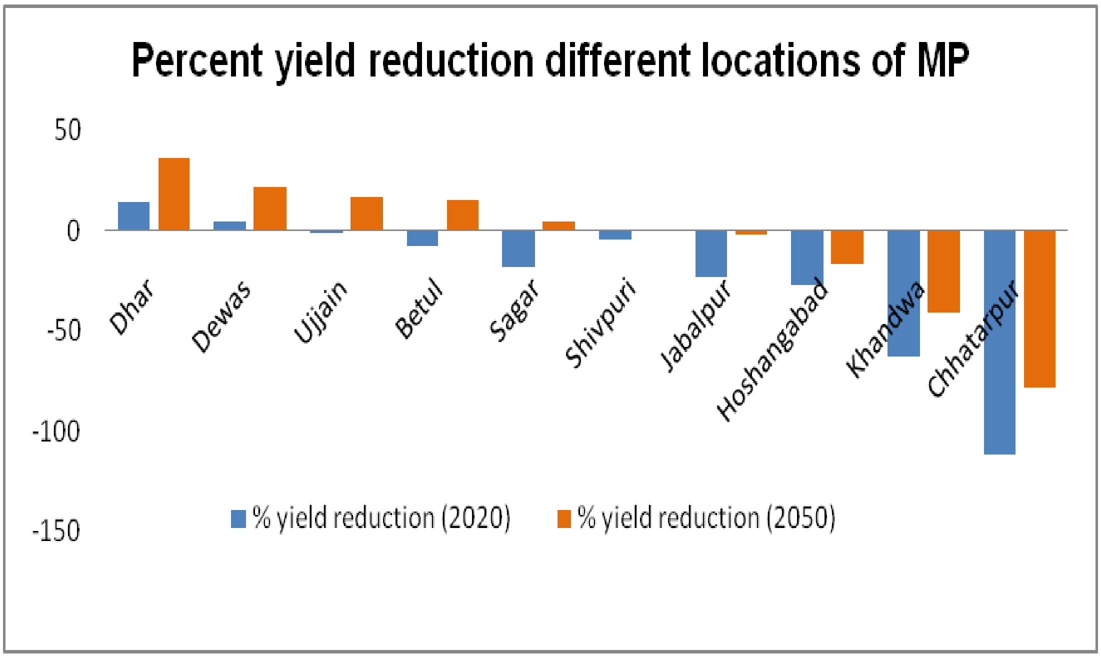

Fig. 8: Projected climate change on soybean yield at different locations of Madhya Pradesh

3.4 Castor

Castor bean (*Ricinus communis L.*) is an important non-edible oilseed crop in India. The crop is grown in semi-arid and arid agro-ecological regions of the country, where rainfall is low and often erratic. A growing period of 140-190 days without frost is required to obtain satisfactory yields. Ideal soil conditions are deep, moderately fertile, slightly acidic, sandy loams and well drained. A well distributed rainfall during growing period will be resulting in achieving reasonably high yields. The crop yield from different cooperating centers of the All India Coordinated Research Project on castor when correlated with rainfall showed a curvilinear relationship (**Fig. 9**) (Vijaya Kumar, 2002). The optimum rainfall was found to be ~ 800 mm, and the reason for more scatter in the relationship is due to the variability in soils, management practices and other climatic conditions. In India, the area of cultivation is mainly confined to two states, *viz.*, Gujarat and Andhra Pradesh accounting for nearly 90 per cent of the total crop (castor) area in India. The difference between the achievable yield and the observed yield is observed to be less in Gujarat, compared to Andhra Pradesh due to the better technology and package of practices (**Fig. 10**).

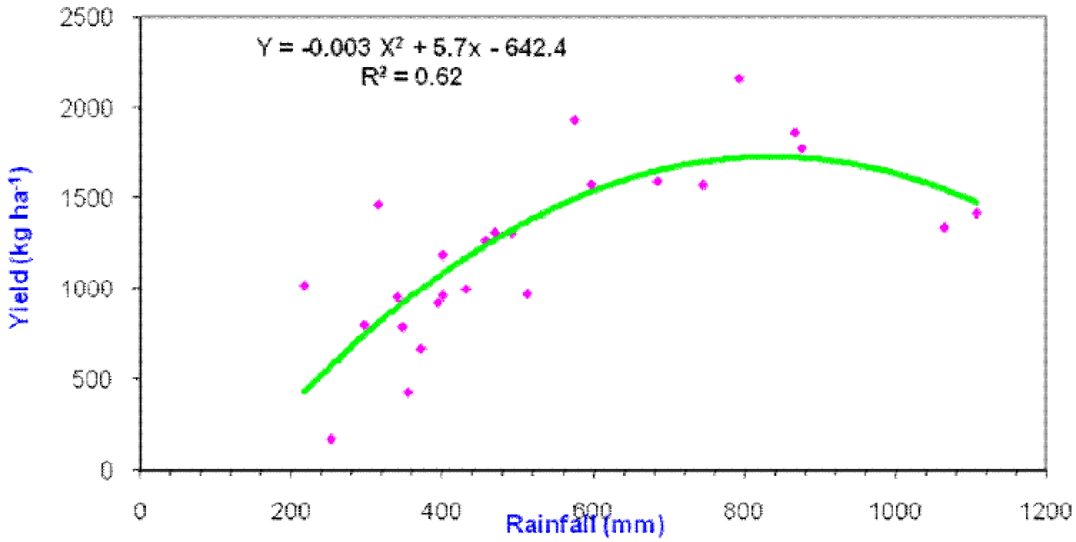

Fig. 9: Relationship between rainfall and yield of castor in multilocational trial

3.5 Sunflower

Sunflower is one of the most important oilseed crop grown in temperate countries and a major source of vegetable oil in the world. The crop grows at an optimum temperature of 23 to 28 °C. However, a wide range of temperatures up to 34 °C shows little effect on its yield. Rainfall required ranges from 500 to 1000 mm. It is a crop that performs well under drought conditions, compared to other crops. India is one of the largest producers of oilseed crop in the

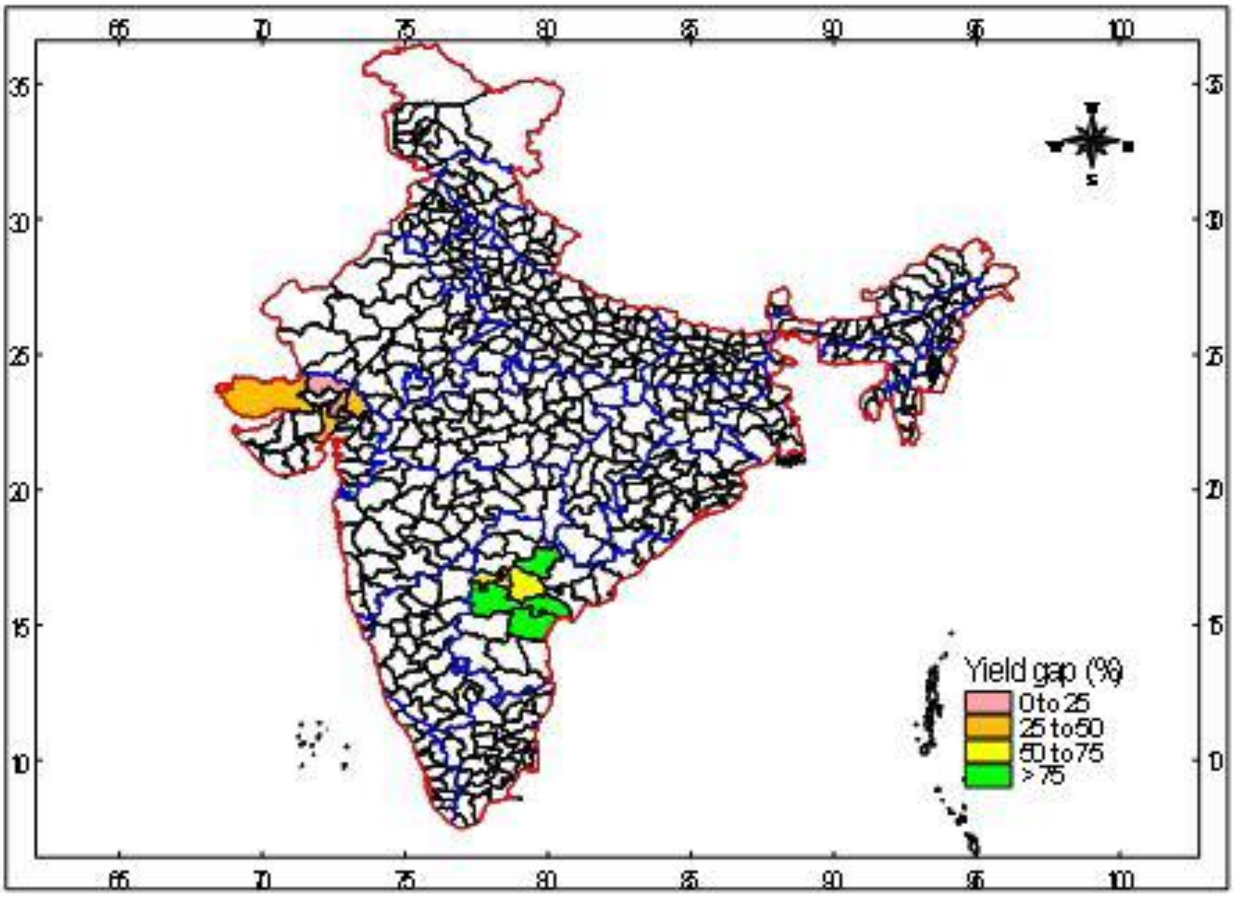

Fig. 10: Yield gap in different castor growing districts

world and it occupies an important position in the country's agricultural economy. Grain yield at Solpaur showed a linear relation with cumulative moisture (CUM) during crop growing period (**Fig. 11a**) and each mm increase in CUM, increases grain yield by 10.4 kg ha^{-1}. Both maximum (**Fig. 11b**) and minimum temperature (**Fig. 11c**) showed significant curvilinear relationship with grain yields. Maximum temperature of above 32 °C and minimum temperature of 21.5 °C were found to be optimum for grain yield of sunflower at Solapur.

4. Conclusion

Indian agriculture is likely to suffer losses due to heat, erratic weather, and decreased irrigation availability. The simulation results indicated that increasing both maximum and minimum temperature poses a serious threat in reducing the growth and yield of major oilseed crops. A 1 °C increase in temperature may reduce yields of soybean, mustard and groundnut by 3-7%, whereas higher losses are anticipated at higher temperatures. Productivity of most crops to decrease only marginally by 2020 but 10-40% by 2100. Increased CO_2 levels are expected to favour growth and increase crop yields and therefore, will be helpful in counteracting the adverse effects of temperature rise in future. In the long-term better adapted varieties are needed to adapt to multiple stresses linked with climate change. In short-term, several options relating to technology transfer, its adoption, appropriate policies, and land and water management are available which can help in minimizing the negative impacts.

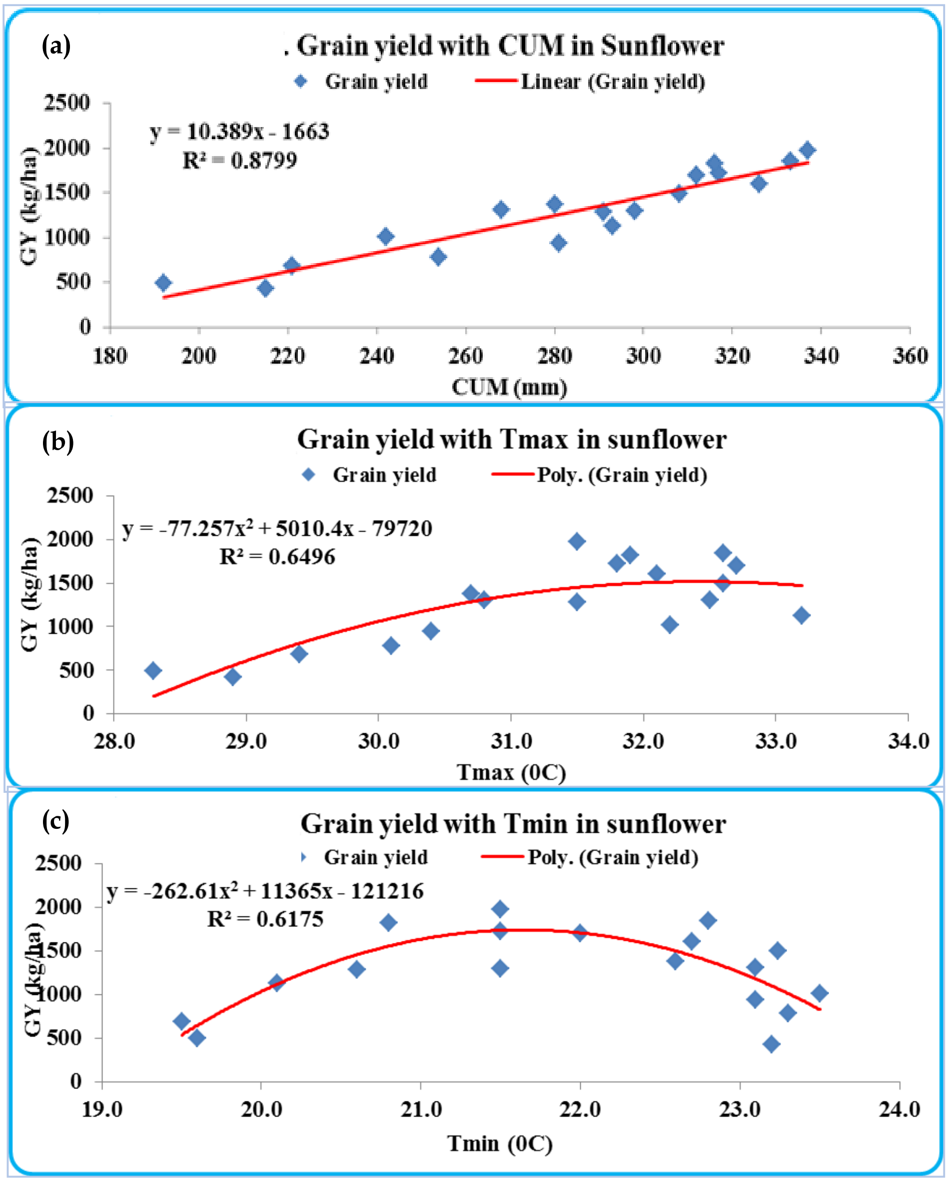

Fig. 11: Relationship between yield and (a) CUM (b) T_{max} and (c) T_{min} at Solpaur

5. REFERENCES

Bapuji Rao, B., Santhibhushan Chowdary, P., Sandeep, V.M., Rao, V.U.M. and Venkateswarlu, B. (2014). Rising minimum temperature trends over Indian in recent decades: Implications for agricultural products. *Glob. Planet. Change*, **117:** 1-8.

Boomiraj, K., Chakrabarti, B., Aggarwal, P. K., Choudhary, R. and Chander, S. (2010). Assessing the vulnerability of Indian mustard to climate change. *Agric. Ecosyst. Environ.*, **138:** 265-273.

FAO. (2003). FAOSTAT. Food and Agriculture Organization of the United Nations, Rome.

IPCC. (2007). “Impacts, Adaptation and Vulnerabilty”, the intergovernmental Panel on Climate Change, Cambridge University Press, 2007, U.K.

Khanala, A.R. and Mishra, A.K. (2017). Enhancing food security: Food crop portfolio choice in response to climatic risk in India. Global Food Security, **1 (12):** 22-30.

Rao, G.S.L.H.V., Rao, G.G.S.N. and Rao, V.U.M. (2010). Climate Change and Agriculture over India. PHI Learning Private Limited, New Delhi, 328 p.

Vijaya Kumar, P. (2002). Studies on the influence of climate and weather on castor beans grown under rainfed conditions.

4. Abiotic stress in oilseedsPlant water use -its relationship with seed yield under Drought

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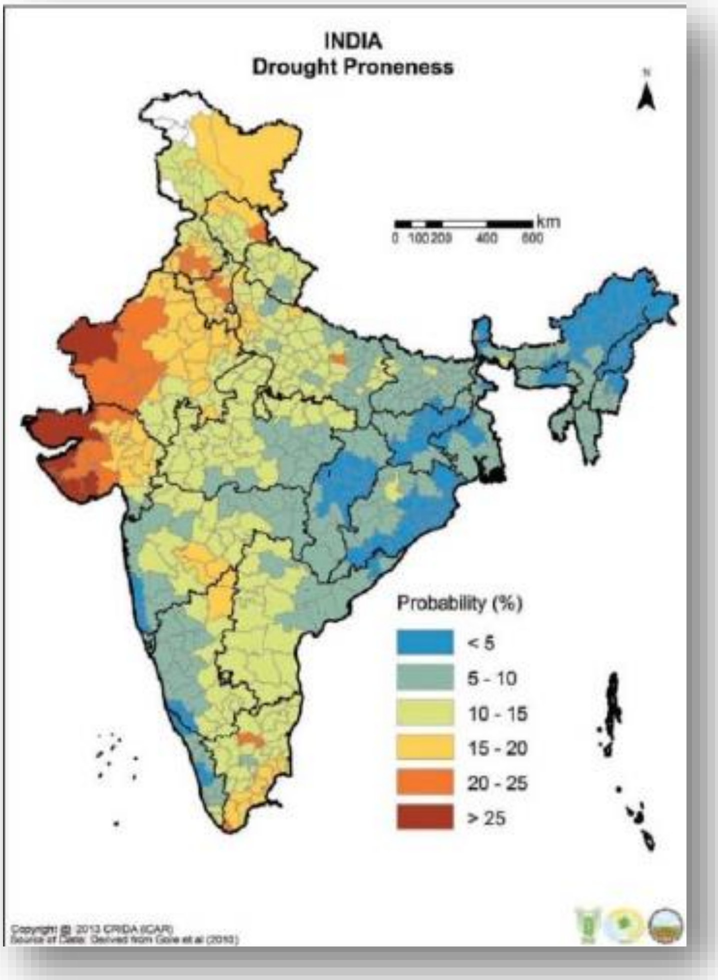
Abiotic stress is one of the important consequences of climate change that will have a telling effect on crop growth and productivity in the near future. The impact of abiotic stress on crop production has emerged as a major research priority during the past decade. Several forecasts for the coming decades project increase in atmospheric CO_2 and temperature and changes in precipitation, resulting in more frequent droughts and floods, cold and heat waves and other extreme events. Rainfed agriculture constitutes 80% of global agriculture and plays a critical role in achieving global food security. However, growing world population, water scarcity and climate change threaten rainfed farming through increased vulnerability to different abiotic stresses like droughts and other extreme weather events. Drought, salinity, temperature, radiation and heavy metal stresses are among the major stresses, which adversely affect plant's growth and productivity. Various forms of abiotic stresses limit agricultural production on most of the world's 1.4 billion cultivated hectares (Srinivasarao et al 2017).

Drought has been a frequent feature of agriculture in India. In the past, India experienced 24 large-scale droughts, with increasing frequencies during the periods 1891–1920, 1965–1990 and 1999–2012 (NRAA 2013). Rainfed areas in India experience 3–4 years of drought in every 10-year period. Of these, two to three are in moderate and one or two may be of severe intensity (Srinivasarao et al. 2013). Droughts in India have periodically led to famines, including the Bengal famine of 1770, in which up to one third of the population in affected areas died and the 1876–1877 and 1899 famines in which over 5 million and more than 4.5 million people died, respectively (Srinivasarao et al 2017).

Fig.1: Probabilities of drought occurrence in India (Rao and Gopinath 2016).



Drought tolerance

Drought tolerance is a complex trait in which plants have developed the following strategies: escape, avoidance, tolerance and recovery. The plant either takes advantage of developmental flexibility to match its phenology to the length of the period of soil moisture availability (drought escape), or increases its water absorption ability and decreases its water loss (drought voidance). Tolerance to drought is likely to be conditioned by many genes under strong environmental influence and thus the networks involved in drought tolerance are quite complex in nature (Gautami et al 2012).

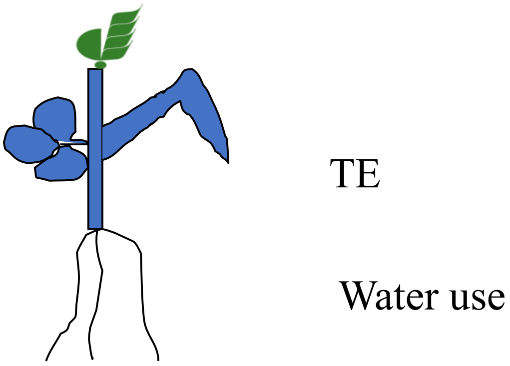
Water-use efficiency (WUE)

Water-use efficiency (WUE) has been considered to be an important drought avoidance trait that concerns using soil water more efficiently for biomass production (Blum 2005; Collins et al. 2008). Raising the WUE of both irrigated and rainfed crop production is an urgent imperative (Nigam et al. 2005). Transpiration efficiency (TE), an important component of

WUE, is also considered to be an important target trait for developing drought-tolerant genotypes for water-limited environments. TE measurements can be done through high-throughput portable lysimetric system (Ratnakumar et al 2009). Surrogate traits for TE, such as specific leaf area (SLA) (Ratnakumar et al 2012) and SPAD chlorophyll meter reading (SCMR), have been considered in earlier studies (Hubick et al. 1986; Nageswara Rao and Wright 1994; Rebetzke et al. 2002), though concerns have also been raised in some recent studies (Krishnamurthy et al. 2007; Devi et al. 2011). SLA is a measurement of leaf thickness and density, which influence plant water use (Kholova´ et al. 2010a, b), while SCMR indicates the nitrogen status.

Phenotype- link with yield

A frame for drought research



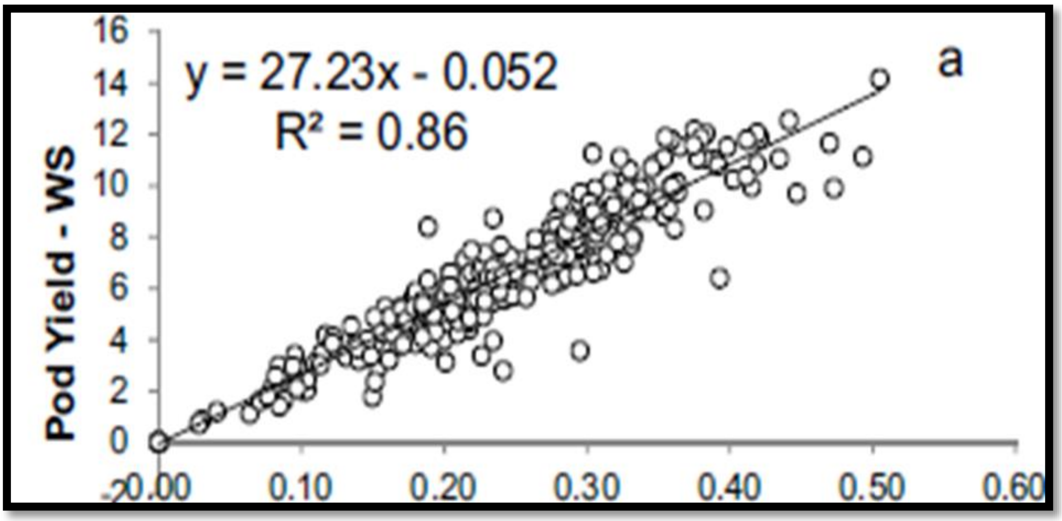
Yield = WU x TE x HI x M
(Passioura, 1977)

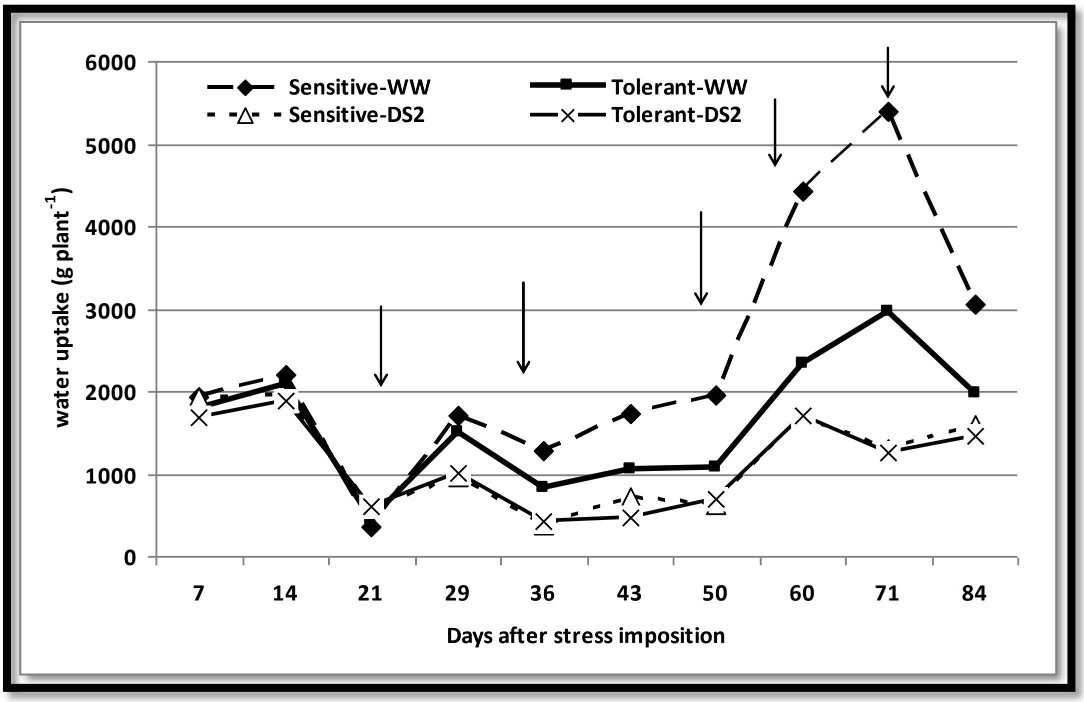
High-throughput Lysimetric system for TE measured gravimetrically throughout the crop life cycle.

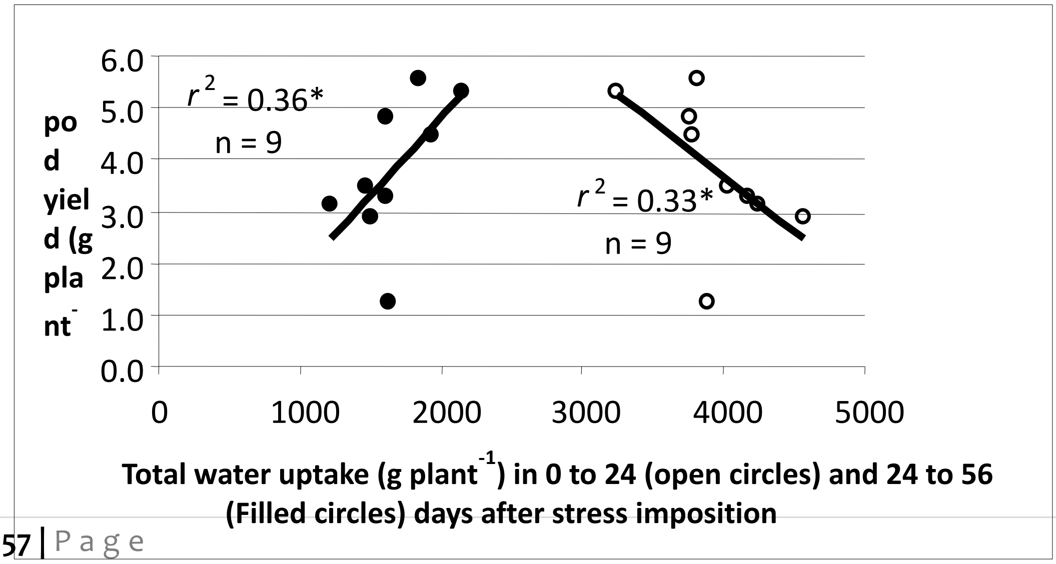
Plant water use and Seed yield

Transpiration efficiency (TE) is an important trait for drought tolerance in peanut (Arachis hypogaea L.). The variation in TE was assessed gravimetri- cally using a long time interval in nine peanut genotypes (Chico, ICGS 44, ICGV 00350, ICGV 86015, ICGV 86031, ICGV 91114, JL 24, TAG 24 and TMV 2) grown in lysimeters under well-watered or drought conditions. Transpiration was measured by regularly weighing the lysimeters, in which the soil surface was mulched with a 2-cm layer of polythene beads. TE in the nine genotypes used varied from 1.4 to 2.9 g kg-1 under well-watered and 1.7 to 2.9 g kg-1 under drought conditions, showing consistent variation in TE among genotypes. A higher TE was found in ICGV 86031 in both well-watered and drought conditions and lower TE was found in TAG-24 under both water regimes. Although total water extraction differed little across genotypes, the pattern of water extraction from the soil profile varied among genotypes. High water extraction within 24 days following stress imposition was negatively related to pod yield (r2 = 0.36), and negatively related to water extraction during a subsequent period of 32 days (r2 = 0.74). By contrast, the latter, i.e. water extraction during a period cor- responding to grain filling (24 to 56 days after flowering) was positively related to pod yield (r2 = 0.36). TE was positively correlated with pod weight (r2 = 0.30) under drought condition. Our data show that under an intermittent drought regime, TE and water extraction from the soil profile during a period corresponding to pod filling were the most important components.

Fig.2: (a) Variation and relationship of groundnut genotype under irrigated and water stress condition for pod yield; (b) water uptake kinetics during intermittent dry spells: (c) pod yield in relationship with water uptake during flowing and seed filling stages of groundnut.


y = 27.23x - 0.052
R² = 0.86
a
Pod Yield - WS
16
14
12
10
8
6
4
2
0
-20.00
0.10
0.20
0.30
0.40
0.50
0.60


Sensitive-WW
Sensitive-DS2
Tolerant-WW
Tolerant-DS2
water uptake (g plant-1)
6000
5000
4000
3000
2000
1000
0
7
14
21
29
36
43
50
60
71
84
Days after stress imposition


pod yield (g plant-
6.0
5.0
4.0
3.0
2.0
1.0
0.0
r² = 0.36*
n = 9
r² = 0.33*
n = 9
0
1000
2000
3000
4000
5000
Total water uptake (g plant-1) in 0 to 24 (open circles) and 24 to 56 (Filled circles) days after stress imposition

TE and Surrogates

Surrogates for TE (specific leaf area, SLA, and SPAD chlorophyll meter readings,SCMR) never showed any significant correlation to TE measurements. Therefore, TE is an important fac-tor explaining yield differences in groundnut under high VPD environments, suggesting that stomatalregulation under high VPD, rather than high photosynthetic rate as proposed earlier, may have a key roleto play in the large TE differences found, which open new opportunities to breed improved groundnutfor high VPD.

Water use and Roots

The maximization of water uptake is essential for growth and production under limited water availability. In several crops, adaptation to drought is closely associated with root development, which provides plants with a better water extraction ability (Jongrungklang et al. 2011). Most of the work performed on roots so far has relied on the basic underlying assumption that rooting differences in depth, length density or weight will result in higher water uptake and then in higher yield.

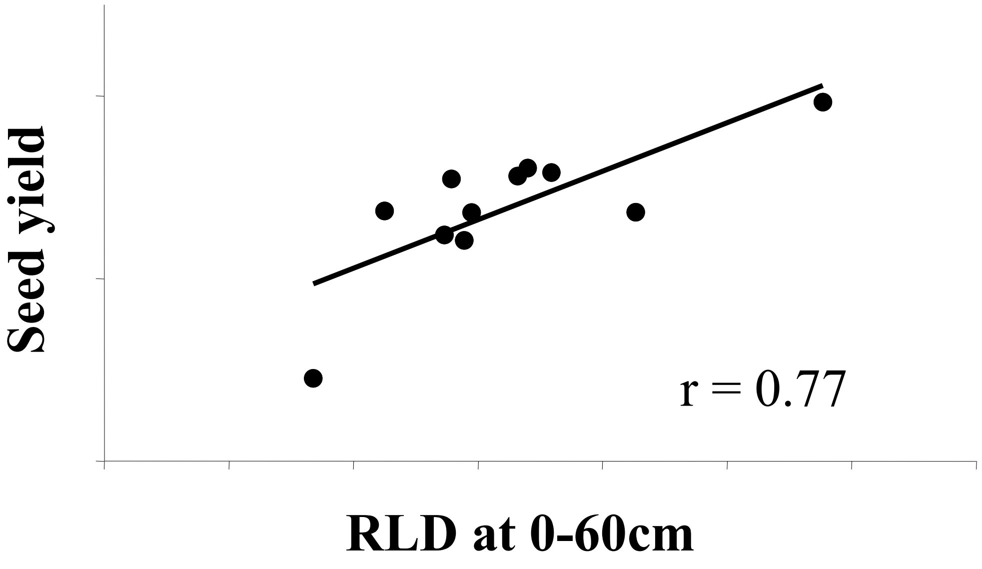
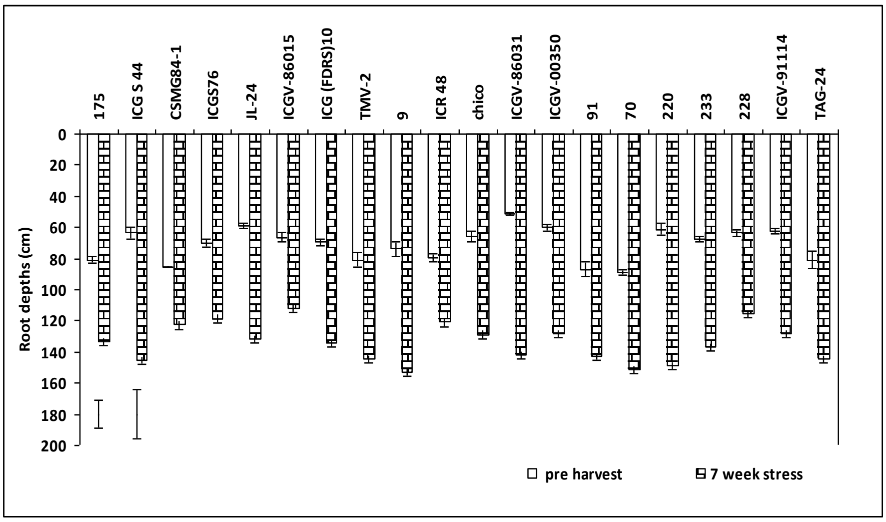
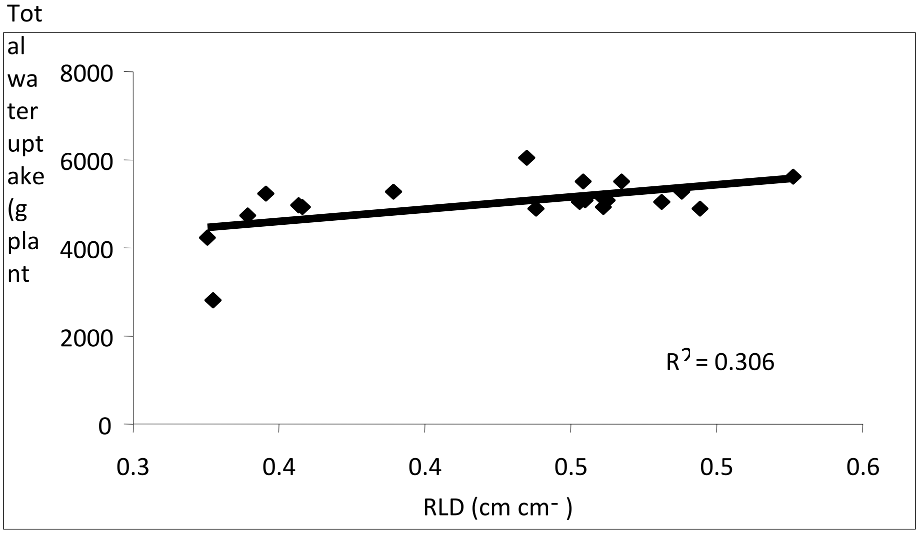


Fig. 3: Water uptake is crucial during key stages such as flowering and grain filling (Boyer and Westgate 2004; Vadez et al. 2007b), and small differences in water uptake at these stages can bring large yield benefits in groundnut (Boote et al. 1982; Ratnakumar et al. 2009) and other crops (Zaman-Allah et al. 2011).

Fig.4 : Variation of rooting depth at different layers of soil profile in groundnut genotypes after seven weeks of water stress imposition by withholding irrigation. Data are the means (± SE) of five replicated plants for each genotype. Bar indicates LSD; Relationship between RLD and total water uptake. (Ratnakumar and Vadez 2012)





Water Use and canopy temperatures

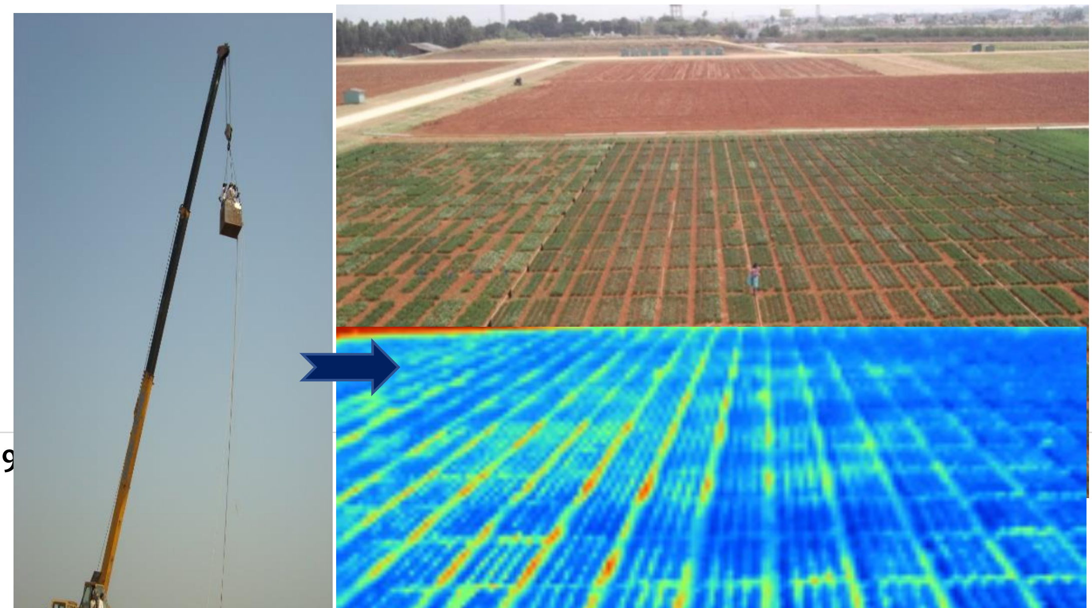


Fig.5**:** *Field level capturing of canopy temperatures in figure.* Plant water statues can also measure by quantifying the canopy temperatures using IR camera.

- Root depth and RLD did not discriminate tolerant from sensitive genotypes and related poorly to net water extraction, suggesting that the measurement of morphological root attributes may not be a research priority.
- Tolerance to drought was mostly explained by the capacity to maintain reproductive processes success.
- Smaller canopy genotypes are prepared, while larger canopy would lead to higher water use during drying cycles and then more damaging consequences on the reproductive processes.
- Water is crucial for plant at the time of seed filling and flowering.

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5. Pest Challenges and Management Strategies in Oilseed Crops Under Climate Change Scenario

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According to Intergovernmental Panel on Climate Change (IPCC), climate change is defined as "change in climate over time, either due to natural variability or as a result of human activity" (IPCC, 2001). While rise in sea levels, increased cyclonic activity, etc. are the consequences of global warming, changes in the temperature, atmospheric carbon dioxide concentrations, precipitation, etc. will have serious implications to agriculture and in particular damage caused by insect pests. Apart from these major factors, increase in the frequency and severity of extreme weather events including droughts, windstorms, and floods also disrupt natural predator-prey relationships threatening agricultural productivity at large. The last assessment report from IPCC predicted an average rise in mean temperature from 1.1°C to 6.4°C by 2100 (IPCC, 2007). Global temperature has been steadily rising since 1900 with an increase of about 1°C since then. World agriculture is facing a serious threat due to global warming and developing countries suffer more than the richer nations. Developing countries are predicted to suffer 10-25% reduction in agricultural productivity by 2080s. Because of climate change, Indian agriculture is doubly vulnerable. More than 60% of India's cultivated land are rainfed and may have serious impact due to climate change, Further, more than 80% of the Indian farmers are still small and marginal and have lesser capacity to cope up with climate change. Though the greatest increase occurred in northwestern America, India's temperature has increased between 0.2°C and 1°C. The mean temperature in India is projected to increase up to 1.7ºC in *kharif* (July to October) and up to 3.2º C during *rabi* (November to March) season, while the mean rainfall is expected to increase by 10 per cent by 2070 (Gupta, 2011). The Asia-Pacific region is to face the worst impacts of climate change with an estimated grain loss to the tune of 50% (wheat), 17% (rice) and 6% (maize) (ADB, 2009).

Insects are cold-blooded organisms - the temperature of their bodies is approximately the same as that of the environment. Therefore, temperature is probably the single most important environmental factor influencing insect behavior, distribution, development, survival, and reproduction. Anthropogenic CO_2 is almost twice more important for temperature increase than other long-lived greenhouse gases combined. Although increased CO_2 should not directly deleteriously affect insects, the temperature increases driven by the increase in anthropogenic CO_2 already affect insects in profound ways including their distribution, nutrition, phenology and role as disease vectors. The article discusses the impact of climate change on insect pests and Impact of climate change on insect pests, pest challenges and management strategies in oilseed crops under changing climate scenario.

I. Impacts of climate change on insect pests:

Effects of elevated CO_2 on insect pests: In general, host plants grown under elevated CO_2 are less nutritious to insect herbivores, which can affect their behavior and performance. Phenotypic host-plant changes typically make leaf material eaten by insects less nutritious. As a consequence, insects have a more difficult time converting the food they eat into biomass. In order to mitigate the effects of less nutritious food, insect herbivores often consume more. Insect herbivore performance is positively correlated with leaf nitrogen concentrations. Zvereva and Kozlov (2010) reported that the leaf nitrogen content decreased for mustard and collard grown under elevated CO_2. Leaf chewing insect herbivore performance is positively correlated with leaf water content. Decrease in leaf water contents was observed under elevated CO_2 for both mustard and collard. Plants can also defend themselves mechanically, either by having tough leaves or by structures such as leaf trichomes. Levels of mechanical defense are negatively correlated with herbivore performance. Elevated CO_2 increased trichome densities on radish. Several studies, mostly considering leaf toughness, leaf thickness, and specific leaf weight, have also observed increases in mechanical defense due to elevated CO_2. Hamilton (2005) reported higher percent leaf damage or consumption due to cabbage white butterfly fed either mustard or collard grown under elevated CO_2. Similar results have been obtained in leaf miners on a variety of woody species. Zvereva and Kozlov (2010) detected a significant negative effect of elevated CO_2 on insect herbivore performance. They observed that overall herbivore communities were lower on plants grown under elevated CO_2 vs. ambient CO_2. This is likely in part due to higher mortality rates due to both parasitoids and other natural enemies. Natural enemies are thought to have better success under elevated CO_2 because their prey are more apparent. Insects typically take longer to develop, making them more apparent in time to natural enemies. Higher consumption rates also cause increased leaf damage and increased frass production, both cues to natural enemies.

Hamilton et al. (2005) measured levels of herbivory in soybean grown in ambient air and air enriched with CO_2 or O_3 using free air gas concentration enrichment (FACE). Under open-air conditions and exposure to the full insect community, elevated CO_2 increased the susceptibility of soybeans to herbivory early in the season, whereas exposure to elevated O_3 seemed to have no effect. In the region of the canopy exposed to high levels of herbivory, the percentage of leaf area removed increased from 5 to more than 11% at elevated CO_2. They found no evidence for compensatory feeding at elevated CO_2 where leaf nitrogen content and C:N ratio were unaltered in plants experiencing increased herbivory. However, levels of leaf sugars were increased by 31% at elevated CO_2 and coincided with a significant increase in the density of the invasive species *Popillia japonica* (Japanese beetle). In two-choice feeding trials, Japanese beetles and Mexican bean beetles (*Epilachna varivestis*) preferred foliage grown at elevated CO_2 to foliage grown at ambient CO_2. Hence, the increased level of sugar in leaves grown at elevated CO_2 may act as a phagostimulant for the Japanese beetle.

