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CONTENTS

Development of high protein groundnut (*Arachis hypogaea* L.) mutant through induced mutagenesis

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ABSTRACT

Groundnut is used as a food crop for its oil, protein content and other valuable bioactive compounds. Induced mutagenesis played an important role to generate genetic variability in this crop. Here we report the identification of a high protein mutant from a mutagenized population of a rust resistant breeding line, TG 66. The mutant, TGM 206 revealed a 19.8 per cent increment of seed protein content compared to its parent. Through protein analysis it was found that the conarachin fraction was selectively increased in this mutant.

Keywords: *Arachis hypogaea,* Conarachin, Gamma rays, Groundnut, Mutant, Protein, Sodium azide

Groundnut (*Arachis hypogaea* L.) is one of the major oilseed crop grown in India. It ranks fifth in the world among oilseeds with an area of 25.67 million ha, production of 42.32 million tonnes and productivity of 1.65 tonnes/ha (FAOSTAT, 2016). About two-thirds of the world's groundnuts are utilized for edible oil. Besides oil, groundnut is a source of protein for both humans and animals (Janila *et al.,* 2013). For economic and social reasons, millions of people in Asia and Africa depend on groundnut and other legumes for their dietary proteins. Groundnut seeds contain 44-56 per cent oil and 22-30 per cent protein on a dry seed weight basis (Ozcan, 2010; Sarvamangala *et al*., 2011). In several wild species, the protein (undefatted) content is varying from 18.5 to 31.4 per cent (Jambunathan *et al*., 1993). Groundnut flour (defatted), which is mainly used for food fortification contains protein ranging from 47.0 to 55.0 per cent with mean being 50.0 per cent. The nutritive value of groundnut protein is much better than the wheat protein as evident from its higher protein efficiency ratio and relative nutritive value. The storage proteins arachin and conarachin account for about 63 per cent and 33 per cent, respectively, of the total protein content of groundnut kernels. Arachin is less soluble than conarachin and it contains limited amounts of cysteine and methionine than conarachin. The lysine and methionine contents of conarachin fractions are significantly higher than arachin (Savage and Kannan, 1994). Thus improvement for nutritive value of groundnut protein would be possible by increasing the conarachin at the expense of arachin. Present study reports the isolation of high protein mutant in groundnut and its possible changes in polypeptide content.

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MATERIALS AND METHODS

Induced mutagenesis: Seeds of TG 66 (200 each) were treated with gamma rays (200 and 300 Gy) or sodium azide (1, 2 and 3 mM) singly or combination of both (Mondal *et al*., 2007). M1 generation was grown at Bhabha Atomic Research Centre, Mumbai during summer 2004. In M2 generation, 74 mutants were selected for various traits from 1177 progenies consisting 20,619 plants. True breeding behaviour of these mutants was confirmed in the M3 and M4 generations.

Protein and oil estimation: Of the 74 mutants, 46 mutants were selected for protein and oil estimations. Mutants were grown in the field in randomized complete block design in two replications during *kharif* seasons of (June to September) 2007 and 2008 at Trombay, Mumbai as well as during *kharif* 2011 at Gauribidanur, Karnataka. Groundnut seeds from each of the 46 mutants from both replications were ground to fine paste. Approximately 140 to 200 mg of seed paste was defatted with 1 ml of petroleum ether (bp 60-80°C). Total nitrogen in the defatted seed meal was estimated using an automated Micro-Kjeldal system (Foss Analytical A/S, Hilleroed, Denmark). The resulting N % was later converted to protein content (%) by multiplying with factor 5.46 (Singh and Jambunathan, 1980). Oil content of the mutants from 2008 *kharif* season was analysed by the Nuclear Magnetic Resonance (NMR) Spectrophotometer (Oxford MQA 6000 Model, Oxford Instruments UK Ltd., Oxan, UK) after oven drying. The per cent protein and oil content variables were transformed by an arcsine square root transformation in order to alleviate the effects of heterogeneity of variance. An analysis of variance was performed for the arcsine transformed data using IRRISTAT 2.0 software (IRRI, 2003).