Effects of elevated temperature on insect pests: Many of the effects of increased temperature on insect performance have to do with the direct effects of temperature on insects. Because insects are exothermic, they tend to be more active under warmer conditions. A typical effect of elevated temperature is therefore to increase consumption rates and therefore decrease the time to pupation, making them less apparent to natural enemies and in some cases increasing the potential number of generations per season. It has been estimated that with a 2^{o} C temperature increase insects might experience one to five additional life cycles per season (Yamamura & Kiritani 1998). Elevated temperatures increase gypsy moth performance, both decreasing its development time and increasing its survival rate (Williams et al. 2003). However the survival rate of another member of its genus, the nun moth, is very different under increased temperatures. If gypsy moths react more favorably to future environments than competitors, they may become more prone to outbreak. Elevated temperatures (on the scale of expected global warming) can also have direct effects on plant phenotypes, but not typically to the extent that elevated CO_2 has, and those factors affected (like total nonstructural carbohydrates, starches, and sugars) don't typically affect insect herbivores as much as host-plant characteristics affected by elevated CO_2.

Temperature may change gender ratios of some pest species such as thrips (Lewis 1997) potentially affecting reproduction rates. Insects that spend important parts of their life histories in the soil may be more gradually affected by temperature changes than those that are above ground simply because soil provides an insulating medium that will tend to buffer temperature changes more than the air (Bale et al. 2002). Lower winter mortality of insects due to warmer winter temperatures could be important in increasing insect populations (Harrington et al. 2001). Insect species diversity per area tends to decrease with higher latitude and altitude (Andrew & Hughes 2005), meaning that rising temperatures could result in more insect species attacking more hosts in temperate climates (Bale et al. 2002).

Effect of changes in Rainfall pattern on insect pests: Early and timely planting become more uncertain under climate change. During the 2009 rainy season, delay in onset of monsoons by 45 days resulted in delayed plantings of pigeonpea that are prone to damage by *Helicoverpa armigera* and caused heavy damage (Sharma, 2010). As with temperature, precipitation changes can impact insect pest predators, parasites, and diseases resulting in a complex dynamic. Fungal pathogens of insects are favored by high humidity and their incidence would be increased by climate changes that lengthen periods of high humidity and reduced by those that result in drier conditions. Some insects are sensitive to precipitation and are killed or removed from crops by heavy rains, this consideration is important when choosing management options for onion thrips (Reiners and Petzoldt, 2005).

II. Direct and indirect effects of climate change on insect pests

Expansion of host range: There are indications of shift of insect pests of plantation crops to new crops and new areas. The rhinoceros beetle, *Oryctes rhinoceros* (Linnaeus) is an established pest of coconut palms in India. Quite recently, it has become a problem for oil palm in southern states of India. The incidence of the pest in oil palm plantations closer to natural forest areas has been noticed at many places.

Extension of geographical range of certain pests: The mealy bug, *P. solenopsis* whichwas observed for the first time on cotton in USA in 1991 noticed on *Solanum muricatum* in Chile during 2002, and extended to tomato in Brazil during 2005. During 2006, *P. solenopsis* appeared for the first time on cotton crop in Punjab and caused severe losses in Ferozepur, Muktsar and Bhatinda districts. Since then, *P. solenopsis* is a serious pest in several states of India and extending its host range widely. Tea mosquito bug, *Helopeltis antonii* Signoret is a serious constraint in cashew (west coast-Kerala, Karnataka, and east coast-Tamil Nadu). Cashew tracts of Andhra Pradesh, West Bengal and Orissa are free from this pest. The hot spot areas of the bug across the cashew tract of the whole country have been demarcated, taking into consideration the optimum temperature during flushing and following stages. The pest may spread to new areas under current scenario of climate change and states like Andhra Pradesh, West Bengal and Orissa may come under this pest attack in the changed situation.

Rapid population growth: Understanding the shifts that occurred in rice crop can provide a broader perspective of the shifting pest trends. Before green revolution, stem borer, gall midge, rice hispa, whorl maggot, cut worm and thrips were considered as major pests of rice. But, today, rice yellow stem borer, *Scirpophaga incertulas* (Walker), brown planthopper, *Nilaparvata lugens* (Stal), whitebacked planthopper, *Sogatella furcifera* (Horvath), leaf folder *Cnaphalocrocis medinalis* (Linnaeus), gall midge, *Orseolia oryzae (*Wood-Mason), green leafhopper, *Nephotettix virescens* (Distant) and gundhi bug *Leptocorisa* spp., have assumed National significance. Whorl maggot, *Hydrellia* spp., rice hispa, *Dicladispa armigera*, climbing cutworm, *Mythimna separata* Walker, swarming caterpillar, *Spodoptera mauritia* Boisduval, panicle mite, *Steneotarsonemus spinki* and thrips, *Stenchaetothrips biformis* have attained regional significance.

Minor pests becoming major pests: Stem borer incidence was low upto 1970s, moderate till 1975 and severe and widespread from 1980 onwards and still remains as a major rice pest. BPH not considered as a pest till 1970s assumed major pest status from 1990s to till date. Moderate incidence due to WBPH is reported since 2000 and it has assumed serious proportions in the last decade, particularly in irrigated ecologies. Leaf folder which was moderate till eighties, has become a serious pest in the recent decades. Likewise in cotton, American and spotted bollworms attained secondary pest status, and tobacco caterpillar, pink bollworm, mirids and mealy bugs are emerging as major pests. Adoption of Bt cotton has not only changed the cultivation profile, but also the pest scenario. While there is a decline in the pest status of bollworms; the sap feeders, viz. aphids, jassids, mirids and mealy bugs are emerging as serious pests (Vennila, 2008). Recently, mirid bugs, *Ragmus* spp. and *Creontiades biseratense* (Distant) appeared in epidemic form in South India. Also, some of the minor pests like thrips, *Thrips tabaci* Linderman; shoot weevil, *Alcidodes affaber* Aurivillius and stem weevil, *Pempherulus affinis* (Faust) are becoming serious on Bt cotton.

Increased risk of invasion by migrant pests: The mealy bug, *P. solenopsis* whichwas observed for the first time on cotton in USAwere found on *Solanum muricatum* in Chile and tomato in Brazil. During 2006, *P. solenopsis* appeared for the first time on cotton crop in Punjab and caused severe losses in Ferozepur, Muktsar and Bhatinda districts. Since then this pest has spread to several states like Haryana, Rajasthan, Maharashtra and Gujarat and southern states. Besides cotton, *P. solenopsis* has been recorded on several economic crops like okra, tomato, brinjal, chilli, grape, fig, datepalm, apple, avocado, banana, citrus, etc.

Various species of mealy bugs have started appearing in serious proportions on field crops, vegetables, fruits and ornamentals. In fact, mealy bugs have become indicator insects for the current ecosystem alterations due to slow changes in climate during the period from 2002 to 2005. Among these, *Phenacoccus solenopsis* Tinsley on cotton and *Paracoccus marginatus* Williams and Granara de Willink on papaya have become quite serious. The papaya mealy bug, *P. marginatus,* has become quite alarming in Tamil Nadu, challenging the pesticides or other IPM measures.

In the past 10 years (2008-2018), 12 invasive or alien pests invaded Indian geographical boundaries or have been formally reported. More such examples of pest invasion in India include sugarcane wolly aphid, *C. lanigera*; coconut eriophyiid mite, *Aceria guerreronis* Keifer; coffee berry borer, *Hypothenemus hampei* (Ferrari); sapota seed borer, *Trymalitis margarias* Meyrick; Spiralling whitefly, *Aleurodicus disperses* Russell; Serpentine leafminer, *Liriomyza trifolii* (Burgess); Papaya mealybug, *Paracoccus* marginatus; South American tomato leaf miner, *Tuta absoluta*; Rugose spiraling whitefly, *Aleurodicus rugioperculatus* and Fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae).

Impact on arthropod diversity and extinction of species: Main effects of climate change on arthropod diversity include decreased abundance of predators leading to increased herbivory (Zvereva and Kozlov, 2010). Thus, any decrease in the arthropod diversity will directly affect the terrestrial ecosystems. Extreme events like drought would drastically reduce the diversity and upset the natural balance of the ecosystems and their functioning. The diversified arthropod community that exist in agroecosystems are responsible for natural balance between herbivores and natural enemies. Climate change can bring unpredictable alterations in this intricate relationships upsetting the entire agroecosystem functioning.

Change in the host phenology and resultant changes in the pest cycle: The diamondback moth, *Plutella xylostella* (Linnaeus), has consistently remained the most destructive insect pest of crucifer vegetables worldwide. Currently, this insect has become resistant to almost all classes of insecticides used against it in south-east Asian countries. An outbreak of diamondback moth, *Plutella xylostella* (Linnaeus) on cauliflower was reported in North India during 2006. The infestation increased gradually from first fortnight of August and lead to total loss (100 % yield loss) of the crop. Moreover, the current climatic change may lead to increase in severity of this pest in many regions of the world. For instance, *P. xylostella* may have two additional generations per year in Japan.

III. Impacts of climate change on insect pest management

In addition to effects on insects, influence of climate change on insect pest management methods were reported (Sharma, 2010), which are described below

Effect of climate change on the effectiveness of biopesticides and synthetic insecticides: Natural plant products, entomopathogenic viruses, fungi, bacteria, and entomopathogenic nematodes, and synthetic pesticides are highly sensitive to the environment. Increase in temperatures and UV radiation, and a decrease in relative humidity may render many of these control tactics to be less effective, and such an effect will be more pronounced on natural plant products and the biopesticides (Isman 1997). Rapid dissipation of insecticide residues due to increases in temperature and precipitation will require more frequent application of insecticides.Disappointingly, some pesticides like pyrethroids, spinosad, etc. are less effective at higher temperatures.

Effect of climate change on expression of resistance to insect pests: Climate change may alter the interactions between the insect pests and their host plants (Sharma et al. 2010). Climate change may also change the flowering times in temperate regions, leading to ecological consequences such as introduction of new insect pests, and attaining of a pest status by non-pest insects (Willis et al. 2008). However, many plant species in tropical regions have the capability to withstand the phenological changes as a result of climate change. Climate change may result on breakdown of resistance to certain insect pests. Chemical composition of some plant species changes in direct response to biotic and abiotic stresses as a result, their tissues less suitable for growth and survival of insect pests (Sharma 2002). However, problems with new insect pests will occur if climatic changes favor the introduction of insect susceptible cultivars or crops. The introduction of new crops and cultivars to take advantage of the new environmental conditions is one of the adaptive methods suggested as a possible response to climate change. Increased CO_2 may also cause a slight decrease in nitrogen-based defenses (e.g., alkaloids) and a slight increase in carbon-based defenses (e.g., tannins). Acidification of water bodies by carbonic acid (due to high CO_2) will also affect the floral and faunal diversity (Gore 2006).

Effect of climate change on effectiveness of transgenic crops for pest management: Cotton bollworm, *Heliothis virescens* (F.) destroyed *Bt*-transgenic cottons due to high temperatures in Texas, USA (Kaiser, 1996). Similarly, *H. armigera* and *H. punctigera* (Wallen.) destroyed the *Bt*-transgenic cotton in the second half of the growing season in Australia because of reduced production of *Bt* toxins (Hilder and Boulter 1999). Cry1Ac levels in transgenic plants decrease with the plant age, resulting in greater susceptibility of the crop to insect pests during the later stages of crop growth (Greenplate et al. 2000; Adamczyk et al. 2001; Kranthi et al. 2005). Possible causes for the failure of insect control in transgenic crops may be due to inadequate production of the toxin protein, effect of environment on transgene expression, *Bt*-resistant insect populations, and development of resistance due to inadequate management (Sharma and Ortiz 2000). It is therefore important to understand the effects of climate change on the efficacy of transgenic plants for pest management.

IV. Status of insect pests in oilseed crops in the scenario of climate change:

Groundnut: The crop is infested by a large number of insect pests on all the phenophases of its growth. Among the insect pests, defoliators such as the groundnut leaf miner (*Aproaerema modicella*), tobacco caterpillar (*Spodoptera litura*), red hairy caterpillars (*Amsacta albistriga* and *A. moorei*), Bihar hairy caterpillar (*Spilarctia obliqua*) and gram pod borer (*Helicoverpa armigera*) are most important yield barriers in India. Aphids (*Aphis craccivora*), leafhoppers (*Empoasca kerri* and *Balclutha hortensis*) and thrips (*Thrips palmi, Caliothrips indicus* and *Scirtothrips dorsalis*) are the major sucking pests. Apart from causing direct damage to the crop, aphids and thrips are vectors of important viral damage *viz*., Peanut Stripe Virus (PStV) and Peanut Bud Necrosis Disease (PBND), respectively. Among soil insect pests, white grub (*Holotrichia consanguinea* and *H. serrata)*, termite (*Odontotermes obesus*), wire worm (*Penthicoides seriatoporus*) and earwig (*Anisolabis anulipes* Luc.) are important (Thirumalaisamy and Nataraja 2015). Termites and root grubs may cause severe loss upto 100 per cent plants mortality in localized areas in rainfed situations. Leaf miner infests the crop during *kharif* and summer may cause yield losses of about 16-92 per cent (DAC 2014).

Soybean: About a dozen major insect pets attack the soybean crop. Yield losses due to these pests range from 25 to 100%. Major insect pests of national significance include stem fly (*Melanagromyza sojae*), tobacco caterpillar (*Spodoptera litura*), green semiloopers (*Chrysodeixis acuta*, *Gesonia gemma* and *Diachrysia orichalcea*), girdle beetle (*Obereopsis brevis*), gram pod borer (*Helicoverpa armigera*) and white fly (*Bemisia tabaci*). Whereas, major insect pests of regional significance include blue beetle (*Cneorane* spp.) in Western Madhya Pradesh; leaf miner (*Aproaerema modicella*) in Maharashtra and Karnataka; cotton grey weevil (*Myllocerus* spp.) in Delhi and Punjab; Bihar hairy caterpillar (*Spilarctia obliqua*) in Tarai region of Uttarakhand and Western Madhya Pradesh; leaf folder (*Hedylepta indicate*) in Karnataka, Maharashtra, Madhya Pradesh; pink pod borer (*Cydiaptychora* sp.) in Northern Karnataka and leaf defoliator (*Spodoptera exigua*) in Central and Western Madhya Pradesh (Sharma et al. 2014).

Rapeseed-mustard: Among insect pests attacking the crop, mustard aphid (*Lipaphis erysimi*), painted bug (*Bagrada hilaris*), mustard saw fly (*Athalia lugens proxima*)and leaf miner (*Chromatomyia horticola*)are of major concern. Average yield loss of 35 to 50 per cent has been observed due to the pest damage in mustard. Bihar hairy caterpillar (*Spilarctia obliqua*), cabbage head borer (*Hellulaundalis*), diamondback moth (*Plutellaxylostella*) and leaf webber

(*Crocidolomiabinotalis*) and termite (*Odontotermus obesus*) are also reported infesting mustard (Satyagopal et al. 2014).

Sunflower: Capitulum borer (*Helicoverpa armigera*), tobacco caterpillar (*Spodoptera litura*), whitefly (*Bemisia tabaci*), green leafhopper (*Amrasca biguttula biguttla*), Bihar hairy caterpillar (*Spilarctia obliqua*) and semilooper (*Thysanoplusia orichalcea*) have been reported as the major insect pests of sunflower in India (Basappa and Santhalakshmi Prasad 2005; Basappa 2011). Sunflower Stem borer, *Nupserha* sp. near *vexator* (Cerambycidae: Coleoptera) recorded as a new pest of sunflower in Latur region(Marathwada). Grub enters stem above collar region and bores upwards through internal pith tissue. Infested plants lodge during grain formation stage. Yield loss reported to be up to 31.0%. Chaffer beetle, *Gametis* (*Oxycetonia*) *versicolor* (Scarabaeidae: Coleoptera) recorded as a pest in Raichur, Karnataka during *kharif* season. Adults feed on soft stem below head region leading to rotting of infected portion and breaking of stem.

Safflower: Insect pests are the major constraints for safflower production in India and as many as 25 pests were reported to be of economic importance.Safflower aphid, *Uroleucon compositae* is the most destructive pest. The other economically important pests are safflower caterpillar (*Perigaea capensis*), gram pod borer (*Helicoverpa armigera*), Gujhia weevil (*Tanymecus indicus*) and capsule fly (*Acanthiophilus helianthi*) (Singh and Prasad, 2005).

Sesame: Leaf webber and capsule borer, *Antigastra catalaunalis* is the key pest causing heavy damage and lowering yield by 10-60% (Kumaraswamy et al. 2015). The other important pests include gall fly (*Asphondylia sesami*), til hawk moth (*Acherontia styx*), Bihar hairy caterpillar (*Spilarctia obliqua*) and leafhopper (*Orasius albicinctus*).

Castor: In India more than 107 species of insects and 6 species of mites are recorded on castor at different phenological stages of the crop. Among themcastor semilooper (*Achaea janata*), tobacco caterpillar(*Spodoptera litura*), shoot and capsule borer (*Conogathus punctiferalis*), leafhopper (*Empoasca flavescense*), thrips (*Retithrips siriacus*) and whitefly (*Trialeurodes ricini*) are of greater economic importance. In recent years serpentine leafminer (*Liriomyza* *trifolii*) is also becoming serious on the crop. Besides, several hairy caterpillars (*Spilarctia obliqua*, *Euproctis* spp., *Pericalia ricini*, *Amsacta albistriga*, *A. moorei*) andcastor slug caterpillar (*Parasa lepida*), castor gall fly (*Asphondylia ricini*), spiny caterpillar (*Ergollis merione*)and red spider mite (*Tetranychus telarius*)are also assumed regional importance and are sporadic pests. In recent years castor inflorescence thrips (*Scirtothrips dorsalis*) also attained a pest status by infesting the crop at flowering stage causing considerable loss to the crop especially in Gujarat. The polyphagous pest gram pod borer (*Helicoverpa armigera*)also cause considerable damage to castor crop by boring castor capsules apart from feeding on foliage (Basappa et al. 2010). The magnitude of the insect pests problem is quite high in Southern India where castor is grown mainly as rainfed crop, while it is low in Gujarat and Rajasthan under irrigated conditions (Lakshminarayana 2005). The avoidable yield losses due to insect pests on castor ranged from 29.1 to 50.9 per cent during *kharif* season, while the loss was higher (49.1 to 58.5%) during *rabi* season (Lakshminarayana and Duraimurugan 2014).

Linseed: Among 22 insect pests reported damaging the crop, only linseed bud fly (*Dasynuera lini*) has been considered as a national key pest as losses caused are very alarming. Green semilooper (*Thysanoplusia orichalcea*), gram pod borer (*H. armigera*), leaf miner(*Chromatomyia horticola*), thrips(*Caliothrips indicus*) and cutworm (*Agrotis ipsilon*) also cause considerable damage to the crop (Padmavathi et al. 2015).

Niger: Grasshoppers, *Pyrgomorpha bispinosa-conica* and *Chrotogonus trachypterus* species were found damaging seedlings. Niger caterpillar (*Condica conducta*), green semilooper (*Thysanoplusia orichalcea*), niger green bug (*Taylorilygus pallidulus*), tobacco caterpillar (*Spodoptera litura*), gram pod borer (*Helicoverpa armigera*), niger grain fly (*Dioxyna sororcula*), cutworm (*Agrotis ipsilon*) andBihar hairy caterpillar(*Spilarctia obliqua*)were found damaging niger crop at different phenological stages (Suresh et al. 2015).

Conclusion:

Species life history (evolutionary) adaptations may obscure our ability to detect species response to climate change -accordingly, species respond differently to changes in thermal environments. There are many interactions and it is extremely difficult to predict the impact of climate change on insect pests in the future, but we may expect an increase of certain primary pests as well as secondary pests and invasive species. The best economic strategy for farmers to follow is to use integrated pest management practices to closely monitor insect and disease occurrence. Keeping pest and crop management records over time will allow farmers to evaluate the economics and environmental impact of pest control and determine the feasibility of using certain pest management strategies or growing particular crops. Some of the potential adaptation strategies could be developing IPM with more emphasis on biological control and changes in cultural practices, pest forecasting using recent techniques such as simulation modeling and alternate production techniques.

References:

Adamczyk Jr., J.J., Adams, L.C., and Hardee, D.D. 2001. Field efficacy and seasonal expression profiles for terminal leaves of single and double *Bacillus thuringiensis* toxin cotton genotypes. *Journal of Economic Entomology* 94: 1589-1593.

ADB, 2009. Impact of Climate change on Agriculture-Factsheet on Asia” in Asian Development Bank, *Addressing Climate Change in the Asia and Pacific Region*, 2009 http://www.ifpri.org/publication/impact-climate-change-agriculture-factsheet-asia Accessed on 01 February, 2012.

Andrew, N.R. and L. Hughes. 2005. Diversity and assemblage structure of phytophagous Hemiptera along a latitudinal gradient: predicting the potential impacts of climate change. Global Ecol Biogeogr. 14:249-262.

Bale, J.S., Masters G.J., Hodkinson I.D., Awmack, C., Bezemer T.M., Brown V.K., Butterfield J., Buse A., Coulson J.C., Farrar J., Good J.E.G., Harrington R., Hartley Z., Jones T.H., Lindroth R.L., Press M.C., Symrnioudis I., Watt A.D., Whittaker J.B. (2002): Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. Global Change Biology, **8**: 1–16.

Basappa, H 2011. Biodiversity of biocontrol agents in sunflower ecosystem. Journal of Biological Control 25: 182-192.

Basappa, H, Santhalakshmi Prasad M 2005. Insect pests and diseases of sunflower and their management, Directorate of Oilseeds Research, Hyderabad, India. p 70.

DAC, 2014. Status Paper on Oilseeds, Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India. pp 185.

Gore, A. 2006. *An Inconvenient Truth: The Planetary Emergency of Global Warming and What We Can Do About it*. Emmaus, Pennsylvania, USA: Rodale Publisher.

Greenplate, J.T., Penn, S.R., Shappley, Z., Oppenhuizen, M., Mann, J., Reich, B., and Osborn, J. 2000. Bollgard II efficacy: quantification of total lepidopteran activity in a 2-gene product. In: *Proceedings, Beltwide Cotton Conference* (Dugger, P. and Richter, D., eds.). Memphis, Tennesse, USA: National Cotton Council of America. pp. 1041-1043.

Gupta, H.S. 2011. Climate change and Indian Agricultuture: Impacts, mitigation and adaptation. In: Proceedings of X Agricultural Science Congress on soil, plant and animal health for enhanced and sustained agricultural productivity. 10-12 February, NBFGR, Lucknow. Pp.73-81.

Hamilton, J G., Orla Dermody, Mihai Aldea, Arthur R. Zangerl, Alistair Rogers, May R. Berenbaum, and Evan H. Delucia. 2005. Anthropogenic Changes in Tropospheric Composition Increase Susceptibility of Soybean to Insect Herbivory. Environ. Entomol. 34(2): 479 -485.

Harrington, R., Fleming, R.A. & Woiwod, I.P. 2001. Climate change impacts on insect management and conservation in temperate regions: can they be predicted? *Agricultural and Forest Entomology*, 3: 233-240.

Hilder, V.A. and Boulter, D. 1999. Genetic engineering of crop plants for insect resistance - a critical review. *Crop Protection* 18: 177-191.

IPCC, 2007. The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

IPCC, 2001. Climate change 2001: the scientific basis, Contribution of working group I to the third assessment report of the intergovernmental panel on climate change (IPCC). Cambridge University Press, Cambridge http://www.grida.no/climate/ipcc_tar/

Isman, M.B. 1997. Neem and other botanical pesticides: Barriers to commercialization. *Phytoparasitica* 25: 339-344.

Kaiser, J. 1996. Pests overwhelm Bt cotton crop. *Nature* 273: 423.

Kranthi, K.R., Naidu, S., Dhawad, C.S., Tatwawadi, A., Mate, K., Patil, E., Bharose, A.A., Behere, G.T., Wadaskar, R.M., and Kranthi, S. 2005. Temporal and intra-plant variability of Cry1Ac expression in Bt-cotton and its influence on the survival of the cotton bollworm, *Helicoverpa armigera* (Hubner) (Noctuidae: Lepidoptera). *Current Science* 89: 291-298.

Kumaraswamy HH, Jawaharlal J, Ranganatha ARG, Chander Rao S 2015. Safe sesame (*Sesamum indicum* L.) production: Perspectives, practices and challenges. J. Oilseeds Res., 32: 1-24.

Lakshminarayana M 2005. Studies on antixenosis in castor, Ricinus communis L. against major insect pests. I. J. Plant Protection 33: 216-219.

Lakshminarayana M, Duraimurugan P 2014. Assessment of avoidable yield losses due to insect pests in castor (*Ricinus communis* L.). Journal of Oilseed Research 31: 140-144.

Lewis T (1997) Major crops infested by thrips with main symptoms and predominant injurious species (Appendix II). Thrips as Crop Pests (ed. by T Lewis), pp. 675–709. CAB International, New York, NY, USA.

Padmavathi P, Alivelu K, Prasad RD, Duraimurugan P, Murthy IYLN, Suresh M, Khadtare SV, Shinde SK 2015. Handbook on Technologies for Oilseeds Production in Maharashtra. ICAR-Indian Institute of Oilseeds Research, Hyderabad, pp 108.

Reiners, S and C. Petzoldt (eds). 2005. Integrated Crop and Pest Management Guidelines for Commercial Vegetable Production. Cornell Cooperative Extension publication #124VG http://www.nysaes.cornell.edu/recommends.

Satyagopal K, Sushil SN, Jeyakumar P, Shankar G, Sharma OP, Boina D, Sain SK, Chattopadhyay D, Ram Asre, . Kapoor KS, Sanjay Arya, Subhash Kumar, Patni CS, Chattopadhyay C, Pandey A, Pachori R, Thakare AY, Basavanagoud K, Halepyati AS, Patil MB, Sreenivas AG (2014). AESA based IPM package for Mustard/Rapeseed. pp 49.

Sharma AN, Gupta GK, Verma RK, Sharma OP, Someshwar Bhagat, Amaresan N, Saini MR, Chattopadhyay C, Sushil, Ram Asre SN, Kapoor KS, Satyagopal K, Jeyakumar P (2014) Integrated Pest Management Package for Soybean. pp 41.

Sharma, H.C. 2010. Effect of climate change on IPM in grain legumes. In: *5th International Food Legumes Research Conference (IFLRC V), and the 7th European Conference on Grain Legumes (AEP VII),* 26 – 30 th April 2010, Anatalaya, Turkey.

Sharma, H.C. and Ortiz, R. 2000. Transgenics, pest management, and the environment. *Current Science* 79: 421-437.

Sharma, H.C., Srivastava, C.P., Durairaj, C., and Gowda, C.L.L. 2010. Pest management in grain legumes and climate change. In: *Climate Change and Management of Cool Season Grain Legume Crops* (Yadav, S.S., McNeil, D.L., Redden, R. and Patil, S.A., eds.). Dordrecht, The Netherlands: Springer Science + Business Media. pp.115-140.

Sharma, H.C., Sullivan, D.J., and Bhatnagar, V.S. 2002. Population dynamics of the Oriental armyworm, *Mythimna separata* (Walker) (Lepidoptera: Noctuidae) in South-Central India. *Crop Protection* 21: 721- 732.

Singh V, Prasad RD (2005) Insect pests and diseases of safflower and their management.Directorate of Oilseeds Research, Hyderabad. p 48.

Suresh G, Debori KL, Narayanan G, Jain NK, Duraimurugan P, Patel CJ, Bhagwat Rathore, Padmavathi P, Satishkumar GD, Murthy IYLN (2015) Handbook on Technologies for Oilseeds Production in Gujarat, ICAR-Indian Institute of Oilseeds Research, Hyderabad, pp 124.

Willis, C.G., Ruhfel, B., Primack, R.B., Miller, Rushing, A.J., and Davis, C.C. 2008. Phylogenetic patterns of species loss in Thoreau’s woods are driven by climate change. *Proceedings, National Academy of Sciences, USA* 105: 17029-17033.

Yamamura, K. and K. Kiritani. 1998. A simple method to estimate the potential increase in the number of generations under global warming in temperate zones. Appl. Ent. and Zool. 33. 289–298.

Zvereva, E.L. and Kozlov, M.V. 2010. Responses of terrestrial arthropods to air pollution: a metaanalysis. *Environmental Science Pollution Research International* 17: 297-311.

6. Biosynthetic pathways in oilseeds in the wake of climate change

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Introduction

Oilseeds have been the backbone of agricultural economy of India since long. Indian vegetable oil economy is the fourth largest in the world next to USA, China and Brazil. Oilseed crops play the second important role in the Indian agricultural economy next to food grains in terms of area and production. The average productivity of oilseeds in India is around 1.2 t/ha, which is far below that of the developed countries (2.5-3.0 t/ha) and of the world average (2.15 t/ha). The Indian climate is suitable for the cultivation of oilseed crops; therefore, large varieties of oilseeds are cultivated here. But they are grown under energy-starved conditions in India and about 80 percent of the area under oilseeds is rainfed comprising mostly marginal and sub-marginal lands with soils of poor fertility. The major annual oilseeds cultivated in our country are groundnut, rapeseed and mustard, castorseed, sesamum, nigerseed, linseed, safflower, sunflower and soybean. At present, more than 26 million hectares of land is under oilseeds cultivation with an annual production of around 31 million tonnes.

The functional and nutritional values of different vegetable oils are dependent on the nature of the different fatty acids, which are incorporated like building blocks into the oil as triacylglycerides. The main fatty acids present in vegetable oils are palmitic acid (C16:0), stearic acid (C18:0), oleic acid (C18:1), linoleic acid (C18:2), linolenic acid (C18:3) and erucic acid (C22:1). Oilseeds/edible oils are sources for essential fatty acids namely alpha-linolenic acid (an omega-3 fatty acid) and linoleic acid (an omega-6 fatty acid).

Climatic anomalies play an important role in increasing the uncertainties in crop production especially under rainfed production system. Plant species, genotypes, temperature, environmental conditions, and management practices, in decreasing order, influence fatty acids profiles. It is the seed development period when oil accumulation takes place. It is this oil content and its composition which is an important trait for deciding the value of any oilseed crop going for food or industrial applications. Seed development is very sensitive to unfavorable abiotic conditions. Various abiotic stresses lead to a numerous undesirable qualitative as well as quantitative changes in fatty acid production. Precise knowledge of seed development for all oilseeds crops till maturity is required.All oilseeds are C_3 which make them highly susceptible to moisture-deficit stress and thus, will affect the productivity in sub-optimal conditions of cultivation. However, elevated CO_2 level (e[CO_2]) may improve rate of photosynthesis vis-à-vis biomass gain by decreasing the effect of photorespiration, increase in frequency and intensity of drought would offset the gain in photosynthesis. The timing of rains and crop-growing periods will also change and rainless period during the season will be very vital. Climate change is predicted to bring about increased temperatures across the world in the range of 1.6°C to as much as 6°C by 2050. Even high night temperatures which are showing an increasing trend support higher respiration process which is the reverse process of the photosynthesis. Dry matter accumulation takes place when photosynthesis is more than respiration which sustains the plant’s growth and development while vice versa retards the development process. The high night temperature threatens the sustainability of crop production both currently and in the future. Recent meteorological data indicated faster increases in night temperatures than day temperatures. Little is known about metabolic responses of oilseeds to high night temperature conditions.

Oil physical properties (e.g., fluidity) and metabolism are affected by its saturated fatty acids and poly unsaturated fatty acids composition. Unsaturated fatty acid enrichment over saturated fatty acids in edible oils is essential for better quality and human health. Varietal improvement for achieving targeted fatty acids composition and crop production practices including growing environment are vital to decide their shelf life, nutritional index and end use.

Free fatty acids which are highly undesirable in oil are the results of the breaking down (hydrolyzed) of the triacylglycerides (oil) by chemical or microbiological activity accelerated by environmental factors. Free fatty acids must be removed from oil during processing as they reduce the smoke point of frying fats and rapidly oxidize to give rancid flavors. Free fatty acid content is a reflection of seed quality and high free fatty acid content (> 1.0% as oleic acid) is a sign of seed damage and lower grade. There is an increasing trend to use edible oils as biofuels, especially biodiesel. Biodiesel is plant or animal fat or oil that has been chemically altered to form a mono-alkyl ester. This reduces the viscosity and melting point and brings it close to that of mineral oil. Modification of fatty acid composition has been a major goal of most of the breeding programs.

Fatty acid biosynthesis and triacylglycerol (TAG) bio-assembly occurs in developing embryos of oilseed plants (Figure 1). Fatty acid biosynthesis occurs in the plastid. Thioesterase (TE) catalyzes the hydrolysis of FA-ACP to generate free fatty acid (FFA) which may be transported across the inner plastidial envelope by the membrane protein fatty acid export 1 (FAX1). Long chain acyl-CoA synthetase (LACS) catalyzes the ATP-dependent formation of FA-CoA on the outside of the plastid. Fatty acids chains on FA-CoA may be elongated on the endoplasmic reticulum (ER) through elongase action. TAG assembly involves membrane metabolism in the ER. The FA-CoA pool serves as a source of activated FA moieties for a number of acyltransferases involved in glycerolipid biosynthesis. The sn-glycerol-3-phosphate (G3P) backbone for TAG bio-assembly can be produced from dihydroxy acetone phosphate (from glycolysis) through the catalytic action of sn-glycerol-3-phosphate dehydrogenase.

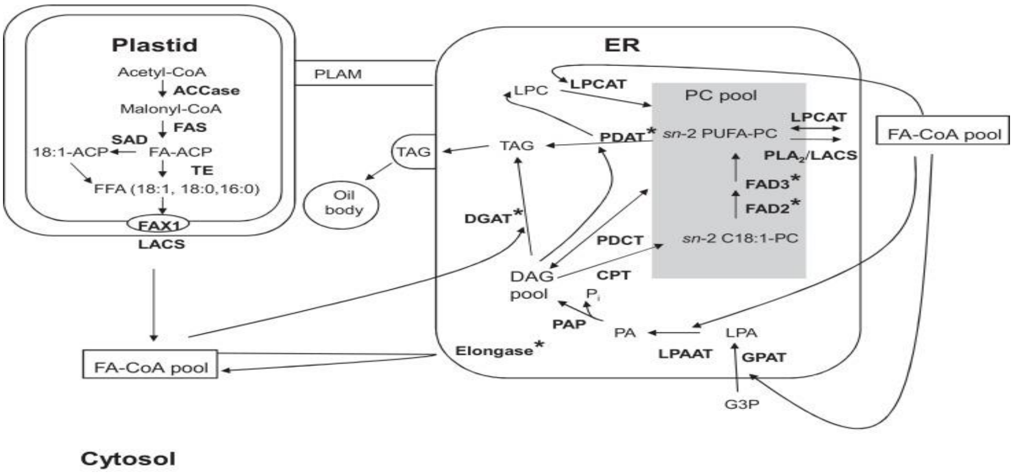

Fig.1: Fatty acid biosynthesis and triacylglycerol (TAG) bio-assembly in developing embryos in oilseeds: TAG production involves the sequential catalytic action of sn-glycerol-3-phosphateacyltransferase (GPAT), lysophosphatidic acyltransferase (LPAAT), phosphatidic acid phosphatase (PAP) and diacylglycerol acyltransferase (DGAT). sn-1,2-diacylglycerol (DAG) may be converted to phosphatidyl choline (PC) through the catalytic action of choline phosphotransferase (CPT). Formation of polyunsaturated fatty acids (PUFA) occurs at the level of PC with fatty acid desaturase FAD2 and FAD3 catalyzing the formation of C18:2 and C18:3, respectively. Phosphatidyl choline: diacylglycerol choline phosphotransferase (PDCT) catalyzes the transfer of the phosphocholine headgroup from PUFA-enriched PC to sn-2 C18:1-

DAG produced in the G3P pathway resulting in the formation of sn-2 PUFA-enriched DAG (to support formation of PUFA-enriched TAG). Phospholipid: diacylglycerol acyltransferase (PDAT) catalyzes the acyl-CoA-independent biosynthesis of TAG using PC as a FA donor in a process that may also channel PUFA into TAG. LPCAT catalyzes the reacylation of lysophosphatidyl choline (LPC) to produce PC and acyl-exchange at the sn-2 position of PC with the FA-CoA pool thereby enriching the FA-CoA pool in PUFA. The FA-CoA pool may also be enriched in PUFA through the catalytic action of phospholipase A2 (PLA2) followed by activation of FFA to form FA-CoA catalyzed by LACS. TAG produced through the catalytic action of DGAT or PDAT accumulates in the outer leaflets of the ER eventually pinching off in the form of acytosolic oil body. Plastid-associated endoplasmic reticulum membrane (PLAM) may provide biochemical continuity between the ER and plastid. Lipid biosynthetic enzymes which may be regulated by environmental effects are indicated with an asterisk. Additional abbrev: LPA—lysophosphatidic acid; PA—phosphatidic acid; Pi—inorganic phosphate

Impact of climatic variables on oil composition

Various abiotic stresses, such as temperature, drought, salt and elevated carbon dioxideresult in a series of morphological, physiological, biochemical and molecular alterations, which negatively influence plant growth, productivity yield and quality. Plants experience multiple effects of these stresses including physiological functions such as photosynthesis, respiration, nitrogen fixation, reproduction, and oxidative metabolism which is ultimately translated into oil content and given fatty acids composition. Temperature stress has the widest and most far-reaching effects on various crops leading to a severe reduction in yield potential. Most oilseed crops are currently grown at temperatures that match their threshold values; however, temperatures are expected to rise over the twenty-first century as a result of global warming and shifts may occur in production areas due to temperature changes beyond critical thresholds for growth, flowering, seed set, and oil production. Nevertheless, differences among oilseed crop cultivars to temperature extremes seem to be larger than for other abiotic stresses. Elevated CO_2 level may improve net rate of photosynthesis vis-à-vis biomass gain by decreasing the effect of photorespiration, increase in frequency and intensity of drought would offset the gain in photosynthesis.

One way these crop plants will respond to global climate change (GCC) is through environmentally induced shifts in phenotypes (i.e., phenotypic plasticity); therefore, understanding plastic responses is crucial for predicting and managing the effects of global climate change on current and future oilseed crops. These predicted changes in climate are expected to have fairly widespread impacts on agriculture, with poor countries in the south highlighted as being particularly vulnerable, having already weak economies, and limited institutional capacities to adapt. Changes in climate are likely to place new pressures on conservation of wild relatives and land races of oilseed crop species. Various studies carried out by the researchers indicate the response of oilseed crops to GCC is primarily dictated by a complex set of interactions to temperature, CO_2, solar radiation and precipitation. The challenge under GCC stress is to simultaneously optimize seed yield and maintain, if not increase, oil content, oil yield, protein yield, and optimize fatty acid profiles whether for food (PUFAs) or industry (SFAs). Broad effects of various types abiotic stresses on seed oil content and fatty acids composition in general in oilseeds crops is presented in Table 1.

Table 1: General effects of various types of stresses on seed oil content and fatty acids composition

Major Abiotic Stress	**Effect on oil content**	**Overall effect on fatty acids composition**
High Temperature	Decrease	Increase in C18:1, Decrease in C18:2 & C18:3
Drought	Decrease	Increase in C18:1, Decrease in C18:2
Salinity	Decrease	Increase in C18:1, Decrease in C18:2 &/ or C18:3
Elevated CO_2	Increase	Increase in C18:1 & C18:2
High Light	Increase	Increase in C18:1, Decrease in C18:2
High Oxygen	Decrease	Decrease in C18:1, Increase in C18:2, C18:3 & C20:1

Differences among plant species, rather than climate, may explain a large part of the relative abundance of common FAs in oilseed crops, while the role of genetics in regulating plastic response to GCC is well documented. In regional studies, the level of PUFAs increased with latitude and decreased with both mean annual temperature and precipitation; temperature's impact was more pronounced than that of precipitation. The contents of two PUFAs (oleic and linoleic) were reduced in response to cold climate and were inversely correlated with the contents of erucic acid; C22:1, which itself increased in cold climates in *B. juncea*. The elevation and geographical location of growing sites and their attendant temperature and solar radiation influenced the contents and ratios of several FAs within PUFAs and SFAs in *B. napus* and *C. sativa*. Fatty acid composition of sunflower seed lipids is determined by plant genotype and depending on it, this composition is more or less affected by environmental conditions such as light and temperature. High levels of oleic acid in oils are related to longer shelf life due to their higher stability and resistance to oxidation. Oil industry and sunflower producers can take advantage of the temperature effects on fatty acids synthesis by managing genotypes and sowing dates in order to have the best response for their needs.

Experiments performed to examine the variation in oil fatty acids composition of three normal oleic peanut market types (Virginia, Valencia, and Spanish) in 2008, 2009, and 2010 indicated variations of botanical variety, year and their interaction to be highly significant for oil content and all fatty acids studied. Virginia had also the highest oleic acid percentage. Higher temperatures during seed development in 2010 resulted in greater oleic contents than 2008 and 2009 while lower temperatures post anthesis in 2009 caused higher linoleic acid. The highest percentages of linoleic acid for Virginia, Valencia, and Spanish were observed in 2010, 2008, and 2009, respectively. The highest negative correlation was noted for oleic and linoleic acids (r: -0.985). Oleic acid was also correlated negatively with arachidic and behenic acids.

Increasing carbon dioxide concentration may have a positive effect on oilseed production; however, this positive effect may be negated by higher temperatures, lower water use efficiency, and subsequent accelerated development resulting in lower seed and oil yields. Altered precipitation patterns, coupled with rising temperatures and increased [CO_2], will affect oilseed crop growth, development, and production, especially where rainfall coincides with the growing season. Lipid profiles and the content of polyunsaturated fatty acids (PUFAs) produced by oilseed crops are influenced by high temperature during plant growth and seed maturation.

Oilseed crops having the C_3 metabolic pathway may respond positively to e[CO2] by producing more biomass and accumulating more carbohydrates, thus diluting seed proteins and macro and micronutrients, and may improve oil quality by raising PUFAs at the expense of SFAs. However, the favorable effect of e[CO_2] may be negated by the attendant higher temperatures, lower WUE, and the subsequent accelerated plant development that could result in reduced seed and oil yields. Therefore, key targets in oilseed improvement under GCC stress include increasing overall oil yield and stability on a per seed or per fruit basis and maintaining very high PUFA content for premium edible oil and high SFA contents for oleochemicals used in industrial and pharmaceutical applications .

The protein-rich residue remaining after the oil has been extracted from oilseeds is an important source of nutrients for farm animals. Oilseed meals from *G. max*, *A. hypogaea*, *B. napus*, and *L. usitatissimum* are rich in protein (∼35%); when mixed with cereal grains, they provide nutritionally balanced feeds.

By mid of 21st century and at an increasing rate of about 2.2 ppm year−1, [CO_2] is expected to reach, if not exceed, 500 ppm (www.co2now.org) as predicted under the A1FI CO_2 emission scenario; consequently, the climate will be warmer by about 2.8°C. Ongoing CO_2 enrichment is likely to increase yields of most C_3 oilseed crops by about 13%; however, yields of C_4 crops will generally be unchanged. Significant genetic variation in response to e[CO_2], when coupled with on-farm adaptation strategies, could help mitigate the expected negative impacts of GCC and potentially improve future crop yields, as demonstrated in *G. max* field studies. Greater whole plant net photosynthesis, dark respiration, daily carbon gain, and thus growth and WUE were achieved under e[CO_2]. Higher seed yield and biomass (mainly as carbohydrates) accumulation under e[CO_2] may dilute the concentration of seed proteins and macro and micronutrients. However, an increase in e[CO_2]- mediated PUFAs compared with SFAs in some oilseed crops, such as *H. annuus*, is a desirable outcome of e[CO_2] for nutrition and oil quality purposes. Heat-responsive genes have been identified in siliquae of *B. napus* at the seed-filling stage through transcriptional profiling.