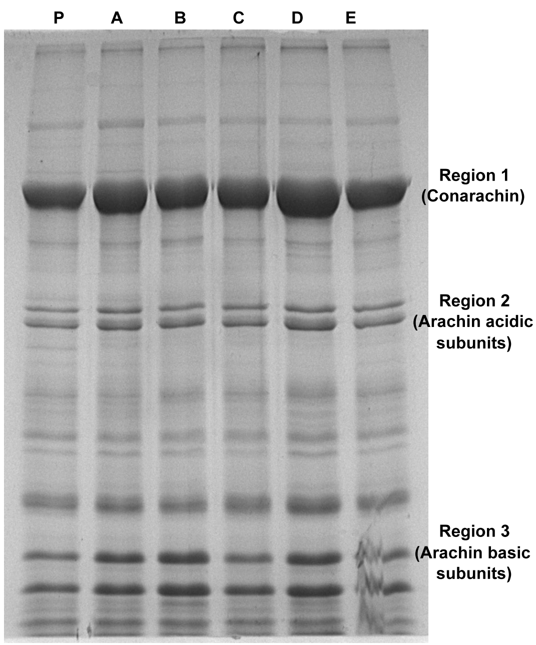
Electrophoretic pattern of seed storage protein: Five selected mutants along with TG 66 were taken for protein extraction and electrophoresis. Seeds without testa were ground and 100 mg of seed meal were defatted with 1 ml petroleum ether (boiling point 60 - 80ºC). The dried defatted meal was extracted with 1 ml of extraction buffer [0.1 M Tris-HCl, pH 6.8 containing 2% sodium dodecyl sulphate (SDS) and 10% glycerol] at room temperature for overnight (Krishna *et al.,* 1986). The mixture was then centrifuged at 12,000 x g for 20 min and supernatant was collected for protein estimation as described by Lowry *et al.* (1951). Four micro litre of aliquot from each sample was mixed with diluent buffer [consisting of 0.05 M Tris-HCl (pH 7.0), 20% glycerol, 1% SDS, 5% 2-macaptoethanol and 0.25 mg/ml coomassie brilliant blue] to obtain a final protein concentration of 1 µg/µl. The mixture was then heated at 100ºC for 3 min for denaturation. After cooling, 25 µl (25 µg of total protein) of each mixture was loaded on 12% homogenous, discontinuous, SDS-polyacrylamide gel system according to Laemmli (1970). Electrophoresis was performed at constant voltage for 700 voltage-hours in high voltage power supply (Consort, Turnhout, Belgium). Gel was fixed and stained in 0.2% comassie brilliant blue R 250 in methanol, acetic acid and water (30: 10: 60 v/v) for overnight. The gel was destained in same solution without the dye and was documented in a gel documentation system (Syngene, Cambridge, USA).

RESULTS AND DISCUSSION

Analysis of variance revealed significant differences for both oil and protein contents among 46 induced mutants of TG 66 (Table 1). Protein estimation indicated that mutant TGM 206 had the highest seed protein with an improvement of 19.8 per cent (based on average over three seasons) compared to its parent, TG 66 (Table 2). In addition, the high protein mutant, TGM 206 had the equivalent seed yield as compared to its parent (Table 2). Thus, the mutant behaves almost an isogenic line with an additional mutated trait of high protein content. The mutant TGM 203 had the lowest seed protein at Trombay during *kharif* 2007, while, TGM 189 and TGM 183 had the lowest protein content at during *kharif* 2008 and at Gauribidanur during *kharif* 2011, respectively. Further, the seeds of TGM 206 also showed an increment in oil content compared to its wild type TG 66 in both 2007 and 2008. Among 46 mutants, TGM 198, TGM 192M, TGM 203, TGM 206 and TGM 207 had higher oil content than TG 66. Whereas, TGM 169 had the lowest oil content but had similar amount of protein as compared to TG 66 (Table 2). Among wild groundnut species, protein content was ranged from 25.0 - 30.1 per cent with the highest (30.1%) protein content in *A. sylvestris* (Grosso *et al.,* 2000). A similar range (22-30%) was also observed in cultivated groundnut (Eshun *et al.,* 2013).

In general, the mutant seeds from *kharif* 2008 at Trombay had higher seed protein than the remaining two environments. Twenty two mutants had significantly higher protein content during 2008 compared to 2007 and 2011. Comparatively, all the mutants including the TG 66 showed significantly lower seed protein in 2011 at Gauribidanur which was due to greater severity of foliar diseases like rust and late leaf spot that resulted in forced maturity of the crop. Jambunathan *et al.* (1992) reported a significant variation in protein content in two different seasons in seven cultivated groundnut varieties. Similar observation of seasonal variation was also noticed in four different groundnut cultivars grown in USA (Basha, 1992).

Four different polymorphic protein profiles were presented by Krishna *et al.* (1986) in cultivated groundnut genotypes. In the present study, we have named the polypeptide subunits as per Krishna *et al.* (1986). The protein profiles in selected mutants revealed no major qualitative changes in banding pattern compared to TG 66. However, the largest polypeptide subunit (region 1, conarachin fraction) was selectively increased in high protein mutant, TGM 206 (Fig. 1). Conarachin contains more lysine and methionine than arachin (Basha and Cherry, 1976). Both methionine and lysine are the limiting amino acids in groundnut protein. Isolation of TGM 206 with increased conarachin through induced mutagenesis will be a genetic resource material for breeding of quality protein in groundnut.



P = Parent (TG 66), A = TGM 168, B = TGM 188, C = TGM 203, D = TGM 206, E = TGM 212

Fig. 1. Total protein profile in selected groundnut mutants and parent based on reducing SDS-PAGE

Table 1 Mean sum of squares for protein content in induced mutants of groundnut grown in three environments

Source of variation	Df	Mean sum of squares			
		2007	2008	2011	Pooled
Mutants	46	6.95**	9.55**	3.84**	6.92**
Replication	1	1.36	0.76	0.42	0.29
Environments	2	-	-	-	683.28****
Mutant x Environment	92	-	-	-	3.44**
Residual	46/140a	0.06	0.31	0.05	0.14

a = residual degree of freedom for pooled ANOVA.

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Table 2 Protein and oil content (%) in induced mutants of groundnut

Mutants	Oil (%)		Protein (%)				Seed yield (g/plant)	
	2007	2008	2007	2008	2011	Pooled	2007	2008
TGM 164	47.0	45.8	27.4	25.8	19.0	24.1	25.0	20.5
TGM 165	46.8	45.2	28.5	29.1	22.0	26.5	10.2	3.3
TGM 166	47.3	45.5	28.1	32.2	20.9	27.1	20.4	15.4
TGM 167	48.2	45.9	25.5	28.5	20.2	24.7	18.7	15.2
TGM 168	46.5	44.8	25.7	27.5	21.5	24.9	15.0	12.3
TGM 169	44.4	42.9	27.9	28.5	21.3	25.9	21.3	16.2
TGM 170	45.2	43.5	28.0	30.0	20.4	26.1	25.2	20.4
TGM 171	47.2	45.0	25.9	28.4	18.6	24.3	8.0	3.3
TGM 172	46.5	44.7	24.5	28.6	21.3	24.8	19.8	15.4
TGM 173	48.0	46.0	26.3	29.9	19.9	25.4	20.5	15.2
TGM 174	47.2	45.2	27.6	30.2	19.9	25.9	16.4	12.3
TGM 175	46.0	44.2	27.2	27.7	21.5	25.5	21.0	16.2
TGM 176	46.8	45.6	26.9	30.3	18.7	25.3	19.6	15.2
TGM 177	47.5	45.8	27.4	28.9	19.9	25.4	24.2	20.4
TGM 178	48.0	46.2	29.8	26.3	24.4	26.9	20.0	15.2
TGM 179	47.4	45.4	29.7	30.5	21.4	27.2	14.3	9.4
TGM 180	47.2	45.4	26.1	27.8	19.1	24.4	6.5	2.4
TGM 182	46.5	44.4	25.6	26.7	21.3	24.5	6.7	2.5
TGM 183	47.9	46.2	23.0	28.6	17.8	23.1	7.0	2.4
TGM 184	46.7	45.2	21.4	29.2	20.3	23.7	12.2	6.3
TGM 188	48.3	46.0	22.2	27.2	19.0	22. 8	10.1	5.5
TGM 189	47.6	45.8	22.2	23.3	19.6	21.9	20.5	16.2
TGM 191	46.0	43.8	24.1	26.7	19.5	23.7	6.1	2.4
TGM 192	49.0	45.0	28.2	29.1	21.0	26.1	10.0	5.8
TGM 192M	48.8	46.6	29.7	29.0	21.3	26.7	15.0	10.2
TGM 193	47.0	44.2	27.2	25.6	19.7	24.2	17.2	14.0
TGM 194	47.2	45.0	26.2	28.1	20.3	24.8	14.7	11.0
TGM 195	48.0	46.6	28.1	26.1	20.5	24.9	12.5	8.5
TGM 196	47.2	45.5	26.8	29.8	19.8	25.5	19.7	16.0
TGM 197	47.5	46.0	25.9	27.3	20.4	24.6	20.4	16.0
TGM 198	49.0	47.0	24.7	30.4	19.9	25.0	26.7	24.4
TGM 199	46.5	45.0	24.1	31.3	22.2	25.9	18.6	13.8
TGM 200	45.4	42.8	25.1	26.4	23.1	24.8	15.8	11.1
TGM 201	47.9	45.2	28.9	27.0	25.7	27.2	16.5	11.7
TGM 202	47.0	44.8	26.0	29.5	22.4	25.9	13.4	8.8
TGM 203	48.4	46.5	20.8	28.9	22.6	24.1	15.2	10.0
TGM 206	48.2	46.6	30.7	32.4	29.5	30.9	16.7	12.7
TGM 207	47.9	47.4	30.1	31.9	23.5	28.5	9.8	4.8
TGM 209	47.2	45.5	28.1	27.3	18.9	24.8	21.5	18.0
TGM 211	48.1	45.0	27.8	26.1	20.0	24.6	8.8	4.5
TGM 212	47.9	43.6	30.1	30.5	18.7	26.4	19.1	15.4
TGM 213	46.1	44.0	30.5	31.5	20.2	27.4	17.2	12.7
TGM 214	45.7	43.6	28.0	28.8	21.5	26.1	20.4	18.0
TGM 215	46.1	43.8	27.8	28.5	19.8	25.4	7.4	6.2
TGM 216	47.2	45.0	27.5	26.5	20.4	24.8	14.8	12.4
TGM 218	47.2	44.8	26.5	30.8	21.5	26.3	18.6	14.4
TG 66 (Parent)	46.1	44.1	29.0	28.8	19.5	25.8	17.3	13.6
LSD (P = 0.01)	0.35	0.36	0.66	1.49	0.63	1.02	3.4	3.5

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Genotypic variability and inheritance of iron, phosphorus, potassium and zinc contents in segregating generations of peanut (*Arachis hypogaea* L.)