Global climatic changes are expected to affect the night temperatures. High night temperatures are showing an increasing trend which affect the general metabolism of the plant. It also have an influence on fatty acids anabolism and catabolism biosynthetic pathways. High night temperatures promoted the expression of the genes in the fatty acids biosynthesis pathway in particular *FAD2* and *FAD3*, but also the genes enhancing GA signal. The enhanced GA signal resulted in the increased expression of *SFAR* genes. The free fatty acids are subjected toβ-oxidation, a process in which fatty acids are degraded into acetyl-CoA. Subsequently, acetyl-CoA is converted into 4-C compounds via the glyoxylate cycle, which occurs partially in the peroxisome.

Effect of elevated CO_2 on seed oil quality and yield in a sunflower hybrid DRSH 1 and variety DRSF 113, raised inside open top chambers and exposed to elevated CO_2 (550 ± 50 ppm) showed 61–68 % gain in biomass and 35–46 % increase in seed yield of both the genotypes, but mineral nutrient and protein concentration decreased in the seeds. The reduction in seed protein was up to 13 %, while macro and micronutrients decreased drastically (up to 43 % Na in hybrid seeds) under elevated CO_2 treatment. However, oil content increased significantly in DRSF 113 (15 %). Carbohydrate seed reserves increased with similar magnitudes in both the genotypes under elevated CO_2 treatment (13 %). Fatty acid composition in seed oil contained higher proportion of unsaturated fatty acids (oleic and linoleic acid) under elevated CO_2 treatment, which is a desirable change in oil quality for human consumption. These findings conclude that rising atmospheric CO_2 in changing future climate can enhance biomass production and seed yield in sunflower and alter their seed oil quality in terms of increased concentration of unsaturated fatty acids compared with saturated fatty acids and lower seed proteins and mineral nutrients.

Elevated CO_2 led to an increase inunsaturated fatty acids and reduction in the saturated fatty acids in Groundnut and Brassica. Significantly higher quantity of linoleic acid and oleic acid was found in the seeds of CO_2 enriched Brassica plants. The conversion of linoleic acid to linolenic acid requires sufficient quantity of O_2 that was not available due to higher intercellular concentration of CO_2, which, in turn, resulted in the reduction of polyunsaturated fatty acid. Although the synthesis of linoleic acid was also a desaturation process, optimum level of O_2 may be available for desaturation in that step. Elevated CO_2 altered the fatty acid composition of seeds. The palmitic, stearic, linolenic and erucic acids were significantly reduced and the linoleic acid and oleic acid contents were increased. It was demonstrated that the elevated CO_2 brought about a reduction in the saturated fatty acids namely palmitic, and stearic acid content, indicating that most of the fatty acids undergo desaturation and produced unsaturated fatty acids due to lower $O_2:CO_2$ ratio. Significantly higher quantity of linoleic acid and oleic acid was found in the seeds of CO_2 enriched plants. The conversion of linoleic acid to linolenic acid requires sufficient quantity of O_2 that was not available due to higher intercellular concentration of CO_2, which, in turn, resulted in the reduction of polyunsaturated fatty acid.

Reduction of the saturated fatty acid pool and some unsaturated fatty acids like linolenic and erucic acid are also important because most of these fatty acids increase blood cholesterol in the human body. However, saturated and monounsaturated fatty acids were less involved in this process. Linoleic acid significantly increased (about 20%) in the seeds of CO_2 enriched plants. The main function of linoleic acid is to lower blood cholesterol, help in the growth and development of human cells, reduce roughness of skin etc. Linolenic acid is also nutritionally desirable but it gets easily oxidized resulting in unpleasant taste.

Conclusion

Various oilseeds species have a predefined fatty acid composition. The functional and nutritional values of different vegetable oils are dependent on the nature of the different fatty acids present in the oil. Varietal improvement for achieving targeted fatty acids composition and crop production practices including growing environment are vital to for shelf life, nutritional index and end use. Oilseeds crops respond to changes in temperature, carbon dioxide levels, solar radiation and precipitation patterns especially under rainfed situations leading to altered oil content and its composition. The influence of changing climatic conditions resulting in altered fatty acids profiles is primarily dictated by plant species, genotypes, temperature, environmental conditions, and management practices, in decreasing order. Exposure to high temperature leads to decrease in oil content with increase in oleic acid and decrease in linoleic and linolenic acid. Drought also leads to decrease in oil content with increase in oleic acid and decrease in linoleic acid. Elevated CO_2 levels may improve rate of photosynthesis vis-à-vis biomass gain by decreasing the effect of photorespiration, increase in frequency and intensity of drought would offset the gain in photosynthesis and WUE. Changes in climate are likely to place new pressures on pattern of cultivation, conservation of wild relatives and land races of oilseed crop species. High levels of oleic acid in oils are related to longer shelf life due to their higher stability and resistance to oxidation while polyunsaturated fatty acids like linoleic and linoleic acid are very important from nutrition and health point of view. The ultimate challenge under changing climate is to simultaneously optimize seed yield and maintain, if not increase, oil content, oil yield, protein yield, and optimize fatty acid profiles.

Suggested Reading:

Bates PD, Stymne S, Ohlrogge J. 2013. Biochemical pathways in seed oil synthesis. Curr Opin Plant Biol. 16:358–364

Baud S, Lepiniec L. 2010. Physiological and developmental regulation of seed oil production. *Prog Lipid Res*. **49:** 235-249 doi: 10.1016/j.plipres.2010.01.001

Bita C, Gerats T. 2013. Plant tolerance to high temperature in a changing environment: Scientific fundamentals and production of heat stress-tolerant crops. Front Plant Sci. 273: 1-18. doi: 10.3389/fpls.2013.00273

Brunel-Muguet S, D'Hooghe P, et al. 2015. Heat stress during seed filling interferes with sulfur restriction on grain composition and seed germination in oilseed rape (*Brassica napus* L.). Front Plant Sci. 6:213. doi: 10.3389/fpls.2015.00213

Hixson SM, Arts MT. 2016. Climate warming is predicted to reduce omega-3, long-chain, polyunsaturated fatty acid production in phytoplankton. Global Change Biol. 22: 2744–2755. doi: 10.1111/gcb.13295

IPCC, 2013: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the IPCC* [Stocker, T.F., et al. (eds.)]. Cambridge University Press, Cambridge, UK and New York, USA, doi:10.1017/CBO9781107415324

Namazkar S, Stockmarr A, Frenck G, Egsgaard H, TerkelsenT, Mikkelsen T, Ingvordsen C H, Jørgensen R B. 2016.Concurrent elevation of CO_2, O_3 and temperature severely affects oil quality and quantity in rapeseed . J Exp Bot. 67: 4117–4125. doi:10.1093/jxb/erw180

Neto AR, Miguel AMRde O, Mourad EA, AL, Henriques, EA, Alves, RMV. 2016. Environmental effect on sunflower oil quality. Crop Breed App Biotech. 16: 197-204

Onemli F. 2012. Impact of climate change on oil fatty acid composition of peanut (*Arachis hypogaea* L.) in three market classes. Chilean J Agric Res. 72(4): 483-488

Schulte LR *et al.*, 2013. Increased growing temperature reduces content of polyunsaturated fatty acids in four oilseed crops, Ind Crops Prod. 51 :212–219

Siemens B. 2017. Quality of Canadian oilseed-type soybeans. Canadian Grain Commission. 1404- 303 Main Street. Winnipeg MB R3C 3G8

Singer SD, Zou J, Randall J W. 2016. Abiotic factors influence plant storage lipid accumulation and composition. Plant Sci. 243: 1–9

Uprety DC, Sen S, Dwivedi N. 2010. Rising atmospheric carbon dioxide on grain quality in crop plants. Physiol Mol Biol Plants 16(3):215–227.DOI 10.1007/s12298-010-0029-3

Yadav SK,Vanaja M, Reddy PR, Jyothilakshmi N, Maheswari M,. Sharma KL, Venkateswarlu B. 2011. Effect of elevated CO_2 levels on some growth parameters and seed quality of groundnut (*Arachis hypogaea* **L.).** *Indian J Agric Biochem.* 24(2) :158-160

Zhou L, Yan T, Chen X, Li Z, Wu D, Hua S, Jiang L. 2018. Effect of high night temperature on storage lipids and transcriptome changes in developing seeds of oilseed rape.J Expt Bot. 69 (7): 1721–1733

7. Impact of drought and high temperature on seed yield and WUE

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The diverse agro ecological conditions in the country are favourable for growing nine oilseeds which include seven edible oilseeds. Oilseeds in India assume great significance in the context of changing climate since approximately 72% of the oilseeds area is confined to rainfed cultivation braving the vagaries of weather.

Sunflower was introduced into India for commercial cultivation in 1972-73. Since its introduction, the crop has been widely accepted because of its short duration and wider adaptability to different agroclimatic conditions and soils. Presently sunflower is being cultivated in an area of 3.29 lakh ha. In the recent past the area under sunflower is decreasing due to instability in yields as a result of erratic rainfall. Important sunflower growing states in India are, Karnataka, Maharashtra, Andhara Pradesh, Punjab and Utter Pradesh. In these states the crop is grown on a wide range of soils. The two major soil types where sunflower is grown are red soils (Alfisols) and black soils (vertisols). It is grown as a rainfed crop in all soil types during monsoon and on receding soil moisture in post monsoon period in black soils. Monsoon crop experience intermittent drought whereas post-monsoon crop experience end season drought. Summer season crop is subjected to heat stress. Though sunflower is considered moderately tolerant to drought stress (Tahir *et al*., 2002), there is a wide gap between potential and realizable yields in rainfed situation. Yield reduction upto 61% was reported under stress condition (Hegde and Damodarm, 1998). The adaptive mechanisms are inadequate to realize potential yields under drought. Therefore identification of genotypes/gene pools with relevant drought tolerance traits and incorporating them through conventional/molecular breeding strategies could be the most reliable approach.

Though drought management is an option to increase realizable yields, genetic improvement for drought tolerance is more rewarding as the seed based technology is easy to transfer to farmers than the more complex knowledge based practices.

Several efforts have been made in different crops to identify single characters, which could serve as the basis for selection for drought tolerance. The important among them were chlorophyll stability, proline accumulation, betaine accumulation, and osmoregulation. However, a relationship between these characters and drought tolerance based on yield is difficult to establish. Therefore, it is not realistic to look for a single trait and the present approach is to select more stable and heritable characters that are amenable for screening.

Among different stages, germination, flowering and seed development are sensitive stages. 20 days before to 20 days after flowering is the most critical and sensitive stage. When drought occurs at germination, seeds must compromise for the establishment of the seedlings (Albuquerque and de Carvalho, 2003). Germination percentage and biomass accumulation decreases and the timing process also increases at higher drought levels (Smok et al., 1993; Sajjan et al., 1999).

Many morphological and biochemical traits related to yield under limited water availability have been identified. Reduction of head size, stem diameter, plant height, seed weight, seed yield, root to shoot ratio, leaf water potential (LWP), relative water content (RWC) of leaves, leaf area index and total chlorophyll content were reported previously (Sharp and Boyer, 1986; Razi and Assad, 1998; Petcu *et al.*, 2001; Hossain *et al.*, 2010; Vanaja *et al.*, 2011). Maury *et al.* (2000) reported increasing of osmotic adjustment and Germ *et al.* (2005) indicated differential response of sunflower cultivars for chlorophyll fluorescence (Fv/Fm). This has opened up the possibility to use these traits as selection criteria to improve drought tolerance in sunflower. Some of the most important traits include canopy temperature, leaf area index, leaf area duration, TDM, HI and seed yield (Giminez and Fereres, 1986; Elizondo, 1991). Stability of leaf area after flowering (stay green effect) is important for high yield under dry conditions (Korell *et al*., 1995). During vegetative development, drought reduced the main stem height, stem diameter, number of nodes or leaves and leaf area (Agele, 2003). The reduction in vegetative biomass resulted in lower plant surface area, which reduced the radiation use efficiency and photosynthetic activities (Stockle and Kiniry, 1990; Badr et al., 2004; Germ et al., 2005). Other studies showed that H. annuus accumulated three times more dry matter per plant than H. petiolaris irrespective of water stress (Sobrado and Turner, 1983; Sobrado, 1986). There is a possibility of combining high yield potential with drought tolerance in sunflower as no association was found between yield and drought susceptibility index (Fereres *et al*., 1986).

Skoric and his group have started breeding for drought tolerance with interspecific H. argophyllus material in 1992 itself. H. argophyllus because of its moderate transpiration and high photosynthetic activity results in high WUE compared to H. annuus. Wild species like H. debilis, H. tuberosus and H. petiolaris possess dehydration avoidance mechanism and higher root/shoot ratio (Baldini *et al*., 1993).

Temperature

Rising temperatures on earth - and the increasing frequency of heat waves in particular - cause lower agricultural yields. The primary factor governing the crop growth rate is temperature (Kaleem et al., 2009). The susceptibility to high temperatures in plants varies with the stage of plant development, heat stress affecting to a certain extent all vegetative and reproductive stages. Heat stress induces changes in respiration and photosynthesis and thus leads to a shortened life cycleand diminished plant productivity.

Major area of the crop is in southern peninsula where increasing temperatures during crop growth period pose a threat to sunflower productivity. Even small increases in temperature can adversely affect plant growth. Up to optimum temperature, each increment from the base temperature is positively related to productivity. Optimum temperature for sunflower growth has been reported as 25-30 °C. The crop is more sensitive to heat stress during anthesis and grain filling stages. Air temperature >30°C was reported to affect pollen viability, stigma receptivity and pollen tube growth .

Plants overcome high temperature stress by adapting several physiological and biochemical mechanisms. These could include morphology or short term avoidance or acclimatization mechanisms involving leaaf orientation, transpirational cooling or alterations of membrane lipid composition. Plants have both inherent ability to survive at high temperature and ability to acquire tolerance to lethal temperatures.

Heat stress affects molecular, cellular, physiological, phenological, and agronomic traits of sunflower. Cellular membrane injuries have been observed under heat stress due to the production of malonaldehyde, which further causes lipid peroxidation of membranes, as well as leakage of K+ and electrolytes (Corbineau et al. 2002).

Optimum temperature range for different processes:

Optimum temperature for growth and germination is 25-30 °C . Base temperatures (Tb) varied between 3.3°C and 6.7°C whereas maximum germination. Temperatures (Tm) varied between 41.7°C and 48.9°C. Maximum rate of germination was attained at 30.4°C - 35.6°C (Khalifa et al 2000). The lower end of the range is 7.2°C in sunflower, i.e., the lowest 'basal temperature' at which germination is barely possible (Robinson 1971). Basal temperature may also vary with growth phase such as 4.7°C for leaf expansion (Granier & Tardieu 1998). From basal temperature upward, growth increases until it reaches the optimum temperature, at 25°C (day) for sunflower, where highest growth rate and maximum production occur while a night temperature of 21°C is considered to be optimum (Manunta & Kirkham 1996). Optimum temperature is critical for biomass production and yield and each increment in the basal atmospheric temperature up to the optimum is positively related with these parameters (Rawson et al. 1984). Threshold temperature also varies among various growth stages of sunflower. Moriondo et al. (2011) showed that sunflower was more prone to heat stress during anthesis compared to other growth stages. Threshold temperature is the critical temperature above which growth and reproduction of a species is affected. Significant variation exists in threshold temperature among plant species. In sunflower, a threshold temperature of 26–29°C has been suggested while temperatures higher than the threshold level pose heat stress (Rondanini et al. 2006).

Sunflower is sensitive to heat stress during the reproductive phase. Heat stress during anthesis causes pollen and ovule sterility showing that reproductive organs have a lower threshold temperature range. Chimenti et al. (2001) showed that 25°C induced the highest growth rate in the embryo during the grain-filling period while high temperatures above 27°C reduced the growth rate and embryo growth duration in sunflower. They also showed that the highest number of grains capitulum−1, grain percent, leaf area and shoot dry weight were obtainable at 25°C. However, the greatest reduction in yield was reported when heat stress occurred during the grain-filling stage (Kalyar et al 2014). A decrease in yield has been attributed to low seed number, the grain-filling period, and to gametophyte fertility in which direct exposure of the sunflower head to heat stress may intensify repressing effects on grain count and its development (Ploschuk & Hall 1995).

Net photosynthetic rate, transpiration, and stomatal conductance also decrease in response to heat stress due to a decrease in the number of grana and thylakoid membranes chloroplast−1 (Dekov et al. 2001; Hassan 2006). The chloroplast envelope was also disrupted due to heat stress while net respiration increased by 19% when night temperature was 5°C higher than the control (21°C) (Manunta & Kirkham 1996). Villalobos and Ritchie (1992) showed that the rate of leaf appearance increased up to 27°C. Rawson and Hindmarsh (1982) showed that leaves appeared at a faster rate (0.022 leaves day−1 °C−1) with increasing temperature while final leaf area decreased and leaf growth period decreased by 1.04 days °C−1. Optimum temp. for primary root growth: 23-25 °C, Secondary root growth: 25-30 °C (McMichael and Quisenberry, 1993)

High temperature has been associated with a decrease in oil yield. High temperatures favor the production of linoleic acid due to the high activity of desaturase (Harris et al. 1978). Contrastingly, sterate desaturase activity was inhibited at a high temperature (39°C), thus increasing the production of stearic acid in a sunflower mutant (Fernández-Moya et al. 2002). There was a negative correlation between temperature and linolenic acid (Werteker et al. 2010). Heat stress accelerates the process of heat unit accumulation which hastens various phenological stages. Accelerated heat unit accumulation results in lower biomass and reduced growth period. Moriondo et al. (2011) showed that heat stress could reduce the reproductive growth period by 15 days. Rondanini et al. (2006) showed that exposure of the sunflower head after 10–12 days post-anthesis resulted in greater yield losses than heat stress in later reproductive phases. Number of days to 50% flowering, days to maturity and seed yield decreased with increase in maximum temperature from 29.0 to 35.8 °C and minimum temperature from 15.0 to 21.9 °C. Rise in mean temperatures from 22 to 28.8 °C (+6.8°C) during crop growth period, reduced crop yield by 54 % and duration by 20 days. Regression analysis indicated reduction of about 8% yield per every 1°C rise in temperature. (Lakshmi et al 2018). Temperature >30° C affect pollen viability, stigma receptivity and tube growth (Rosell et al 1999). 42° C for 40 days caused pollen sterility of 60% (Kalyar et al 2013). Temperatures above 35° C for 4 days at flowering cause significant reduction in yield (Quadri 2007).

Stay green leaves, higher photosynthetic rates, increased thermostability ((Nagarajan et al., 2010) leaf and head bending (Kalyar et al 2014) leaf temperatures (Kalyar et al 2013) are some of the characters for selecting heat tolerant variety. Now novel methods like Temperature induction response (TIR) technique are availabel to assess the genetic variability in acquired stress tolerance to assess intrinsic stress tolerance of seedlings at cellular level (Ganesh Kumar et al., 1999).Sub-lethal induction stress which the plants experience under natural conditions before being subjected to severe stress, triggers the expression of an array of stress responsive genesand these gene products alter several physiological and biochemical processes relevant to stress tolerance (Vierling, 1991; Bohnert et al., 1995). It has been observed that genetic variability is only seen upon an induction treatment prior to severe stress and the observed variability was marginal when the seedlings were exposed directly to the severe stress (Uma et al., 1995). Therefore, while screening for thermotolerance, it is necessary to expose the seedlings to an induction stress before its exposure to the severe stress. For screening under natural conditions, staggered sowings is widely adapted method because of the simplicity of not requiring any additional facilities in spite of its disadvantages. Though the argument is that other weather parameters do change with different sowings, the question is when temperature changes due to climate change do other parameters remain static? In that context, screening with staggered sowings is quite logical.

Breeding to improve abiotic stress tolerance per-se is quite complex and hence identification of constituent traits that impart tolerance is expected to provide the required breakthrough. Introgression of these traits into elite cultivars with high yield potentials through marker assisted selection would significantly improve productivity under water limited conditions.

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8. Response of castor (*Ricinus communis* L.) to abiotic stresses with major emphasis on drought tolerance

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Climate is the primary determinant of agricultural productivity. Given the fundamental role of agriculture in human welfare, concern has been expressed by federal agencies and others regarding the potential effects of climate change on agricultural productivity. Major problems due to climate change include: Drought, Temperature, Salinity, Water logging, elevated CO_2 etc. Castor, a non edible oilseed crop with known drought tolerance is grown in less fertile alfisols without supplemental irrigation as rainfed crop in southern India. Though it survives drought stress, there is yield reduction. Yield gap is very high across rainfed (Telangana & AP - 4 -6 Q) and irrigated (Gujarat- 14 q/ha) areas of the country. India rank first in castor area and production in the world. To sustain this position, the productivity needs to be improved especially in rainfed areas.

General growth characters:

Castor (Ricinus communis L.) is basically a warm region perennial, but can also be grown in temperate and tropical regions of the world. Seeds germinate at a moisture level of 40% field capacity or less, but quick swelling and germination occur at 60-80%. Minimum temperature required for germination of castor seeds is 14-15^{o}C, optimum 31^{o}C and maximum 35-36^{o}C. The best germination was noticed under a constant temperature of 25^{o}C. Castor is basically a long day plant but is adaptable with some loss of yield to a wide range of day length. No difference in growth is observed between plants grown under 12, 14, 16 and 18 hr photoperiods. The surface of castor leaves are positioned almost horizontally to the field, so their upper layer gets more bright light, photo saturation of photosynthesis (Ps) occurs at 1/5 of maximum sunlight intensity, though the leaves are anatomically adapted to high intensity of light. There will be complete cessation of Ps upon turning the lower surface of castor leaf upwards. Though the leaves of castor are suitable for high illumination, the color requirement of Ps is reached with a low intensity of light that is why the energy of radiation is not utilized as efficiently by them as it is by other plants with C3 type of Ps. The maximum assimilation of CO_2 is between 18-27 mg dm^{2-1} hr^{-1}. The production of photosynthates during vegetative period is 6.5-6.9 g $m^{2\ -1}$ $d^{\ -1}$. 80% of assimilants of leaves are in the form of sucrose. High intensity of dark respiration is the characteristic for castorleaves (Moshkin, 1986). Castor is normally cross pollinated. A normal inflorescence is monoecious. The proportion of male to female may vary ranging from 99% pistillate flowers to <5% and flowers of separate sexes to a few hermaphroditic flowers. Environment may also cause a variation in the sex ratio of flowers within a variety.

Drought tolerance:

Drought is defined as the deficiency or dearth of water severe enough to check plant growth. Although drought injury occurs primarily from the deficiency of soil moisture, the atmospheric factors such as high temperature, low humidity, fast winds etc. aggravate the adverse effects of drought. As there is only 1% of earth’s water that is easily accessible, water deficits will continue to be the single most abiotic factor likely to affect our crop yields globally. Crop is often subjected to moisture stress at critical stages i.e. flowering/maturity of either one or more than one of the three spike orders viz., primaries, secondaries or tertiaries, more so with the latter due to cessation of monsoon season by that time. Maximum damage to yield was caused by drought during the period of flowering and fruiting. (Moshkin, 1986). Growth reduction is the most common feature associated with water stress.Earlier stages of growth are more sensitive to water stress than later stages. Seed germination and seedling growth characters are important in determining crop stand density and its establishment under water stress. Seedling characters like germination percent, time taken for germination, seedling growth, leaf area and seedling vigor reduced and root/shoot ratio increased with stress (Manjula *et al*., 2001). At cellular level, water stress reduced callus initiation and further development, decreased nitrate reductase activity and chlorophyll content (Manjula *et al*., 2003). Leaf chlorophyll concentration reduced, increased epicuticular wax load/bloom (Lakshmamma *et al*., 2009), accumulation of proline, total soluble sugars, free amino acids and potassium

(Manjula *et al*., 2001; Babitha, 2003). Higher leaf carbohydrates also favor proline accumulation and contribute to enhanced drought tolerance (Manjula *et al*., 2001).

For a kharif rainfed crop, rainfall received during crop growth is sufficient for primary spike growth, but secondary and tertiary orders of medium and late duration varieties may experience moisture stress at seed development. Thus, contribution from different orders differs with duration of the crop and occurrence of stress. Primary and secondary spike initiation stages are more sensitive to stress (Lakshmamma and Lakshmi, 2006).). Foliar application of P, B, Mo or Mn during stress period greatly reduced its adverse effects and promoted nutrient metabolism and formation of fertile pollen (Kudinova, 1971). Irrigated castor gave 42% higher seed yield than the rainfed castor (Subba Reddy *et al*; 1996). Drought tolerant genotypes show less percent reduction in seed yield due to the adaptive traits they possess (Lakshmamma *et al*., 2003, 2010, Lakshmamma and Lakshmi, 2010). Hybrids were superior in maintenance of adaptive traits and accumulation of compatible solutes for osmoregulation (Babita, 2003). Under conditions of irrigation, utilization of nutrients increased two to five times but decreases with drought.

The drought management though has been an option to increase realizable yields, now it is realized that genetic improvement of the drought tolerance is more rewarding as the seed based technology is easier to transfer to farmers than the more complex knowledge based agronomic practices. Achieving genetic increases in yield under rainfed conditions has always been a challenge for plant breeders which is evident by smaller genetic gains in dry regions. Because of unpredictable and highly variable seasonal rainfall, genetic variation is marked by large GxE interaction (Calhoun *et al* 1994, Van Ginkel *et al* 1998). So major challenge for breeders in dry land environments is to devise the most effective strategy for maximizing genetic gain. A physiological approach can complement empirical breeding and may enhance the rate of yield improvement by identifying readily amenable and cost effective traits with adequate genetic variability and with low GXE interaction and high heritability.

Secondary traits like water use efficiency (WUE) showed significant genetic variability and also has heritability. There are different approaches to identify drought tolerant genotypes and traits related to WUE. They are gravimetry, gas exchange measurements and carbon isotope discrimination (CID) technique. Other alternate approaches for measuring WUE are measuring specific leaf area (SLA), SPAD chlorophyll meter reading (SCMR) and relating it with specific leaf nitrogen (SLN) and mineral ash content etc. Relationships between these traits with WUE were established in different crops (Farquhar and Richards, 1984, Sheshashayee et al. 2001, Nageshwar Rao et al 1995).

At IIOR, Pot (2002-03) and field experiments (2003-05) were conducted to estimate WUE, stage as well as position of leaf to be sampled and to relate them with other traits like SLA, SCMR, SLN etc. Total dry matter (TDM) and WUE showed positive relation with SCMR, SLN,^{18}O and negative relation with SLA and ^{13}C. These relationships are prominent at 55 DAS. Fourth fully expanded leaf from top on primary stem was identified as the index leaf to be sampled as good correlation was seen between different traits with this leaf. Traits like specific leaf area (SLA), leaf area index (LAI), total dry matter (TDM), capsule number, yield of secondaries and total seed yield are associated with drought tolerance (Lakshmamma *et al*., 2003, Jyothi, 2004). SPAD chlorophyll meter reading (SCMR), SLA, specific leaf nitrogen (SLN), ^{13}C can serve as surrogates for WUE in castor (Lakshmamma *et al*., 2010).

Root, WUE and drought tolerance:

Genetic variability for traits related to drought tolerance is scattered in germplasm accessions and may be productive when incorporated to high yielding agronomic back ground. Root as a water mining tool plays a major role in drought tolerance by maintaining the plant water status. Water uptake and transpiration depends to a great extent on the strength of the root system and decreases with reduction of root system. Initial reduction in transpiration due to root excision is considerable in relation to the loss of root volume, but subsequent reduction in transpiration is slower indicating the resistance to increasing water loss and an ability to withstand internal water stress (Gracanin, 1962). Deep rooting, root length density and root distribution have been identified as drought adaptation traits (Li *et al*., 2005). The active and deep root distribution of castor has been attributed to its drought resistance capacity. Root/shoot ratio is higher in rainfed crop than irrigated crop. Temperature also affects root growth.

Experiments were conducted at IIOR for measuring different root characters along with other WUE traits in specially constructed root structures there by identifying genotypes with better root growth and with better WUE traits. Root volume and root dry weight, Leaf area index (LAI) and stem girth showed strong positive correlation with TDM (Lakshmamma *et al*., 2010). Based on an index developed using principal component analysis with recorded root and shoot characters, genotypes possessing best characters were identified. A total of 218 germplasm and 75 breeding lines were screened and selected 59 germplasm and 11 breeding lines with good root growth and WUE traits (Lakshmamma *et al*; 2010,2013,2014). Root growth in contrasting genotypes in root structures show less reduction in root length due to stress. Root volume, dry weight and shoot growth reduced with stress, but the % reduction was less in poor root genotype compared to good root genotype.

Selected good root germplasm and breeding lines were screened for their drought tolerance in field during late *rabi,* and based on seed yield in stress, % reduction in seed yield in stress and DSI, genotypes with drought tolerance were selected. The selected best lines are being used in breeding programs for developing genotypes for *kharif* rainfed conditions (Lakshmamma *et al*; 2017). Among **c**ultivated varieties and hybrids screened, 48-1, DCS-9, DCH-519 and DCH-177 were drought tolerant and traits associated with drought tolerance include TDM, yield of secondaries and total seed yield (Lakshmamma *et al*;2003).

Studies show that bloom content increase in response to stress thus acquire tolerance by minimizing transpiration and also showed negative correlation with DSI values, which also shows its accumulation in drought. Thorough studies are needed to quantify contribution of bloom in imparting drought tolerance and its influence on reducing the loss of seed yield in castor(Lakshmamma *et al*;2009). Selected germplasm with good root traits were screened in lab for germination with Poly Ethylene Glycol (PEG) induced drought stress and best lines for drought tolerance during germination were selected.

Terminal drought stress is common in castor with cessation of monsoon. Stem reserves are an important source of carbon for grain filling when current photosynthesis is inhibited by drought and mobilization of stem reserves towards economic yield is an important trait in selection for terminal drought tolerance. Potassium iodide (KI), a chemical contact canopy desiccant which induce leaf desiccation by reducing chlorophyll content is used to induce drought stress for assessing variability in stem reserve mobilization. Selected lines were screened for terminal drought stress tolerance by spraying KI @1.0% and best lines with more stem reserve mobilization were identified.

Temperature tolerance

Minimum temperature required for germination of castor seeds is 14-15^{o}C, optimum 31^{o}C and maximum 35-36^{o}C. The best germination was noticed under a constant temperature of 25^{o}C. Crop requires a moderately high temperature of 20-26^{o}C with low humidity throughout the growing season to produce maximum yields. It grows best in areas where there are clear sunny days with no frost. Accumulated heat units have significant positive influence on the growth of the crop (Balasubramanian, 1959). Radiation, temperature and humidity are three main weather factors, which influence net photosynthesis of the crop. Drought and temperature come hand in hand. Although drought injury occurs primarily from the deficiency of soil moisture, the atmospheric factors such as high temperature, low humidity, fast winds etc. aggravate the adverse effects of drought.

Ten hybrids and four varieties were sown for two years at four dates of sowing during November, to January, to identify temperature tolerant genotypes. Genotypes with less (<10%) reduction in total seed yield with delayed sowings include Gauch-1, GCH-2, GCH-5 and DCH-519.Temperature Induction Response technique (TIR) was standardized and selected genotypes with temperature tolerance at seedling stage (Lakshmamma and Lakshmi Prayaga, 2006).

Temperature and sex expression:

Castor is normally cross pollinated. A normal inflorescence is monoecious. The proportion of male to female may vary ranging from 99% pistillate flowers to <5% and flowers of separate sexes to a few hermaphroditic flowers. Variation in sex is a characteristic feature in castor (Moshkin, 1986). It has N and S systems of femaleness (Shifriss, 1961). Presence of environmentally sensitive genes for interspersed staminate flowers (ISF) in pistillate lines independent of N and S mechanism was also reported (Ankineedu and Rao, 1973). Presence of more male flowers results in loose spikes and less yields. It is desirable that spikes have to be completely covered by pistillate flowers with a few staminate flowers at the base of the peduncle (Kulakarni and Ramanamurthy, 1977). Relative endogenous balance of ethylene and GA controls sex expression in crops. It depends on many environmental factors, manipulation of which may alter sex ratio in castor. Temperatures >40^{0}C leads to blasting of flowers and results in poor seed set. Adequate moisture supply promotes both male and female flowers without altering sex ratio. The pistillate character, which is polygenically controlled, is highly unstable and it can revert at any stage to monoecism depending on management levels, time of planting, nutrition and other environmental factors. Mid and late summer, high temperatures (mean maximum temperature of 31-32^{0}C promotes ISF) especially during emergence of primary raceme, old plants, low level of nutrition, high vegetative activity, short days (9hrs), bagging of spikes promote maleness, spring and early summer, moderate temperatures, young plants especially in primary racemes, high level of nutrition, moderate vegetative activity, long days (22hrs) promote femaleness.

For maintenance of pistillate parent, refined/modified seed technology developed at Directorate of Oilseeds Research by Ramachandram and Rao (1988) utilizing environmentally sensitive gene (s) for interspersed staminate flower (ISF) character is followed. In this method, seed production for pistillate line should be taken up in summer when the day temperatures are above 32^0C which allows maximum expression of environmentally sensitive gene for ISF. One of the disadvantages of the above method, however, is its dependence for the production of nucleus, breeder and foundation seed in summer season which otherwise entails relatively more costs per unit of produce than regular season. There are problems of irrigation availability, high temperatures, desiccating winds and low yields etc.

Studies were conducted to induce ISF character in normal *kharif* season with growth regulators and chemicals viz; gibberellic acid, silver nitrate, urea etc. These chemicals were sprayed at primary (18 Days after emergence) and secondary spike initiation stages (50 DAE). Spray of GA and silver nitrate up to 100 ppm at primary and secondary spike initiation stages in July 1st fortnight sown crop increased the production of ISF in castor. ISF production is more during October, November and December months (Lakshmamma *et al,* 2002)

Effects of Elevated CO_2:

Atmospheric concentration of CO_2 is constantly increasing and carbon cycle models project the concentration of 540–970 ppm by the end of next century as a result of fossil fuel use and global deforestation. Many plant species respond to enriched atmospheric $CO_2$by enhanced photosynthetic rates and increase in biomass including castor. Assimilation of CO_2 was 40% higher at 700µl l^{-1} than at 350µl $l^{-1}CO_2$ (Grimmer and Komor, 1999). Carbon export was same during the daytime for plants at 350 or 700 ppm which means the phloem loading capacity of the leaves was equally saturated under both conditions, and that the elevated CO_2 conditions did not lead to extra sugar transportation. The main difference between plants in the two CO_2 concentrations occur during the night, where the carbon-export activity declined to half in plants at normal CO_2 concentration while the high CO_2 plants maintained the high daytime export rate also during the night, thriving on their large, stored starch pool. Thus, in *Ricinus,* there is limitation at source in the daytime because of saturation of the phloem-loading system and a limitation at night because of lack of assimilates (Grimmer and Komor, 1999). By the stimulation of photosynthesis with atmospheric CO_2 enrichment (300 µl l^{-1} increase in the air's CO_2 content), an approximate 34% productivity enhancement is achieved (Grimmer and Komor, 1999; Grimmer *et al*., 1999). Elevated CO_2 at 550 and 700 ppm over ambient control reduced the days to initiation and 50% flowering, improved total biomass, root length, volume and dry weight, primary spike length, capsule number. Seed yield and oil yield increased significantly which indicated elevated CO_2 as a positive factor of climate change for castor. Under irrigated conditions where water is not a limitation, it is possible to realize higher yields due to elevation of CO_2 in castor (Vanaja *et al*., 2008). Leaf nitrogen content, C:N ratio, polyphenols increase in leaves under elevated CO_2 conditions (Srinivasa Rao *et al*., 2009). However, none of these studies on effects of elevated CO_2 are studied in combination with increased temperature and such projected increases in production may not be possible to realize in field as the two effects of climate change are inseparable.

Effects of Water logging:

Castor is particularly sensitive to water logging. Soil flooding reduced stomatal conductance (gs) and slowed transpiration, CO_2 uptake and leaf elongation, root hydraulic conductance (Lp), leaf water potentials in castor and caused visible wilting in 3 h at 80% relative humidity. ABA concentrations in the shoot were increased while ABA delivery from flooded roots decreased. The initial stomatal closure is attributed to decreased leaf hydration arising from the reduced hydraulic conductance of oxygen-deficient roots. Water logging increased proline and total free amino acids content but decreased leaf osmotic potential, chlorophyll, soluble sugars, hydrolysable carbohydrates, soluble leaf membranes and dry matter content. Application of kinetin (0-100 mg kinetin l^{-1}) alleviates the effect of water logging by increasing the stability of leaf membranes, chlorophyll, soluble sugars, soluble proteins and dry matter content (Gadallah, 1995).

Effects of Salinity:

Castor seed germination is not sensitive to salt stress, but seedling growth and development is salt-sensitive. Salinity delays and adversely affects seedling emergence, plant growth and seed yield. Salinity decreases leaf water potential, stomatal conductance, transpiration rate and net carbon assimilation rate (Hugo Alves *et al*., 2008). Salt stress promotes an indirect internal water deficit in castor leaves. Seedlings develop mechanisms to acclimatize to high salt conditions. Maintenance of leaf water status and gas exchange under hyper salinity could be achieved by the way of osmotic adjustment, resulting from accumulation of compatible osmolyte solutes such as sugars, organic acids, polyols, and nitrogen containing compounds such as amino acids, amides, proteins (Gang Li *et al*., 2010).Reduction in photosynthesis due to the reduction in stomatal conductance limits sucrose availability for growth and whatever little amount the plant produces accumulates in vacuoles for osmotic adjustment.

Salinity affects almost all the growth and developmental traits resulting in reduction of yield to a varied extent. Plants suffer from restricted root growth and produce low yields. The rate of uptake of salts and water by roots and the factors influencing this are therefore important. Salinity increased root volume, root dry weight, leaf area and shoots dry weight up to 40 meql^{-1} and then decreased. Salinity delays and adversely affects seedling emergence, seedling vigor (Hugo Alves *et al*., 2008), plant height, leaf number, leaf area, raceme length, stem girth, 100 seed weight and seed yield (Kumar *et al*; 1989; Servulo *et al*., 2008). Emergence and yield were the most seriously affected traits. Tolerant strains were marked with more contents of Na and Cl in leaf tissue (Kumar *et al*; 1989). Dwarf varieties of castor are extremely susceptible to salinity. Selected germplasm with good root traits were screened in lab for salinity tolerance during germination with different concentrations of NaCl and germplasm with salinity tolerance during germination were identified.

Castor as phytoextractor

The intense and inadequate use of fertilizers and pesticides in the soil, coupled with the increase in industrial activity and mining are the main reasons for the contamination of soil, waterways and the water table by heavy metals (Malavolta, 1994). Among the existing pollutants, lead (Pb) is the major contaminant of the soil (Gratão et al., 2005) posing significant environmental problems (Shen et al., 2002), including the risk of poisoning for humans and especially children (Lasat, 2002). Some plant species accumulate these heavy metals and help in phytoremediation. Castor plants are able to accumulate large quantities of Pb (10.5 to 24.6 g Pb kg^{-1}) especially in roots and is also tolerant to several other heavy metals, including cadmium, zinc and nickel (Khan *et al*., 1998; Prasad, 2001). As castor being non edible the problem of toxicity to humans is not an issue and it can safely be used for phytoremediation of lead.

References:

Ankineedu G and Rao N G P 1973. Development of pistillate castor. *Indian Journal of Genetics and Plant Breeding*, 33 (3): 416-422.

Babitha, M. 2003. Genotypic variation for osmotic adjustment, growth and yield in hybrids and parents of castor. M.Sc (Ag) thesis submitted to ANGRAU, Hyderabad

Balasubramanian C 1959. Weather on raising of castor crop at Tindivanam. *Indian Oilseeds Journal,* 3: 229-233.

Calhoun D S, Gebeyehu G, Miranda A, Rajaram S and Van Ginkel M 1994. Choosing evaluation environments to increase wheat grain yield under rainfed conditions. Crop Science, 34: 673-678

Farquhar G D and Richards R A 1984. Isotopic composition of plant carbon correlates with WUE of wheat genotypes. Australian Journal of Plant Physiology, 11: 509-552

Gadallah M A A 1995. Effect of waterlogging and kinetin on the stability of leaf membranes, leaf osmotic potential, soluble carbon and nitrogen compounds and chlorophyll content of Ricinus plants. *Phyton Horn*, 35(2): 199-208

Gang Li, Shuwen Wan, Jian Zhou, Zhiyong Yang and Pei Qin 2010. Leaf chlorophyll fluorescence, hyperspectral reflectance, pigments content, malondialdehyde and proline accumulation responses of castor bean (*Ricinus communis* L.) seedlings to salt stress levels. *Industrial Crops and Products*, 31:13–19

Gracanin M 1962. Uber die Rolle des Wuizel systems in der Wasserversongung der Planzen. *Faculty of Science National University*, Skopje, Yugoslavia, 1: 39-64

Gratão P L, Prasad M N V, Cardoso P F, Lea P J, Azevedo R A 2005. Phytoremediation: green technology for the clean up of toxic metals in the environment. *Brazilian Journal of Plant Physiology*, 17:53-64.

Grimmer C and Komor E 1999. Assimilate export by leaves of *Ricinus communis* L. growing under normal and elevated carbon dioxide concentrations: the same rate during the day, a different rate at night. *Planta*209: 275-281.

Grimmer C., Bachfischer T and Komor E 1999. Carbohydrate partitioning into starch in leaves of *Ricinus comunis* L. grown under elevated CO2 is controlled by sucrose. *Plant, Cell and Environment*22: 1275-1280.

Hugo Alves Pinheiro, Jos´e Vieira Silva, Laur´ıcio Endres, Vilma Marques Ferreira, Celene de Albuquerque Caˆmara, Fa´ bio Fe´lix Cabral, Jaqueline Figueredo Oliveira, Lu´ cio Wagner

Torres de Carvalho and Joã o Messias dos Santos 2008.Leaf gas exchange, chloroplastic pigments and dry matter accumulation in castor bean (*Ricinus communis* L) seedlings subjected to salt stress conditions. *Industrial crops and products*, 27: 385–392

Jyothi M 2004. Studies on water stress recovery and regrowth in genotypes of castor. M.Sc (Ag) thesis submitted to ANGRAU, Hyderabad

Khan A G, Chaudhry T M, Hayes W J, Khoo C S, Hill L, Fernandez R, Gallardo P 1998. Physical, chemical and biological characterization of a steelworks waste site at Port Kembla, NSW Australia. *Water Air Soil Pollution*, 104:389-402.

Kudinova L M 1973. Physiological role of phosphorus and trace elements in increasing drought resistance in castor. *Biologicheskie-issledovaniya*, 1973, 80-90

Kulkarni L G and Ramanamurthy G V 1977. Genetics. In: *Castor*. Eds Kulkarni, L.G. and Ramanamurthy, G.V. ICAR, New Delhi, 38-43

Kumar D, Daulay H S and Sharma P C 1989. Tolerance of castor to soil salinity. *Annals of Arid Zone*, 28 (3 & 4): 249-255

L Parvathaneni, L Prayaga and A Karusala (2017) Selection of castor germplasm with important traits for drought tolerance under field conditions. *Indian Journal of plant physiology*. 22 (3), 295-303 Lakshmamma P and Lakshmi Prayaga (2001) Physiological analysis of yield variations in rainfed castor (*Ricinus communis* L.) *Journal of oilseeds Research*, 18, 2 244-246 DOR, Hyderabad.

Lakshmamma P and Lakshmi prayaga (2006). Identifying the sources of tolerance for drought in castor, *Ricinus communis* L. *Journal of oilseeds Research*, 23 (2): 348-352

Lakshmamma P and Lakshmi Prayaga (2006). Screening castor (Ricinus *communis* L.) germplasm lines for thermal tolerance. *Journal of oilseeds Research*, 23 (2): 353-355

Lakshmamma P and Lakshmi Prayaga (2010): Variability for water use efficiency traits and drought tolerance in castor (*Ricinus communis* L.) germplasm lines. *Journal of Oilseeds Research*, 27 (1): 81-84

Lakshmamma P, Lakshmi Prayaga and Padmavathi P (2003) Morpho- physiological plant traits related to drought tolerance in castor (*Ricinus communis* L.). *Agricultural Science Digest,* 23(1) 1-5

Lakshmamma P, Lakshmi Prayaga and Sarada C (2013): Genetic variability for root, shoot and water use efficiency traits in castor (*Ricinus communis* L.). *Journal of Oilseeds Research*, 30 (1): 85-89

Lakshmamma P, Lakshmi Prayaga and C. Sarada (2016). Response of contrasting root genotypes of castor (*Ricinus communis* L.) to water stress. *Journal of Oilseeds research*, 33 (4): 212-215.

Lakshmamma P, Lakshmi Prayaga, and Prabhakara Rao N (2010) Traits related to water use efficiency in castor (*Ricinus communis* L.) *Journal of Oilseeds Research* (special issue), 27: 220-222

Lakshmamma P, Lakshmi Prayaga, Lavanya C and Sarada C (2014):Genetic diversity, variability and heritability for root, shoot and water use efficiency traits in castor (*Ricinus communis* L.) genotypes. *Indian Journal of Plant genetic Resources*, 27 (3): 230-237

Lakshmamma P, Prayaga L, Lavanya C and Anjani K (2009). Growth and yield of different castor genotypes varying in drought tolerance. *Annals of Arid Zone* 48(1): 35-39

Lasat M M 2002. Phytoextraction of toxic metals: A review of biological mechanisms. *Journal of Environmental Quality*, 31:109-120.

Li SG, J Asanuma, W Eugster, A Kotani, SJ Liu, T Urano, T Oikawa,G Davaa, D Oyunbaatar and M Sugita (2005) Net ecosystemCO2 exchange over grazed steppe in central Mongolia. *GlobalChange Biol*. 11: 1941-55.

Malavolta E 1994. Fertilizantes e seu impacto ambiental: micronutrientes e metais pesados – mitos, mistificação e fatos. Petroquímica, São Paulo.

Manjula K, Sarma P S, Nageshwar Rao T G and Ramesh T 2001. *In vitro* screening of castor genotypes for stress tolerance. *Journal of Oilseeds Research*, 18 (2): 292-293

Manjula K, Sarma P S, Ramesh T and Nageshwar Rao T G 2003. Screening of castor genotypes for drylands using PEG induced stress. *Journal of Oilseeds Research*, 20 (1): 170-171

Moshkeon 1986. Castor. Edited by V.A. Moshkeon, Oxen Press, New Delhi, pp 28-92.

Prasad M N V 2001. Metals in the environment: analysis by biodiversity. New York, Marcel Dekker.

Nageshwara Rao R C, Udayakumar M, Farquhar G D, Talwar and Prasad T G 1995. Variation in carbon isotope discrimination and its relationship to specific leaf area and ribulose bis phosphate content in groundnut genotypes. Australian Journal of Plant Physiology, 22: 545-51

Ramachandram M and Ranga Rao V 1988. Seed production in castor. *Technology bulletin*. Directorate of Oilseeds Research, Hyderabad, pp 62.

Sérvulo M S Silva, Allan N Alves, Hans R Gheyi, Napoleão E de M, Beltrão, Liv. S. Severino. and Frederico A L Soares 2008. Growth and production of two cultivars of castor bean under saline stress. *Revista Brasileira de Engenharia Agrícola e Ambiental*, 12 (4): 335-342

Shen, Z.G., Li, X.D., Wang, C.C., Chen, H.M., Chua, H.2002. Lead phytoextraction from contaminated soil with high biomass plant species. *Journal of Environmental Quality*, 31:1893-1900.

Sheshashayee M S, Nageshwar Rao R C, Bindu Madhava H, Dharmarajan M, Udayakumar M and Wright G C 2001. On the relationship between leaf reflectance and transpiration efficiency in groundnut (*Arachis hypogaea* L.). Training manual on “Application of stable isotopes to study physiological processes for crop improvement” held at GKVK, Bangalore, 4-16 March, 2002

Shifriss O 1956. *Sex instability in Ricinus.* Genetics, 41 (2): 265-280

Shifris, O1961. Gibberellin as sex regulator in *Ricinus communis* L. *Science*, 133: 2061-2062

Srinivasa Rao M, Srinivas K, Vanaja M, Rao G G S N, Venkateswarlu B and Ramakrishna Y S 2009. Host plant (*Ricinus communis* Linn.) mediated effects of elevated CO2 on growth performance of two insect folivores. *Current Science*, 97 (7): 1047-1054

Subba Reddy G, Gangadhar Rao D, Venkateswarlu S and Maruthi V 1996. Drought management options for rainfed castor in alfisols. *Journal of Oilseeds Research*13 (2): 200-207

Van Ginkel M Calhoun D S, Gebeyehu G, Miranda A, Tianyou c, Lara R P, Trethowan R M, Sayre K, Crossa J and Rajaram S 1998. Plant traits related to yield of wheat in early, late or continuous drought conditions. Euphytica, 100: 109-121

Vanaja M, Jyothi M, Ratnakumar P, Vagheera P, Raghuram Reddy P, Jyothi Lakshmi N, Venkat Reddy Y (1992). Growth analysis in castor genotypes. M.Sc (Ag) thesis, ANGR Agricultural University, Hyderabad.

9. Advances in genomics of oilseed crops

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Introduction

Climate factors affect manifestation of biotic and abiotic stresses in agricultural fields which in turn place major limits on crop productivity. Development of crop cultivars that are adapted to variable and changing climatic conditions are the need of the hour. Developments in the fields of genetics and genomics have the potential to assist plant breeders to come up with the climate resilient crop cultivars. Genomics is an interdisciplinary field of science that deals with the structure, function, evolution, mapping, and editing of genomes. The genomics field is fast evolving owing to next generation sequencing (NGS) technologies (Kchouk et al. 2017). Currently, whole genome sequencing of crops have become routine and several of them have been published (Thottathil et al. 2016).

Among various domains of genomics, ‘genome mapping’ assumes immediate relevance to crop improvement.Genome mapping permits the study of morphological, physiological, and developmental processes in which genetic variants exist (Paterson and Wing 1993). In simple terms, chromosomal locations of genes contributing for trait variation are determined through genome mapping techniques. DNA markers and quantitative trait loci (QTL) mapping are the most important tools used in genome mapping process. The genome sequencing projects, not only offers genomic information for deep analysis of genomes but also offers numerous DNA markers; for instance, simple sequence repeats (SSR) and single nucleotide polymorphisms (SNPs), which are fundamental for tracing genes associated with agronomic traits (Bolger et al. 2017).

DNA markers are the kind molecular markers, which are basically the sequence polymorphisms between or among the genomes of individuals. They are highly advantageous over morphological or biochemical markers because they fulfill most of the ideal properties of a genetic marker system: abundance, neutrality, reliability and amenability for automation. Molecular markers are widely used for characterizing germplasm, mapping of genes/quantitative trait loci (QTLs) associated with important traits, positional cloning of genes/QTLs, mining of alleles at candidate gene loci and marker-assisted selection (MAS) for pyramiding of desirable genes/QTLs for cultivar improvement purposes. Numerous genes conferring resistance to biotic stresses have been genetically mapped and are being used in breeding programmes through MAS. In contrast, tolerance to abiotic stresses is genetically complex - exhibits quantitative inheritance controlled by multiple genes and influenced by the environment – that make genetic enhancement through plant breeding more challenging.

Identification of genes/alleles through genome mapping process begins with finding of suitable germplasm with target trait, development of mapping populations (bi-parental populations produced from two genotypes that are contrasting for the target trait or ‘natural population’ such as germplasm collection). Basically, two genome mapping strategies are followed namely linkage mapping and association mapping (linkage disequilibrium based). The linkage mapping involves (1) development of bi-parental mapping populations (RILs/DHLs/BILs/$F_{2:3}$), (2) construction of genetic linkage maps and (3) marker-trait association using appropriate statistical tools. The association mapping involves two strategies namely genome-wide association analysis (GWAS) and candidate gene based allele mining. The GWAS include (1) development of genotype panels – germplasm/MAGIC/NAM populations, (2) high throughput genotyping, (3) phenotyping the panels and (4) marker-trait association through appropriate statistical tools. The allele mining include (1) development of genotype panel, (2) resequencing of candidate genes, (3) phenotyping the panel and (4) marker-trait association with traits using appropriate statistical tools. Once the QTL/gene is mapped, efforts are made to fine map, validate and design marker assays for prediction of them in breeding populations by MAS. In general, the traditional breeding methods such as pedigree selection, backcrossing and recurrent selection can be improved by integrating markers in the scheme. Accordingly, those breeding methods are referred as marker-assisted pedigree selection (MAPS), marker-assisted backcrossing (MABC) and marker-assisted recurrent selection (MARS). Recently, with the availability of high throughput genome-wide marker system, 'genomic selection' is gaining momentum with the plant breeders. More details on the process of genome mapping and molecular breeding can be found in Collard et al. (2005) and Collard and Mackill (2008).

Progress in genomics of oilseed crops

Brassica spp.

Brassica spp. are the front runner among oilseed crops in terms of molecular breeding research. The multi-national *Brassica rapa* genome sequencing project has been completed (Wang et al. 2011) and resequencing of several Brassica genomes are in progress (http://www.brassica.info/resource/sequencing.php). With the availability of genome sequences in the public domain, unlimited numbers of DNA markers (DArts, SSRs and SNPs) have been developed (Raman et al. 2014). Genes and QTLs associated with several traits have been mapped: turnip yellow virus (TuYV) (Dreyer et al. 2001), turnip mosaic virus (TuMV) (Quian et al. 2013), blackleg resistance genes (*Rlm1, Rlm3 and LepR3*) (Larkan et al. 2014) etc.

Soybean

Reference genome of soybean has been sequenced (Schumutz et al. 2010), which has facilitated development of unlimited number of SSR and SNP markers. A large number of genetic linkage maps have been developed in soybean (Hyten et al. 2010). Genes and QTLs associated with the traits: resistance to cyst nematode (*rhg1*, *rhg2*, *rhg3*, *Rhg4* and *Rhg5*) (Concibido et al. 2004), soybean mosaic virus (*Rsv1*, *Rsv3*, *Rsc14*) (Yang et al. 2013), Phytophthora (*Rps1*, *Rps2*, *Rps3*, *Rps4*, *Rps5*, *Rps6*, *Rps7*, and *Rps8*)(Burnham et al. 2003),rust, powdery mildew (*Rmd*) (Kang and Mian 2010), drought susceptibility (Du et al. 2012). MAS protocols have been developed for soybean cyst nematode resistance genes *Rhg1* (Kandoth et al. 2011) and *Rhg4* (Liu et al. 2012), soybean mosaic virus resistance genes *Rsv1* and *Rsv3* (Jeong and Sahai-Maroof 2004)etc. Improved soybean germplasm lines carrying multiple genes have been developed for use in MAS. For instance, a soybean germplasm line, LS-G96, resistant to soybean sudden death syndrome (SDS) and soybean cyst nematode (SCN) race 3 have been registered. This line carries four loci for SDS resistance and a single gene (*Rhg1*) for SCN resistance, which have been tagged with molecular markers for use in MAS (Schmidt et al. 1999). Arelli et al. (2006) registered a high yielding and multiple resistant soybean germplam line JTN-5503S carrying SCN resistant alleles *viz*., *rhg1*, *Rhg4*, and *Rhg5*, which was developed through MAS.

Groundnut

The International Peanut Genome Initiative has made substantial progress in sequencing of reference genome in peanut (https://peanutbase.org/files/IPGC/IPGI_StratPlan_2017-2021_FINAL_v3_3-31-16.pdf). Pandey et al. (2012) reviewed the status of genetic and genomic resources in groundnut which include >40 mapping populations, >7000 SSRs, >22 genetic maps and >272 QTLs. However, with the use of next generation sequencing technologies, high throughput SNP marker based linkage maps have started emerging (Zhu et al. 2014). Application of MAS in groundnut started with high oleic content in seed oil. Chu et al (2011) pyramided high oleic trait with nematode resistance in a nematode resistant cultivar Tifgaurd through MAS and developed ‘Tifgaurd high O/L’. Khedikar et al. (2010) reported a major QTL for rust resistance. Subsequently, Varshney et al. (2014) introgressed this QTL from cultivar 'GPBD 4' into three rust susceptible varieties ('ICGV 91114', 'JL 24' and 'TAG 24') through marker-assisted backcrossing.

Sunflower

Sunflower genome has recently been sequenced (Badouin et al. 2017). Globally, substantial efforts have been made to develop marker-assisted breeding in sunflower. High resolution genetic maps based on SSR and SNP markers have been developed (Talukdar et al. 2014). Several genes and QTLs have been mapped for the traits *viz*., downy mildew, rust, Orabanche, and chlorotic mottle virus; resistance to downy mildew, black stem, mid stalk rot and basal stem rot, drought, salinity or chilling stresses. Markers have been developed for selection of downy mildew and rust resistance (Lawson et al. 1998; Jocić et al. 2010) and high oleic trait (Schuppert et al. 2006). PCR based markers have been developed based on *Acetohydroxyacid synthase* (*AHAS*, also known as *Acetolactate synthase*, *ALS*) gene for selection of resistance to herbicides (imidazolinone and sulfonylurea) in sunflower. A form of the AHAS large subunit enzyme (*AHASL*) is less sensitive to herbicide inhibition and is conferred by a single, partially dominant nuclear gene. Use of *Ahasl* gene specific markers in screening of inbred lines for resistance against imidazolinone and sulfonylurea based herbicides has been demonstrated (Bulos et al. 2013).

Safflower

Reference safflower genome is not yet available. However, numerous DNA markers such as SSRs/SNPs has been developed (Chapman et al. 2009; Mayerhofer et al. 2010; Hamdan et al. 2011; Yamini et al. 2013; Lee et al. 2014). A high density SNP map has been published (Bowers et al. 2016). Mapping of stress tolerance traits in safflower is rare. Mirzahashemi et al. (2015) and Ebrahimi et al. (2017) reported association of molecular markers with drought tolerance in safflower. But there is a long way before utilization of marker information in breeding for drought tolerance in safflower.

Sesame

Genomic resources have been fairly developed in sesame. Nuclear (Wang et al. 2014) and chloroplast (Yi and Kim 2012) genomes of sesame have been sequenced. Wei et al. (2009) first constructed genetic linkage map of sesame with limited number of markers. Subsequently, Wei et al. (2011) and Zhang et al. (2012) developed a large collection of SSR markers from transcriptome sequences. Trait mapping studies are very limited in sesame. Recently, a GWAS study detected several QTLs associated with drought and salinity stress tolerance traits in sesame (Li et al. 2018).

Castor

Nuclear and organelle genomes of castor have been sequenced (Chan et al. 2010; Rivarola et al. 2011). A collection of SSR (Qiu et al. 2010 and SNP (Foster et al. 2010) markers has been developed in castor. However, global efforts are very limited. Currently, SNP genotyping system in castor has been developed at IIOR, Hyderabad and mapping of genes for disease resistance is underway (Senthilvel, Personal communication).

Linseed

Wang et al. (2010) reported *de novo* sequencing of linseed genome. Cloutier et al. (2012) developed consensus genetic and physical map. A large number of SSR (Kale et al. 2012) and SNP (Kumar et al. 2012) markers have been developed using NGS technologies. Asgarinia et al. (2013) reported three QTLs associated with powdery mildew resistance. Recently, Chandrawati and Yadav (2018) reported QTLs for oil content and yield attributes in linseed.

Niger

Till date, only one study by Dempewolf et al. (2010) reported development of genomic tools-the development of a library of expressed sequence tags, microsatellite loci, and the sequencing of its chloroplast genome.

Conclusion

Molecular plant breeding has been recognized as the foundation for crop improvement in 21st century to increase crop production (Moose and Mumm 2008; Tester and Langridge 2010). The MAS is an important tool which would certainly empower plant breeders to make their breeding programmes highly efficient and productive. A phenomenal success in developing stress tolerant cultivars by utilizing genomics information has been demonstrated in cereal crops. However, such stories are limited in the oilseed crops. Multi-disciplinary efforts need to be intensified for application of genomics for improvement of oilseed crops.

Cited references

Arelli, PR, Young LD and Mengistu A (2006) Registration of high yielding and multiple disease-resistant soybean germplasm JTN-5503. Crop Science 46: 2723- 2724.

Asgarinia P, Cloutier S, Duguid S, Rashid K, Mirlohi A, Banik M and Saeidi G (2013) Mapping quantitative trait loci for powdery mildew resistance in flax (*Linum usitatissimum* L.). Crop Science 53: 2462-2472.

Badouin H et al. (2017) The sunflower genome provides insights into oil metabolism, flowering and Asterid evolution. Nature 546: 148-152.

Bolger ME, Weisshaar B, Scholz U, Stein N, Usadel B and Mayer KFX (2014) Plant genome sequencing - applications for crop improvement. Current Opinion in Biotechnology 26: 31-37.
Bowers JE, Pearl SA and Burke JM (2016) Genetic mapping of millions of SNPs in safflower (*Carthamus tinctorius* L.) via whole-genome resequencing. G3 (Bethesda) 6(7): 2203-2211.

Bulos M, Sala CA, Altieri E and Ramos ML (2013) Marker-assisted selection for herbicide resistance in sunflower. HELIA 36 (59): 1-16.

Burnham KD, Dorrance AE, Francis DM, Fioritto RJ, and St. Martin SK (2003) Rps8, a new locus in soybean for resistance to *Phytophthora sojae*. Crop Science 43:101-105.

Chan AP, Crabtree J, Zhao Q, Lorenzi H, Orvis J, Puiu D, Melake-Berhan A, Jones KM, Redman J, Chen G, Cahoon EB, Gedil E, Stanke M, Haas BJ, JR Wortman, Fraser-Liggett CM, Ravel J and Rabinowicz PD (2010) Draft genome sequence of the oilseed species *Ricinus communis*. Nature Biotechnology 28:951-956.

Chandrawati and Yadav HK (2017) Development of linkage map and mapping of QTLs for oil content and yield attributes in linseed (*Linum usitatissimum* L.). Euphytica 213: 258. http://doi.org/10.1007/s10681-017-2050-x

Chapman MA, Hvala J, Strever J, Matvienko M, Kozik A, Michelmore RW, Tang S, Knapp SJ and Burke JM (2009) Development, polymorphism, and cross-taxon utility of EST-SSR markers from safflower (*Carthamus tinctorius* L.). Theoretical and Applied Genetics 120: 85-91.

Chu Y, Wu CL, Holbrook CC, Tillman BL, Person G and Ozias-Akins P (2011) Marker-assisted selection to pyramid nematode resistance and the high oleic trait in peanut. Crop Science 4:110-117.

Cloutier S, Ragupathy R, Miranda E, Radovanovic N, Reimer E, Walichnowski A, Ward K, Rowland G, Duguid S and Banik M (2012) Integrated consensus genetic and physical maps of flax (*Linum usitatissimum* L.). Theoretical and Applied Genetics 125:1783–1795.

Collard BCY and Mackill DJ (2008) Marker-assisted selection: an approach for precision plant breeding in the twenty-first century. *Philosophical Transactions of the Royal Society B*: *Biological Sciences* 363:557–572.

Collard BCY, Jahufer MZZ, Brouwer JB, Pang ECK (2015) An introduction to markers, quantitative trait loci (QTL) mapping and marker-assisted selection for crop improvement: The basic concepts. Euphytica 142: 169-196.

Concibido VC, Diers BW and Arelli PR (2004) A decade of QTL mapping for cyst nematode resistance in soybean. Crop Science 44:1121-1131.

Dempewolf H, Kane NC, Ostevik KL, Geleta M, Barker MS, Lai Z, Stewart ML, Bekele E, Engels JMM, Cronk QCB and Rieseberg LH (2010) Establishing genomic tools and resources for *Guizotia abyssinica* (L.f.) Cass.—the development of a library of expressed sequence tags, microsatellite loci, and the sequencing of its chloroplast genome. Molecular Ecology Resources doi: 10.1111/j.1755-0998.2010.02859.x

Dreyer F, Graichen K and Jung C (2001) A major quantitative trait locus for resistance to turnip yellow virus (TuYV, syn. beet western yellows virus, BWYV) in rapeseed. Plant Breeding 120:457-462.

Du W, Wang M, Fu S and Yu D (2012) Mapping QTLs for seed yield and drought susceptibility index in soybean (*Glycine max* L.) across different environments.Journal of Genetics and Genomics 36:721-731.

Ebrahimi F, Majidi MM, Arzani A and Mohammadi-Nejad G (2017) Association analysis of molecular markers with traits under drought stress in safflower. Crop and Pasture Science 68(2): 167-175.

Foster JT, Allan GJ, Chan AP, Rabinowicz PD, Ravel J, Jackson PJ and Keim P (2010) Single nucleotide polymorphisms for assessing genetic diversity in castor bean (*Ricinus communis*) BMC Plant Biology10:13.

Hamdan YAS, García-Moreno MJ, Redondo-Nevado J, Velasco L and Pérez-Vich B (2011) Development and characterization of genomic microsatellite markers in safflower (*Carthamus tinctorius* L.) Plant Breeding130:237-241.

Hyten DL, Cho IL, Song Q, Specht JE, Carter TE, Shoemaker RC, Hwang EY, Matukumalli LK and Cregan PB (2010) A high density integrated genetic linkage map of soybean and the development of a 1536 universal soy linkage panel for quantitative trait locus mapping. Crop Science 50:960-968.

Jeong SC and Saghai Maroof MA (2004) Detection and genotyping of SNPs tightly linked to two disease resistance loci, *Rsv1* and *Rsv3,* of soybean. Plant Breeding 123:305-310.

Jocić S, Cvejić S, Hladni N, Miladinović D and Miklič V (2010) Development of sunflower genotypes resistant to downy mildew. Helia 33(53):173-180.

Kale SM, Pardeshi VC, Kadoo NY, Ghorpade PB, Jana MM and Gupta VS (2012) Development of genomic simple sequence repeat markers for linseed using next generation sequencing technology. Molecular Breeding 30:597-606.

Kandoth PK, Ithal N, Recknor J, Maier T, Nettleton D, Baum TJ and Mitchum MG (2011) The soybean ***Rhg1*** locus for resistance to the soybean cyst nematode ***Heterodera glycines*** regulates the expression of a large number of stress- and defense-related genes in degenerating feeding cells. Plant Physiology 155:1960-1975.

Kang ST and Mian MA (2010) Genetic map of the powdery mildew resistance gene in soybean PI 243540. Genome 53:400-405.

Kchouk M, Gibrat J-F and Elloumi M (2017) Generations of sequencing technologies: from first to next generation. Biol Med (Aligarh) 9: 395. doi:10.4172/0974-8369.1000395

Khedikar YP, Gowda MVC, Sarvamangala C, Patgar KV, Upadhyaya HD and Varshney RK (2010) A QTL study on late leaf spot and rust revealed one major QTL for molecular breeding for rust resistance in groundnut (*Arachis hypogaea* L.). Theoretical and Applied Genetics 121:971–984.

Kumar S, You FM and Cloutier S (2012) Genome wide SNP discovery in flax through next generation sequencing of reduced representation libraries. BMC Genomics 13:684.

Larkan NJ, **Lydiate DJ**, **Yu F**, **Rimmer SR** and **Borhan MH**(2014) Co-localisation of the blackleg resistance genes ***Rlm2*** and***LepR3*** on ***Brassica napus*** chromosome A10. ***BMC Plant Biology*** **14**:387.

Lawson, WR, Goulter KC, Henry RJ, Kong GA and Kochman JK (1998) Marker assisted selection for two rust resistance genes in sunflower. *Molecular Breeding* 4(3): 227-234.

Lee G-A, Sung J-S, Lee SY, Chung JW, Yi JY, Kim YY, Lee M-C (2014) Genetic assessment of safflower (*Carthamus tinctorius* L.) collection with microsatellite markers acquired *via* pyrosequencing method.Molecular Ecology Resources 14: 69-78.

Li D, Dossa K, Zhang Y, Wei X, Wang L, Zhang Y, Liu A, Zhou R and Zhang X (2018) GWAS uncovers differential genetic bases for drought and salt tolerances in sesame at the germination stage. Genes 9, 87; doi: 10.3390/genes9020087

Liu S, Kandoth PK, Warren SD, Yeckel G, Heinz R, Alden J, Yang C, Jamai A, El-Mellouki T, Juvale PS, Hill J, Baum TJ, Cianzio S, Whitham SA, Korkin D, Mitchum MG and Meksem K (2012) A soybean cyst nematode resistance gene points to a new mechanism of plant resistance to pathogens. Nature 492:256-260.

Mayerhofer R, Archibald C, Bowles V and Good AG (2010) Development of molecular markers and linkage maps for the *Carthamus* species *C. tinctorius* and *C. oxycanthus*. Genome53: 266-276.

Mirzahashemi M, Mohammadi-Nejad G and Golkar P (2015) A QTL linkage map of safflower for yield under drought stress at reproductive stage. IRANIAN JOURNAL of GENETICS and PLANT BREEDING, 4(2): 20-27.

Moose SP and Mumm RH (2008) Molecular plant breeding as the foundation for 21st century crop improvement. Plant Physiology147:969–977.

Pandey MK, Monyo E, Ozias-Akins P, Liang X, Guimarães P, Nigam SN, Upadhyaya HD, Janila P, Zhang X, Guo B, Cook DR, Bertioli DJ, Michelmore R and Varshney RK (2012) Advances in *Arachis* genomics for peanut improvement. Biotechnology Advances 30:639-651.

Paterson AH and Wing RA (1993) Genome mapping in plants. Current Opinion in Biotechnology 4(2): 142-147.

Qian W, Zhang S, Zhang S, Li F, Zhang H, Wu J, Wang X, Walsh JA and Sun R (2013) *Mapping and candidate-gene screening of the novel turnip mosaic virus resistance gene retr02 in Chinese cabbage (Brassica rapa L.).* Theoretical and Applied Genetics 126: 179-188.

Qiu L, Yang C, Tian B, Yang JB and Liu A (2010) Exploiting EST databases for the development and characterization of EST-SSR markers in castor bean (*Ricinus communis* L.). BMC Plant Biology 10:278.

Rivarola M, Foster JT, Chan AP, Williams AL, Rice DW, et al. (2011) Castor bean organelle genome sequencing and worldwide genetic diversity analysis. PLoS ONE 6(7): e21743. doi:10.1371/journal.pone.0021743

Schmidt ME, Suttner RJ, Klein JH, Gibson PT, Lightboot DA, Myers O Jr. (1999) Registration of LS-G96 soybean germplasm resistant to soybean sudden death syndrome and soybean cyst nematode race 3. Crop Science 39:598.

Schmutz et al. (2010) Genome sequence of the palaeopolyploid soybean. *Nature* 463: 178-183

Schuppert G, Tang S, Slabaugh M and Knapp SJ (2006) The sunflower high-oleic mutant *Ol* carries variable tandem repeats of *FAD2-1*, a seed-specific oleoyl-phosphatidyl choline desaturase. Molecular Breeding 17: 241-256.

Talukder ZI, Gong L, Hulke BS, Pegadaraju V, Song Q, et al. (2014) A high-density SNP map of sunflower derived from RAD-sequencing facilitating fine-mapping of the rust resistance gene R_{12}. PLoS ONE 9(7): e98628. doi:10.1371/journal.pone.0098628

Tester M and Langridge P (2010) Breeding technologies to increase crop production in a changing world. Science 327:818-822.

Thottathil GP, Jayasekaran K and Othman AS (2016) Sequencing crop genomes: a gateway to improve tropical agriculture. Tropical Life Sciences Research, 27(1): 93-114.

Varshney R, Pandey M, Janila P, Nigam S, Sudini H, Gowda M, Sriswathi M, Radhakrishnan T, Manohar S and Nagesh P (2014) Marker-assisted introgression of a QTL region to improve rust resistance in three elite and popular varieties of peanut (*Arachis hypogaea* L.) Theoretical and Applied Genetics 127:1771.

Wang et al. (2010) The genome of flax (*Linum usitatissimum*) assembled *de novo* from short shotgun sequence reads. The Plant Journal 72: 461-473.

Wang et al. (2011) The genome of the mesopolyploid crop species *Brassica rapa*. Nature Genetics 43:1035-1039.

Wang et al. (2012) The genome of flax (*Linumusitatissimum*) assembled de novo from short shotgun sequence reads. The Plant Journal 72: 461-473.

Wang L, Yu S, Tong C, Zhao Y, Liu Y, Song C, Zhang Y, Zhang X, Wang Y, Hua W, Li D, Li D, Li F, Yu J, Xu C, Han X, Huang S, Tai S, Wang J, Xu X, Li Y, Liu S, Varshney RK, Wang J and Zhang X (2014) Genome sequencing of the high oil crop sesame provides insight into oil biosynthesis. Genome Biology 15:R39

Wei LB, Zhang HY, Zheng YZ, Miao HM, Zhang TZ and Guo WZ (2009) A genetic linkage map construction for sesame **(***Sesamum indicum* L**.).** *Genes and Genomes* 31(2)**:**199-208.

Wei W, Qi X, Wang L, Zhang Y, Hua W, Li D, Lv H and Zhang X (2011) Characterization of the sesame (*Sesamum indicum* L.) global transcriptome using Illumina paired-end sequencing and development of EST-SSR markers. BMC Genomics 12:451.

Yamini KN, Ramesh K, Naresh V, Rajendrakumar P, Anjani K and Dinesh Kumar V (2013) Development of EST-SSR markers and their utility in revealing cryptic diversity in safflower (*Carthamus tinctorius* L.). Journal of Plant Biochemistry and Biotechnology 22: 90-102.

Yang Y, Zheng G, Han L, Dagang W, Yang X, Yuan Y, Huang S and Zhi H (2013) Genetic analysis and mapping of genes for resistance to multiple strains of soybean mosaic virus in a single resistant soybean accession PI 96983. Theoretical and Applied Genetics 126:1783-1791.

Yi DK and Kim KJ (2012) Complete chloroplast genome sequences of important oilseed crop *Sesamum indicum* L. PLOS One 7(5) e35872. Doi:10.1371/journal.pone.0035872.

Zhang HY, Wei LB, Miao HM, Zhang TD and Wang CY (2012) Development and validation of genic-SSR markers in sesame by RNA-seq. BMC Genomics 13:316.

Zhou X, Xia Y, Ren X, Chen Y, Huang L, Huang S, Liao B, Lei Y, Yan L and Jiang H (2014) Construction of a SNP-based genetic linkage map in cultivated peanut based on large scale marker development using next-generation double-digest restriction-site-associated DNA sequencing (ddRADseq). BMC Genomics 15:351.

10. Biotechnology: A tool to understand and enhance stress tolerance in plants

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In this primer, an attempt has been made to provide a perspective for the role of biotechnology in understanding the mechanisms adopted by plants in coping up with the stress imposed by climate change. During discussion in the interaction session, suitable examples will be taken to illustrate the concepts as well as provide examples of successful application of biotechnology tools in alleviating effects of climate change.

Plants being sessile are forced to face a whole range of stresses and need to adapt themselves to cope up with the vagaries of nature. In the process of evolution, plants have developed different mechanisms to overcome these stresses. The famous quote by evolutionary biologist Charles Darwin “it is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change” sums up the importance of adapting to the changing environment. Based on this fundamental principle, different crops and genotypes within the crops, have developed alternate strategies to counter the stresses which are more prevalent in the growing conditions they have evolved in. Several studies have revealed the underlying principles and mechanisms that govern stress alleviation strategies in different plant systems and germplasm lines. In general, the stress resistance mechanisms have been classified into three categories: avoidance (prevents exposure to stress), tolerance (including adaptation - ability to maintain functioning when exposed to a wide range of conditions, reduce the deleterious effect of stress compared to normal conditions, genetic and inherited and therefore, exploitable through crop improvement methods) and acclimation (physiological changes brought in by some cultural or management techniques to avoid effect of stress and not inherited). Plants have evolved to live in environments where they are often exposed to different stress factors in combination and they have developed specific mechanisms (that impart ability to tolerate stress conditions) that allow them to detect precise environmental changes and respond to complex stress conditions, minimizing damage while conserving valuable resources for growth and reproduction.

Plants activate a specific and unique stress response when subjected to a combination of multiple stresses. In light of this, interestingly, it has been reported that plants often adopt antagonistic pathways to counter biotic and abiotic stresses. Therefore, it becomes imperative that one understands the intricate and complex measures plants follow to face the challenges of stresses before embarking on the ways to genetically improve stress tolerance. Even though, the importance of the studies that concentrate on implications of a single stress factor cannot be downplayed, it is necessary to appreciate that such stand alone experiments do not provide an overall picture of what plants actually do when faced with multiple stresses. It is learnt that many factors such as stress characteristics (duration, intensity, frequency and combined or individual stress), plant characters (genotype, developmental stage, tissue under consideration), response (resistance v/s susceptibility) and the end result (survival or death) determine the ultimate plant response to a stress condition. Under these circumstances, techniques and methods that will provide an overall idea of changes the plants try to bring in, at different levels of organization *viz*., molecular, biochemical, physiological that manifest as traits at cellular, tissue, organ level, plant and population levels, take central stage in understanding the responses of plants to different stress conditions. Stress physiology has become a specialized field of study that tries to understand these changes and tries to provide an overall idea of underlying routes that lead a plant to be tolerant to stress conditions. Ever since biologists have appreciated that plants (and their genotypes) are differently enabled to cope up with stress(es), continued efforts are on to understand this differential reaction of plants so that it provides a means to bring such traits together into one genotype that can withstand the stress better. As a basic rule, plant will have to tinker the expression of a set of genes that it has in its genome ensemble to nullify the harmful effects (such as release of ROS, damage to the macromolecules in structure and/or function, etc) caused by stress and take up corrective steps to either contain the stress or overcome the stress. Thus it is prudent to understand the stress tolerance mechanism in a holistic manner and then exploit that information in combining the traits from different sources to develop a stable genotype with horizontal tolerance to multiple stresses.

Plant breeders have been tackling the issue of stress tolerance by combining relevant traits from the available germplasm lines that show different traits. But, to transfer single stress related traits from different donors into one agronomically superior genotype, is not only time consuming but also not precise. Usually there will be compromise in the performance of the introgressed lines due to linkage drag. Also, to assess precisely the contribution of each of the ancillary traits towards the ultimate stress tolerance is extremely difficult through conventional approaches of study. Under these circumstances, to enable biologists understand the significance of contributing traits and the exact cellular processes and pathways that lead to the manifestation of these traits, applying modern tools and techniques is imperative. Biotechnology, as a tool has contributed in a big way in this endeavour. Starting with the development of techniques (like development of vectors, ligation methods, precisely combining the component sequences to result in expression units) for basic recombinant DNA related work, identifying differentially expressed genes under stress conditions [through low throughput techniques such as RT-PCR (reverse transcriptase PCR), Northern analysis to moderately high throughput techniques such DDRT-PCR (differential display reverse transcriptase PCR), SAGE (Serial analysis of gene expression), subtractive hybridization and high throughput techniques such as microarrays and RNA-seq], genetic engineering tools have revolutionized our understanding of the molecular basis of stress tolerance. Advent of 'omics' technologies have paved way for understanding the global changes that happen at transcript, protein and metabolite level during stress conditions. Multi-omics approaches have provided a clearer picture of understanding the changes happening at the cellular processes at different levels of organization and this has been summed up in Fig. 1.

With so many techniques, a large volume of data is generated and to make scientific interpretations and biological meaning out of that data, bioinformatics (an interdisciplinary field that develops methods and software tools for understanding biological data; As an interdisciplinary field of science, bioinformatics combines molecular biology and genetics, computer science, information engineering, mathematics and statistics to analyze and interpret biological data) has come up as a mainstream science section and has helped in a broader understanding of the data generated. With this melange of techniques, it has now been possible to identify the key players (genes and their encoded proteins) that help plants in sensing the stress condition quite well in advance, trigger a subset of master regulators (transcription factors or other gene regulators like microRNAs, chromatin modulators) that in turn turn-on pathways and biological processes (that bring in next level of defence) to come to the rescue of plants not only from the damage caused by stress but also help plants in adopting coping-up mechanisms and continue to put forth growth under sub-optimal conditions created by stress. Several labs around the world have engaged in unravelling the biological processes and pathways that play pivotal role in imparting the resilience to plants that empower them in circumventing stress induced ill effects. These studies, taken together, have ushered in a new era in not only our understanding of plant response to stress but also have made us understand the real complexity and gene network that operate in the phenomenon of stress tolerance.

Fig.1. Different 'omics' technologies and their utility to study the changes at different levels of hierarchy at cellular and molecular levels (reproduced from Meena et al., 2017).

Biotechnology tools have not only allowed us to look at the global changes that happen at molecular level but also have helped in precisely establishing the functional role of the genes. This has paved way in precisely understanding the role of gene(s) in imparting stress tolerance. Genetic engineering tool which refers to 'the artificial manipulation, modification and recombination of DNA or other nucleic acid molecules in order to modify an organism or population of an organism' has made it possible to create new gene constructs with precisely regulated expression patterns (that are either spatial or temporal). Once these gene constructs (recombinant molecules) are introduced into the plants through different approaches (collectively called transformation process), and the resultant transgenic (defined as 'of, relating to, or being an organism whose genome has been altered by the transfer of a gene from sexually incompatible species') plants are analyzed through appropriate methods (including molecular, biochemical and bioassays), the precise effect of the introduced gene(s) in imparting stress tolerance would be established unequivocally. One special advantage of genetic engineering is the ability to transform plants with genes from other species rather than just tinkering (up or down-regulating) an already existing plant stress response. Once this is achieved, in most of the cases, the same gene constructs could be used to impart the trait in any other genotype of the same species or in other species as well. Depending on the hierarchy of the introduced gene(s) in the cellular or biochemical pathway, many genes and pathways could be simultaneously tinkered (up or down regulated) and thus bring in more generic or precise changes in the stress related traits. There are now innumerable examples where precise roles of the gene(s) have been established and also products (transgenic lines) have been developed that have proven superior in tolerating one or many stress(es). Thus, once the differentially expressed gene(s) are identified through any of the molecular techniques, the exact role and function of that gene will be established by transforming a target plant and analyzing the resultant transgenic plants. Fig 2 gives a very simplistic scheme of this process.

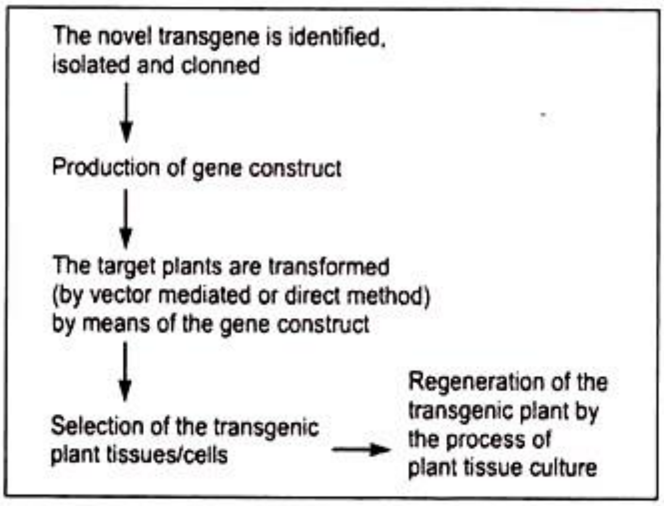

Fig.2. A simplified version of plant transformation - the flow of establishing the role of a new gene that has been identified to play a role in stress tolerance

Using all the techniques in the repertoire of biotechnology toolkit, several model systems have been studied and the complexity of gene action is being understood. These studies have not only identified the broad consensus that operates in different plant systems to cope up with climate change induced stress(es) but also have identified the multitude of specific molecular responses that operate in 'plant specific' and 'genotype specific' manner. Needless to say, there are commonalities in response to different stresses as well as unique responses to each of the stresses. These complexities have led to an understanding that concerted efforts are needed to unify the concepts in mechanisms operating at molecular level as observed in different systems and then use that information to develop stress tolerant genotypes.

During the course of discussion, examples will be drawn to illustrate the utility of biotechnology in basic studies (of understanding the mechanisms of stress tolerance) as well as to provide an overview of the type of responses seen in plants during different stresses. Also, examples of adopting biotechnology tools in developing transgenic plants with improved stress tolerance will be discussed to provide an overview of the utility of biotechnology in addressing the issue of coping up with climate change related problems.

References: Readers are referred to the following reviews that provide updated information regarding how biotechnological tools have helped us in understanding molecular basis of stress tolerance as well as how it has helped in developing genotypes with improved stress tolerance.