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ABSTRACT

Micronutrient malnutrition is a serious health issue affecting billions of people in developing countries. Peanut is rich in several mineral elements required for human nutrition. The objective of this study was to understand genetic variability and inheritance pattern of phosphorus (P), potash (K), zinc (Zn) and iron (Fe) concentrations in F_2 and F_3 generations of two peanut crosses namely Girnar-3 × FDRS-10 (Cross-A) and TG-37A × FDRS-10 (Cross-B). P_{shell}, Zn_{shell}, K_{shell}, Fe_{shell}, and Fe_{kernel} were positively skewed indicating additive gene action. Kurtosis for most of the characters moved in positive direction from F_2 to F_3 generation indicating a reduction in variation as generation advances. Phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV) revealed that traits were under genetic control and possessed substantial variability and hence a good scope for improving these characters. Both additive and non-additive types of gene actions were observed with the predominance of additive gene action for the inheritance of P, K, Fe and Zn in shell and kernels. Dominance variance (H) also played an important role in the inheritance of P, K, Fe and Zn in peanut. Average degree of dominance for most of the traits was greater than unity indicating over dominance for these traits. Mineral elements had significant association among themselves but very few associations with pod yield. Selection and hybridization followed by pedigree breeding method are suggested in the later generations for genetic improvement to identify high yielding peanut genotypes rich in P, K, Fe and Zn.

Keywords: Heritability, Iron, Peanut, Phosphorus, Potassium, Variability, Zinc

In India, 230 million people were reported to be undernourished, accounting for more than 27 per cent of the world's undernourished population (Lodha *et al*., 2005). Among the micronutrients required for human diet, Fe and Zn are considered to be very important and deficiency of these micronutrients affect health and economic development of a country (Hunt, 2005). A possible annual loss due to micronutrient deficiencies is at least US$5 billion in China and India alone (Micronutrient Initiative, 2009). Among the macronutrients, K ions are vital to keep cells alive through Na-K pump in human and animal systems whereas in plants K helps in maintaining the water status and turgor pressure, opening and closing of the stomata, accumulation and translocation of carbohydrates. P also plays an important part in energy metabolism, since it is a constituent of adenosine triphosphate (ATP) and is therefore important in absorbing and transporting nutrients, in regulating protein activity and in the acid base balance (Cozzolino, 2007).

Nutritive value makes peanut an excellent candidate for developing cultivars biofortified with P, K, Zn and Fe. Several strategies have been proposed for reducing mineral nutrient malnutrition in human diet and bio-fortification through plant breeding has been identified as potentially more sustainable and less expensive (Bheemappa and Patil, 2013; Nguni *et al*., 2012). Development of cultivars biofortified with mineral nutrients requires the knowledge of physiological and genetic basis of nutrient-accumulation process in crop tissues (Chatzav *et al*., 2010) to exploit the natural genetic variation in food crops (Gomex-Bexerra *et al*., 2010). Till date studies related to inheritance pattern of these mineral elements in peanut are very scarce. Hence, present study was designed to study genetic variability and inheritance pattern of P, K, Zn and Fe concentrations in F_2 and F_3 generations of peanut. The present study also envisages understanding interrelationships of these mineral elements among themselves and with pod yield which would help breeder to adopt suitable breeding strategy for simultaneous improvement of yield and mineral concentrations.

MATERIALS AND METHODS

Materials used for this study consisted of F_2 and F_3, generations from two crosses of peanut namely Girnar-3 × FDRS-10 (Cross-A) and TG-37A × FDRS-10 (Cross-B). Hybridization was carried out during July, 2011 by emasculating flowers during evening followed by pollination

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next day in morning. Morphological traits such as plant type, flower colour and pod characters were used as markers to check the trueness of F_1 plants. F_1 generation was raised during summer 2012 to identify true hybrids. The crosses were planted to advance generations (i.e., F_2 and F_3) during *kharif* 2012 by keeping 50% of F_2 seed as remnant. During summer 2013 remnant 50% F_2 seeds and F_3 seeds harvested during *kharif* 2012 were sown to raise F_2 and F_3 generations simultaneously. Observations were recorded on 25 randomly selected plants in F_2 and 75 randomly selected plants in F_3 generation in both the crosses. Crop was harvested at maturity, dried in sun for a week and 1g of shell and kernel samples were digested separately with 3:1 nitric and perchloric acid mixture. Concentration of P in digests was measured spectroscopically using Fiske and Subbarao blue colour method. Fe, K and Zn estimation was done using atomic absorption spectrophotometer (Perkin Elmer AA400).