Agarwal PK, Gupta K, Lopato S and Agarwal P. 2017. Dehydration responsive element binding transcription factors and their applications for the engineering of stress tolerance. Journal of Experimental Botany 68: 2135–2148, 2017. doi:10.1093/jxb/erx118

Ahanger MA, Akram NA, Ashraf M, Alyemeni MN, Wijaya L, Ahmad P. 2017. Plant responses to environmental stresses from gene to biotechnology. AoB PLANTS 9: plx025; doi:10.1093/aobpla/plx025

Ahuja I, de Vos RCH, Bones AM and Hall RD. 2010. Plant molecular stress responses face climate change. Trends Plant Sciences 15: 664-674. https://doi.org/10.1016/j.tplants.2010.08.002

Djami-Tchatchou AT, Sanan-Mishra N, Ntushelo K and Dubery IA. 2017. Functional roles of microRNAs in agronomically important plants—Potential as targets for crop improvement and protection. Front. Plant Sci. 8:378. doi: 10.3389/fpls.2017.00378

Egamberdieva D, Wirth SJ, Alqarawi AA, Abd_Allah EF and Hashem A. 2017. Phytohormones and Beneficial Microbes: Essential Components for Plants to Balance Stress and Fitness. Front. Microbiol. 8:2104. doi: 10.3389/fmicb.2017.02104

Filichkin S, Priest HD, Megraw M and Mockler TC. 2015. Alternative splicing in plants: directing traffic at the crossroads of adaptation and environmental stress. Current Opinion in Plant Biology 2015, 24:125–135

Fuganti-Pagliarini R, Ferreira LC, Rodrigues FA, Molinari HBC, Marin SRR, Molinari MDC, Marcolino-Gomes J, Mertz-Henning LM, Farias JRB, de Oliveira MCN, Neumaier N, Kanamori N, Fujita Y, Mizoi J, Nakashima K, Yamaguchi-Shinozaki K and Nepomuceno AL. 2017. Characterization of soybean genetically modified for drought tolerance in field conditions. Front. Plant Sci. 8:448. doi: 10.3389/fpls.2017.00448

Haak DC, Fukao T, Grene R, Hua Z, Ivanov R, Perrella G and Li S. 2017. Multilevel regulation of abiotic stress responses in plants. Front. Plant Sci. 8:1564.doi: 10.3389/fpls.2017.01564

Hennig L Plant gene regulation in response to abiotic stress. Biochimica et Biophysica Acta 1819 (2012) 85

Imadi S. R., Kazi A. G., Ahanger M. A., Gucel S. and Ahmad P. 2015 Plant transcriptomics and responses to environmental stress: an overview. J. Genet. **94**, 525–537

Khraiwesh B, Zhu JK and Zhu J. 2012. Role of miRNAs and siRNAs in biotic and abiotic stress responses of plantsBiochimica et Biophysica Acta 1819: 137–148doi:10.1016/j.bbagrm.2011.05.001

Kumar A, Sengar RS, Singh,A, Dixit R and Singh R. 2017. Biotechnological tools for enhancing abiotic stress tolerance in plant. In S. Sengar, A. Singh (eds.), Eco-friendly

Agro-biological Techniques for Enhancing Crop Productivity, pp: 147-174https://doi.org/10.1007/978-981-10-6934-5_8

Lata R, Chowdhury S, Gond SK and White Jr JF. 2018. Induction of abiotic stress tolerance in plants by endophytic microbes. Letters in Applied Microbiology 66: 268-276 doi:10.1111/lam.12855

Li Y, Chen Q, Nan H, Li X, Lu S, Zhao X, et al. 2017. Overexpression of GmFDL19 enhances tolerance to drought and salt stresses in soybean. PLoS ONE 12(6): e0179554. https://doi.org/10.1371/journal.pone.0179554

Meena KK, Sorty AM, Bitla UM, Choudhary K, Gupta P, Pareek A, Singh DP, Prabha R, Sahu PK, Gupta VK, Singh HB, Krishanani KK and Minhas PS. 2017. Abiotic stress responses and microbe-mediated mitigation in plants: The ‘omics’ strategies. Front. Plant Sci. 8:172 doi: 10.3389/fpls.2017.00172

Mishra A and Tanna B. 2017. Halophytes: potential resources for salt stress tolerance genes and promoters. Front. Plant Sci. 8:829. doi: 10.3389/fpls.2017.00829

Moustafa I and Cross JM. 2016. Genetic approaches to study plant responses to environmental stresses: An Overview. Biology 5: 20 doi:10.3390/biology5020020

Mushtaqa M, Bhata JA, Mirc ZA, Sakinab A, Alid S, Singha AK, Tyagi A, Salgotra RK, Dare AA and Bhata R. 2018. CRISPR/Cas approach: A new way of looking at plant-abiotic interactions. Journal of Plant Physiology 224–225: 156–162https://doi.org/10.1016/j.jplph.2018.04.001

Nejat N and Mantri N. 2017. Plant immune system: Crosstalk between responses to biotic and abiotic stresses the missing link in understanding plant defence. Curr. Issues Mol. Biol. (2017) 23: 1-16. DOI: http://dx.doi.org/10.21775/cimb.023.001

Nguyena HC, Linb KH, Hoc SL, Chiangd CM and Yange CM. 2018. Enhancing the abiotic stress tolerance of plants: from chemical treatment to biotechnological approaches. Physiologia Plantarum. E- published ahead of print.doi:10.1111/ppl.12812

Noman A, Fahad S, Aqeel M, Ali U, Anwar AS, Baloch SK, Zainab M. 2017. miRNAs: Major modulators for crop growth and development under abiotic stresses. Biotechnol Lett. 39:685–700. DOI 10.1007/s10529-017-2302-9

Pandey S, Fartyal D, Agarwal A, Shukla T, James D, Kaul T, Negi YK, Arora S and Reddy MK. 2017. Abiotic Stress Tolerance in Plants: Myriad Roles of Ascorbate Peroxidase. Front. Plant Sci. 8:581. doi: 10.3389/fpls.2017.00581

Per TS, Khan NA, Reddy PS, Masood A, Hasanuzzaman M, Iqbal MRK and Anjum NA. 2017. Approaches in modulating proline metabolism in plants for salt and drought stress tolerance: Phytohormones, mineral nutrients and transgenics. Plant Physiology and Biochemistry 115 :126e140ehttp://dx.doi.org/10.1016/j.plaphy

Pérez-Clemente RM, Vives V, Zandalinas SI, López-Climent MF, Muñoz V and Gómez-Cadenas A. 2013. Biotechnological Approaches to Study Plant Responses to Stress. BioMed Research International Volume Article ID 654120, 10 pages http://dx.doi.org/10.1155/2013/654120

Ramu VS, Swetha TN, Sheela SH, Babitha CK, Rohini S, Reddy MK, Tuteja N, ReddyCP, Prasad TG and Udayakumar M. 2016. Simultaneous expression of regulatory genes associated with specific drought-adaptive traits improves drought adaptation in peanut. Plant Biotechnology Journal 14:1008–1020. doi: 10.1111/pbi.12461

Rasmussen S, Barah P, Suarez-Rodriguez MC, Bressendorff S, Friis P, Costantino P, Bones AM, Nielsen HB and Mundy J. 2013. Transcriptome responses to combinations of stresses in Arabidopsis. Plant Physiol 161: 1783–1794. www.plantphysiol.org/cgi/doi/10.1104/pp.112.210773

Reguera M, Peleg Z and Blumwald E. 2012. Targeting metabolic pathways for genetic engineering abiotic stress-tolerance in crops. Biochimica et Biophysica Acta 1819: 186–194. doi:10.1016/j.bbagrm.2011.08.005

Shulaev V, Cortes D, Miller G and Mittler R. 2008. Metabolomics for plant stress response. Physiologia Plantarum 132: 199–208. doi: 10.1111/j.1399-3054.2007.01025.x

Urano K, Kurihara Y, Seki Mand Shinozaki K. 2010. Current Omics' analyses of regulatory networks in plant abiotic stress responses. Opinion in Plant Biology 2010, 13:132–138. DOI 10.1016/j.pbi.2009.12.006

Wanga Z, Yanga C, Chena H, Wangb P, Wanga P, Songa C, Zhanga X, Wanga D. 2018. Multi-gene co-expression can improve comprehensive resistance to multiple abiotic stresses in *Brassica napus* L. Plant Science 274: 410–419https://doi.org/10.1016/j.plantsci.2018.06.014

Xuan Lan Thi Hoang XLT, Nhi DNH, Thu NBA, Thao NP and Tran PLS. 2017.Transcription factors and their roles in signal transduction in plants under abiotic stresses. Current Genomics, 2017, 18, 483-497.DOI: 10.2174/1389202918666170227150057

Yongqing Yang and Yan Guo. Elucidating the molecular mechanisms mediating plant salt-stress responses.New Phytologist (2018) 217: 523–539 doi: 10.1111/nph.14920

Zargar SM, Nagar P, Deshmukh R, Nazir M, Wani AA, Masoodi KZ, Agrawal GK and Rakwal R. 2017. Aquaporins as potential drought tolerance inducing proteins: Towards instigating stress tolerance. Journal of Proteomics 169 (2017) 233–238

11. Strategies for sustaining oilseeds production under dryland conditions

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Introduction

India accounts for about 2.3% of world's geographical area and 4.2% of its water resources but has to support almost 18% of world's human population and 15% of the livestock. Agriculture remains the most important sector of Indian economy with 18% share in GDP at 2011-12 prices, 11% of exports and 53.3% share in total employment or workforce in 2013-14. Rainfed agroecosystems occupy a significant place in Indian agriculture covering about 80 M ha, in arid, semiarid, and subhumid climatic zones, constituting nearly 54% of the net cultivated area. These areas contribute almost 100% of forest products, 84–87% of coarse grain cereals and pulses, 80% of horticulture, 77% of oilseeds, 60% of cotton, and 50% of fine cereals including rice, wheat, maize, sorghum etc. (Srinivasarao *et al*., 2015). Further, rainfed regions support 60% of livestock and 40% of human population and contribute 40% of food grains and several special-attribute commodities such as seed spices, dyes, herbs, gums etc.

Major challenges

The major challenges of rainfed agriculture would be to sustain the livelihoods of the small and marginal farmers who are dependent on agriculture despite increased climate variability and shrinking land holding size. Droughts and famines are the general features of rainfed agriculture in India. Long-term data for India indicate that rainfed areas experience 3-4 drought years in every 10-year period. Of these, two to three are in moderate and one or two may be of severe intensity. The occurrence of the drought is very frequent in the sub-divisions like West Rajasthan, Tamil Nadu, Jammu & Kashmir and Telangana. Very high incidence of drought (>20%) is observed in a few districts in Rajasthan and Gujarat. The incidence is relatively low in the Western ghats, Eastern and North-Eastern India (Rama Rao *et al*., 2013).Agricultural production in India is closely linked to the performance of summer monsoon (June to September) which contributes about 75% of the annual precipitation. Extreme climatic events such as drought and floods occurring in the same crop growing season can seriously undermine our efforts to enhance production using current technology.

Similarly, edaphic constraints like poor water and nutrient retention capacity, low soil organic matter (SOM) make rainfed agriculture highly vulnerable and less resilient requiring a different outlook and strategy. Severe soil organic carbon (SOC) depletion is a major constraint in rainfed agro-ecosystems because it directly influences soil quality, crop productivity and sustainability (Srinivasarao, 2011). The soil organic carbon, which is a seat of major soil processes and functions, is < 5 g/kg in rainfed soils whereas the desired level is 11 g/kg. Soil crusting in red and black soils; shallow depth, poor drainage in heavy textured soils of Madhya Pradesh, Maharashtra, Chhattisgarh, Northern Karnataka and Eastern Maharashtra; sodic soils of Haryana, Tamil Nadu and Andhra Pradesh; universal deficiency of macro- and micro-nutrients (Zn, B); are major issues. Change in rainfall intensity could cause more soil erosion. Unlike irrigated systems, harnessing the synergy between soil moisture and applied nutrients in rainfed crops is a major challenge due to erratic distribution of rainfall.

Resilient rainfed technologies for higher oilseed production

Central Research Institute for Dryland Agriculture (CRIDA) and All India Coordinated Research Project for Dryland Agriculture (AICRPDA) in association with State Agricultural Universities, Technical Universities and Research Institutes of Indian Council of Agricultural Research have developed location specific technologies particularly for rainfed cultivation of soybean, groundnut, castor and sunflower, during past 4 decades and these technologies are being upscaled into ground level implementation through various government departments. Improved water storage through *in-situ* moisture conservation and stored runoff are basics for bringing resilience to drought or moisture stress conditions often encountered by the rainfed oilseed crops. Other strategies for bringing resilience are through soil management, resilient intercropping systems, drought tolerant short duration cultivars, and suitable farm implements for small holdings.

Rainwater conservation and harvesting

Effective rainwater management is critical for drought mitigation and successful cultivation of oilseed crops under rainfed conditions. *In-situ* soil and water conservation (SWC) practices improve soil structure and soil porosity, increase infiltration and hydraulic conductivity, and consequently increase soil water storage and promote crop growth and build adequate soil cover. Based on extensive research conducted at various locations in the country, several soil and water conservation measures have been recommended (Table 1) and many of these practices are being adopted in a significant area in the country.

Table 1. Location specific *in-situ* moisture conservations practices

Practice	Crops/cropping system	Remarks
Compartmental bunding	sunflower,safflower	Theimpactof the practice is more during sub-optimal rainfall years. It alsosignificantlycontrolsrunoff. Thispracticeisadoptedon more than 800 hainNorthernKarnataka
Conservation furrow	Fingermillet/ groundnut + pigeonpea (8:2), soybean + pigeonpea (4:2), cotton + soybean (1:1)	Opening of conservation furrow enhances *in-situ* moisture conservation, thus the crops can overcome the effect of dry spells resulting in increased rainwater use efficiency, better performance of crops and additional net returns.
Broad bed & furrow (BBF)	Soybean, groundnut	BBF system helps draining out of excess water from the black soils. Further, the rainwater conserved in the furrows helps in better performance of crop during long dry spells.
Set furrow	Pearlmillet-sunflower, pigeonpea + groundnut (2:4)	Conservesmoremoistureandmakeitavailableforlongertimetothecrops. Thishelpstoovercometheeffectofdrought.
Inter-plot rainwater harvesting	Sunflower	This practice makes possible to take up two crops even in drought years mainly by allowing rainfall infiltration into the soil profile.

Source: Srinivasarao and Gopinath (2016)

In addition to *in-situ* conservation, efforts need to be made to divert the surplus water into storage structures which can be used either as standalone resource or in conjunction with groundwater for meeting the critical irrigation requirements. In relatively high rainfall regions, the strategy is to conserve as much rainwater as possible and to harvest the surplus water for life saving irrigation and also for enhancing the cropping intensity and to maximize returns from the harvested water. Apart from enhancing the availability of water by various methods, increasing the water use efficiency should be the focus by arresting various kinds of losses associated with utilization of water. For example, at Anantapuramu, application of 1.0 cm irrigation through sprinklers to groundnut during stress at pod development stage gave pod yield of 1023 kg/ha compared to control (820 kg/ha). The capital (Rs. 41,500/-) recovery can be made over a period of 4 to 5 years by adoption of farm pond technology with a groundnut pod yield increase by 20 to 30% annually (Srinivasarao *et al.*, 2014).

Soil management

Dryland soils are not only thirsty but also hungry. Without regular application of organic manure and recycling of crop residues, it is difficult to maintain and sustain productivity and ensure high responses to NPK fertilizers. Applications of recommended quantity of fertilizers and INM practices have shown to increase the productivity of several rainfed crops up to 15–32%. Some recommended practices for soil fertility management include diverse crop rotations with legumes, and INM involving addition of farmyard manure (FYM), use of groundnut shells (GNS) and other crop residues (CRs), green leaf manuring (GLM), etc. For each ton of soil organic carbon improvement, productivity enhancement ranging from 50 to 300 kg/ha was recorded among different agro-ecoregions. In Anantapuramu, soil test based fertilizer application in groundnut gave a mean pod yield of 929 kg/ha, compared to farmers practice (807 kg/ha), and reduced cost of cultivation by Rs 900/ha with a B:C ratio of 1.72 compared to farmers’ practice with B:C ratio of 1.30. Application of sulphur (30 kg/ha) in bands along with recommended dose of N and P increased soybean seed yield by 66% and net income by 124% with a B:C ratio of 2.30 compared to farmers’ practice (729 kg/ha). In Saurashtra zone of Gujarat, integrated nutrient management (basal application of 50% recommended dose of N and P i.e., 6.25 kg N +12.5 kg P_2O_5/ha along with application of castor cake @ 500 kg/ha) increased groundnut pod and haulm yield by 20 and 23% as compared to farmer practice (1191 kg/ha) and gave additional net returns of Rs.7511/ha (Srinivasarao *et al.*, 2014).

Cropping systems

Crop based approaches include growing crops and varieties that fit into changed rainfall and seasons. In addition, adoption of intercropping systems, crop diversification, and improved agronomic practices helps to cope with any adverse event, and in particular rainfall variability and drought. Based on the analysis of long-term climatic data in terms of probability of the onset of monsoon, withdrawal of monsoon, and occurrence of dry spells, effective cropping seasons have been worked out for different regions of the country. These will serve as a good guide in selection of efficient crops and their sowing time. Similarly, short-duration varieties/hybrids with higher harvest indexes that have potential to mitigate the effects of drought periods (often occurring at the beginning and the end of the growing season) have been evolved for different agro-climatic conditions (Srinivasarao *et al*., 2014). Agroclimatic zone and soil zone-wise efficient intercropping systems involving oilseed crops in major rained production systemsare given in Table 2.

Table 2. Agroclimatic zone and soil zone-wise efficient intercropping systems

Soil zone/ Agroclimatic zone/State	**Intercropping system**
a. Vertisols and Vertic Inceptisols	
Malwa plateau, Madhya Pradesh	Soybean + pigeon pea (4:2)
Vidharbha, Maharashtra	Soybean + pigeonpea (4:2)
Southern Rajasthan	Groundnut + sesame (6:2)
Northern Dry zone, Karnataka	Pearl millet + castorbean (3:1)
Northern Saurashtra, Gujarat	Groundnut + castorbean (3:1)
	Groundnut + pigeonpea (3:1)
Baghelkhand region, Madhya Pradesh	Soybean + pigeonpea (3:1)
b. Inceptisols and related soil zone	
Eastern Plain zone, Uttar Pradesh	Pigeonpea + sesame (2:1)
c. Alfisols zone	
Southern dry zone, Karnataka	Groundnut + pigeonpea (8:2)
Scarcity zone, Andhra Pradesh	Groundnut + pigeonpea (7:1)
Aridisols zone	
Northern zone, Gujarat	Castor bean + cowpea (1:2)

Source: AICRPDA (2003); Ravindra Chary *et al*. (2016)

With the available dryland technologies like rainwater management, choice of crops, short duration varieties, and other agronomical practices, a greater portion of drylands can be put under intensive cropping systems including relay cropping and double cropping. Double cropping is also possible with rainwater harvested in farm ponds which is used for establishing winter crop. A number of new double cropping systems involving millets, legumes and oilseeds have been evolved for different agro-climatic regions of India.

Contingency crop planning

Contingency crop planning is essentially aimed at stabilization of crop output in the situation of late onset of monsoon, mid season and terminal droughts. Contingency planning covers different drought situations i.e. late onset of monsoon (delay by 2-8 weeks); mid season drought (at vegetative stage, at flowering/fruiting stage) and terminal drought (early withdrawal of monsoon). ICAR-CRIDA, AICRPDA and AICRPAM in association with SAUs have developed district level agricultural contingency plans for more than 620 districts so far. These plans are intended to benefit district authorities and line departments in the event of weather aberrations, and help to understand various contingency measures. The suggested drought contingency measures include change in crop/cropping systems, crop management, soil nutrient and moisture conservation measures.

Any contingency measure, either technology related (land, soil, water, crop) or institutional and policy based, which is implemented based on real time weather pattern (including extreme events) in any crop growing season is considered as Real TimeContingency Planning (RTCP). If done timely and effectively, RTCP contributes to household and village food and fodder security (Srinivasarao *et al*., 2013). During 2011 to 2016, varieties of major rainfed crops were assessed for their suitability under delayed onset of monsoon conditions in the villages and best performing varieties were identified (Table 3).

Table 3. Suitable crops/varieties for delayed onset of monsoon

Rainfed agroecology/delay in onset of SWM/ AICRPDA Centre	**Crop/variety**
Semiarid (hot dry), Inceptisols/15 days (Agra)	Sesame (T 78)

Semiarid (hot moist), Vertisols/22 days (Akola)	Soybean (JS 9560)
Semiarid (hot dry), Inceptisols/20 days (Chianki)	Sesame (Shekhar)
Semiarid (hot moist), Vertisols/15 days (Indore)	Soybean (RVS 2001-4, JS 335)
Semi-arid (hot moist), Vertisols/18 days (Parbhani)	Soybean (MAUS 71)
Semiarid (hot moist), Oxisols/25 days (Rajkot)	Groundnut (GG 20), sesame (G Sesamae 2), castor (GCH 7)

Source: Ravindra Chary *et al*. (2017)

Early season drought may at times result in seedling mortality needing re-sowing or may result in poor crop stand and seedling growth. Further, the duration of water availability for crop growth gets reduced due to the delayed start, and the crops suffer from an acute shortage of water during reproductive stage due to early withdrawal of monsoon. The effect of early season drought is less on the crop, because during this period sowing is carried out. Under AICRPDA-NICRA programme, several interventions were implemented to cope with early season drought. The impacts of real-time contingency measures under early season drought in rainfed regions are presented in Table 4.

Table 4. Impactofreal-timecontingencymeasuresduringearlyseasondrought

Affected zone	**Intervention**	**Impact**
Central, eastern and southern dry zone in Karnataka	Intercropping of groundnut + pigeonpea (8:2) with conservation furrow	Gave higher groundnut eq. yield (1085 kg/ha) compared to without conservation furrow (629 kg/ha)
Malwa Plateau of Madhya Pradesh	Foliar spray of thiourea @ 50 g/ha in soybean	The yield (1000 kg/ha) was increased by 7% compared to farmers' practice of no foliar spray
	Foliar spray of VAM-C @ 375 ml/ha in soybean	The yield (950 kg/ha) was increased by 9% compared to farmers' practice of no foliar spray

Central Plateau zone of Maharashtra	Opening Conservation furrow at 35 DAS of soybean	The yield (832 kg/ha) was increased by 21% compared to farmers' practice of no conservation furrow

Source: Ravindra Chary *et al*. (2017)

Stunted growth takes place if mid-season drought occurs at vegetative phase. If it occurs at flowering or early reproductive stage, it will have an adverse effect on the ultimate crop yield. The impacts of the major interventions implemented in AICRPDA-NICRA villages to cope with mid-season drought are presented in Table 5.

Table 5. Impact of real-time contingency measures during midseason drought

Affected zone	**Intervention**	**Impact**
Malwa Plateau in Madhya Pradesh	Foliar apray of VAM-C50%SL @ 3.75 1/ha in soybean	Yield increased by33%in soybeancomparedto control (nofoliarspray)
Central Maharashtra plateau zone in Maharashtra	Foliar spray of KNO_3 in soybean	Foliar spray of KNO_3 in soybean gave 11-13% higher yield over no foliar spray (931 kg/ha)
North Bank Plain zone of Assam	Foliar spray of KNO_3 @ 2% before flowering in toria	Higher seed yield (738 kg/ha) with net return of Rs.10171/ha
Northern Gujarat zone	Supplemental irrigation (5 cm) through drip at flowering to capsule development in castor	Gave higher yield of castor (1055 kg/ha) as compared to without supplemental irrigation (456 kg/ha)

Source: Ravindra Chary *et al*. (2017)

Terminal or late season drought normally occurs due to early withdrawal of monsoon and affects seed/grain filling and maturity stage of the crop. Terminal droughts are more critical as the grain yield is strongly related to water availability during the reproductive stage. Further, these conditions are often associated with an increase in ambient temperatures leading to forced maturity. The impacts of the major interventions implemented in AICRPDA-NICRA villages to cope with mid-season drought are presented in Table 6.

Table 6. Impact of real-time contingency measures during terminal drought

Affected zone	**Intervention**	**Impact**
Central Maharashtra plateau zone in Maharashtra	Supplemental irrigation to soybean	Supplemental irrigation to soybean at pod development and grain filling stage through harvested rainwater gave 55% higher yield compared to rainfed crop (632 kg/ha)
North Saurashtra zone in Gujarat	Supplemental irrigation (50 mm at pod development stage) to groundnut	Pod yield was increased by 40% with higher net return (Rs.27250 kg/ha), due to supplemental irrigation compared to rainfed crop
Northern Gujarat	Supplemental irrigation through drip in castor	Gave 65% higher castor yield (1350 kg/ha) as compared to without supplemental irrigation
Central Maharashtra plateau zone of Maharashtra	Supplemental irrigation at pod development and seed filling stages of soybean	Gave 72% higher soybean yield (768 kg/ha) as compared to without supplemental irrigation

Source: Ravindra Chary *et al*. (2017)

Conclusions

To make oilseed production more economical and sustainable under increasing frequency of droughts, decrease in number of rainy days, and extreme & untimely rainfall, efficient use of water, soil and farm management practices in an integrated approach is both essential and a prerequisite (Srinivasarao and Gopinath, 2016). There are a number of options in soil, water, crop and nutrient management technologies which contribute to higher production and profitability of oilseed crops under rainfed situations.

References

AICRPDA. 2003. Annual Reports 1971-2001. Eldoscope Electronic document. All India Co-ordinated Research Project for Dry land Agriculture (AICRPDA), Central Research institute for Dry land Agriculture (CRIDA), Hyderabad, India.

Rama Rao, C.A., Raju, B.M.K., Subba Rao, A.V.M., Rao, K.V., Rao, V.U.M., Kausalya, R., Venkateswarlu, B. and Sikka, A.K. 2013. Atlas on vulnerability of Indian agriculture to climate change. Central Research Institute for Dryland Agriculture, Hyderabad, India. pp. 29.

Ravindra Chary, G., Gopinath, K.A. and Narsimlu, B. 2017. Coping with weather aberrations for sustaining the productivity of rainfed farming. *Current Advances in Agricultural Sciences*9(2): 153-161.

Ravindra Chary, G., Srinivasa Rao, Ch., Gopinath, K.A., Sikka, A.K., Kandpal, B. and Bhaskar, S. 2016. Improved agronomical practices for rainfed crops in India. All India Coordinated Research Project for Dryland Agriculture, Central Research Institute for Dryland Agriculture, India. 292 p.

Srinivasarao, Ch. 2011. Nutrient management strategies in rainfed agriculture: constraints and opportunities. *Indian Journal of Fertilizers*7(4): 12-25.

Srinivasarao, Ch. and Gopinath, K.A. 2016. Resilient rainfed technologies for drought mitigation and sustainable food security. *Mausam* 67(1): 169-182.

Srinivasarao, Ch., Chary, G.R., Mishra, P.K., Subba Rddy, G., Sankar, G.R.M., Venkateswarlu, B. and Sikka, A.K. 2014. Rainfed farming - A compendium of doable technologies, All India Coordinated Research Project for Dryland Agriculture, CRIDA, Indian Council of Agricultural Research, Hyderabad, 194 p.

Srinivasarao, Ch., Lal, R., Prasad, J.V.N.S., Gopinath, K.A., Singh, R., Jakkula, V.S., Sahrawat K.L., Venkateswarlu, B., Sikka, A.K. and Virmani, S.M. 2015. Potential and challenges of rainfed farming in India. *Advances in Agronomy* 133: 113-181.

Srinivasarao, Ch., Ravindra Chary G., Mishra, P.K., Nagarjuna Kumar, R., Maruthi Sankar G.R., Venkateswarlu, B. and Sikka, A.K. 2013. Real time contingency planning: Initial experiences from AICRPDA, All India Coordinated Research Project for Dryland Agriculture (AICRPDA), Central Research Institute for Dryland Agrciulture (CRIDA), ICAR, Hyderabad - 500 059, India, 63 p.

12. Management of castor and groundnut under aberrant weather conditions

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Background

Indian Agriculture mainly depends on monsoon as lion's share of cropped area is under cultivation during *kharif* season. Successful monsoon i.e., amount and even distribution of rainfall coupled with favourable humidity and temperature is always important for successful crop production. However, as the monsoon is influence by several factors like incidence of *El Nino* and *La Nino,* deforestation, pollution and other anthropogenic activities, and above all, global climate change, the Indian Agriculture is experiencing aberrant weather conditions. They include late onset of monsoon during June, prolonged mid season dryspell during August, and terminal dry spell during September. Furthermore, excess rains in the initial stages, initial drought after germination, cyclonic rains and prolonged dryspell followed by heavy rainfall are other weather aberrations that influence crop growth and development. Such conditions are leading to partial or complete failure of crops depending on the duration of dryspell thus economic loss.

Among nine primary oilseed crops grown in India, castor and groundnut are unique. Castor, a non-edible oilseed crop is grown under irrigated conditions in North Indian states like Gujarat, Rajasthan and Haryana, while, under rainfed conditions in South Indian states like Telangana, Andhra Pradesh, Tamil Nadu and Karnataka. Groundnut is the most important edible oilseed crops grown as a rainfed crop during *kharif* season and an irrigated crop during *rabi,* summer and spring seasons across various states in India. Though, both castor and groundnut are drought resistant crops, late receipt of rains and drought at different stages of crop growth drastically affect crop growth and productivity. Both are C_3 crops, hence, tolerate elevated CO_2 and temperature. The effects of various weather aberrations and mitigation strategies in castor and groundnut are enumerated in this chapter.

CASTOR

Castor can be grown in areas lying between 40°N and 40°S and 300 m to 1800 m above mean sea level. It requires 20-26°C temperature with low humidity during the growing season. High temperature above 41°C even for short period results in blasting of flowers thus poor seed set. While low temperature delays the emergence of seed and prolongs vegetative period. It can be grown in areas with 600-700 mm rainfall with 100 mm evenly distributed rainfall per month during first four months of growing period. Continuous drizzling associated with high humidity (>90%) promotes incidence of botryotinia gray rot (BGR). A frost free growing period of 130-

190 days is required for satisfactory yields. Being a long day plant, it requires a day length of 12-18 hours. Temperature above 31^0C promotes production of interspersed staminate flowers (ISF) while lower temperature resulting in fully female racemes in hybrid seed production**.** Castor, due to its' C_3 nature, the plant can adapt to climate change in the event of global warming. It can tolerate drought due to its' deep rooted nature and presence of whitish bloom on leaves, stems and capsules and spines on capsules. Thus, castor is an efficient and resilient crop with many mechanisms for adaptability in diversified environments. It can be grown as catch crop or contingent crop under late sown conditions due to late onset of monsoon.

Aberrant weather and Mitigation strategies

I. Late onset of monsoon

Under rainfed conditions, castor is generally sown from June 15th onwards. Optimum cut-off date is July 15th and last cut-off date is July 31st. Sowing time is an important non-monetary input that influences vegetative and reproductive growth periods, length of growing season and growing degree days, pests and disease incidence thus finally seed quality and yield. Timely sowing helps in efficient utilization of resources and growing season through production of deeper roots leading to more biomass production thus higher economic yield (Getachew et al., 2014). Under the conditions of delayed onset of monsoon, the crop can be sown upto first week of August. Under the conditions of delayed onset of monsoon, castor can be profitably grown with two options.

a) Facilitating timely sowing through pot watering or sprinkler irrigation

Timely sowing of castor could be possible if there is a farm pond filled with rain water or borewell. One classical example is explained here. We have received high intensity rainfall of 113 mm and 82 mm in the midnight of 22nd April, 2011 and 27th April, 2012 with which farm pond was filled with runoff water to its fullest capacity. As monsoon was delayed during these years, dry sowing of castor was done followed by application of measured quantity of water to each hill so as to facilitate germination and establishment at right time i.e. 16 June. Once the population was established, the crop was grown rainfed. This technique helped to establish the crop at right time and reap 17% higher seed yield and Rs. 4302 ha^{-1} additional net returns in PCH-111 and 61% and Rs. 11928 ha^{-1} in Haritha variety of castor (Table 1). If water is sufficient, this could also be utilized through sprinkler irrigation or alternate furrow irrigation.

Table 1: Seed yield of castor as influenced by pot watering at RARS, Palem

Treatments	**Hybrid: PCH-111**					
	2011	2012	Pooled	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
250ml $hill^{-1}$ twice	736	1598	1167	35010	16560	1.90
500ml $hill^{-1}$ twice	834	1632	1233	36987	18362	1.99
Control (Rainfed)	660	1444	1052	31560	14060	1.80
CD (0.05)	33	201				

	Variety: Haritha					
250ml hill^{-1} twice	903	1020	962	28845	10395	1.56
500ml hill^{-1} twice	973	1313	1143	34296	15671	1.84
Control (Rainfed)	583	833	708	21243	3743	1.21
CD (0.05)	82	118				

(Annual report 2011-12 and 2012-13, RARS, Palem; Ramprakash et al., (2013)

b) Delay sowing with suitable agronomic manipulation

Growing castor with little manipulation of agronomic practices like selection of varieties (Haritha, Kranthi and DCS-9), adoption of close spacing of 60x30 cm with 30% higher population and 25% more N than recommended dose and frequent intercultivation after each rain to create dust mulch so as to reduce evaporation have to be adopted to reap higher yields to the tune of >900 kg ha^{-1} (Table 2)

Table 2: Performance of genotypes in relation to fertilizer application under delayed sowing (*Kharif* 2009, RARS, Palem)

Genotypes/ fertilizer level	**Control**	**50 % RDF**	**100% RDF**	**150% RDF**	**Mean**
48-1	206	683	672	485	512
Haritha	488	531	613	**932**	641
GCH-4	296	485	**817**	743	585
PCH-111	164	532	**730**	**804**	558
DCH-177	377	524	**732**	**800**	609
Mean	306	551	713	753	
SEm±	67				
CD (0.05)	192				

RDF: 80-40-30 kg N, P_2O_5, K_2O ha^{-1} for hybrids; 60-40-30 kg N, P_2O_5, K_2O ha^{-1} for varieties
Sowing time: 10th August 2009 (Source: Annual Report 2009-10)

II. Excess rainfall in early stages

In case of excess rain in the early stages of crop growth, there are chances of seedling blight with which, young seedlings will die slowly. Care should be taken to avoid ill drained, damp and low lying fields. Seed treatment with Carbendazim (3 g kg^{-1}) or *Trichoderma viride* (10 g kg^{-1}) formulation can reduce disease incidence. Soil drenching with copper oxychloride @3g lit^{-1} or spraying with Dithane M-45 @ 3 g lit^{-1} will also control the disease.

III. Prolonged mid season or terminal dryspell

Dryspell for a longer period and extreme temperatures result in stunted growth and production of male flowers thus low yield. Hence, drought proofing mechanism have to be adopted to enable the crop to putforth more female flowers, good growth and yield.

a) Intercultivation

Frequent intercultivation but to a shallow depth has to be done in rainfed crops including castor can help create dust mulch and earthing up thus moisture conservation. This enables the crop to sustain during drought period. Making dead furrows at an interval of 2.4-3.6 m will also help conserve moisture as compared to that of flat bed. However, in view of the problem in availability of cattle pair for intercultivation, we have tried tractor drawn blade (can cover 2 rows) and minitractor drawn rotavator (can cover 1 row) for interctulivation in order to save labour (10 ha^{-1}) and time (35 hours ha^{-1}) and also conserve moisture besides effective weed control. However, spacing has to be suitably adjusted to facilitate mechanical intercultivation. It means, instead of 90x60 cm spacing, 120cmx45 cm has to be adopted. Care must be taken not to run the intercultivation equipment to a shallow depth, otherwise, it will exhaust the inherent soil moisture

b) Life saving irrigation

At RARS, Palem, Telangana state, during 2011, no rainfall was recorded after 12th September leading to prolonged mid season to terminal dryspell. Likewise, during 2012, there was mid season dryspell for 23 days from 3rd to 29th September. As our farm pond was already during April, the same could be utilized for scheduling life saving irrigation to castor. But, sometimes, when farm ponds are filled to an extent of 40-50% their capacity due to limited run-off or when there is less yield from borewells, it may not allow full irrigation. Hence, we need to adopt efficient irrigation methods for scheduling life saving irrigation at critical stages to mitigate the effect of dryspells. Hence, different methods viz., check basin, sprinkler and drip irrigation were tried in castor This not helps in improving economic yield and irrigating more cropped area thus water use efficiency.

Mean data of two years of experimentation showed that irrigation to castor through drip system @ 30 mm (2005 kg ha^{-1} seed yield; 2.68 kg ha^{-1} mm^{-1}) at primary spike development and secondary spike formation stages was superior to sprinkler @ 40 mm (1399 kg ha^{-1}; 2.75), check basin @ 100 mm (1516 kg ha^{-1}; 2.0) and rainfed control (1242 kg ha^{-1}; 2.0) in respect of seed yield and water use efficiency (Ramanjaneyulu et al., 2018) (Table 3). Life saving irrigation should always be coupled with application of recommended dose of fertilizer depending on the crop stage for achieving higher seed.

Table 3: Response of castor to life saving irrigation with farm pond water at RARS, Palem (Mean yield of two years)

Method of irrigation	Seed yield (kg ha^{-1})	Water use efficiency (kg ha^{-1} mm^{-1})*
Check basin irrigation	1516	2.00
Sprinkler irrigation	1399	2.75
Drip irrigation	2005	2.68

Rainfed control	1242	2.01

*Effective rainfall and irrigation water applied were considered

(Ramanjaneyulu et al., 2018)

IV. Extended monsoon

Generally, South West Monsoon (SWM) recedes by the end of September. But, sometimes, the monsoon extends October or November.

- If normal rainfall is received, top dressing can be done with 50 kg urea and 25 kg MOP ha^{-1} in the presence of soil moisture. Furthermore, as castor crop is highly sensitive to excess moisture, care should be taken to avoid waterlogging at any stage. Sufficient drainage or slope has to be provided to drain out excess water from the field. Otherwise, crop will be affected by *Fusarium* wilt. In case of wilt incidence, drenching has to be done with Carbendazim (3 g lit^{-1}) or SAAF (2.5-3.0 g lit^{-1}).
- In the event of cyclonic rainfall coupled with continuous drizzling and high humidity (90% RH), castor will be affected by *Botryotinia* gray rot (BGR). Based on weather forecast, Propiconazole @ 1.0 ml lit^{-1} has to be sprayed on the crop especially spikes, before and after cessation of cyclonic rains, prophylactically. Top dressing has to be done as explained above, to enable the crop to rejuvenate and putforth further growth and yield thus compenstate the yield loss due to BGR.

V. Prolonged drought followed by excess rainfall

Castor will be affected by sucking pests like jassids and thrips during dry weather and sometimes during wet weather coupled with high humidity.

- Growing double/triple bloom genotypes like DCS-9, 48-1, DCH-519 which are resistant/tolerant to jassids. Monitor the pest incidence through light traps/coloured sticky traps. When ETL (2-3 adults leaf^{-1}) is crossed, spray Neem oil @ 5.0 ml lit^{-1} or Monocrotophos @ 1.6 ml ltr^{-1}/Dimethoate @ 2.0 ml ltr^{-1}/Acephate @1.5 g ltr^{-1} in sequential manner depending on the need. Repeat the spray if required.
- In case of thrips, monitor the pest incidence through light traps/coloured sticky traps. When ETL (2-3 adults leaf^{-1}) is crossed, spray Fipronyl/Dimethoate/Methyl-o-demeton/Monocrotophos @ 2.0 ml ltr^{-1}
- Incidence of castor semilooper and tobacco caterpillar will be more in the event of dryspell followed by high rainfall. Hence, removal of affected leaves in the early stages of the pests, hand picking of older larvae and arranging bird perches @ 20-25 and pheromone traps @ 10 ha^{-1} have to be done. In case of severity, spraying of Novoluron 1 ml lit^{-1} will take care off these pests.

Other precautionary measures

1. Deep tillage

Deep ploughing once in two to three seasons is advocated to break the hard pan and allow rain water to infiltrate/percolate into soil profile thus conserve the moisture. MB plough/Disc plough and sub soiler can be used for this purpose. Thereafter, fields have to be ploughed twice with cultivator, then clods should be crushed by using disc harrow followed by leveling the using tractor drawn blade.

2. Addition of organic manures

In India, it is estimated that approximately 1/3rd of crop residues and half of the livestock dung are available for usage in agriculture. Hence, use of such materials will add lot of organic matter which improves soil fertility and productivity. They further bring out overall improvement in soil physical, chemical and biological properties thus helps to improve water holding capacity of soil which inturn help plants to sustain drought to some extent.

3. Insurance against crop failure through intercropping

Drought is common in rainfed agriculture. Many a times, dependence only on sole cropping without proper crop rotation and intercropping will be a futile exercise. The chances of failure of a crop and loosing investment due to severe dryspells can be reduced by adopting intercropping. The reduction in pest and disease incidence and weed menace are few other advantages if crop combinations are properly selected. Castor can be grown as sole crop or intercrop. Castor+pigeonpea (4:1 or 6:1) is the most predominant intercropping system among the farmers in the state, however, for higher economic returns, Castor+pigeonpea (1:1) should be followed. It can also be intercropped with greengram, cowpea, groundnut, blackgram and clusterbean. Castor can be rotated with pigeonpea, cotton or groundnut. The yield and economic advantages of castor+pigeonpea intercropping can be seen from the Tables 4-7 (Annual reports 2009-10-, 2010-11, 2015-16, 2016-17).

Table 4: Summary of Castor FLD results conducted in Mahabubnagar district, Telangana (*Kharif* 2009)

Technology	**Mean seed Yield (kg/ha)**		**% Increase in yield**	**Cost of cultivation (Rs./ha)**		**Gross returns (Rs./ha)**		**B: C Ratio**	
	IT	**FP**		**IT**	**FP**	**IT**	**FP**	**IT**	**FP**
DCH-177	898	798	13	11720	12254	20495	19180	1.7	1.6
Haritha	1113	833	34	11265	10384	25588	19167	2.3	1.8
Castor+ Pigeonpea (2:2)	1582	750	111	12573	12828	36375	17475	2.9	1.4

Table 5: Summary of Castor FLD results conducted in Mahabubnagar district, Telangana (*Kharif* 2010-11)

Yield (q ha^{-1})		**Cost of cultivation (Rs ha^{-1})**		**Gross returns (Rs ha^{-1})**		**Net returns (Rs ha-^{1})**		**B:C ratio**	
I	**L**	**I**	**L**	**I**	**L**	**I**	**L**	**I**	**L**
Kharif 2010-11 (PCH-111+PRG-158 4:1 Vs Sole crop GCH-4)									
7.9	5.0	21025	19495	31571	20000	10606	505	1.5	1.0

Table 6: Summary of Castor FLD results conducted in Mahabubnagar district, Telangana (*Kharif* 2015)

Technology	**Yield (q ha^{-1})**		**Cost of cultivation (Rs ha^{-1})**		**Gross returns (Rs ha^{-1})**		**Net returns (Rs ha-^{1})**		**B:C ratio**	
	I	L	I	L	I	L	I	L	I	L
PCH-111+PRG-176 Vs. GCH-4+local pigeonpea intercropping (1:1)										
1	10	8.65	25503	25498	40000	34600	14498	9103	1.57	1.36
2	8.55	9.2	25503	25498	32500	35200	6998	9703	1.27	1.38
3	9.73	8.85	25503	25498	37000	33613	11498	8115	1.45	1.32
Average	**9.43**	**8.91**	**25503**	**25498**	**36500**	**34471**	**10998**	**8973**	**1.43**	**1.35**
PCH-111 castor +PRG176 pigeonpea (1:1) Vs. Sole castor PCH-111										
4	8.8	7.5	25498	24248	29000	24750	3503	503	1.14	1.02

I: Improved plot **L:** Local plot

Table 7: Summary of Castor FLD results conducted in Mahabubnagar district, Telangana (*Kharif* 2016)

	Yield (q ha^{-1})		**Cost of cultivation (Rs ha^{-1})**		**Gross returns (Rs ha^{-1})**		**Net returns (Rs ha-^{1})**		**B:C ratio**	
Technology	**IP**	**FP**	**IP**	**FP**	**IP**	**FP**	**IP**	**FP**	**IP**	**FP**
1:1 Vs sole castor	16.1*	10.0	35795	29970	55900	35000	20105	5030	1.6	1.2
2:1 Vs sole castor	15.3*	10.0	35545	29970	52500	35000	16955	5030	1.5	1.2
3:1 Vs sole castor	14.1*	9.4	34610	30220	49313	32813	14703	2593	1.4	1.1
4:1 Vs sole castor	14.4*	10.0	34610	30220	51000	35000	16390	4789	1.5	1.2
Average	15.0*	9.8	35140	30095	52178	34453	**17038**	4360	**1.5**	1.1
Sole castor Vs Sole pigeonpea	9.79	9.50	29100	25723	34271	44994	5171	**19271**	1.18	**1.75**

1:1/2:1/3:1/4:1 indicates the ratio or rows in which Castor and pigeonpea are grown in intercropping *indicates castor equivalent yield

IP: Improved practice FP: Farmers practice

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3. Enhancing income through value addition

Under rainfed conditions, we should make efforts to enhance net farm income by all means. Hence, value addition will make a big difference in this regard.

- For additional income, castor leaves can be fed to eri silkworms (Ericulture) to produce 'eri silk' (poor man's silk) and is proved as a subsidiary occupation to a large number of rural and tribal populations. Approximately 30% of the defoliated leaves can be fed to eri silk worms without jeopardizing the yield. The farmers can get an additional income upto Rs. 6000 to 7500 ha^{-1} through ericulture which is a boon for a rainfed castor growers. Further, eri pupae are very much relished by tribal people and considered to be on par with mutton or chicken. The neutral lipid of silkworm pupae (*Bombax mori* L.) is a good source of alpha linolenic acid (ALA), an essential fatty acid. Due to presence of linolenic acid to the tune of 43% in eri pupal oil, it is considered as a good source of omega 3 fatty acid.
- The castor cake, a by product of castor oil industry, can be used as organic manure to improve the fertility of Agricultural fields as it contains 6.6%N, 2.6% P_2O_5 and 1.2% K_2O (cake from decorticated seed) and 4.5% N, 0.7%P_2O_5 and 1.9% K_2O (cake from undecorticated seed). It encourages soil microbial activity, promotes root development and winter cold hardiness.
- The castor leaf fall (1.5-2.0% N) adds fertility to soil on decomposition. Castor stubbles and shelled capsules can be incorporated in to the soil or can be used in the preparation of vermicompost which in turn can be further applied to agricultural fields to improve the soil fertility. The same can also be marketed for additional income as it fetches Rs. 5-8 kg^{-1} depending on the location.