Genetic parameters *viz.,* phenotypic coefficient of variance (PCV), genotypic coefficient of variance (GCV), heritability in broad sense genetic advance (GA) and genetic advance as per cent mean (GAM) were estimated (Singh and Chauhan, 2013). PCV and GCV and GA and GAM were classified into low (0-10%), moderate (10.1-20%) and high (>20%). Heritability in broad sense was classified into low (0-30%), moderate (30.1-60%) and high (>60%). Skewness and kurtosis were estimated using PAST statistical software (Hammer *et al.,* 2001). Heritable [additive (D)] and non-heritable [dominance (H) and Environment (E)] components of variance were derived as per the formula suggested by Mather and Jinks (1971). After solving the equation for total variance in F_2 and F_3, D and H components were obtained and are given below:

Total variance in F_2 (VF_2) = 1/2D + 1/4H + E1
Total variance in F_3 (VF_3) could be divided into variance of means of F_3 progeny (V_1F_3) and mean of variance of F_3 progeny (V_2F_3),
$V_1F_3 = 1/2D + 1/16H + E2$
$V_2F_3 = 1/4D + 1/8H + E1$
E1 = ½ VF1
E2 = 1/n E1
Additive Variance (D) = $2/3\ (4V_1F_3 - VF_2 + E_1 - 4E_2)$
Dominance Variance (H) = $16(VF_2 - V_1F_3 - E_1 + E_2)/3$
Where, 'n' refers to number of plants used for recording observations. The association between yield and its associated characters was worked out as a simple phenotypic correlation coefficient.

RESULTS AND DISCUSSION

Mean performance in F_2 and F_3 generations: Data on P, Fe, Zn and K concentrations in shell and kernels of the two crosses (cross A and B) their mean, range, skewness, kurtosis, PCV, GCV, heritability and GAM are presented in Table 1. The difference between mean values of F_2 and F_3 generations for all the traits was meagre except for Zn_{kernel} and K_{shell} in both crosses and Zn_{shell} in cross-B. The F_3 exhibited higher concentrations for Zn_{shell}, K_{kernel}, Fe_{shell} and Fe_{kernel} in cross-A, and higher concentrations for P_{shell}, P_{kernel}, Zn_{kernel} and K_{shell} in cross-B when compared to F_2. However the concentrations of P_{shell}, P_{kernel}, Zn_{kernel}, K_{shell} in cross-A and Zn_{shell}, Zn_{kernel}, K_{shell}, Fe_{shell} and Fe_{kernel} in cross-B were higher in F_2 than in F_3. Comparison of mineral concentrations revealed that phosphorus and zinc concentrations were higher in kernels than in shell whereas it was opposite for potassium and iron.

Skewness and kurtosis in F_2 and F_3 generations: The skewness and kurtosis studies indicate the nature of variability existing in the population. The study of population distribution using skewness and kurtosis provide information about nature of gene action and number of genes controlling the trait. Negative skewness indicate the predominance of dominant gene action and thus there is a difficulty in immediate fixing of desirable alleles in early generations, whereas positive skewness indicates predominance of additive gene action and desirable alleles could be fixed in early generations (Roy, 2000). Studies on gene interactions are needed to increase the efficiency of selection in breeding program. Selection intensity and progress in improving the population performance could be higher under complementary than under duplicate interactions (Choo and Reinbergs, 1982).

In cross-A, distribution of populations in both the generations were positively skewed for P_{shell}, Zn_{shell}, K_{shell}, K_{kernel}, Fe_{shell} and Fekernel and negatively skewed for P_{kernel}. In cross-B distribution of population was positively skewed for P_{shell}, Zn_{shell}, K_{shell}, Fe_{shell} and Fe_{kernel} and negatively skewed for P_{kernel} in both the generations. Distribution of Zn_{kernel} was positive in F_2 and negatively skewed in F_3 generation; distribution of K_{kernel} was negatively skewed in F_2 and positively skewed in F_3 generation (Table 1). Comparison of skewness between shell and kernel revealed that distribution curve of shell was highly skewed towards positive side than kernels. As generation advances, there was a shift in skewness from positive to negative for Zn_{kernel} and *vice-versa* for K*kernel*.

In cross-A, peak in both the generations was leptokurtic for P_{shell}, Fe_{shell} and Fe_{kernel} and for P_{kernel}, Zn_{shell}, K_{shell} and K_{kernel} peak was platykurtic in F_2 and leptokurtic in F_3 generation. In cross-B peak was leptokurtic in both the generations for all the characters except K_{kernel} in F_2 and Fe_{shell} in F_3 generation. The traits with leptokurtic and platykurtic distribution are controlled by fewer and many genes, respectively. Kurtosis is negative or close to zero in absence of gene interaction and positive in presence of gene interaction (Yu *et al.,* 1998). Positive kurtosis values for most of the traits in both crosses indicate the presence of gene interactions. Kurtosis values in the present study are moving in positive direction over generations indicating that variation is reducing and homozygosity is increasing as generation advances and are in agreement with the findings of Preetha and Raveendren (2008) in cotton.

Genetic variability: Variability of genotypes can be assessed using parameters like GCV, PCV, heritability and GA and GAM which is of paramount significance for initiating an efficient breeding programme. Crop breeding program demands the presence of large variation for a breeder to make selection. Hence, variability plays an important role in crop breeding programs.

In F_2 generation of cross-A, PCV ranged from 28.42 to 62.34% with highest PCV in Zn_{shell} and least in P_{kernel}, whereas in F_3 it ranged from 14.82 to 45.97% with the highest in Fe_{kernel} and least in P_{kernel}. The PCV values of cross-B ranged from 27.3 (P_{kernel}) to 116.1% (Fe_{kernel}) and 27.2 (P_{kernel}) to 179.1% (Fe_{kernel}) in F_2 and F_3, respectively (Table 1). The GCV values of cross-A ranged from 24.45 (P_{shell}) to 59.73% (Fe_{shell}) and 11.41 (P_{kernel}) to 38.54% (Fe_{shell}) in F_2 and F_3 generations, respectively. In cross-B, the GCV values ranged from 23.37 (P_{kernel}) to 55.65% (Fe_{shell}) and 7.29 (Fe_{kernel}) to 61.54% (P_{shell}), respectively in F_2 and F_3 generations. In cross-A the PCV and GCV values were high for K_{shell}, K_{kernel} and Fe_{shell} in both the generations; Zn_{shell} and Zn_{kernel} in F_2 generation and Fe_{kernel} in F_3 generation. For P_{shell} and Fe_{kernel}, PCV was higher and GCV was moderate in F_2 generation whereas Zn_{shell} and Zn_{kernel} had high PCV and moderate GCV in F_3 generation. In cross-B, PCV and GCV values were higher in both the generations for P_{shell}, Zn_{shell} and Fe_{shell}.

The present study revealed the presence of wide variability among F_2 and F_3 populations for most of the traits studied. The estimates of PCV were higher than their corresponding GCV estimates for all the traits studied indicating that the characters are under genetic control and are less influenced by the environment (Shukla *et al.,* 2005) and selection based on phenotype will be effective (Ravindra Babu *et al.,* 2012). High PCV and GCV values indicate the presence of substantial variability and scope for improving these characters (Bhadru *et al.,* 2011; Visakho *et al.,* 2013). Susmita and Selvi (2014) recorded high PCV and GCV for total zinc content and moderate values for iron content.

Heritability and genetic advance: Heritability estimates along with genetic gain would be more useful than the heritability alone in selecting the best individuals. In cross-A high heritability and high GAM was observed for K_{shell}, K_{kernel} and Fe_{shell} in both generations; in F_2 generation for P_{shell}, P_{kernel}, Zn_{shell} and Zn_{kernel}. This indicates that most likely the heritability is due to additive gene effects and selection may be effective (Eid *et al.,* 2009; Kumar *et al.* 2014). Traits P_{shell}, Zn_{shell} and Zn_{kernel} had moderate heritability and high GAM in F_3 generation (Table 1) suggesting the involvement of both additive and non-additive gene action and they can be improved by practicing selection in later generations. In cross-B, P_{shell}, Zn_{kernel} and Fe_{shell} had high heritability and high GAM in both generations; P_{kernel}, Zn_{shell}, K_{shell} and Fe_{shell} had high heritability and high GAM in F_2 generation and Zn_{shell}, K_{shell} and K_{kernel} had moderate heritability and high GAM in F_3 generation.

Table 1 Estimates of genetic variability parameters for Zinc, Potassium, Iron and Phosphorus in two peanut crosses

	Phosphorus (ppm)				Zinc (ppm)				Potassium (ppm)				Iron (ppm)			
	Shell		Kernel		Shell		Kernel		Shell		Kernel		Shell		Kernel	
	F_2	F_3	F_2	F_3	F_2	F_3	F_2	F_3	F_2	F_3	F_2	F_3	F_2	F_3	F_2	F_3
								Girnar-3 × FDRS-10								
Minimum	660.0	600.0	1840.0	2140.0	4.4	6.1	3.3	1.7	5920.0	3254.0	4422.0	4842.0	103.9	107.9	65.7	70.2
Maximum	1580.0	1780.0	5680.0	4220.0	25.7	33.2	82.9	48.2	26420.0	25320.0	15280.0	27780.0	666.6	665.1	354.3	488.5
Mean	976.8	914.6	3861.5	3381.7	13.2	14.4	46.5	31.1	15089.4	11717.8	8472.4	11122.5	273.4	357.1	175.9	176.9
Skewness	2.40	3.25	-0.41	-1.34	0.70	1.62	0.14	-0.22	0.67	0.69	0.56	0.64	1.03	4.06	3.31	5.73
Kurtosis	7.60	18.38	-1.11	1.59	-0.56	3.00	-1.12	-0.01	-0.19	0.23	-1.06	0.71	0.32	25.31	12.70	39.88
PCV	30.29	29.75	28.42	14.82	62.34	38.36	56.66	40.57	42.62	40.75	46.49	36.27	61.15	39.83	43.28	45.97
GCV	24.45	22.81	27.19	11.41	58.25	28.87	52.85	27.90	40.70	37.35	45.77	35.74	59.73	38.54	28.35	32.50
h^2bs	65.15	58.80	91.52	59.33	87.33	56.63	87.00	47.28	91.19	84.02	96.93	97.08	95.39	93.63	42.91	50.00
GAM	40.65	36.03	53.59	18.11	112.14	44.75	101.54	39.52	80.06	70.52	92.82	72.53	120.17	76.81	38.26	47.35
								TG-37A × FDRS-10								
Minimum	400.0	440.0	1400.0	1369.0	11.1	4.9	14.2	24	6856.0	5355.0	3656.0	3335	104.8	71.5	93.5	63.6
Maximum	2240.0	4500.0	5400.0	5380.0	53.2	40.2	87.2	60.8	30650.0	26430.0	27160	18140	766.9	575.8	446.8	390.3
Mean	1040.7	1202.2	3671.3	4047.2	23.1	14.8	50.5	44.9	15961.1	11044.2	13443.0	7693.3	390.4	243.8	240.5	155.7
Skewness	2.02	2.62	-0.52	-1.86	1.76	1.56	0.51	-0.97	0.87	0.94	-0.07	2.40	1.90	0.86	4.82	8.02
Kurtosis	5.12	7.68	0.05	3.49	3.80	1.50	0.30	0.48	0.54	1.76	-0.86	8.48	3.85	-0.21	25.31	68.27
PCV	50.76	65.14	27.26	18.53	46.42	56.19	34.70	20.74	40.60	36.27	46.98	35.28	62.38	59.62	41.55	45.05
GCV	44.36	61.54	23.37	13.47	36.33	33.29	34.65	20.63	36.32	25.07	44.73	24.77	55.65	47.70	29.97	7.29
h^2bs	91.77	89.24	92.39	52.83	62.77	35.10	89.62	98.92	93.38	47.77	86.67	49.30	93.16	64.02	80.17	2.62
GAM	95.96	119.75	51.88	20.16	60.02	40.62	64.06	42.26	78.09	35.69	83.87	35.83	119.71	78.63	68.61	2.43