GROUNDNUT

Groundnut continues to be one of the most important edible oilseed crops grown along with rape seed & mustard and soybean in India. India occupies approximately 30% of area and 22% of global groundnut production. Though, India ranks first in area and second in production, next to China, its rank in productivity is tenth in the world. *Inter alia*, its cultivation under rainfed conditions to the tune of 6.0-6.5 million ha on marginal and submarginal lands can be the main factor attributed to low and unstable productivity levels. Being a C_3 plant, it can come up well even under the conditions of elevated CO_2 and temperature.

Soil moisture deficit stress at various stages of crop growth during rainy season and low temperature during germination and vegetative stage but high temperature during the pod filling and maturation stage during summer, hampers the productivity.

Moisture stress during crop growth has been reported to adversely influence water relations and thereby growth and yield of groundnut. Flowering and pegging stages were considered as most sensitive ones and the period of maximum sensitivity to drought occurs between 50-80 days after sowing (Reddy, 1988) during which the demand of photosynthetic products for active sinks (pods) is higher.

I. Aberrant weather and effect

a) Effect of drought on seedling and vegetative stages

Infact, drought or no irrigation is advocated for initial 20 days after germination in groundnut as it helps regulate vegetative growth and enable roots to go deep and extract moisture and nutrients. In case, if there are frequent or excess rains during seedling or vegetative stage, groundnut putforths excessive vegetative growth. In that case, pegs will not reach/penetrate into ground rather hang in the air, leading to no formation of pods thus poor yield. This problem can be obviated by pressing with bamboo mats by placing them on the crop or by spraying growth retardants like Paclobutrazol (PBZ) @ 250ppm twice at 30 and 50 days after emergence (DAE). This chemical retard the growth by producing shorter plants (upto 28% less plant height) but higher dry matter and yield (Manashi et al., 2018).

b) Effect of drought on flowering, pegging and pod development

Drought stress reduces rate of flower production but not the total no. of flowers plant^{-1}. It is because, when the stress is relieved, plants will putforth flowering again (Janamatti et al., 1986). If stress occurs during 30–45 DAS, the flowers produced up to 45 DAS do not form pegs, however, flowers produced after re-watering compensates for this loss (Gowda and Hegde, 1986).

If drought occurs at pegging and pod development, it results in drastic reduction in pod yield. This yield reduction may be less in drought resistant varieties and more in susceptible ones. Peg elongation is dependent on the turgor, hence, will be delayed under moisture deficit conditions (Boote and Ketring, 1990). Adequate moisture and darkness are needed for peg penetration and pod development. Adequate pod zone moisture is critical for development of pegs into pods.

c) Harvesting

If drought persists for longer period at harvesting stages, it become difficult for the farmers to pull out the plants with pod from the field thus results in considerable loss of pods. Harvesting is done when 75% of pods are matured. Duration of most of the groundnut varieties are from 95 to 120 days. Delay in maturity occurs with severe drought. The duration of the TMV-2 variety is 105 days but crop is harvested from 90 to 145 days depending on the distribution of rainfall. If rains are received around 90 to 95 days, the crop is harvested by the farmers, even if it is 10 days early, because, pulling of plants become difficult if soil is dried. Spraying of fungicides for the control of late leaf spot helps in harvesting at correct time and even if it is delayed for a week to ten days, there will be no economic loss (Table 8).

Table 8: Returns as influenced by late leaf spot management and extending pod growth period

Treatment	**Gross returns (Rs ha^{-1})**	
	1998	**1999**
T1 : Control	16218	15338
T2 : Fungicidal spray	17523	15850
T3 : Spray + harvest extended by 10 days	18233	12348
T4 : Spray + harvest extended by 20 days	13642	12655
C.D @ 5%	2674	1493

II. Drought mitigation techniques

Identification and adoption of drought mitigation techniques help in sustaining the area and productivity of groundnut in rainfed regions.

A. Pre - drought management strategies

a) Adjusting sowing window

Decision regarding sowing time has to be taken depending on the historical rainfall data of a particular geographical location. For eg. in Rayalaseema region of Andhra Pradesh, which benefits from both south west and north east monsoon, July is best month for sowing in *kharif* season, while, it is June month in other parts. According to Malleswari et al., (2017), the groundnut crop requires 195 mm rainfall, 20.8°C minimum temperature and 32.1°C maximum temperature during pod development to maturity stage for getting higher yield. Further, crop sown during the 1st and 2nd fortnight of July will receive optimum rainfall and temperature during pod development to maturity stage, whereas the crop sown during 1st Fortnight of August will receive below optimum temperatures and rainfall. The rainfall analysis has revealed that groundnut crop sown during 1-31 July will receive 85- 102 mm rainfall during pod development to maturity stage, whereas the crop is sown in August will receive 39 to 86 mm of rainfall and this will also decreases with delay in sowing. The probability of receiving wet weeks, wet week followed by wet week with 10 mm rainfall during pod development to maturity stage is high for July sown crop, whereas probability of getting dry weeks, dry week followed by dry week, continuous dry weeks is more for August sown crop. Considering all these, the cut-off date for sowing of groundnut in Ananthapuram district is 31st July and it is recommended to go for contingency crops from 1st of August onwards.

b) Method of sowing

In rainfed agriculture, for want of sufficient soil moisture, the sowings have to be completed within short period. Tractor drawn Anantha groundnut planter (8 row) can help for timely sowing and germination. Timely sowing can also be done by using aqua planter developed by ARS, Anantapur by using 1600 to 3200 lit per acre depending up on the moisture content of the soil.

c) Cropping pattern

Groundnut is a monocrop is Rayalaseema region. Drought is very common in the region which leads to partial or complete cop failure. It is also advocated to go for intercropping in groundnut as detailed below to avoid crop failure and sustain farmers income (Table 9)

Groundnut + Red gram - 7:1 or 11:1
Groundnut + Castor - 7:1
Groundnut + Sorghum - 6:2
Groundnut + Pearlmillet - 6:2
Groundnut + Fieldbean - 7:1

Table 9: Groundnut based intercropping systems in other states

State	Region	Intercropping	Row ratio
Jarkhand		Groundnut + Maize	6 : 1
		Groundnut + Sesame	4 : 1

Gujarat	Saurashtra	Groundnut + Castor	3 : 1
		Groundnut + Pigeonpea	3 : 1
		Groundnut + Pearlmillet	1 : 1 or 2 : 1
		Groundnut + Sesame	1 : 1
		Groundnut + Sesame	1 : 1
	Rajkot	Groundnut + Castor	3 : 1
		Groundnut + Sunflower	1 : 1
Karnataka		Groundnut + Pigeonpea	4 : 1
		Groundnut + Cotton	3 : 1
		Groundnut + Sunflower	4 : 2
		Groundnut + Sorghum	6 : 1
		Groundnut + Chilli	4 : 2
Kerala		Groundnut + Tapioca	3 : 1
Maharashtra		Groundnut + Pigeonpea	6 : 1
		Groundnut + Pearlmillet	4 : 1
		Groundnut + Sorghum	4 : 1
		Groundnut + Sunflower	3 : 1
Madhya Pradesh	Rewa region	Groundnut + Maize	3 : 1
		Groundnut + Pigeonpea	3 : 1
		Groundnut + Pearlmillet	4 : 1
		Groundnut + Sesame	4 : 1
Tamilnadu		Groundnut + Pigeonpea	6 : 1
		Groundnut + Cotton	5 : 1
		Groundnut + Sorghum/ Pearlmillet	6 : 1
		Groundnut + Sesame	4 : 1
		Groundnut + Blackgram	6 : 1
		Groundnut + Rice	2 : 2
Uttar Pradesh		Groundnut + Pearlmillet	4 : 1
		Groundnut + Sesame	4 : 1
		Groundnut + Pigeonpea	6 : 1
		Groundnut + Rice	2 : 2
Orissa and West Bengal, NEH region		Groundnut +Maize	3 : 1
		Groundnut + Rice	3 : 2
		Groundnut + Soybean	2 : 1

d) Soil management technique

Generally, some portion of rain water is lost through run-off. If it is harvested *insitu* or *exsitu,* it helps to maintain high soil moisture. It can be done by the following ways.

- Deep ploughing once in three years to break the hard and improve infiltration
- Performing agronomic operations including ploughing and sowing across the slope

- Formation of contour bonding for every 50mt (in 2% slope)
- Plough with sub soiler in soils prone to sub surface crust for better moisture retention, root growth and yield
- Application of groundnut shells @ 5t ha^{-1} at 10 DAS helps in higher pod and haulm yields of groundnut. Sand application @ 40 t ha^{-1} before sowing, lime spray (1%) during late stress, spraying of urea (2%) after late stress will also influence yields positively

B. Post-drought management strategies

a) Early season drought

Early season drought immediately after sowing results in poor plant stand thus fields looks gappy. This leads to high weed growth and poor economic yields. As groundnut seed is costlier than any other field crop, early season drought will be a bane for the farmers. Hence, proper crop stand has to be established by scheduling life saving irrigation through overhead sprinklers.

b) Mid season drought

Mid season drought during flowering to pod formation stage leads to delay in flowering, poor penetration of pegs into soil, restricted growth and poor pod and kernel yield. Life saving irrigation with harvested or borewell water and spraying of antitransparants like kaolin 3-5% or liquid paraffin 1% will help overcome this kind of drought. Low cost drought proofing mechanisms like *In situ* moisture conservation with contour cultivation+compartmental bunding could help increase 13% higher yield over farmers' practice of sowing across the slope only in Anantapur district (Table 10).

Table 10: Groundnut pod yield (kg/ha) as influenced by *in situ* moisture conservation practices

Treatment	1995	1996	1997	1998	Mean
Contour cultivation + compartmental bunding	1610	885	439	2143	1269
Farmers' practice (sowing across the slope only)	1415	863	188	1940	1102

c) Early cessation of monsoon

This leads to terminal drought which intun reduces crop duration, poor grain filling, low shelling percentage and low yield. This problem can be overcome by life saving irrigation to reap better crop yield and also harvesting of groundnut crop for fodder. Sowing of short duration varieties which can escape terminal drought is an another option.

Life saving irrigation at critical stages

Flowering and pod formation stages were reported as the most sensitive growth periods by Sarma and Sivakumar (1989), Reddy and Reddy (1993). If dryspell coincides with critical stages like flowering, peg formation, pod formation and development and harvesting, it results in enormous loss in groundnut. Instead, if life saving irrigation is given at these critical stages, it can save the crops thus higher yields and net returns. However, traditional methods of irrigation consume more water and cover less cropped area thus low water use efficiency. Hence, efficient irrigation methods like sprinkler and drip systems have to be adopted. According to literature, for a given depth of water, drip method saved 50% of pond water compared to modified sprinkler and surface method of application.

As the amount of water available in farm ponds is limited, decision on quantity of water is very important. For example, it was found that at Anantapur, there was no significant difference in pod yield (1395 to 1400 kg ha^{-1} in 2001 and 650-695 kg ha^{-1} in 2002) of groundnut between 10 mm, 15 mm and 20 mm depth of irrigation water. Hence, 10 mm depth of water is to be given. In groundnut, 10 mm supplemental irrigation through sprinkler irrigation is more efficient compared to surface irrigation. Groundnut responds to 10 mm of irrigation through sprinkler on alfisols during pod development stage (Yellamanda Reddy and Sulochanamma, 2008). The benefit of supplemental irrigation is last for one week (Yellamanda Reddy and Sulochanamma, 2003). At Anantapur, yield of groundnut was increased by 27% with one protective irrigation of 10 mm during pod filling stage. Application of 10 mm irrigation to groundnut during stress at pod development stage gave 1023 kg ha^{-1} with 24.8% yield advantage over control (820 kg ha^{-1}). At Anantapur, yield of groundnut could be increased by 27% with one life saving irrigation of 5 cm during pod filling stage.

In many rainfed regions across the country, in case of failure of monsoon, water may not be present in farm pond and borewells. Hence, lorry Tanker (12000 lt) fitted with motor both for lifting water and supplemental irrigation to crop can be used. The water available at one place will be filled by the motor and can be transported where supplemental irrigation by sprinklers with motor of the tanker. Even tractor tanker water with 4000 lts capacity can be used for either drip or sprinkler irrigation.

OTHERS

a) Breeding and cultivation of drought resistant varieties

Deep roots, higher WUE, high SPAD meter values, relative water content, leaf characters like leaf rolling, leaf waxing are to be considered while development drought resistant varieties. Drought tolerant varieties like DHARANI, ABHAYA from RARS, Tiruapti and K-9 from ARS, Kadiri are popular among farmers in A.P. and Telangana.

b) Chemical spray

Spraying urea (2%) after prolonged dryspell showed 48% and 10% increase in groundnut pod and haulm yields over control. In another study spraying di ammonium phosphate (2%) on groundnut immediately after the dryspell recorded better yields than water spray.

c) Efficient weed control

Timely control of weeds either physical or chemical or mechanical means will help to overcome weed menace and enable the crop withstand competition from weeds and yield better. Indigenous implements are available with farmer both in Andhra Pradesh and Gujarat. Intercultivation is generally done from 25 to 30 days after sowing and second intercultivation is being done at 40 to 45 DAS. Intercultivation with cattle pair or Anantha intercutlivation equipment followed by line weeding has to be done. Weeding becomes a problem once in 4 to 5 years when continuous rains are received in early stages of the crop. The most effective pre-em. herbicides are pendimethalin @ 1 kg a.i. ha^{-1} or Butachlor @ 1 kg a.i. ha^{-1} which will take care off the weeds for 15-20 DAS. Thereafter, Imazethapyr 750 g ha^{-1} or Odyssy 100 g ha^{-1} can be sprayed as post-emergence herbicides.

d) Enhancing farm income through integrated farming systems (IFS)

In order to provide year round employment, besides groundnut based intercropping systems, sheep and milch cow can be maintained. Sheep/livestock can be fed with available dry fodder such as groundnut haulms and horsegram bhusa for five months for additional income by selling well grown sheep or milk. According to Sahadeva Reddy et al., (2010), rainfed groundnut and sheep rearing is a profitable farming system compared to groundnut crop alone for scarce rainfall regions. Location specific IFS modules have to be identified for fetching continuous income to the farmers.

REFERENCES

Annual Report 2009-10, RARS, Palem, Professor Jayashankar Telangana State Agricultural University, Telangana state, India

Annual Report 2011-12, RARS, Palem, Professor Jayashankar Telangana State Agricultural University, Telangana state, India

Annual Report 2012-13, RARS, Palem, Professor Jayashankar Telangana State Agricultural University, Telangana state, India

Annual Report 2015-16, RARS, Palem, Professor Jayashankar Telangana State Agricultural University, Telangana state, India

Annual Report 2016-17, RARS, Palem, Professor Jayashankar Telangana State Agricultural University, Telangana state, India

Boote, K.J. and Ketring, D.L. 1990. Peanut. In: Stewart B.A. And Nielson D.R. (Eds.), Irrigation of Agricultural Crops. Asa- Groundnut - A Global Perspective. International Crops Research CSSA-SSSA, Madison.

Getachew, E., Mohammed, A., Tesfaye, A. and Nebiyu, A. 2014. Growth and yield response of green beans (Phaseolus vulgaris L.) in relation to time of sowing and plant spacing in the humid tropics of Jimma, southwest Ethiopia. International Journal of Soil and Crop Science 2(5): 061-067.

Gowda, A. and Hegde, B.R. 1986. Moisture Stress and Hormonal Influence on The Flowering Behavior and yield of Groundnut. Plant Physiology, 66: 835–837.

Janamatti, V.S., Sashidharv, R., Prasad, I.G., Sastry, K.S.K. 1986. Effect of Cycles of Moisture Stress on Flowering Pattern, Flower Production, Gynophore Length and Their Relationship To Pod Yield In Bunch Types Of Groundnut, Journal of Agricultural Research, 1(2): 136–142.

Manashi, B., Sunil Kumar, G., Puste, A.M. and Pankaj, D. 2018. Effects of Paclobutrazol on Growth and Yield Attributes of Groundnut (*Arachis hypogaea* L.). Indian Journal of Ecology 45(2): 321-324.

Malleswari, S., Narayana Swamy, G., Sahadeva Reddy, B., Nataraj, K.C., Rabindranatha Reddy, B., 2017. Cutoff date for sowing of *kharif* groundnut in Ananthapuramu district of Andhra Pradesh. In: Compendium of abstracts (Ed., Ratikanta Maiti et al.,), 3rd International Conference on Bioresource and Stress Management, 8-11 Nov 2017, Jaipur, Rajasthan, India, pp.190. ISBN: 978-93-84553-03-6.

Ramanjaneyulu, A.V., Neelima, T.L., Venkata Ramana, M., Krishna, A., Ramulu, V., Kumar, K.S., Shashibhushan, D. and Teekam Singh 2018. Farm pond technology for efficient rainwater management. In: Rana, K.S., Choudhary, A.K. and Bana, R.S. 2018 (Ed.,). Climate resilient agro-technologies for enhanced crop and water productivity under water-deficit agro-ecologies' (ISBN 978-93-83168-31-6), ICAR-Indian Agricultural Research Institute, New Delhi. pp. 51-64.

Ramprakash, T., Ramanjaneyulu, A.V., Neelima, T.L. and Yellamanda Reddy, T. 2014. Farm Pond Technology for Sustainable Water and Food Security in Rainfed Agriculture 60-87. Advances in Agro-technology Vol.-II. Edited by Humberto Gonzalez Rodriguez, Narayan Chandra Sarkar, A V Ramanjaneyulu, Ratikanta Maiti, Puspa Publishing House, pp. 352, ISBN 978-93-84553-01-2.

Reddy, C.R. 1988 Studies on yield response to water in groundnut (*Arachis hypogaea* L.) Ph. D. Thesis, Andhra Pradesh Agricultural University, Hyderabad.

Reddy, C.R. and Reddy, S.R. 1993. Scheduling irrigation for peanuts with variable amounts of available water. Agricultural Water Management, 23(1): 1-9.

Sarma, P.S. and Sivakumar, M.V.K. 1989. Response of groundnut to drought stress in different growth stages. Agriculture Water Management 15 (93): 301-310.

Sahadeva Reddy, B., Malliswara Reddy, A., Jalajakshi, K., Ravindranatha Reddy, B. and Vijaya Sai Reddy, M. 2010. Studies on groundnut based farming systems for scarce rainfall zone of Andhra Pradesh. Progressive Researc

13. Organic farming for biodiversity restoration and sustaining crop yields

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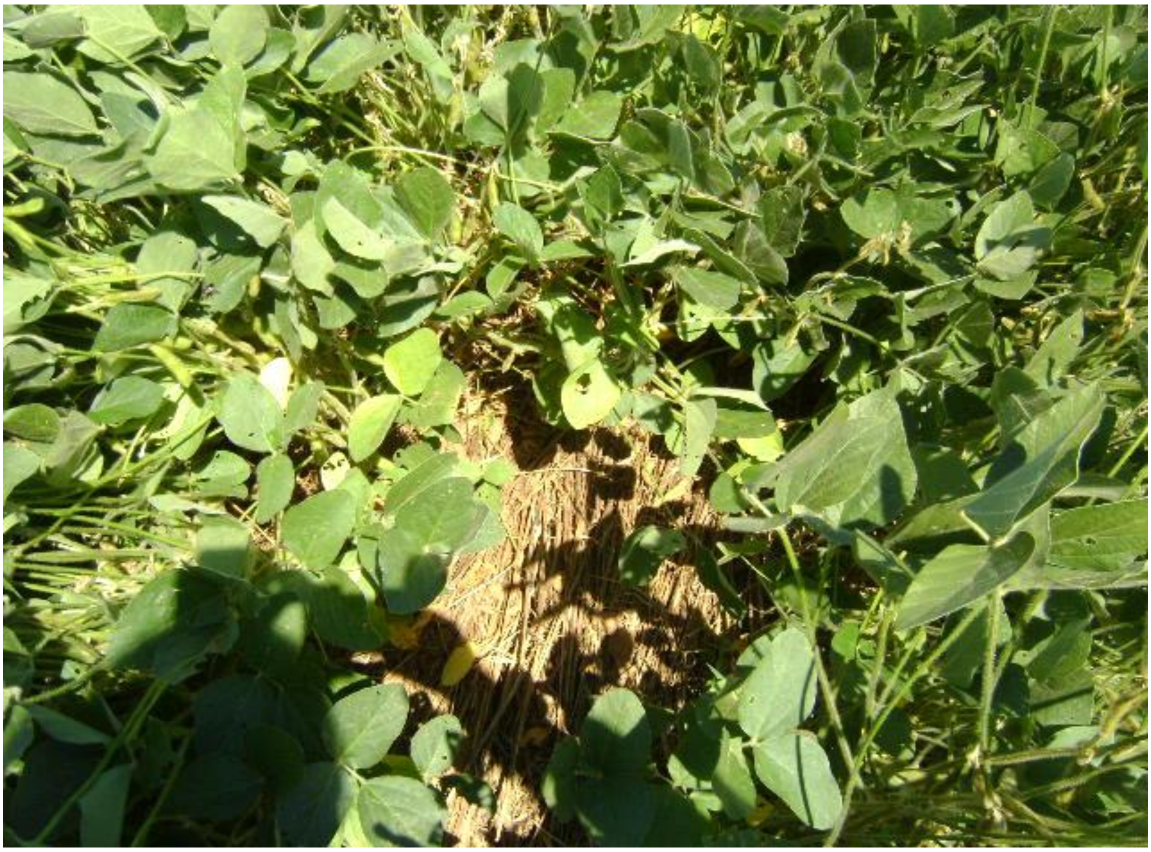
Abstract

Organic farming is an age old practice which goes hand in hand with the nature. The natural ecosystem maintains the basic tenets of biodiversity and houses multiple organisms at different species levels (both below and above ground) with mutual associations and benefits. Organic farming principles contemplate to mimic this natural eco system in the man-made farming systems. Agricultural development has undergone a tremendous change through various phases of developmental processes and each stage had its own impact on the eco-system and biodiversity (Ramesh et al. 2001).The intensification of agriculture enterprise throughout the world to feed the teeming billions is a single most serious threat to biodiversity which led to a growing concern over the sustainability of intensive farming practices. The so called sustainability concept which also envisages organic farming is considered to be a possible alternate to the loss of biodiversity. Only an array of focused activities in a farm can be a successful model for organic farming. As such each activity is linked in the holistic organic farming concept and is a self-generating system. Multiple/mixed cropping, poultry/livestock enterprise, composting system and green manure/cover crops focus on the biodiversity in organic farming. Companion/border cropping of *Sesbania rostrata* Berm. and dual cropping of *Azolla* could enhance soil microbial biodiversity (Ramesh, 2002). Incorporation of green manures either as pre-season or intercrop could enhance the soil biodiversity through increased population of earth worms in a rice-rice cropping system under western region of Tamil Nadu (Ramesh and Chandrasekharan, 2006). Experiments at Indian Institute of soil Science, Bhopal since 2004 have witnessed the visit of “myna” to the fields for collection of insect larvae

MATERIALS AND METHODS

Experiment I:

Field experiments were conducted at Tamil Nadu Agricultural University (TNAU), Coimbatore during 2000 - 2002 to study the influence of intensive manuring in rice-rice cropping system on earth worm abundance, fresh and dry weightthrough pre-season as well as intercropping of *Sesbania rostrata* Berm. with different organics/bio-species.Rice cv ASD 18 (June to September) and CO 43 (October to February) were selected. The treatments consisted of Factor A (Cropping systems): A_1 : Fallow - Rice - Rice; A_2 : GM-Rice - Rice; A_3 : GM-Rice + GM - Rice; A_4 : GM-Rice- Rice + GM;A_5 : GM-Rice + GM - Rice + GM and Factor B (Organics and Bio-species): B_1 : Control; B_2 :



Farm Yard Manure (FYM) 12.5 t ha^{-1}; B_3 : Poultry manure (PM) 5 t ha^{-1}; B_4 : *Azolla* Hybrid (AH) 500 kg ha^{-1} (Dual cropping as self-regenerating system).

Experiment II.

A field experiment was initiated during 2004 with 3 management practices *viz.* 100 % organic, 100 % inorganic and integrated nutrient management (50:50) in soybean based cropping systems. In organic treatment, well composted cattle dung manure along with rock phosphate were applied (to supply P). In inorganic treatment, 30 - 26.2 -16.6 kg/ha of NPK was applied through commercial fertilizers. In integrated nutrient management, 50 % of nutrients were supplied through organic and rest through chemical fertilizers. Soybean var JS 335 was raised as rainfed crop at a spacing of 45×15 cm. This was rotated with four predominant rabi crops viz., wheat (Legume-cereal system), mustard (Legume - oil seed system), gram (Legume - legume system) and Isabgol/linseed (Legume - oil seed system). Use of pheromone traps and keeping bird perches were adopted in organic nutrient management system, while chemical management methods were followed for inorganic nutrient management system. Regular crop and weed management methods were carried out as per standard crop management practices.

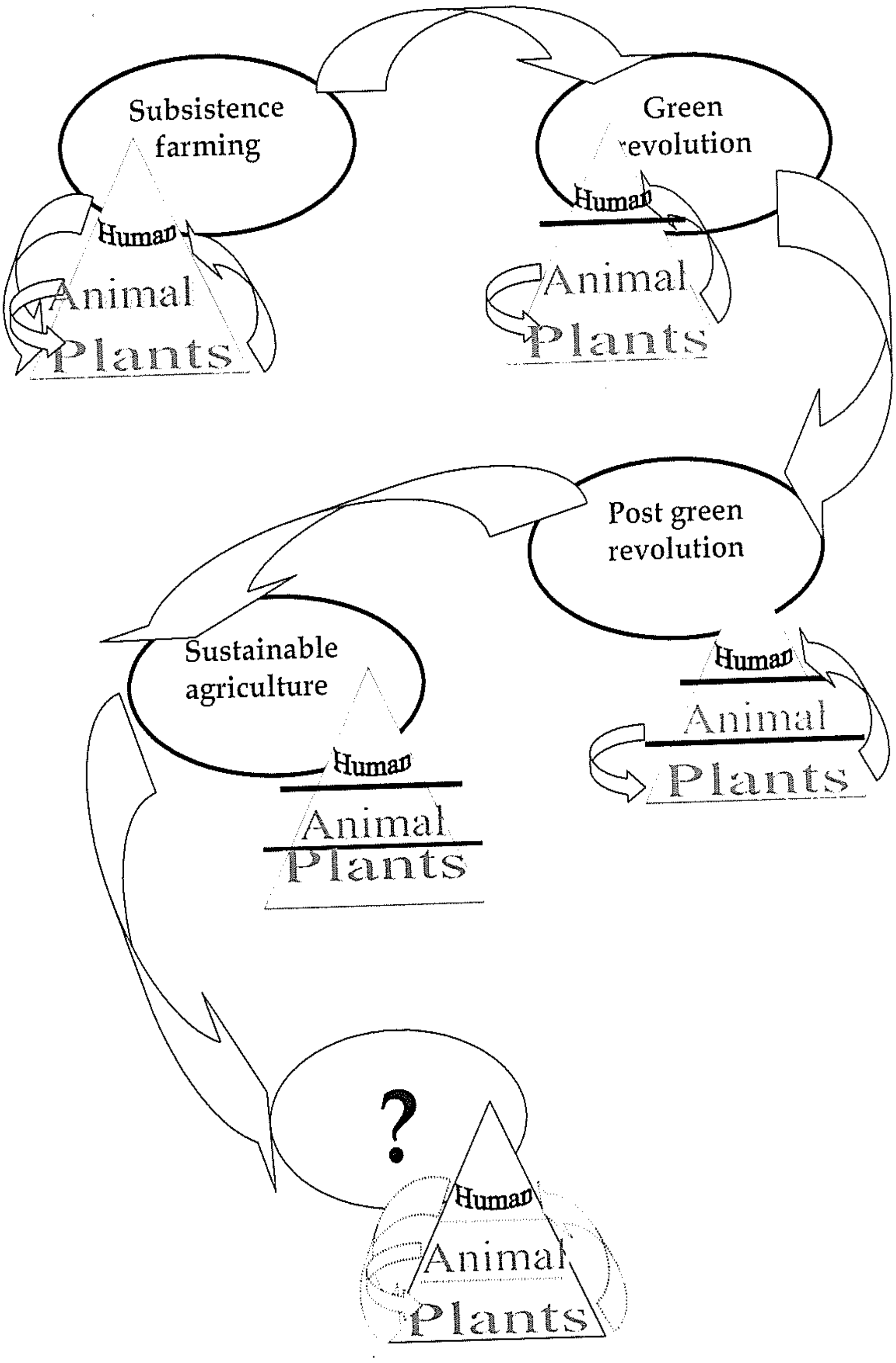


Fig. 1. Biodiversity and farming

RESULTS

Agro bio-diversity is a sub set of bio-diversity that includes structure and functions in agro-eco systems relevant for agricultural production. Cropland eco-system assumes paramount significance in view of the problems of emerging present day predicaments arising out of faulty crop management practices. This eco-system is highly subjected to human interference and thus called as the man engineered eco-system (Sharma.1991). This eco-system is unstable, as the human community modify the practices to satisfy his changing needs by replacing the natural eco-system. The present day food sufficiency has undergone a tremendous change through various phases of developmental processes and each stage had it’s own impact on the eco-system.

GM-Rice + GM - Rice + GM significantly enhanced earthworm abundance and biomass. And he magnitude was 122.84 for earthworm abundance, 48.13 for earthworm fresh weight and 47.97 per cent for earthworm dry weight (over no green manuring) respectively during the kharif season while it was 74.43, 73.56 and 74.4 for the rabi season. Further Azolla dual cropping exhibited higher earthworm abundance and biomass.

Experiments at Indian Institute of soil Science, Bhopal since 2004 have witnessed the visit of “myna” to the fields for collection of insect larvae. It is stressed that organic farming in the long run will curtail the loss of biodiversity.

References

Ramesh, K. *et al.* (2001) Developmental phases of agriculture and Eco-system – An analysis. Abstract of the “National Symposium on bio diversity vis-a vis resource exploitation: An introspection ", Central Agricultural Research Institute, Andaman. Apr 23-24. p.25.

Ramesh, K and B. Chandrasekaran (2006) Effect of green manure intensification and green manuring on earth worm abundance, fresh and dry weight in double rice cropping system. In: Abstracts of the Second International Rice Congress, Oct 9-13, New Delhi p.336

14. Management of soil phosphorus and micronutrients for sustainable crop under climate change scenario

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Introduction

Climate change is not a myth but it is a fact very frequently its negative impacts are commonly recorded around the globe. High temperature and erratic rainfall events contribute immensely on declining agricultural production, sustainability of agriculture in countries like India where it is dependent on monsoons. Due to excessive and intense rains, there is extensive soil erosion in Indian subcontinent. Soil erosion not only results in loss of fertile soil layerbut also silt deposition in water bodies reducing their storage capacity. As much as 5334 million tonnes of soil gets eroded every year in India accounting for about 16.4 t ha^{-1}year^{-1}. Of the soil so eroded, 29% is permanently lost to sea, 10% is deposited in reservoirs resulting in loss of their storage capacity and rest 61% is transported from one place to another. Thus, land degradation is posing a big threat to the natural resources base resulting in soil and nutrient losses (5.94 Mt NPK year^{-1}), loss in productivity and destruction of floral and faunal wealth.

Relevance of Phosphorus

Phosphorus is one of the sixteen essential nutrients required for plant growth (Ragothama, 1999). It is the second most important macronutrient next to nitrogen in limiting crop growth. Plant dry weight may contain up to 0.5% phosphorus and this nutrient is involved in an array of process in plants such as in photosynthesis, respiration, in energy generation, in nucleic acid biosynthesis and as an integral component of several plant structures such as phospholipids (Vance *et al.*, 2003). Despite its importance in plants growth and metabolism, phosphorus is the least accessible macronutrient and hence most frequently deficient nutrient in most agricultural soils because of its low availability and its poor recovery from the applied fertilizers. The low availability of phosphorus is due to the fact that it readily forms insoluble complexes with cation such as aluminum and iron under acidic soil condition and with calcium and magnesium under alkaline soil conditions whereas the poor P fertilizer recovery is due to the fact that the P applied in the form of fertilizers is mainly adsorbed by the soil, and is not available for plants lacking specific adaptations. Moreover, global P reserves are being depleted at a higher rate and according to some estimates there will be no soil P reserve by the year 2050 (Vance *et al.*, 2003; Cordell *et al*., 2011).

More than 40% of the world soils are deficient in phosphorus and the acid-weathered soils of tropical and subtropical regions of the world are particularly prone to P deficiency (Vance *et al*., 2003). On the other hand, in order to cope with the ever increasing world population agricultural production and productivity need to paralelly increase with the increasing population. One option to enhance soil P availability and hence crop yield is to apply P containing fertilizers. However, there is scarcity, particularly of chemical fertilizers, in tropical and subtropical regions where most of the earth’s population is concentrated. Moreover, lack of fertilizer infrastructures, financial constraints by farmers, and poor transportation facility in the rural areas all make P fertilization unattainable for these areas. Sustainable management of P in agriculture requires that professionals in the area of crop sciences discover mechanisms that either enhance plant P acquisition ability and/or efficient P utilization ability or further exploit these adaptations to make plants more efficient to thrive under P limiting conditions.

Soil phosphorus management options for sustainable crop production

Sustainable crop production aims at maintaining high crop yield without adversely affecting ecosystems to meet the need of current as well as future generations (Tilman *et al*., 2002). Since phosphorus in agriculture is the second most growth limiting macronutrient after nitrogen, its proper management in soil contributes significantly to sustainable crop production. In such soils where yield is limited because of inherent low P concentration (P deficient soils), application of relatively higher amount of mineral P fertilizers is the only way to enhance soil available P status to a target value in a long run that can sustain high crop yield. However, once the target value is reached, the available soil phosphorus concentration can be kept at a level that can sustain high crop yield through maintenance fertilization (replacing only the P removed from the field along with the harvested crops). The P contained in crop residues left in the field can be recycled by incorporating the residues into the soil whereas part of P in crop residues fed to livestock can be returned back to the soil in the form of manure and also as bone meal. The mineralization of such organic P sources can occur through the action of microorganisms and plants exuding phosphatases

and phytases. However, the P removed along with cereal grains, other edible vegetable parts and livestock products such as cow dung, milk and meat used for human consumption need to be replaced through mineral P fertilizer application. Therefore, under condition where P removed from the soil by harvested crop can be returned as crop residues and manures, the amount of mineral P fertilizer required for maintenance. Fertilization becomes less. In a nutshell, regular application of maintenance P fertilizers, incorporation of crop residues and application of organic manures can reduce nutrient mining and contribute to sustainable crop production.

P-efficient crops/cultivars and their role in sustainable crop production

Phosphorus efficiency, which is the ability of a crops/ cultivar to produce high yield under P limiting condition (Graham, 1984), can be attained through improved P uptake efficiency (the ability to take more P from the soil under P limiting condition) and/or through improved P utilization efficiency (the ability to produce higher dry matter yield per unit of P taken up) (Gahoonia and Nielsen, 1996). Thus, P-efficient cultivars produce reasonably high yield in low P soils through either ways and thus can reduce mineral P fertilizer input requirement in agricultural production. Phosphorus uptake efficient cultivars may contribute to sustainable crop production by producing reasonably high yield under P deficient condition due to their ability to exploit greater soil volume for accessing more P through producing larger root system (higher root-shoot ratio), longer root hairs or via forming association with mycorrhiza. Such cultivars may also enhance the applied mineral P fertilizers recovery and improve P availability, since they may be adapted to mobilize mineral P fertilizers fixed by the soil after application through exuding organic anions and protons. Additionally, P uptake efficient cultivars may also be able to mineralize organic P sources (including those of plant and microbial origin) by releasing acid phosphatases, phytases and/or RNase, thereby increasing soil available P to sustain high yield. Thus, P uptake efficient cultivars are able to produce high yield at relatively low soil P status which can be reached by applying less amount of mineral P fertilizer. On the other hand, P utilization efficient cultivars produce high yield per unit of absorbed P under P deficient conditions, since they have low internal P demand for normal metabolic activities and growth and hence have low requirement for mineral P fertilizer inputs to produce reasonably high yield. Moreover, they remove less P from soil during growth and therefore the quantity of P removed along with the harvestable parts of the crop would obviously be less, consequently reducing the quantity of mineral P fertilizer inputs required for maintenance fertilization.

Importance of seed phosphorus content

Annual crops exhibit a characteristic time course of P acquisition and internal P redistribution during their life cycle. Seed P is the only P source available to sustain the initial growth of seedlings and, upon germination, seed P reserves are rapidly mobilized and translocated to emerging root and shoot tissues. This P source is subsequently supplemented by P uptake by the developing root system. Once seed P reserves are exhausted, plant growth must be supported by root P uptake alone, and the P concentrations in plant tissues are determined largely by the ability of the roots to acquire P from the soil and tissue growth rates. If root P acquisition is insufficient to meet the P demand for new growth, characteristic biochemical, physiological and morphological responses occur both to improve the P economy of tissues and to increase P acquisition from the soil. The P concentration in seeds of a mature plant varies with the phytoavailability of P in the soil and with environmental factors affecting plant growth and development. It also differs between plant species and between genotypes of the same plant species grown in the same environment (Schultz and French 1978). Although the P contained in a seed contributes little to the final P content of the mature plant it produces, it contributes significantly to the P nutrition of a young seedling. Greater seed P reserves allow seedlings to sustain faster and ultimately produce plants with higher yields.

Contribution of seed reserves to the micronutrient nutrition of seedlings

In addition to supplying the seedling with P, seeds are a source of other essential elements required for plant growth, and the length of time that seed reserves can meet the requirements of a seedling growing at its maximal rate can be estimated. It would appear that, with the exception of P, a wheat seedling, for example, growing at 20°C rapidly exhausts the supply of macronutrients in the seed. However, there are sufficient amounts of the micronutrients Fe, Zn, Mn, Cu, B, Ni and Mo in the seed to fulfil the requirements of the seedling for at least 2.5 phyllochrons after germination. This is a significant observation since it has been reported that increasing seed concentrations of micronutrient elements, such as Zn, Mn, Cu and Mo, often improves crop establishment and leads to increased yields on soils that have restricted phytoavailability of these elements. Greater seed reserves of micronutrients with low phytoavailabilty in the soil are likely to assist root system development, faster resource acquisition, and vigorous early growth.

Management of micronutrients

Micronutrients are required in small quantities for sustainable crop production. However, over a period of time after green revolution, most of the Indian are found to be deficient micronutrient in the following order: Zn> Fe> B> Mn> Cu> Mo. This situation has arrived due to intensive agriculture with high yielding varieties/hybrids with imbalanced fertilizer application and has led to excessive mining of plants nutrients without replenishment of native fertility. Thus, productivity of soils has gone down and resulted in low factor productivity of food grains to 3.7kg/kg in 2010 from once it was 14kg/kg at the beginning of green revolution. The stagnation of productivity can be improved if balanced application of nutrient application is adopted based on soil testing.

- The primary role of boron is in with Ca-metabolism and appears to be concerned to keep Ca in soluble form and increases its mobility in plants. Besides its role in nitrogen absorption it efficiently acts as a regulator of K-Ca ratio in plants.
- Rapeseed and Mustard: Restricted growth, epical bud dries up, pod formation affected, seed size is also decreases.
- Ground Nut: Chlorosis and browning of leaves occur. The seeds become black and small in size.
- If excess rains in *kharif*, well drained soils, and chances of B deficiency is high for *rabi* crop, B application to oilseed crops is a must.
    - Soil application of borax @10-15kg ha^{-1}.

  - Foliar application of borax @ 0.25-0.50%, 1 or 2 spraying before flowering depending on severity.
  - Seed treatment with borax- seed soaking in 1% borax solution for 2 hrs.
- Zinc is the main constituent of those enzyme systems which regulates the oxidation-reduction reaction and various other metabolic reactions in plants.
- Influences the process for formation of some growth hormones in plants and thus helpful in reproduction of plants.
- It is very much associated with water uptake and water reaction in plant body.
- Flowering and fruit development reduced

Option for mitigation climate change and sustainable P and micronutrient management for oilseeds production

Conservation agriculture (CA) with a motive preserve soil and water resources along with carbon sequestration would be one of the best option to mitigate climate change effects on sustainable oilseeds/crop production. CA offers farmers an array of practices, but at its core are three interlinked principles that can be applied in a variety of combinations to meet the needs of resource poor farmers:

  - Continuous minimal mechanical soil disturbance,
  - Permanent organic soil cover,
  - Diversified crop rotations of annual crops and plant associations of perennial crops. (Minimum soil and water losses)

CA methods can improve the efficiency of input, increase farm income, improve or sustain crop yields, and protect and revitalize soil, biodiversity and the natural resource base.

Further readings

1. Cordell, D., Rosemarin, A., Schroder, J.J., and Smit, A.L. 2011. Towards global phosphorus security: A systems framework for phosphorus recovery and reuse options. *Chemosphere*, 84,747-758.

2. Gahoonia, T.S., Nielsen, N.E. 1996. Variation in acquisition of soil phosphorus among wheat and barley genotypes. *Plant and Soil,* 178,223-230.
3. Graham, R.D. 1984. Breeding for nutritional characteristic in cereals. *In*: Tinker P B, Lauchli A (eds.) Advances in Plant Nutrition. Praeger, New York. 1, pp 57-102.
4. Raghothama, K.G. 1999. Phosphate acquisition. *Annual Review of Plant Physiology and Plant Molecular Biology,* 50,665-693.
5. Schultz J.E., French R.J. 1978. The mineral content of cereals, grain legumes and oilseed crops in South Australia. *Aust J Exp Agric Anim Husb,* 18:579–585
6. Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R., Polasky, S. 2002. Agricultural sustainability and intensive production practices. *Nature,* 418,671-677.
7. Vance, C.P., Uhde-Stone, C., Allan, D. 2003. Phosphorus acquisition and use: critical adaptation by plants for securing non-renewable resources. *New Phytologist* ,15,423-447.

15. Quality profile of major edible oils from cultivated oilseed crops

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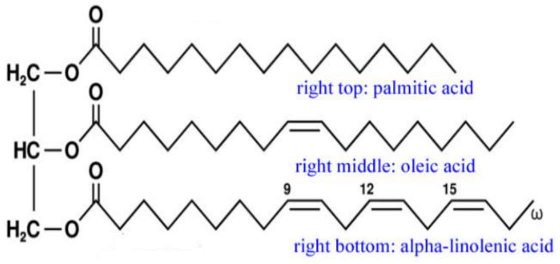
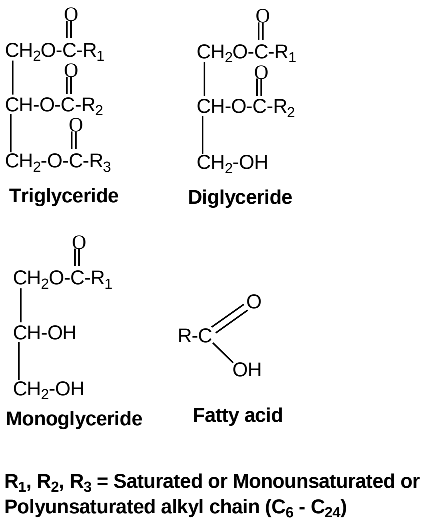
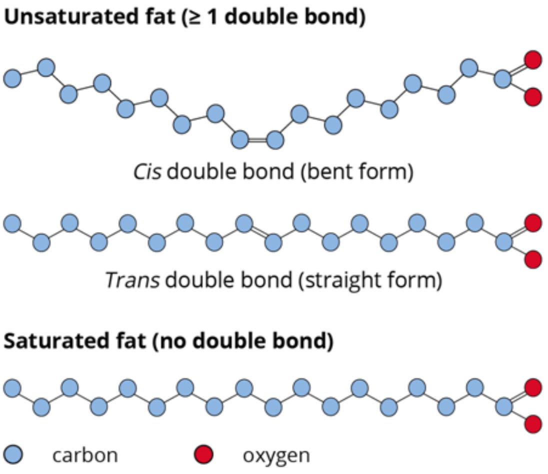
Edible vegetable oils are food stuffs which are composed primarily of glycerides of fatty acids being obtained only from vegetable sources. They may contain small amounts of other lipids such as phosphatides, of unsaponifiable constituents and of free fatty acids naturally present in the fat or oil (CODEX STAN 210-1999).