PCV = Phenotypic coefficient of variance; GCV = Genotypic coefficient of variance; GAM = genetic advance as percent mean; h^2bs = broad sense heritability

Table 2 Genetic variance components and allied parameters for zinc (Zn), potassium (K), iron (Fe) and phosphorus (P) in two peanut crosses

		D	H	E	(H/D)0.5
		Cross-A: Girnar 3 × FDRS 10			
P (ppm)	Shell	1803.9	224360.5	30500.0	11.2
	Kernel	-617595.9	5636126.9	102114.3	3.0
Zn (ppm)	Shell	-45.8	454.7	13.2	3.1
	Kernel	-234.1	2267.1	67.3	3.1
K (ppm)	Shell	-2011770.0	154759841.6	3642345.8	8.8
	Kernel	-2864158.1	65802148.4	475840.0	4.8
Fe (ppm)	Shell	-2885.1	112357.4	1288.6	6.2
	Kernel	8949.5	-7860.5	3307.7	0.9
		Cross-B: TG 37A × FDRS 10			
P (ppm)	Shell	735451.8	-610779.1	65960.0	0.9
	Kernel	-139370.9	3220218.5	265250.0	4.8
Zn (ppm)	Shell	103.8	75.2	44.6	0.9
	Kernel	-159.1	1540.4	0.9	3.1
K (ppm)	Shell	8120259.2	118190813.6	8379150.0	3.8
	Kernel	-21817956.4	187901998.4	3734408.3	2.9
Fe (ppm)	Shell	15220.8	88294.1	7600.2	2.4
	Kernel	1438.6	17918.3	4789.2	3.5

Additive-dominance variance: Additive variance indicates sum of average effect of allele substitution at 'n' number of locus. Thus, the contribution of a locus to additive variance depends simultaneously on its own allele frequencies as well as the allele frequencies of all other segregating loci. Dominance variance represents summation of variance due to interaction effects between two alleles at different loci. Furthermore, dominance variance is indicative of dominance effects in one or more loci (Abney *et al*., 2001).

Results from the estimates of the additive-dominance variance model and the degree of dominance are presented in Table 2. The additive (D) and dominance (H) genetic variance components were estimated assuming no epistasis. In cross-A, H was higher than D for all the characters except Fe_{kernel}. Hence, degree of dominance was more than unity for these characters. In cross-B, H was higher than D for P_{kernel}, Zn_{kernel}, K_{shell}, K_{kernel}, Fe_{shell} and Fe_{kernel}. As a result, degree of dominance was more than unity for these characters. These results suggested that the genetic variation for this trait was largely unexpressed or may be the environmental effects were large and masked observable genetic variation which is in agreement with the reports of Cannings *et al.* (1978). H was superior over D for most of the characters studied. Estimates of D were negative for most of the characters in cross-A and for P_{kernel}, Zn_{kernel}, and K_{kernel} in cross-B. Negative estimates of D and H have been recorded in crops such as rice (Khaleque *et al*., 1978), Jute (Paul *et al*., 1978), wheat (Shahid., 1966) and pigeonpea (Ajay *et al*., 2012), etc. mainly due to genotype-environment interaction (Hill, 1996) and are to be considered as zero or as small but positive.