Structures of TG, DG, MG, FFA, cis and trans double bonds

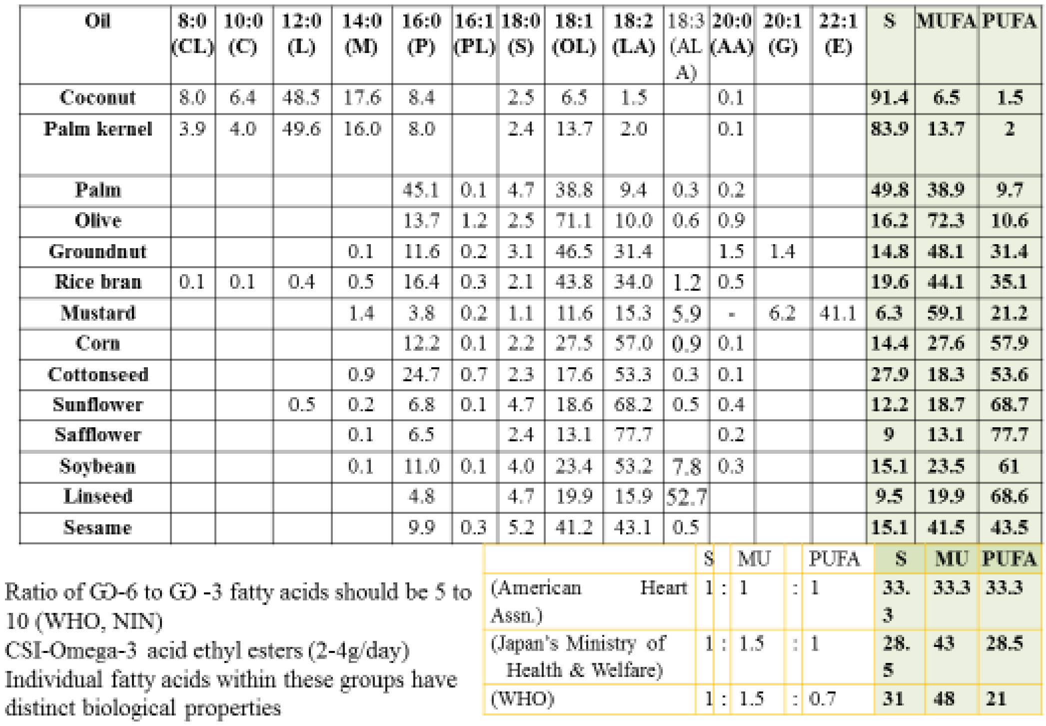


Triglyceride molecule





Fatty acid composition of edible oils and dietary recommendation



Oil	8:0 (CL)	10:0 (C)	12:0 (L)	14:0 (M)	16:0 (P)	16:1 (PL)	18:0 (S)	18:1 (OL)	18:2 (LA)	18:3 (ALA)	20:0 (AA)	20:1 (G)	22:1 (E)	S	MUFA	PUFA
Coconut	8.0	6.4	48.5	17.6	8.4		2.5	6.5	1.5		0.1			**91.4**	**6.5**	**1.5**
Palm kernel	3.9	4.0	49.6	16.0	8.0		2.4	13.7	2.0		0.1			**83.9**	**13.7**	**2**
Palm					45.1	0.1	4.7	38.8	9.4	0.3	0.2			**49.8**	**38.9**	**9.7**
Olive					13.7	1.2	2.5	71.1	10.0	0.6	0.9			**16.2**	**72.3**	**10.6**
Groundnut				0.1	11.6	0.2	3.1	46.5	31.4		1.5	1.4		**14.8**	**48.1**	**31.4**
Rice bran	0.1	0.1	0.4	0.5	16.4	0.3	2.1	43.8	34.0	1.2	0.5			**19.6**	**44.1**	**35.1**
Mustard				1.4	3.8	0.2	1.1	11.6	15.3	5.9	-	6.2	41.1	**6.3**	**59.1**	**21.2**
Corn					12.2	0.1	2.2	27.5	57.0	0.9	0.1			**14.4**	**27.6**	**57.9**
Cottonseed				0.9	24.7	0.7	2.3	17.6	53.3	0.3	0.1			**27.9**	**18.3**	**53.6**
Sunflower			0.5	0.2	6.8	0.1	4.7	18.6	68.2	0.5	0.4			**12.2**	**18.7**	**68.7**
Safflower				0.1	6.5		2.4	13.1	77.7		0.2			**9**	**13.1**	**77.7**
Soybean				0.1	11.0	0.1	4.0	23.4	53.2	7.8	0.3			**15.1**	**23.5**	**61**
Linseed					4.8		4.7	19.9	15.9	52.7				**9.5**	**19.9**	**68.6**
Sesame					9.9	0.3	5.2	41.2	43.1	0.5				**15.1**	**41.5**	**43.5**

Ratio of ω-6 to ω -3 fatty acids should be 5 to 10 (WHO, NIN)
CSI-Omega-3 acid ethyl esters (2-4g/day)
Individual fatty acids within these groups have distinct biological properties

	S		MU		PUFA	**S**	**MU**	**PUFA**
(American Heart Assn.)	1	:	1	:	1	**33.3**	**33.3**	**33.3**
(Japan's Ministry of Health & Welfare)	1	:	1.5	:	1	**28.5**	**43**	**28.5**
(WHO)	1	:	1.5	:	0.7	**31**	**48**	**21**

Source: Published Literature

Essential fatty acids

Humans and other animals must ingest these fatty acids because they cannot be synthesized by the body. Alpha-linolenic acid and linoleic acid are essential fatty acids while DHA and GLA are conditional essential FA. Major role of essential fatty acids are given below

- ✓ Regulate steroid production, hormone synthesis, pressure in the eyes, joints, and blood vessels, response to pain, inflammation, and swelling
- ✓ Mediate immune response and dilate or constrict blood vessels
- ✓ Regulate bodily secretions and their viscosity, smooth muscle and autonomic reflexes
- ✓ These primary constituents of cellular membranes
- ✓ Necessary for the transport of oxygen from the red blood cells to tissues and for proper kidney function and fluid balance
- ✓ Prevent red blood cells from clumping together
- ✓ Regulate the rate at which cells divide and nerve transmission

VEGETABLE OIL-BASED NUTRACEUTICALS

- ORYZANOL
- LECITHIN (PHOSPHOLIPIDS)
- TOCOPHEROLS & TOCOTRIENOLS
- STEROLS
- STANOL ESTERS
- OCTACOSANOL (improve exercise performance including strength, stamina, and reaction time)
- ALA, GLA, CLA, EPA, DHA (omega-3 and omega-6 Fatty Acids)
- Phenolic compounds (hydroxytyrosol, tyrosol, vanillic acid, p-coumaric acid, ferulic acid, and vanillin; Lignans- Sesamin, sesamol & sesmolin)

Dietary recommendation of total fats/FA (FAO/WHO/NIN)

According to FAO guidelines 30% of total energy should come from the fat/oils.

For an adult moderate worker requiring 2730 Kcal/day, the recommended dietary intake of visible fats is of 30 g per day (ICMR-NIN).

Visible fat requirement= Total Fat requirement – Invisible fats present in food

Cereal, pulses, milk, egg, almonds, walnut, peanut, spices, avocado etc. are the sources of invisible fats

Oil extraction processes

Three different methods are commonly used for the production of oils from oilseeds:

1. Pressing
2. Solvent extraction
3. Combination of pre-pressing and solvent extraction

The efficiency of these methods can be improved with the assistance of enzymes or supercritical carbon dioxide. Some oils undergo a refinement (alkali treatment), Bleaching (passing the oil through fuller's earth or clay and then filtering the oil) and deodorization (blowing high temperature steam through the oil to vaporize the aromatic components) process in order to remove impurities, improve the color or texture, or stabilize the shelf life of the oil.

1. **Pressing method**

   Oil extraction from pressing method can be done by two ways:

   a. Virgin oils are obtained, without altering the nature of the oil, by mechanical procedures, e.g. expelling or pressing, and the application of heat only. They may have been purified by washing with water, settling, filtering and centrifuging only. No food additives are permitted in virgin oils. (CODEX STAN 210-1999).

   b. Cold pressed oils are obtained, without altering the oil, by mechanical procedures only, e.g. expelling or pressing, without the application of heat. They may have been purified by washing with water, settling, filtering and centrifuging only. No food additives are permitted in cold pressed oils (CODEX STAN 210-1999).

2. **Solvent extraction method**

   Solvent extraction methods use large-volumes of solvent *i.e* hexane and long extraction times (8–16 h) to remove the oil from the ground seeds. The process is very efficient, but hexane elimination after the extraction is a major problem.

Cold press *vs* solvent extracted oil:

Parameters	**Cold Press method**	**Solvent extraction method**
Heat Treatment	No	Yes
Chemical treatment	No	Yes
Refining	NO	Yes
Harmful solvent residues	No	May Be Present

Added chemicals or preservatives	No	May Be Present
Natural antioxidants	Yes	Decreased
Natural flavour and odour	Retained	Decreased
cholesterol free	Yes	Yes
Oil recovery from seed	70-90% (depends upon the instrument used to extract oil)	98-99%
Metals, poly-aromatic hydrocarbon and insecticides & pesticide residues	Yes, if present in raw material	Can be removed

In 2002, European Commission (EC) Regulation No. 1019/2002 introduced new marketing standards for olive oil. According to Art. 5: (a) the indication ‘first cold pressing’ can only be used for Virgin olive oil (VOO) or extra-VOO obtained at temperatures below 27 ºC from the first mechanical pressing of olive paste by a traditional extraction system using hydraulic presses; (b) the indication ‘cold extraction’ can only be used for VOO or extra-VOO obtained at temperatures below 27 ºC by percolation or centrifugation of the olive paste, though such criteria in India have not been established.

Cold pressing is a process that involves no thermal or chemical treatments to extract oil. In addition, cold pressing involves no refining process wherein the recovered lipids may contain a high level of lipophilic phytochemicals including natural antioxidants. Cold pressed oils generally exceed refined oils in their nutritional value. They contain more natural beneficial ingredients such as tocopherols, sterols, carotenoids, and phospholipids which are partially removed as a result of oil refining [Gogolewski et al., 2000; Koski et al., 2003].

The refining process caused a decrease by over 40% of tocopherol content in fully refined rapeseed oils (Wroniak et al., 2008) Many different data confirm good sensory and chemical quality of cold pressed rapeseed oils [Rotkiewicz et al., 1995; De Panfilis et al., 1998; Koski et al., 2002; Górecka et al., 2003; Matthäus & Brühl, 2003]. VOO is known to contain a higher amount of phenolic compounds with respect to plant oils, which are solvent-extracted and then refined. These compounds contribute to the complex global flavour (Kiritsakis, 1998), provide antioxidant effects (Del Carlo et al., 2004; Franconi et al., 2006; Lavelli, 2002), and are largely responsible for the shelf-life of the product (Di Lecce, Bendini, Cerretani, Bonoli-Carbognin, & Lercker, 2006; Gomez- Alonzo, Mancebo-Campos, Salvador, & Fregapane, 2007; Servili & Montedoro, 2002).

However, Contaminants like poly-aromatic hydrocarbons and hydrocarbons of mineral origin, and pesticide residues can largely be removed by refining. For many years, this Food Safety Assurance System has proven to be effective in controlling contaminant levels in refined vegetable oils and fats (Van Duijn and Den Dekker, 2010).

Cold pressed oils have been part of a supplemental diet in many parts of the world and their consumption is also becoming increasingly popular in the non-producer countries. Yet these oils rich in bioactive lipids (phenolics and tocols) may bring nutraceutical and functional benefits to food systems.

Lipid oxidation is a major deterioration problem in oils and fats. This is relevant when the lipidic substrates are composed of unsaturated or polyunsaturated fatty acids (PUFA) that are sensitive to oxidation. Oxidation imparts undesirable flavors and aromas, compromises the nutritional quality of oils, and leads to the induction of toxic compounds. Lipids involved in the oxidation process contain unsaturated fatty acids and long chain PUFA; however, other unsaturated lipids such as sterols do become oxidized. Oxidation could alter the flavor of these products by inducing toxic substances and undesirable volatile compounds during oxidation. Hydroperoxides are primary oxidation products which are colorless and odorless. These products are labile and quickly turn into secondary oxidation products such as alkanes, alcohols, aldehydes, and acids. The volatile compounds of secondary oxidation products have an impact on the lipids flavor at extremely low concentrations. Different volatile oxidation products could be derived from various conditions like heat, light and metal. Hexanal, 2-decenal, 2,4-decadienal, 2-decenal, and pentane were identified as volatile oxidation compounds by SPME methods in thermally oxidized at 60 ºC soybean and corn oils. In addition, hexanal, pentane, propenal and 2,4-decadienal were identified in high levels in canola oil during heating. Oils with high content of PUFA are not quite suitable for frying due to oxidation at elevated temperatures (Anwar et al., 2007). To overcome the problem of poor oxidative stability (OS) of traditional oils, ways of reducing the unstable PUFA content and increasing natural antioxidants were sought. One way to improve the OS of these oils is by blending with oils of high-oleic acid contents and/or high antioxidants' levels (Mariod et al., 2005; Anwar et al., 2007; Ramadan et al., 2008). The oxidation of edible fats and oils can be controlled by application of antioxidants and using processing techniques that minimize loss of tocopherols and other antioxidants (Miraliakbaru and Shahidi, 2008).

Free radicals may cause reversible or irreversible damage of biological molecules such as DNA, proteins or lipids (Goldberg 2003). These damages may cause cancer, heart disease, arthritis and accelerate aging of organisms (Cadenas and Davies 2000; Wang and Quinn 1999). Recently, cold-pressed oils have given importance/ increased interest as these edible oils have high nutritive and health-promoting properties. Cold pressing is being considered as an interesting substitute for traditional extraction because of consumers desire for safe food (Parry et al., 2006; Lutterodt et al., 2010). Cold-pressed oils contain compounds with pro- and antioxidative properties of not univocally explained effect on the oxidation process because of multi-directional mechanism of free radical reaction.

At different concentrations of cold pressed oils, Oxidative stability (OS) of high-linoleic sunflower oil was enhanced and blends enriched with cold pressed oils had strong radical scavenging activity (RSA). (Ramdan M. F., 2013). Cold press oil have specific characteristics and flavors, and often contain valuable bioactive substances. Apart from valuable unsaturated fatty acids, these oils contain more natural antioxidants, such as tocopherols and phenolic compounds, than their refined counterparts. (Yu LL, 2005; Yoon and Kim, 1994; Van Hoed et al., 2006)

Cold-pressed oils have long shelf life stability due to the presence of antioxidants and other molecules that stabilize the oil with respect to auto-oxidation. However, the organoleptic properties and health benefits of cold-pressed oils, which result from the content of natural minor components, are increasingly valued by consumers. Cold press or virgin oils may contain insecticides and pesticides residues. Hence it is important to purchase organic oils when going cold-pressed or virgin oils

References:

De Panfilis F., Toschi G.T., Lercker G., Quality control for cold pressed oils. INFORM, 1998, 9, 212-221.

EC 2002 Commission Regulation (EEC) 1019/2002 of 13 June 2002 on marketing standards for olive oil. (2002). Official EC Journal, L155, 0027–0031.

Gogolewski M., Nogala-Kałucka M., Szeliga M., Changes of tocopherol and fatty acid contents in rapeseed oil during refining. Eur. J. Lipid Sci. Technol., 2000, 120, 618-623.

Górecka A., Wroniak M., Krygier K., The influence of heat treatment of rapeseed on the pressed oil quality. Rośliny Oleiste, 2003, 24, 567-576 (in Polish; English abstract).

Koski A., Pekkarinen S., Hopia A., Wahala K., Heinonen M., Processing of rapeseed oil: effects on sinapic acid derivative content and oxidative stability. Eur. Food Res. Technol., 2003, 217, 110-114.

Matthäus B., Brühl L., Quality of cold-pressed edible rapeseed oil in Germany. Nahrung/Food, 2003, 47, 413-419.

Ramadan, M. F. Healthy blends of high linoleic sunflower oil with selected cold pressed oils: Functionality, stability and antioxidative characteristics. *Ind. Crop. Prod.* 43, 65-72 (2013)

Rotkiewicz D., Konopka I., Sobieski G., Stability of the rapeseed oil: cold pressed and extracted. Rośliny Oleiste, 1995, 16, 293- 300 (in Polish; English abstract).

STANDARD FOR NAMED VEGETABLE OILS. CODEX STAN 210-1999. Adopted in 1999. Revision: 2001, 2003, 2009. Amendment: 2005, 2011, 2013 and 2015.

Van Hoed V, Depaemelaere G, Ayala JV, Santiwattana P, Verhe R, De Greyt W (2006) Influence of chemical refining on the major and minor components of rice brain oil. J Am Oil Chem Soc 83:315–321

Van Duijn, G. & Den Dekker, G. (2010). Unilever food safety assurance system for refined vegetable oils and fats.OCL,17, 100–103.Wroniak M, Krygier K, Kaczmarczyk M (2008) Quality of cold pressed and virgin rapeseed oils vs. industrial oils. Pol. J. Food Nutr. Sci. 2008, Vol. 58, No. 1, pp. 85-89

Yoon SH, Kim SK (1994) Oxidative stability of high-fatty acid rice bran oil at different stages of refining. J Am Oil Chem Soc 71:227–229

Yu LL, Zhou KK, Parry J (2005) Antioxidant properties of coldpressed black caraway, carrot, cranberry, and hemp seed oils. Food Chem 91:723–729

16. Disease Management Strategies in Oilseed Crops and Shift in Status of Sunflower Diseases - A Case Study in the Climate Change Scenario"

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Plant diseases are one of the important factors which have a direct impact on agricultural productivity which cause losses of 10–16% of the potential production . Climate change is one the biggest threat of the present century and its impact on agriculture will further aggravate the disease problems and on crop yields situation. Climate models predict a gradual rise in CO_2 concentration and temperature all over the world, but are not precise in predicting future changes in local weather conditions. Local weather conditions such as rain, temperature, sunshine and wind in combination with locally adapted plant varieties, cropping systems and soil conditions can maximize food production as long as plant diseases can be controlled. Currently, we are able to secure food supplies under these varying conditions. However, all climate models predict that there will be more extreme weather conditions, with more droughts, heavy rainfall and storms in agricultural production regions. Such extreme weather events will influence where and when diseases will occur and impose severe risks on crop failure. The eight annual oilseed crops viz., Groundnut, Rapeseed - mustard, Sesame, Niger, Sunflower, Safflower, Castor and Linseed are cultivated under diverse agro climatic conditions in India. One of the obvious reasons for low productivity is damage caused by diseases. In order to overcome such yield losses it is necessary to know the most economically important diseases. This information provides on major diseases of oilseed crops and how to combat them and so as to bring down the crop losses due to diseases and increase the oilseed production in India**.**

1. GROUNDNUT

(i) Seed and seedlingdiseases : Seed or soil borne species of *Pythium, Rhizoctonia*, *Fusarium* and *Macrophomina* are among the important causal agents of seed and seedling diseases.

Management: Cultural practices viz., planting high quality seed free from diseases, seed treatment with thiram @ 3 g/kg seed or Bavistin @ 2g/kg seed, avoiding groundnut monocropping, planting the crop in raised beds or by broad-bed and furrow planting method 4-8 cm deep, maintenance of adequate plant water relations and need based use of fertilizer are important to avoid this problem

(ii) Collar & Stem rot : Collar rot (*Aspergillus niger*) occurs seriously in light sandy soils while stem rot (*Sclerotium rolfsii)* is widely recognized problems in black soils.

***Management* :** Follow one year crop rotation with cereals like maize or grain sorghum in preventing severe infection though two to four year rotation. Summer ploughing, clean cultivation and destruction of crop residue are major steps in managing the disease.

(iii) Yellow mold or aflaroot : Itis a severe problem in tropical groundnut and toxins produced by the causal fungi *Aspergillus flavus* and *A. parasiticus* are potent carcinogens.

Management: Improved crop husbandry and prevention of entry of the pathogen into seed by means of avoidance of mechanical damage to seed, maintenance of proper moisture (8%) in seed before storing through adequate drying, prevention of wetting the seed in store, storage at low temperature and humidity are useful in safeguarding against this problem. Genetic resistance depends on presence of undamaged seed testa. However, resistance to seed colonization is available in two cultivars viz., J-11 and 55-437.

(iv) Early and late leaf spot and rust : These foliar diseases are caused by *Cercospora arachidicola* and *Phaeoisariopsis personata* are most important in terms of distribution and severity of damage.

Management: Crop management practices that reduce initial inoculum will aid in control of foliar diseases. Crop rotation preferably with cereals, destruction of crop residue and volunteer plants, proper fertilizer management and inter cropping system are found to be beneficial. Several genotypes resistant to rust and leaf spot diseases have been identified viz., ICGV 86699, ICGS 76, etc. Fungicides happen to be an important component in management of foliar diseases. Fungicide application may be reduced by judicious integration with host plant resistance. Spraying carbendazim (0.05%) + mancozeb (0.2%) at 15 days interval controls the leaf spot diseases. Chlorothalonil (0.3%) or Hexaconazole (0.1%) spray was found to control both leaf spots and rust effectively.

(v) Bud necrosis disease : It is an important widely distributed viral disease caused by tomato spotted wilt virus and transmitted by *Thrips palmi*.

Management: Use resistant varieties like Robut 33-1, Kadiri-3 and ICGS-11 in disease endemic areas. The variety TMV-2 is highly susceptible to bud necrosis. Sow the crop early; mid-June in kharif and in November in the rabi season to minimize the disease incidence. Intercrop groundnut with fast growing cereals like pearl millet reduces the disease spread.

2. RAPESEED - MUSTARD

(i) Alternaria blight: It is caused by *Alternaria brassicae, A. brassicicola* and *A. raphani* that result in yield losses up to 47% in *Brassica juncea*, , 30% in *B. campestris* and *B. napus*.

Management: Early sown crop suffers less damage. Experimental evidences established that the pathogen gets eliminated from seed after storage for five months (April-September) in Northern India (35°C). The sources of resistance to the diseaseare:

Brassica juncea:	EC-129126-1, PHR-1, YRT-3, RC-781
B. campestris:	PT-303, PT-855, PYS-841, PYS-842
B. napus:	Midas, HNS-3, GSL-1, Tower, G-3, G-7027, GS-7006, HC-1

The varieties Saurabh, RH 8113 and Pusa Jaikisan. RH 781 (*B. juncea*), KVR tall, SR 142-2, PHR 1, Jatai Sarson are resistant to the disease. Two sprays of mancozeb (0.25%) or Iprodione (0.3%) or Propiconazole (0.1%) at 60 and 80 DAS are effective in managing the disease. Clean cultivation, removal of weeds, and crop residue help in the disease management

(ii).Seedling blight and damping-off: Soil fungi mainly *Pythium, Rhizoctonia solani, Sclerotium rolfsii*, etc. causeSeedling blight and damping-off disease. The pathogens occur in high humidity areas with low soil temperatures.

Management: To prevent this problem, seed treatment with thiram (0.2 - 0.3%) or captafol (0.1 - 0.2%) should be used.

(iii) Downy mildew& white rust: Downy mildew (*Peronospora parasitica)* and white rust (*Albugo candida)* are important diseases of the crop that may occur singly or in combination resulting in deformation or proliferation of the inflorescence with sterility due to early infection. They may appear 20-25 days after sowing.

Management: RC 781, PYSR 8, PR 10 in *B. juncea*, PYS 16 in *B. campestris* var. *yellow sarson* and PT 77, Bhawani in var. *toria* are resistant to white rust. *Brassica carinata, B. napus, B. alba* are resistant to both these diseases. Seed dressing with Apron 35 SD @ 6g/kg and early sowing are effective in disease management. Rotation with non-cruciferous crop and clean cultivation, destruction of crop residue is very important in managing the disease**.**

iv) Sclerotinia rot: Sclerotinia rot (*Sclerotinia sclerotiorum*) is an important disease in Assam, West Bengal and Uttar Pradesh.

Management: Seeds contaminated with Sclerotia should be avoided for sowing. Seed treatment with *Trichoderma viride* 10 g/kg or carbendazim 2g/kg found effective. Affected plants along with the Sclerotia should be removed. Crop rotation preferably with wet rice or other cereals should be followed.

3. SESAME

(i) Stem-root rot/ charcoal rot: The disease is caused by *Macrophomina phaseolina* . It is a very destructive occurring in all sesame growing areas of India. In *kharif* 1993 and 1994 there was very high incidence of the disease in the states of Rajasthan, Maharashtra and Tamilnadu. Yield loss has been estimated up to 100% at 66% infection. High soil temperature of 25-30 ^{o} C and moisture favour the spread of the pathogen and increase the disease severity. Periods of drought between heavy rains favour disease development. The pathogen has a wide host range and is seed and soil borne.

Management: Seed treatment with carbendazim @ 0.1% a.i., Thiram + Captan or with biocontrol agents like *Gliocladium virens* and *Trichoderma viride* are found effective. Seed treatment with botanicals viz., neem leaf extract @ 1% (w/v) before sowing also can reduce the disease significantly. Soil solarization by covering the soil with transparent polyethylene mulch of 50u for six weeks during hot summer after ploughing and irrigation helps in controlling the disease and increasing yield under Indian conditions.. Inter cropping sesame with moth bean at 1:1 ratio is effective in managing the disease. Clean cultivation in well drained soil is advisable.

(ii) Phytophthora blight: The disease is caused by *Phytophthora parasitica* var. *sesami* Its incidence is reported to be up to 100% with up to 79.8% yield loss The disease is known to cause heavy crop losses in the Tikamgarh area of Madhya Pradesh state. The disease can attack at all stages of the plant growth after it attains 10 day age

Management: Seed treatment with Apron 35 SD @ 6g/kg is useful. Application of Bordeaux mixture at 3:3:50 ratio, copper oxychloride or Ridomil MZ as spray @ 0.3% or even extract of *Lawsonia* may be used when conditions favourable for the disease prevail with 3 sprays at seven day interval. Soil amendment with mustard cake is reported to cause significant disease reduction. Clean cultivation, destruction of crop residues and crop rotation is advisable. There are some sources of resistance against the disease in the germplasm screened in India, viz., TKG-22.

(iii) Bacterial leaf spot: This disease is caused by *Ralstonia syringae* pv.*sesami*. Symptoms appear on all above ground parts of the plant.

Management*:* Seed treatment with hot water at 52 C for 10 min. Steep the seed in Agrimycin-100 (250ppm) or Streptocycline suspension (0.05%) for 30 minutes. Foliar spray with streptocycline (500ppm) after appearance of the disease and continue two more sprays at 15 days interval if necessary.

(iv) Powdery mildew: Small whitish spots appear on the upper surface of the leaves and the spots coalesce to form a patch, finally covering the entire leaf surface with dirty white fungal growth. Severly infected leaves drop off.

Management: Varieties SI-1926, KRR-2 has been found to be resistant to the disease. Foliar spray of 0.2% wettable sulphur (wetsulf /sulfex) at flowering to capsule formation stage or by dusting sulfur dust @20Kg /h reduces the powdery mildew incidence.

(v) Phyllody: It is a serious disease capable of causing heavy yield losses. The disease is caused by Phytoplasma, which is transmitted by leafhopper, *Orocius albicinctus* in a persistant manner. The disease is favoured by dry weather. Moderate temperature (25^0C), low humidity (65%), minimal rainfall (0.6mm) and dry season during February-March are found congenial for the disease.

Management: Delay sowing in the endemic areas reduces the vector population thereby reduction in incidence of the disease. Application of phorate @10Kg /h in soil or alternatively 2-3 sprays of Dimethoate or Monocrotophos (0.03%) or oxydemeton methyl 0.05 %. at flowering reduces the vector population.

4. NIGER

(i) **Foliar diseases**:: *Alternaria* blight caused by *Alternaria porii*. Develops as brown to blackish circular to irregular spots with gray centres and concentric rings. Under warm and humid weather, spots increase in size and cover the entire leaf. Infected floral buds do not open and become black.. Powdery mildew caused by Sphaerotheca and Oidium appear as small cottony spots on the infected leaves and gradually spread over the lamina covering the entire leaves with powdery mass of the fungus. Severe infection results in defoliation. The pathogens survives on crop debris, seed and alternate hosts.

Management: Seed treatment with thiram @ 3 g/kg and two foliar sprays with Dithane or Mancozeb (0.3%) for the Alternaria blight and Sulfur dusting @ 2 kg/ha for the Powdery mildew are effective in controlling the diseases.

(ii) Phanerogamic parasite *(Cuscuta hyalina)* :Cuscuta seeds get mixed with niger seed and are generally sown inadvertently. Plants infested with cuscuta vines are stunted, pale yellow, bear less number of flowers and capsules. Sometimes all the plants are damaged.

***Management*:** Sieving to remove the *Cuscuta* seeds from niger seeds.

5. SUNFLOWER

(i) Alternaria blight and leaf spot: Alternaria blight and leaf spot caused by *Alternariaster helianthi* is an important disease. The disease has been reported to reduce the seed and oil yields by 27 to 80% and 17 to 35% respectively. The disease also affects the quality of sunflower seeds which adversely affects the seed germination and vigor of seedlings. The loss in seed germination varies from 23-32%. Disease development is favored at25-27^{0}C temperature with at least 12 hours of wet foliage. The pathogen over winters as mycelium in infected plant residues and survives for about 20 weeks in soil under dry conditions.

Management: No source of resistance is available for this disease till date. However, few tolerant lines have been identified recently. Some wild species of *Helianthus* are also found to be highly resistant to the disease. Closer spacing increases plant populations that induces more disease buildup. Incidence of the disease in spring crop sown in late February is higher than the one sown in first week of January. Seed treatment with captan/thiram @ 2.5 g / kg or carbendazim 2.0 g/kg or SAAF @3g/kg seed or Seed dressing with *Pseudomonas fluorescence*@ 10g /kg seed. Foliar spray with Hexaconazole /Propiconazole @ 0.1% at 45 DAS and *P. fluorescence* @ 1.0% at 60 DASor Two foliar sprays of SAAF @ 0.2% or Rovral (0.05%) at 30 and 45 DAS or spray with Mancozeb (0.3%) 3-4 times at 15 days interval from 30 DAS

(ii) Downy mildew: The disease is caused by the fungus *Plasmopara halstedii* (Farl.). It is caused by an obligate parasite which may result in up to 95 per cent destruction of the plants under favourable conditions.. The disease is soil, seed and airborne. Plants deficient in boron are more susceptible to downy mildew. Outbreak of downy mildew occurs due to water stagnation, deep sowing, continuous sunflower growing etc,.

Management: *:* Early sowing and shallow planting will escape from the disease. A six-year crop rotation in sunflower found useful in control of downy mildew disease..Clean cultivation, rouging of infected to reduce the incidence. Most of the recently released hybrids by public or private sector are resistant to the disease. The systemic fungicide metalaxyl (Ridomyl 25 WD or Apron 35 SP) gives good protection against the disease. Seed treatment of Apron 35 SD @ 3-6 gm kg/seed combined with foliar sprays of metalaxyl offers best method for control of the disease.

(iii) Charcoal rot : It is important disease under the arid situation in spring-summer sunflower crop. The disease is caused by *Macrophomina phaseolina* (Tassi) Goid. The pathogen survives in the soil through sclerotia, is carried in crop residues and is seed borne. Disease incidence is favoured by higher salt concentration in irrigation water, higher (25-35°C) temperature and moisture stress.

Management: Seed treatment with thiram @ 0.4 per cent is reported to control the seed borne infection. Choosing sowing time and/ or cultivar to escape the mid-summer heat, balanced fertilizer application with ammonium sulphate or calcium nitrate or calcium ammonium nitrate for nitrogen and calcium superphosphate for phosphorus may be useful.

(iv) Rhizopus head rot: It occurs sporadically but may be severe under wet weather conditions. The disease is caused by *Rhizopus arrhizus* (*R. stolonifer*). Larvae of *Heliothis armigera* have been reported to predispose the head to infection by *Rhizopus* spp. ***Management***:A single spray by copper oxychloride (Blitox 50wp) @ 0.4% a.i at completion of flowering stage is reported to control the disease. Three sprays of any contact insecticide at blooming stage have been found to give efficient control of the larvae.

(v) Powdery mildew:

Powdery mildew caused bycaused by *Golovinomyces cichoracearum* Var. *cichoracearum*appears after flowering when the lower leaves start to senescence Earlier, the disease on sunflower was observed during *rabi* and spring seasons under conditions of cool weather, high relative humidity and in shady areas. Of late, the infection levels have become so high and the disease is seen even on crop cultivated during rainy and post rainy seasons also.

Powdery mildew flourishes when the days are warm, the nights are cool with dew formation on the foliage early infections cause severe losses.

Management:Sources of resistance to powdery mildew have been identified in the wild sunflowers and their derivatives . Among cultivated hybrids KBSH-1, KBSH-41, were found to be tolerant . When symptoms just appear, application of wettable sulphur dust at 25-30 kg/ha or calixin (0.1%) or karathane (0.2%) or Benlate (0.2%) three times at 15 days interval effectively controls the disease. Under high incidence of powdery mildew, two sprays of difenoconazole (0.05%) or propiconazole (0.1%) at 45 and 60 DAS are highly effective which reduced the disease severity by 46 to 87 percent and increased the seed yields up to 31 to over 100 percent .

(vi) Sunflower necrosis disease: The recently recorded dreaded virus disease on sunflower is known as sunflower necrosis disease. The tobacco streak virus of Ilar virus group is causal organism for the disease. The disease is transmitted through insect vector, thrips as a pollen carrier from infected plants. The virus has wide host range in crop plants swell as among weeds. The affected plants exhibit necrosis on leaves, stem, twisting and bending ultimately leading to the death of the plants. As the infected flower heads are completely sterile, yield loss is 100%.. The incidence and severity of the disease in the field varies depending on the weather parameters which affect the vector population in nature. Dry weather favours fresh infections and spread of the disease.

Management: Clean cultivation by removing the weed plants specially *Parthenium, Commelina* etc on bunds and in surroundings will not allow the suspected vector to breed on collateral host in off season and on alternate host in the main season. Growing barrier crop with sorghum and pearl millet (sowing 10 days prior to the main crop) reduce the vectors movement to go to the main crop. Seed treatment with Imidacloprid 70 WS @ 5 to 7.5 g/kg seed has been observed effective in checking the disease incidence up to 45 days after sowing. Spraying with imidacloprid 200 SL@ 100 ml / ha also helps in keeping the crop free of necrosis infestation up to 15 to s0 days after its spraying, hence, at least 2 rounds of spraying would be essential to keep the crop free of disease infection in standing crop.

6. SAFFLOWER

(i) Leaf spot and blight: Leaf spot caused by *Alternaria carthami*, Ramularia and Cercospora can attack is at the seedling stage to grain formation stage of crop and reported to cause losses.

Management: Sow the crop in time / October month. Avoid growing in low land areas and under flood irrigation. Remove and destroy the disease plant. Avoid continuous cultivation of the crop. Spray the crop with mancozeb 0.25 % immediately after disease is observed and repeat the spray 15 days later depending on the intensity of disease.\

(ii) Wilt: The safflower wilt caused by *Fusarium oxysporum* f. sp. *carthami* has been found to be threatening the safflower cultivation in the Indian Deccan Plateau. The disease spreads wildly, through seedborne and build up of inoculum in soil due to continuous use of short duration wilt susceptible local varieties.

Management: A long term strategy to breed for disease resistance has been undertaken. and genotypes 86-93-36A, 237550, JSI-61,MKH-9,VB-75-4, T-45-1, VI-92-4-2 were identified. Soil solarization to immediately bring down the inoculum level in affected soils have been worked out. Continuous cultivation in the same field should be avoided. Seed treatment with *Trichodermaviride* 10g/kg or carbendazim 2g/kg and soil application of *T.viride* @ 2.5 kg incubated in 125 kg FYM/ha for the control of wilt.

7. CASTOR

Castor (Ricinus communis L) is an non-edible oilseed crop grown in semi-arid and arid region of India. There are several castor diseases, which cause serious qualitative and quantitative loss at any stage of crop growth, depending on the seasonal conditions.

(i)Seedling blight: It is a common soil borne disease observed up to one moth old crop in kharif season. The disease is noticed mostly after heavy rainfall in damp and low lying fields. Cold wet soils and fluctuating soil moisture favour fungal attack.

Management*: Treat* the seed with thiram/captan @ 3g/kg or carbendazim 1g/kg or metalaxyl 3g/kg providing adequate drainage keeps the disease under check.

(ii) Wilt: The wilt is a complex disease. Though several organisms have been intercepted from wilt affected castor plants, *Fusarium oxysporum* f. sp. *ricini* and/ or *Rotylenchulus reniformis* have been proven to be primary agents for causing the syndrome.

Management: Cultivate wilt tolerant varieties like Jyothi, Jwala and hybrids like DCH-177, GCH-7. Seed treatment with *Trichoderma viride* 10g/kg or carbendazim 2g/kg and soil application of *T.viride* @ 2.5 kg incubated in 125 kg FYM/ha for the control of wilt. Rouge out disease affected plants regularly Cultural practices such as proper field drainage, regulation of irrigation water, rouging of diseased plants also reduces disease spread.

(iii) Botrytis gray mold: Caused by *Botryotina ricini* is one of the major constraints in castor. It is related to occurrence of heavy and continuous rains during spike/capsule formation for five days. Specific epidemiological studies need to be conducted to ascertain the exact conditions favouring the disease to enable the farmers undertake timely control measures.

Management: Adjusting planting time in such a way that crop maturation occurs during dry season, adoption of wider spacing (90 x 90 cm) are helpful in disease avoidance. The pathogen is otherwise known to be a weak one and well directed studies can lead to identification of tolerant sources and framing of sound control strategies. Burn infected crop debris to reduce the pathogen inoculum. Spray carbendazim or propiconazole @ 0.3%/before the onset of cyclonic rains based on weather forecast followed by second spray soon after disease appearance.

8. LINSEED

Linseed (*Linum usitatissimum* L.) is an important rabi oilseed crop of industrial value.

(i) Leaf spot : Leaf spot caused by *Alternaria lini* and *A. linicola* causes heavy damage to crop particularly in low lying ill-drained areas. The temperatures between 26° and 33°C and humid conditions are most favourable for infection of the plant.

Management: Seed treatment with thiram at 3 g/kg and spraying of mancozeb @ 0.3 % or Iprodione 0.2% controls the disease. Seed dip for 30 minutes in 0.2 percent Thiophanate methyl solution and sowing after drying of seed is most effective for controlling the disease.

(ii) Wilt: It is caused by *Fusarium oxysporum* f. sp. lini. The fungus also known to be seed brone. Soil temperature is one of the factors responsible for the spread of the disease. If at the time of attack, the soil dries the disease becomes more serious. Maximum infection is observed at temperature of 25°C to 28°C.

Management: Number of high yielding wilt resistant varieties are available viz: NP (RR) 9, NP (RR) 45, R-552, R-1156, LCK-172, BS-44, K-2, Hira, Mukta, Neelum and Jawahar Linseed-23. Follow of 2-3 year crop rotation, treating seed with thiram 3g/kg seed or Carbendazim 1.5 g a.i./kg seed are useful. Acidic soils should be avoided for linseed cultivation. Application of FYM and NPK are effective in managing the disease.

(iii) Powdery mildew: It is caused by *Oidium lini* occurs mainly when the crop grown in rich soils under irrigated conditions.

Management:The disease controlled by spray of wettable sulphur 0.2% or Karathane 0.1%

(iv) Rust: It is caused by *Melampsora lini* (Pers.) is one of the most destructive diseases of linseed in India and the losses have been estimated to vary from 70-100 per cent. For infection and disease development 13° to 21°C appears to be favourable. In India, seven races of the pathogen have been identified.

Management: The disease can be effectively managed by cultivation of resistant varieties like Jawahar 7, Jawahar 17, Jawahar 552, LCM 54, LC 185, K2, Hira, Mukta, Neelum, Jawahar-Linseed-23, Garima, Shubra and Sweta. Need based sprays with mancozeb or zineb @ 2 g a.i./lit. Checks the disease. In Madhya Pradesh the disease can be escaped by sowing the crop early, (third week of October). Application of phosphorus and potash fertilizers reduces disease intensity.

Sunflower Disease Scenario Past and Present - Shift in Status: Effect of Climate Change?

Sunflower (*Helianthus annuus* L.) is one of the most important oilseed crop in India. Due to its wide adaptability it is grown under different agro-ecological situations, seasons and cropping systems. In states of Karnataka, Maharashtra, Andhra Pradesh, Telangana, Tamil Nadu it is cultivated under *kharif* and *rabi* , where as in Punjab, Haryana, Bihar , West Bengal during *rabi* and *spring* seasons. After introduction of sunflower crop in India during early seventies,with a modest beginning of the area under cultivation has reached to a maximum of 2.5 million ha during 1994 which declined drastically to 6.9 lakh hectares by 2015 . Among the biotic stresses, diseases are major problem which causes severe economic losses in yield. Development of diseases is strongly dependent upon the temperature and humidity. During the past few decades, a warming trend has been observed along the west coast, in central India, the interior peninsular and Northeastern parts of India. Any small change in temperature can result in changed aggressiveness as well as appearance of new pests in a region. It is fact that during the last four decades the disease scenario of sunflower had under gone tremendous changes in terms of major and minor disease status, new diseases, yield losses etc., The enumeration of sunflower diseases, their status, region wise, season wise , appearance of new diseases etc., and changes occurred from the early years of its introduction to subsequent years were compared and discussed. For convenience the sunflower areas were grouped into three different geographical and climatic zones. The ***Zone I***: It comprises the traditional sunflower growing areas of Karnataka, Tamilnadu, Andhra Pradesh, Telangana and Maharashtra. ***Zone II***: The states of Punjab, Haryana, parts of UP and Bihar. ***Zone III***: West Bengal and Odissha states.

This information depicts the disease scenario of sunflower in early years of its introduction and in subsequent years which could be due to impact of changes occurred in climate.

The disease scenario during different periods

- ***During 1963-1983*****:** During early years of sunflower introduction the *Alternaria* leaf blight (*Alternariaster helianthi*) was the only important and major disease in all part of Zone-I. During the period several fungal diseases were reported on the crop which of no economic importance(Nagaraju *et al* 1994)
- ***During 1984-1995*****:** The downy mildew (*Plasmopara halstedi*) disease was recorded for the first time in Marathwada region of Maharashtra. For long time it was confined to the Marathwada region, later it spread to all parts of the Zone-I. In some places, the disease was very high and resulted into severe yield losses. As a result of serious efforts by researchers several resistant cultivars and good management practices were developed which reduced the disease incidence (Patil 1992). *Alternaria* leaf spot and downy mildew were continued to be major problem on sunflower.
- ***During 1996-2000*****:** A new viral disease later named as sunflower necrosis disease (SND) was noticed in 1996 at Bagepally of Karnataka state. Within 1-2 years of its appearance the disease became epidemic and spread to many parts of Karnataka and Andhra Pradesh. Later it has spread to Tamil Nadu and Maharashtra, which posed a serious threat to sunflower cultivation. The causal agent of the disease was identified in the year 2000 as *Tobacco Streak Virus* (TSV) of Ilar virus, which is the first ever reported virus from Asian continent (Prasad Rao *et al* 2000). Later several crop plants were found infected by TSV and it has a wide host range. The complete etiology, disease development, nature of transmission etc., were well established on sunflower by ICAR-IIOR. So far no resistant source is found for TSV in the available sunflower germplasm. The disease continued to be a number one status in Zone-I till 2010 later the disease severity has come down. The disease was also recorded in low to medium range in some parts of Zone-II and in traces in Zone-III.
- ***From 2010 onwards*****:** The powdery mildew (*Golovinomyces cichoracearum*) disease of sunflower earlier which was considered as minor disease became rampant and posed a serious economic threat to sunflower cultivation in many parts of Zone-I. From 2000 onwards it had attained the status of major disease and considered as important as of *Alternaria* and more than SND. The yield losses due to the disease estimated to be as

30% and 64% at disease severity of 20.5% and 52.6% respectively (Pratap Reddy *et al* 2012). In Zone-II the disease is in the range of low to medium.

During the year 2010 another new viral was recorded on sunflower at MARS, Raichur, later named as sunflower leaf curl virus (SuLCV) incited by Begamovirus of Geminiviradae. (Govindappa *et al* 2011). The incidence of disease was recorded up to 80% in experimental fields at UAS, Raichur. The disease was reported in other areas of Karnataka, some parts of Andhra Pradesh, Telangana and Maharashtra also in the range of low to medium.

- **Disease scenario at different zones:**

➢ In Zone-I: The *Alternaria* leaf spot, SND and powdery mildew considered to be as major diseases. While downy mildew, *Sclerotinia* root rot, SuLCV, rust and head rot as minor diseases.

➢ In Zone-II: The rots caused by *Sclerotinia*, *Sclerotium*, *Pythium* and charcoal rot (*Macrophomina phaseolina*) are as major problem. Downy mildew, *Alternaria* leaf spot, SND as minor diseases.

➢ In Zone-III: The root rot by *Sclerotina* and *Sclerotium* as major problems and none other of any important.

Besides, several minor disease of fungal and viral were reported from all the sunflower growing areas which are of very low economic importance.

- **The disease occurrence in different seasons**

There is a clear cut difference in appearance of the diseases in different season/environmental condition.

➢ The *Alternariaster* leaf spot is higher in *kharif* to late *kharif* seasons and less in *rabi* or summer seasons.

➢ The SND is higher in the early sown *kharif* and February-March sown crops. Less during August-January sown crops. The disease epidemics are usually seen during the periods when heavy monsoons followed by dry spells for 2-3 weeks, i.e. generally during July-August months.

➢ Powdery mildew is higher in the September-October sown crops. Whereas rust is reported sporadic in the range low to medium appears in the late *kharif* sown crops and severe during *rabi* particularly in some parts around Coimbatore of Tamil Nadu.

- The root rots and wilts caused by *Sclerotinia, Sclerotium, Pythium* are usually higher in the spring/summer season cultivated sunflower ,usually in the Northern and Eastern parts of sunflower growing areas.

Conclusion

This compilation of studies clearly indicates the disease scenario is very dynamic in nature and it varies from season to season, region to region. It is inheridant to say the climate plays a major role in the severity levels of the diseases. The occurrence of new diseases, change in the status of the diseases are apparently due to change in environmental conditions. The future study requires precision of epidemiological studies in relation to the weather conditions and disease development.

References *(for the case study portion only)*

Anonymous. (2016). Annual Progress Report: AICRP - Sunflower, 20015-16. All India Coordinated Research Project on Oilseeds. DOR, Hyderabad. P.

Govindappa, M.R., Shankergoud, I., Shankarappa, K.S., Wickramaarachchi, W.A.R.T., Anjaneya Reddy, B. and Rangaswamy, K.T., (2011). Molecular Detection and Partial Characterization of Begomovirus Associated with Leaf Curl Disease of Sunflower (*Helianthus annuus*) in Southern India. *Plant Pathology Journal* (9): 1-7

Kallamadi Prathap Reddy, Sankaraneni Chander Rao, Pulugurtha Bharadwaja Kiriti, Mulpuri Sujatha (2012) Development of a Scoring Scale for Powdery mildew (*Golovinomyces cichoracearum*(DC.) V.P. Heluta) disease and identification of resistance sources in cultivated and wild sunflowers. *Euphytica.* 190 (3): 385-399.

Nagaraju, Jayarame Gowda, Gangappa, E. and Virupakshappa, K. (1994). Integrated management of Alternaria leaf spot of sunflower. *In Sustainability of oilseeds*. Prasad, M.V.R.et.al. (Eds.) Indian Soci. Oilseeds Res. Hyderabad. Pp: 283-286.

Patil, M.A., Mayee, C.D. and Phad, H.B. (1992). Sunflower downy mildew. Information Bulletin, ORS, MAU, Latur. Pp: 76.

Prasad Rao, R.D.V.J., Reddy, A. S., Chander Rao,S., Varaprasd, K.S., Thirumala Devi. K, Nagaraju,V., Muniyappa,V And D.V.R.Reddy (2000).Tobacco Streak Ilar Virus As Causal Agent Of Sunflower Necrosis Disease In *Indian. J. of Oil Seeds Research* Vol:17 (2).401-402.

17. MANAGEMENT OF STORAGE PESTS IN OILSEEDS

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Introduction

Oilseeds under storage are damaged by storage pests such as insects, rodents, fungi and birds which cause both quantitative and qualitative losses in oilseeds.

Storage insect pests are classified in to two groups: 1. Major / Primary pests 2. Minor / secondary pests

Major pests: These pests can break the kernal and make them powder. They can cause huge damage and storage loss. They also contaminate the grains.

Minor pests: These pests cannot break the kernal. They feed on broken kernals and milled products. They contaminate the oil seeds and milled products.

Storage Pests of Oilseeds

During storage of oilseeds and other agricultural commodities, considerable quantitative and qualitative losses are caused by the storage insect pests. At high moisture, their growth and multiplication is very fast. The optimum conditions of temperature and relative humidity for the rapid growth and multiplication of storage insect pests range from 25 to 35 ^{o}C and 60 to 65% respectively. The important pests of oilseeds are described below

1. *Tribolium castaneum* (Herbst)

Order: Coleoptera

Family: Dermestidae

Common name: Red flour beetle

Hindi name: Aate Ka keet.

Identification: - The red flour beetle is reddish-brown in colour and its antennae ends in a three-segmented club. The head of the red flour beetle is visible from top, does not have a beak and the thorax has slightly curved sides. Adult beetle is very active, flattened, moves fast and light reddish brown in colour. Length of the adult is about 3-4 mm. Antennae are with distinct 3 segmented club. The eggs are white, microscopic and often have bits of flour stuck to their surface. The slender larvae are creamy yellow to light brown in colour. They have two dark pointed projections on the last segment of the body.

Commodity damaged: - It is commonly found in broken cereals and their milled products like atta, maida and suji. It is also found in all cereals, groundnut, oilseeds and feed mills.

Habits and History: - About 450 eggs are laid at random by a female over a period of many months. The larvae are creamy whitish in colour and cylindrical in shape. The egg to adult development is completed within 20 days. Damage is caused both by adult and larva. Life cycle is 57 days at 24 -30 degree centigrade and 66-92 % relative humidity. Temperature range is 15-32 degree centigrade and 40% relative humidity. Adults are long lived, can fly and feed.

2. *Groundnut Bruchid,* Caryedon ***serratus***

Order: Coleoptera

Family: Bruchidae

Common name: Khapra beetle

Identification:- The adult is a brown beetle. Small translucent milky-white eggs can be seen attached to the pod wall. The larva burrows through the pod wall, and starts eating the seed. Fully grown larvae often leave the storage sack and pupate in large numbers at the bottom of the pile of sacks.

Commodity damaged:- The first sign of attack is the appearance of 'windows' cut into the pod wall by the larva. The larva burrows through the pod wall, and eats the seeds. Thus, groundnut seeds are too badly damaged for human consumption or oil expulsion.

3. *Ephestia cautella* (Walker)

Order: Lepidoptera

Family: Pyralidae

Common name: Almond /Warehouse moth

Hindi name: Godam ka patanga

Identification:- When fresh, wings are grey with vague darker markings. Larvae are light pink coloured with a small black spot at the base of each hair.

Commodity damaged:- It is a serious pest of cereals and cereal products and also infests the dried nuts/ fruits.

Habits and History:- Up to 300 eggs are laid at random by the female in 3-4 days . The life cycle is completed in 28 days at optimum temperature of 30 ^{o}C and 75 % relative humidity. Temperature range is 17-37 ^{o}C. Larvae are mobile and produce large quantities of silk webbings. Adults are short lived, do not feed and are active flier at dusk and dawn.

4. *Oryzaephilus surinamensis* (Linnaeus)
Order: Coleoptera
Family: Silvanidae
Common name: Saw toothed grain beetle
Hindi name: Chawal ki sursuri

Identification:- Adult beetle is a slender dark brown to grey colour beetle and 2.0 to 3.0 mm in size with characteristic teeth running down the pro-thorax (six tooth like projections on each side of thorax).

Commodity damaged:- The larva and adult damage cereals mainly broken grains and other stored products/foods. Both make the grain surface rough.

Habits and History:- Being a minor pest, larvae feed on grain and germ. The saw toothed grain beetle lays its egg loosely (at random) on grain @ 6-10 eggs per day with total 370 eggs per female. Larvae are mobile and not concealed. Total life cycle may be completed in 20 -80 days at 33 ^{o}C and 80% relative humidity. Temperature range is 18-38 ^{o}C and relative humidity. 10-90%. Adults are long lived, feed, can fly and walk long distance rapidly. It can enter into packaged food.

5. Grain Psocids:- Grain Psocids are small in size, pale, long hair like antennae, belong to Liposcelis spp. Some are wingless other are having wings. These are scavenger and common pest found in grain stores. Most common in slightly damp stores/materials. Life cycle is 21 days at 30 ^{o}C and 70% relative humidity. Temperature range is 18-36 ^{o}C and minimum relative humidity. Requirement is 60%. Eggs are laid at random. Nymphs are similar in appearance to adults but smaller and paler in colour. Adults are long lived, feed, runs rapidly in jerky manner.

6. Management of Storage pests in oilseeds

6.1 Prophylactic measures:

"Prevention is better than cure". Hence the following preventive measures can be undertaken at storage places in order reduce the pest incidence

i. Proper inspection and analysis of stocks received before acceptance
ii. Hygiene or sanitation inside and outside the godowns
iii. Aeration of godowns
iv. Prophylactic spraying with insecticides

6.1.1. Proper inspection and analysis of stocks received before acceptance for storage

When the stocks are received at storage point or whichever the oilseeds that are going to be stored have to be thoroughly inspected before start storage of those commodities. Representative sample has to be taken and it has to be analysed for moisture content and presence of insects. The commodities beyond safe storage moisture content will deteriorate quickly and prone to insect and mould attacks. Before accepting the food grain stocks, the godowns shall be inspected to check hygiene, cleanliness, storage worthiness and the godown is pest free.

Sampling	Random samples shall be drawn from the food grain bags with the help of *parkhi* on all sides of the lot received through wagon/truck
Visual Inspection	Visual Inspection shall be done at the time of receipt of food grains to ascertain the following points i) Food grains shall be inspected for identifying damage, infestation, slack bags and cut & torn bags. ii) Unsound bags shall be segregated and kept separately, duly identified and recorded.

Inspection process	i)	For food grains further inspection shall be carried out by testing the grains moisture followed by analysis, classification, categorization / grading. The maximum moisture percentage for safe storage of rice and paddy is be 14% and for wheat is 12%.
	ii)	If the food grains are found within the prescribed quality specifications the same shall be accepted for storage.
	iii)	In case of storage of FCI stocks, receipt of food grains with quality complaint shall be informed to the depositor or consignor in writing within 72 hours detailing the complete quality issue
	iv)	The infested stocks shall be fumigated within 48 hrs hours to avoid cross infestation to pest free stocks

6.1.2. Hygiene or sanitation inside and outside the godowns

6.1.2.1. Sanitation inside the godowns

- Necessary repairs like arresting roof and cable wall leakage, replacement of damaged sheets, securing windows and ventilators with wire mesh shall be done to make the godowns storage worthy.
- Before storage of commodities inside the godown ensure that the godown is well cleaned. Godowns shall be cleaned thoroughly to avoid any residual infestation
- Empty godown shall be kept clean & tidy free from any harbouring insects, cobwebs, spiders and other pests
- Floor sweeping has to be done on regular basis and spillages has to be collected on day-to-day basis, cleaned and bagged to mother stack.
- Wall cleaning has to be done. No cracks and crevices should be there in wall to avoid harboring of pests.
- Cob webs removal has to be done regularly to improve the hygiene condition inside the godown
- Disposal of waste / damaged grains has to be done timely to avoid further deterioration and pest multiplication.

- Sacks / gunnies used shall be sound enough. The cut and torn portions has to be stitched and closed.
- Ventilators & windows secured with wire mesh to prevent the escape of insects during prophylactic spraying with insecticides
- Roof leakages and cable wall leakages have to be arrested immediately to avoid entry of rain water. The rain water can soak the grains leading to sprouting or decrease in bulk density of grains makes it unsuitable for storage.
- Proper Stacking is very much required to take up spraying and fumigation operations inside the godown.
- Sufficient gap should be given from the walls, stack to stack, Passage etc.
- Material should not be stored on the floor
- Proper Dunnage - timber pallets/Poly pallets/ or Bamboo mats or black polythene sheets can be used.
- Goods of different classes or grades or quality have to be stored separately and arranged in such a way that stock taking and verification becomes easy and effective.

6.1.2.2. Sanitation outside the godowns

- Clean platform – The platforms where loading and unloading operations happens has to be clean without any spillages. If there are spillages will attract storage insects and rodents and will result in damage of grains and pest multiplication.
- No steps should be kept in the platform for having entry to godowns. Keeping the steps will make the platform not rodent free. The rodents will have easy access and movement into the godowns.
- Clean roads – Keeping the roads inside the warehouse premises is an important measure to avoid harborage of pests and also for easy movement of trucks.
- Dumping wastes – No waste has to be thrown here and there in the warehouse premises. The wastes and damaged grains have to be disposed of safely by following laid down procedures.
- Vegetation free – The warehouse premises should not be occupied by green vegetation. Vegetative growth should be removed at periodical intervals to keep the depot premises free from insect breeding, reptiles, bird nests, rat burrows and to ensure overall hygienic condition. One can do away the control of vegetation by spray of Glyphosate SL.

- The vegetation like small trees that are growing on the top roof and side wall of godowns / building shall be periodically removed to avoid damage to the structures.
- No spillage should be on roads and platforms to avoid attraction of insects and rodents.
- Proper drainage system should be in place to avoid flooding of godowns and damage of stocks during rainy season.

6.1.3. Aeration:

Aeration is a process of passing air through stored grain at low flow rates. This can be achieved by keep opening the windows and ventillators and also all doors / shutters open during the day time. Aeration helps in excess moisture removal, temperature reduction inside the godowns, for quality maintenance in the commodities and highly useful when moisture content is high.

6.1.3.1. Objectives of aeration:

- Removal of generated heat and moisture inside the godown
- Maintenance of uniform condition inside the godown
- Removing/ reducing odour from grains which have higher moisture
- Removing dry heat generated by respiration of insects and grains
- Reduce moisture accumulation
- Helps in fumigant application

6.1.3.2. Aeration inside the warehouse / godowns

- Doors installed opposite to alleyways each other and has to be opened daily to ensure movement of air inside the godown
- 6% of wall space for ventilators should be provided while constructing the godowns for proper ventillation
- Doors shall be kept open during day
- Movement of natural air shall be ensured

6.1.3.3. Benefits of Aeration

- Reduces insect pest population in the godowns with food grains
- Grain quality is preserved

- There will be moisture reduction
- Temperature reduction can be realized
- Reduces the mould attack in food grains
- Colour and aroma can be maintained in spices by proper aeration.

6.1.4. Prophylactic spraying with insecticides

- Immediately on receipt of stocks spraying with malathion 50% EC can be done
- Prophylactic spraying can be repeated once in two weeks
- Air-charging inside the warehouse is done with DDVP 76% EC. However the insecticide DDVP will not be in Indian markets after 31st Dec 2020 as it will be banned.
- Prophylactic spraying helps to control flying / crawling insects
- Generally prophylactic spraying is done during the later part of the day prefereably evening and in the week ends for more efficacy
- Before spraying godown should be cleaned and spillage collected and covered to avoid contamination by insecticides.

6.1.4.1. Effect of spraying sub lethal doses:

Sufficient care has to be taken to go with correct and required dosage of chemical while undertaking prophylactic spraying. Undertaking spraying operation with sub lethal dosage of insecticides is always harmful and results in

- Development of resistance to insecticides in insects
- Sudden increase in insect population
- Difficult to control the insects that got resistance
- Damages the commodities
- Storage loss will be high
- Public problems will come due to high population of insect pests inside the godown.

6.1.4.2. Procedure for undertaking prophylactic spraying inside the godowns:

Need identification	Spraying shall be on the basis of requirement fortnightly prophylactic treatment i) air-charging of empty godown space before storage of food grains ii) post fumigation spray

Preparation for spraying	i) Identification of area / volume to be sprayed ii) Calculation of correct dosage of required pesticide iii) ensure availability of good spraying equipment (Knapsack/foot sprayer/power sprayer) iv) Prepare the pesticides with correct volume of water and ensure that the pesticide is mixed properly with water v) Sprayer should be of good one without any leakage and clear nozzle for effective spraying. vi) While using wettable powder formulation, uniform mixing shall be done to avoid accumulation of powder at the bottom of sprayer. This will lead to inefficient spray, patches on the bags and walls and is likely to induce resistance in insects.
Spraying process	i) Spraying shall be carried out by using appropriate pesticide as per the CIBRC recommendation with correct dosage. Uniform spraying shall be done. ii) Light and gentle spraying shall be done on bags without drenching which will lead to moisture increase in the food grains. iii) Spraying shall be resorted to evening. iv) For effective air-charging, the windows and ventilators shall be secured with wire mesh permanently. v) After spraying/air-charging, godown doors/shutters shall be closed for 24 hours. In order to achieve this spraying shall be given regularly during week end so that transactions in the godown will not be affected.
Calculation of insecticide	**a) Deltamethrin 2.5% WP** **Frequency:** once in 3 months **Dilution:** 120 g in 3 litre of water **Dosage:** 3 Litres/100 sq.m. for surface treatment on bags containing stocks, wall and alleways. **b) Malathion 50% EC** **Frequency:** once in two weeks

	Dilution: 30ml in 3 litre of water **Dosage:** 3 Litres/100 sq.m. for surface treatment on bags containing stocks, wall and alleways. **c) DDVP 76% EC** **Frequency:** once in two weeks **Dilution:** 20ml in 3 litre of water **Dosage:** 3 Litres/100 sq.m. for air-charging in empty spaces, platforms and walls.
Preparation for spraying	i) Before undertaking spraying the area for treatment shall be swept, cleaned and spillage shall be collected to avoid contamination with insecticides. ii) The nozzle and delivery pipe of spraying machine should be checked for blockage and leakage. iii) Spray solution shall be prepared by mixing correct dosage of insecticide in required quantity of clean water
Spraying process	Spraying shall be carried out by the experienced personal by using good sprayer preferably in the evening.
Post spraying activity	The exit door shall be closed and sealed after spraying. ii) Excess/unused pesticide solution shall be used outside on platform/verandah or tree barks iii) The delivery pipe, tank, nozzle etc. has to be cleaned with running clean water

6.1.4.5. Precautions to be taken:

- Personal protective equipment (PPE) like hand gloves, eye-shield, gum boots and nose mask should be used during handling and spraying of pesticides.
- Before spraying, the sprayer and its nozzle shall be checked thoroughly. Nozzle and lance should not be blown with mouth.
- Spraying should not be done alone
- Spraying against the direction of wind should not be done
- While spraying movement shall be backwards to avoid body contact with treated area

- Eating, chewing, drinking or smoking should be avoided while spraying
- Along with personal protective equipment, the person spraying should wear aprons.
- After spraying, hands and other parts of the body should be thoroughly washed with soap & water
- The empty pesticide containers should be crushed and disposed of as per insecticide act, 1968.
- Godowns should be kept open for few hours before entry so that accumulated chemical fumes are diffused out
- In case of giddiness/headache, the affected person shall be taken out in fresh air and shown to a physician if required.

7. Curative Measures

This is being done with using Aluminium phosphide 56% Tablets

Work Procedure:

	Activity	Description
7.1	Calculation of Aluminium phosphide Tablet	For cover fumigation – 9 g/MT (3 tab/MT) For shed fumigation – 360 to 420g /100 m^3
7.2	Exposure period	7 days for all storage pest 10 days for *Leamophloeus* sp.
7.3	Fumigation process	**a) Cover fumigation** i) Take the required quantity of Aluminium phosphide tablets as per the dosage mentioned above. ii) Install monitoring tubes on top back, middle and front side of the stack and fold and clip the edges at bottom. iii) Distribute the pre-calculated dosage in 6 to 8 enamelled/paper plates of at least 9” diameter spreading the tablets in single layer and keep them at different locations including beneath the crates, sides & top of stack. 3 – 4 tablets can be kept in between the bags using paper bag/cloth bag.

		iv) Spread the fumigation cover on the top of stack and then cover the stacks. Ensure that the cover is a sound one not torn or having holes. v) Seal the fumigation cover on the floor level using sand snakes to prevent leakage of phosphine gas. The cover shall be secured in such a way it should be in tight with stocks. Loose cover or oozing shall be avoided. vi) Check the gas leakage on all sides using phosphine gas leak check detector. vii) Monitor the phosphine gas concentration regularly by attaching the tubes fixed before fumigation at top, middle and front side of the stack, using Phosphine gas monitor. viii) For effective control the phosphine gas concentration shall not be less than 760 ppm/m^3 **b) Shed fumigation** i) Take the required quantity of Aluminium phosphide tablets as per the dosage mentioned above. ii) Seal all the window panes, ventilators and doors except exit door. iii) Distribute the tablets on a paper plate and keep it at different places uniformly on the stackes iv) After placing tablets, ensure that no one is present inside the shed. The come out and close the exit door and seal it.
7.4	Post fumigation operations	i) Remove the cover after completion of exposure period and fold it properly ii) Take representative sample from the stack and check for live insect, if any in order to ensure the fumigation is effective. iii) Brush the bags thoroughly and clean the godown to remove dead insects and residual powder within 2 days.

iv) Spray with malathion at recommended dosage as post fumigation spray.

7.5 Precautions:-

Personal protective equipment (PPE) like hand gloves, eye-shield, gum boots, face mask with canister etc., should be used during handling and application of fumigants.

Check the fumigation covers for cut, holes etc., and resort to repairing, if needed before putting on the stack

Leave the site of fumigation as soon as the process is over

Display ‘DANGER’ symbols on the fumigated stack and exit door of the shed.

Entire operation of fumigation should be carried out in the presence of technical in-charge and supervision of accredited fumigation operator under NSPM 22

Fumigation should not be done alone

Eating, chewing, drinking or smoking should be avoided during application of fumigants and while de-gassing

The empty pesticide containers should be crushed and disposed as per I.A 1986existing guidelines

Godowns should be kept open for few hours before entry so that accumulated chemical fumes are diffused out

In case of giddiness/headache etc., the affected person shall be taken out in fresh air given first and shown to a physician if required.

In case of gas leakage indicated by characteristic smell, strengthen the sealing.

Roof leakage should be avoided by appropriate sealing of leakage points there in the godowns where fumigation with Aluminium phosphide is undertaken.

Always keep the firefighting equipment ready as the gas is inflammable during the process of fumigation.

18. Competency Enhancement for Technology Transfer in Oilseeds with particular reference to Soybean

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I have always looked at my competencies before accepting my responsibility

N. R. Narayan Murthy

Today’s agricultural extension organisations demand a challenging combin.ation of individual talent and collective ability and effort. Extension workers as leaders to rural community must develop the right level of leadership competencies. Competencies have become a leading construct in human resource practices, such as recruitment and selection, career development, performance management, and the management of change.

Move over, the link between competency and job performance is addressed in “model of effective job performance”. This model specifies that effective action, and therefore performance, will occur when all of the critical components namely organizational environment, job demands and an individual’s competencies are consistent or fit. According to this model an individual’s competencies represent capability that an employee brings to the job situation as required by the job tasks. These job requirements can be considered the job demands on an individual. In agricultural extension work contexts, competencies refer to extension workers’ skills and knowledge (e.g. human development, leadership development, communication and program development skills), which are necessary to successfully performed extension tasks. Thus, an extension worker who is aware, for example, of his or her ability to communicate or interact well with people of the rural community; plans, implements and evaluates extension program, may use these skills in order to increase performance.

COMPETENCE MAPPING AND DEVELOPMENT

Competency mapping is essential for identification of required job and behavioral competencies of an individual in an organization/ institution. It is a process where key competencies of an individual/ organization are identified. It is also essential for revamping the quality of any educational institute. Over the past few years, the higher education in India is undergoing rapid changes to meet the emerging challenges. Competency of teachers assumes a significant importance in this regard for quality education, which is the driving force for the development of society. Therefore, competency mapping of the faculty is the major challenge and prime concern. The academic institutions need to identify competencies required for faculty for teaching excellence to meet the challenges and expectations of students as it forms the basis for continuing professional development (*Anitha and Reema, 2014*).

A competency model describes the combination of knowledge, skill and characteristics needed to effectively perform a role in an organization and is used as a human resource tool for selection, training and development, appraisal and succession planning (*McLegan, 1989*).

Competency model is a valid observable and measurable list of knowledge, skills and attributes demonstrated through behavior that results in outstanding performance in a particular work context. A competency model is a behavioral job description that must be defined by each occupational function and each job. (*Fogg et al. 1999*).

COMPETENCY LEVEL

Level 1 Awareness	Aware of competency
2 Basic Skill	Having basic skill, always need supervision
3 Skilled	Having skilled, Occasional supervision

4 Advance Skilled	Exceeded the skill level, No need supervision
5 Mastery	Ability to supervise and train others
6 Expert	Acknowledged as an expert by professional association (Advisory Board Member)

COMPETENCY ON CONVERGENCE

Approaches to agricultural extension in India and worldwide continue to evolve. Since the Green Revolution in the 1970s and 1980s and the acknowledged unsustainability of the training and visit (T&V) program, agricultural extension, with its focus on increasing production via technology transfer, has adopted decentralized, participatory, and demand-driven approaches in which accountability is geared toward the users. While the call for demand-driven agricultural extension has existed for several decades now, new modes of reaching out to farmers could have significant impact in India, as they might better reflect the local information needs of farmers. The diverse nature of the Indian subcontinent, with its wide variety of ago climatic regions and broad range of socioeconomic conditions in the rural population, calls for agricultural extension approaches that are context and situation-specific. With more than 81 percent of Indian farmers cultivating an area of 2 hectares or less, there is an increasing need for stronger intermediaries that can facilitate information access for diverse smallholder farmers. Further progress in poverty and hunger reduction crucially depends on the increased productivity and profitability of these farmers, which in turn depends on the successful delivery of agricultural extension.

Several emerging challenges confront Indian farmers. These include limited land and water availability, which is further exacerbated by degradation of natural resources; climate changes; changes in demand and consumption patterns, moving toward high-value agriculture; increasing population pressure; and liberalization of trade. Recent global food price increases and high levels of inflation have provided an opportunity to increase farmers' profitability. However, to realize the benefit of higher prices, farmers need to access a wider range of information, related not only to production technologies but also to postharvest processes, access to remunerative markets, price information, and business development. This information could be integrated with services that support the use of the information. For example, technology information needs to be supported with information about reliable sources for that technology, and where credit can be accessed. In India, the role of agricultural extension in improving agricultural growth is today being recognized with increasing investment. India's 10th and 11th five-year plans emphasize agricultural extension as a key to increasing agricultural growth by reducing the yield gap in farmer fields, and therefore stress the need to strengthen agricultural extension in India.

However, despite the renewed interest and investment in agricultural extension in India, the coverage of such services is inadequate. Government extension programs, extension services of the national agricultural research system, cooperatives, and nongovernmental extension programs have a very limited outreach (NSSO 2005). The 2003 National Sample Survey Organization (NSSO) survey showed that 60 percent of farmers had not accessed any source of information on modern technology to assist in their farming practices in the past year. Of those who had sourced information, 16 percent received it from other progressive farmers, followed by input dealers. Of those farmers who had accessed information, the major problem of extension services was found to be the practical relevance of the advice (NSSO 2005). The coverage and relevance of information provided to farmers through the agricultural extension system is therefore questionable. While this may be partly due to inadequate contact by the services, which need to reach a large and complex farming community, inappropriate or poor-quality information could also be a key hindrance to farmers' use of extension services. In other words, the content of the information provided by agricultural extension approaches, and the information farmers actually need, may not be aligned. There is therefore a need to re-examine the current agricultural extension approaches in India to understand where information gaps exist and determine why farmers are not accessing information through the large, well-established public-sector extension system in addition to emerging private and third-sector actors.

REVIEW OF SELECTED AGRICULTURAL EXTENSION APPROACHES IN INDIA

1. Public-Sector Extension:

a) State Departments of Agriculture: Staff of the DoA receive their information from various sources, including the research stations of the Indian Council for Agricultural Research (ICAR). However, the linkages between the two systems, research and extension, are well known to be weak, and information flow remains linear and top-down. Feedback from extension to research is limited, so research agendas are not influenced by extension. The information the DoA provides still relates to the transfer of technology to bridge the yield gaps between farmers' fields and research stations, and largely focuses only on crop production

b) Agricultural Technology Management Agency (ATMA): ATMA provides a platform for encouraging the flow of information between the public research and extension systems, and encourages diversification in cropping practices. But in terms of information provision and sharing, ATMA currently still relies on the existing capacity of the public-sector system, which has already been described as focusing on technology transfer for crop production.

c) State Agricultural Universities (SAUs): The main extension activities of the central autonomous Indian Council for Agricultural Research (ICAR) are achieved through the 40 Agriculture Technology Information centers (ATICs) and 569 district-level Krishi Vigyan Kendras (KVKs), or farm science centers. Additionally, each state has a State Agricultural University (SAU), which provides extension and training activities through the Directorate of Extension and Education but activities and organizational setup differ widely by state.

d) Knowledge Transfer through Krishi Vigyan Kendra: KVK or farm science center is a multi - disciplinary educational institution situated at the district level, with funding and technical supervision from ICAR. Each KVK is in one of 15 ago climatic zones, and the zonal coordinator pays a visit to each of them every three months. Within each center, around 20 scientists are employed from different disciplines, including crop production, plant protection, agricultural engineering, and home science to provide extension services.

2. Public-Private Partnership: The Agriclinic and Agribusiness Centers (ACABC): ACABC provide agricultural advisory services to farmers through technically trained agricultural graduates at the village level, known as "agripreneurs." Bank loans are available for the agripreneurs to start an agriclinic. The central government provides 25 percent of the cost as a subsidy. In addition, the states have adopted the approach and add their own additional subsidies for agriclinic implementation. The objectives of the program are to supplement the public extension system, increase the availability of inputs and services for farmers, and provide employment to agriculture graduates. The role of an agriclinic is to provide expert services and advice to farmers, while agribusiness centers provide inputs and farm equipment hire. This service aims to fill the gap in the public-sector extension system where currently the input dealer plays a major role in providing advice to guide input use.

3. Private-sector Extension: e-ChoupaI: In 2000, the Indian Tobacco Company (ITC) launched an initiative called e-Choupal. The project is a private commercial initiative in agricultural extension. The e-Choupal provides farmers with an alternative marketing channel, information on local district weather, agricultural best practices, feedback on quality of crops, and input sales with accompanying field-specific testing such as soil tests. The e-Choupal initiative has had a supposedly positive effect on the incomes of participating farmers, as the system has brought efficiency to the supply chain by removing intermediaries and reducing transaction costs.

4.Farmer Field Schools: Since the 1990s, farmer field schools (FFSs) have been established by the Government of India in partnership with the Food and Agriculture Organization of the United Nations (FAO) and European Union to provide integrated pest management (IPM) tor-cotton farmers.

5.Civil Society Organizations: Due to the number of smallholder farmers, farmer-based organizations (FBOs) and self-help groups (SHGs) are key organizations to make extension demand-driven. In groups, it is easier to get feedback on the information needs of the members.

6. Mass Media and Information and Communication Technology Approaches: ICT is consequently given a high priority, particularly as a tool for improving the marketing aspects of farm enterprises. ICT has the ability to reach farmers directly, can enable two-way information sharing processes, has greater storage capacity, is faster, and can increase market efficiency by addressing information gaps and blockages.

7. Other Private-sector Approaches: Many private agri. food businesses are introducing rural business hubs that serve as one-stop shops for rural communities, supplying consumables, farm inputs and technical information. Like ITC e-Choupals, Haryali Kisaan Bazaar, Tata Kisan Sansar etc.

CHALLENGES AND CONSTRAINTS TECHNOLOGY TRANSFER APPROACHES:

Public Sector: Information flow within the public sector moves linearly, with content focusing on the transfer of technology for increasing crop production. A wider definition of agricultural extension, beyond improving crop productivity, has not been embraced. Information flow is supply-driven and not needs-based or area-specific, so farmers see the quality of the information provided by the public extension staff as a major shortcoming. This is due to the static and inflexible nature of the organization, where a top-down hierarchical approach continues. Access to extension is also an issue, because of the low level of by public extension services. This is partly due to the public staff being overburdened with implementing state and centralized schemes, which are also not easily modified to suit local needs and conditions. There are also insufficient funds for operational costs, training, and capacity development, which limits the activities and continual development of the extension staff. Of the required 1.3 million to 1.5 million extension personnel required, there are only about 100,000 on the job. At the state level, the various line departments have been criticized for working in isolation, with weak linkages and rare partnerships, which limits information flow. Additionally the research-extension link has been criticized for not absorbing or using feedback from farmers and extension staff Extension personnel and farmers are passive actors, and scientists have limited exposure to field realities. The various components of the public-sector extension system suffer from duplication of programs, without convergence. While ATMA is pushed as the platform through which the multiple agencies can converge, the implementation difficulties are proving too great for effective integration, with shortages of both personnel and funds. The 2010 revision of ATMA attempts to address this, but enabling the new personnel to achieve the necessary understanding of the concept for proper implementation will require strong training and capacity development.

Private Sector: Private-sector examples in agricultural extension are developing context-specific models and using ICT tools to bring information directly to the farmer. The private sector is increasingly playing a role in extension services in India. The public sector acknowledges this, with the policy framework for agricultural extension referring to the need for public extension services not to crowd out private services. Additionally, the policy framework for agricultural extension notes that "public extension by itself cannot meet the specific needs of various 27 regions and different classes of farmers". One alternative discussed in pluralistic extension systems is that the private sector can provide services related to proprietary goods, while the public sector can provide extension services related to public goods, which tend not to be addressed by private-sector firms. Although few empirical studies have been carried out, the performance of private extension is said to vary widely; it tends to focus its services on areas with sufficient resources and is limited to a few crops and areas where profits can be assured. This has already been suggested in the discussion of the e-Choupal initiative, which services larger villages and specific crops. Additionally, the private sector serves a corporate interest, working with individual farmers, so social capital is not built. Moreover, private extension can only work well if farmers are willing and able to pay. One option suggested by Swanson (2008) is that the private sector could serve the needs of medium-size and commercial farmers, while the public sector could work in remote areas, which are currently not serviced well. This sort of system would require public-private partnerships that currently do not exist in India. It would mean changes in the way the public sector views and interacts with the private sector.

Relying on the public sector may also be difficult for remote and resource-poor farmers, considering the existing problems and poor reach of the public sector in those areas.

Third Sector: Within the information value chain, the capacity of farmers to articulate their needs will influence their ability to obtain the information they need. Considering the large number of marginal and small land holdings in India, FBOs and SHGs could play important roles in articulating the needs of farmers to knowledge intermediaries. FBOs and SHGs can operate side by side with either NGOs or the public sector, but challenges exist in both sectors. Public capacity to build FBOs and SHGs is limited, while NGOs, which are not numerous, rely on donor funds and would need public support to develop the technical skills to facilitate the groups. Within FBOs or SHGs, problems related to social identity, including gender and caste, mean that these organizations may not be completely inclusive and are subject to elite capture problems. When farmer groups interact with other institutions, social identities and other social status perceptions mean that they may be too weak to articulate their concerns. Building the capacity of such groups, and promoting the development of leadership and management skills so that farmers can demand the information they need, is therefore an important component of agricultural extension approaches.

AREAS OF IMPROVEMENT:

View extension within a wider rural development agenda: The emerging view of extension is not that of a service or system, but of a knowledge and information support function for rural people. Because rural knowledge and information needs are so diverse, there are benefits from having a range of providers to deliver advice, technology innovations, and facilitation services.

Define an extension policy for a pluralistic system: The design of an extension policy should begin with an inventory of the actors (who provides what to whom) and an assessment of the quality of the services rendered before deciding on any reform. Extension strategies need to identify the over-all objectives for public sector involvement in extension and define the role and responsibilities expected of various service providers, and of public funding. While it is important to have a strategy for a national extension system, this requires a country-led vision and political support independent of donor agendas, but in line with country-driven processes such as PRSPs and NEPAD.

Make long-term commitments: The new approaches will take many years to be fully institutionalized. Long-term commitments must be made within a widely-shared vision and strategy at different levels - international, national, regional, and community

Develop a stakeholder coordinating mechanism: It is important to consider some type of coordinating body for the various participants in extension to provide a common framework in which all actors can operate. On the other hand, coordination should not be so strict that it discourages competition and innovation. At a minimum, policies and mechanisms need to harmonize behavior and strategies (such as minimum levels for co-financing, prioritization, and area selection).

Build capacity of RPOs, the public sector, and service providers: Capacity building at all levels is critical. Funding should include a component for capacity building and institutional strengthening to widen the pool of qualified service providers and ensure strong links with and modernization of the various components of the agricultural education system, universities, vocational schools, etc.

Be realistic about the limits of fully private extension: The private sector will play an increasingly important role in rural knowledge systems, but total privatization is not feasible, even for commercial agriculture. The appropriate mix of public and private roles can only be determined through piloting and learning from experience.

Focus public financing on the poor: Poverty reduction should be the focus of public funding whether provided by public employees or contracted out. In fact, given the emphasis on poverty reduction and the increasing knowledge intensity of rural income, generating activities operating in a globalizing economy, the role of public funding is likely to increase. However, extension must tap new sources of public funding, given that the hulk of financing available for rural development now bypasses public agencies charged with agriculture, forestry, and environment. There are missed opportunities for extension involvement in CDI) programs, social funds, and fiscal transfers that have a strong focus on the poor.

Introduce some cost recovery: There is greater scope for cost-sharing and fee-for-service programs than is usually acknowledged. Reforms should encourage valuing information/ knowledge services, and fee-for-service mechanisms will encourage a market tor knowledge services.

Decentralize administration of public funds: Extension services should be a part of the decentralization and devolution agenda that engages local government units and grass roots organizations. This facilitates access to broader rural development financing other rural development and fiscal transfer programs, local government financing, and user funding. A clear definition of the roles of different actors must be spelled out and investment is usually needed to enhance local government capacity to successfully decentralize extension programs. Pilot programs are useful to identify problems and good practice in decentralization reforms.

Provide appropriate research support: Access to timely information and continuous updating of the knowledge and skills of field level extension staff both public and private, should he given highest importance. Still, the strong consensus of workshop participants was that formal research programs are only one source of such innovation and information for extension programs, which have an agenda much broader than technology transfer.

Develop a strong system for M&E from the beginning: All types of providers need a system to assess extension outcomes and feed this information back to policy and coordination units. For private services, and especially for NGOs and specialist advisory firms financed with public funds, some type of 'certification' might be useful to provide better information on skills and talents of specific agencies.

TECHNOLOGY TRANSFER ON SOYBEAN

Soybean (Glycine max (L.) Merrill) is an important leguminous oilseed crop, which is the economical source of good quality protein and edible oil. The commercial cultivation of Soybean that got momentum in 1980s’ in India is stabilizing now. The crop has made unique place among the traditional oilseeds of the country. The limited area of 0.03 m ha in 1970 is now it has 10.88 million hectare area producing 10.43 million tones with 0.95 ton per ha productivity (SOPA, 2014). Soybean is nutritionally important grain legume crop due to better quality edible oil (20%) and proteins (40%). It contributes 40 per cent of oilseed area and 25 per cent of edible oil production; besides 8 million ton of soy-meal production in the country. Madhya Pradesh, Maharashtra, Rajasthan, Karnataka and Andhra Pradesh are the leading Soybean producing state in India. To harvest a good yield of soybean, it is necessary to sow the crop at proper time, t maintain optimum plant density and to provide adequate nutrition. In combination with these important parameters, selection of suitable genotype plays a vital role in crop production. The choice of right genotypes of soybean helps to augment crop productivity by 20-25 per cent (Sing et al., 2013.) Increase in the seed rate ultimately results into increased density of plants per hectare. Either higher or lower density of plants than the optimum leads to the reduction in yield. Highly dense crop suffers from low space for growth; compete for soil moisture, sun light and nutrition. On the other hand, crop with low plant population per hectare is unable to produce yield to its potential, resulting in low yield. Supply of insufficient quantities of nutrients also leads to reduced crop yields.

For the last four and half decades, the soybean is commercial cultivated by the farmers and considered the crop is an export oriented commodity. After extraction of oil, about 58 per cent of resultant soy meal is being exported and remaining 42 per cent of it is utilized for poultry and fish meal domestically (Sharma et al., 2014). In spite of capabilities to mitigate energy-protein malnutrition and health benefits, its domestic utilization as processed food in any form was found to be negligible (Agarwal et al., 2013). However, the supplementation of edible oil by nearly 25 per cent (Sharma and Bhatia, 2015) by the crop has helped the country to reduce its import and thereby drain of valuable foreign exchange. Soybean is considered to be a functional food as it contains significant levels of bio logical active compounds that impact health benefits besides basic nutrition (TAAS, 2014).

In view of the above there is a need to transfer the technologies on soybean production and to promote the food use of soybean by the extension system. The competency of the extension officials have to be enhanced through number of capacity building programmes by reputed organizations.

References:

1. Adhiguru, P.P.S. Birthal and B. Ganesh Kumar 2009. Strengthening pluralistic agricultural information delivery systems in India. Agrl Economics Research Review.
2. Agarwal D K, Billore S D. Sharma A N, Dupare B U and Srivastav S K. 2013. Soybean: Introduction, improvement and utilization in India-Problems and prospects. Agricultural Research (December 2013) 2(4): 293-400.
3. Agriculture and Rural Development Discussion Paper 4 - Extension and Rural Development, Converging Views on Institutional Approaches?
4. Discussion paper on ARD Workshop, Nov 2002 at Washington DC, Extension and Rural Development, Converging Views on Institutional Approaches?
5. IFPIR discussion Paper 01048, Dec 2010, Review of Agricultural Extension in India.
6. Sharma P and Bhatia V S. 2015. Oilseed and Edible Oil Economy in India: Enhancing Supplies through Augmenting Productivity. In: Souvenir 53rd All India Convention on Oilseeds, Oils Trade and Industry, 24th – 25th October, 2015 at Nagpur.
7. Sharma P, Pate R M and Srivastava S K. 2014. Comparative advantage of Indian soymeal vis-à-vis major exporters, Soybean Research 12 (spl. 1); 129-43.
8. Singh Rakesh, Sharma H B, Praveen Kumar, Dinesh Kumar Pailwal and Pradeep Kumar. 2013. Effect of integrated nutrient management on growth, yield and nutrient uptake by soybean (Glycine max) cultivars. Indian Journal of Agronomy 58(3): 379-83.
9. SOPA. 2014. Estimates of area, productivity and production of soybean in India during kharif 2014 (www.sopa.org.).
10. TAAS 2014. Proceedings and Recommendations of Brainstorming workshop on “Soybean for Household Food and Nutrition Security” organized on 21-22 March, 2014 by Trust for Advancement of Agricultural Sciences, Indian Council of Agricultural Research and National Academy of Agricultural Sciences, New Delhi.

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Glimpses of the training

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Filed/ high throughput facilities visits

Hands on experience

Lectures/Presentations

Certificate Distribution

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Agrisearch with a human touch