Average degree of dominance for most of the traits in both the crosses was greater than unity indicating over dominance for these traits. Due to the presence of over dominance type of gene action selection for these traits in early generation will be difficult. Hence superior homozygotes with high yield and high Zn, K, P and Fe concentrations could be obtained by bi-parental mating followed by recurrent selection or di-allele selective mating and is in agreement with earlier reports (Eshghi and Akhundova, 1978) in barley.

Character associations: Breeding and selection for high yield associated with high mineral concentrations demands knowledge of interrelationships among mineral elements (i.e. Zn, K, P and Fe) and with pod yield. This will help the breeder in simultaneous improvement of several characters. Association of economically important traits is statistically determined by correlation coefficient which is quite useful as basis of selection. The association among mineral elements in shell and kernels are presented in Table 3. P_{kernel} showed significant positive association with Zn_{kernel} in F_2 population of both crosses and in F_3 population of cross-A. The Zn_{kernel} showed significant positive association with K_{kernel} in F_2 population of both crosses and in F_3 population of cross-A. P_{shell} had significant positive association with Zn_{shell} in F_3 population of both crosses. Meanwhile association of P_{shell} with P_{kernel} and Fe_{kernel} with Zn_{shell} were significant and positive in cross-A. Association of pod yield with mineral elements is presented in Table 4 where P_{shell} had positive association with pod yield in F_2 of cross-A and F_3 of cross-B whereas P_{kernel} and Zn_{kernel} had negative association in F_3 of cross-B. K_{shell} had negative association in F_3 of both crosses. Fe_{kernel} and Zn_{shell} had no association with pod yield. Zn_{kernel} had negative association with Fe_{kernel} in F_2 of cross-B.

Table 3 Correlation coefficients (r) among zinc (Zn), potassium (K), iron (Fe) and phosphorus (P) in F_2 and generations of two peanut crosses

Traits	Cross-A: Girnar-3 × FDRS-10		Cross-B: TG-37A × FDRS-10	
	F_3	F_2	F_3	F_2
P_{shell} :P_{kernel}	0.19**	0.35*	0.09	0.26
P_{shell} :Z_{nshell}	0.14*	-0.26	0.53**	0.13
P_{shell}:K_{shell}	0.10	-0.03	-0.11	0.38*
P_{kernel}:Zn_{kernel}	-0.21**	0.38*	0.32**	0.39*
Zn_{shell}:Fe_{kernel}	0.44*	0.07	-0.01	-0.07
Zn_{kernel}:K_{kernel}	-0.10	0.50*	0.23*	0.51**
Zn_{kernel}:Fe_{kernel}	-0.10	0.25	0.04	-0.27**
Fe_{kernel} : Zn_{shell}	0.26**	0.60**	-0.07	-0.01

*, ** Correlation is significant at the 0.05 and 0.01 levels, respectively

Table 4 Association of pod yield with zinc (Zn), potassium (K), iron (Fe) and phosphorus (P) in F_2 and F_3 generations of two peanut crosses

Traits	Correlation coefficient (r)			
	Cross-A: Girnar-3 × FDRS-10		Cross-B: TG-37A × FDRS-10	
	F_3	F_2	F_3	F_2
P_{shell}	0.03	0.46**	0.19*	-0.17
P_{kernel}	-0.06	0.20	-0.26*	-0.08
Zn_{shell}	0.02	-0.07	0.12	0.17
Zn_{kernel}	0.06	0.29	-0.23*	-0.18
K_{shell}	-0.14*	0.24	-0.20*	-0.07
K_{kernel}	-0.05	-0.07	0.02	-0.08
Fe_{shell}	0.09	-0.22	0.01	0.51*
Fe_{kernel}	-0.13	0.24	-0.07	0.09

*, ** Correlation is significant at the 0.05 and 0.01 levels, respectively

In the present investigation some characters revealed changes in magnitude of association from generation to generation which was attributed to difference in gene complementation of linkage blocks and an indication of unstable nature of breeding population which was also supported by previous workers (Preetha and Raveendren, 2008). The present study also revealed that association of P in kernels has significant influence on the accumulation of Fe, Zn and K indicating that increase or decrease in P concentration in kernels influence on the accumulation of Fe, Zn and K. This is further supported by the fact that P is stored in the kernels as a complex with other mineral elements known as phytic acid. Correlation between Fe and Zn in kernels was significant which is in agreement with earlier studies in pearlmillet (Gupta *et al.,* 2009), maize (Mazia-Dixon *et al.,* 2000) and rice (Zeng *et al.,* 2005). Association of pod yield with mineral elements in shell and kernel mostly, with the exception of few associations, was not significant. This indicates that accumulation of mineral elements is independent of each other and hence it is possible to have genotypes with high yield and ability to accumulate more minerals in the kernels.

In the present study substantial genetic variability and heritability was observed for P, K, Fe and Zn among segregating generations in peanut. The study concluded that, mineral elements Fe, Zn, P and K in shell and kernels were governed by dominance genetic variance with the predominance of additive type of gene action. Pedigree breeding method with hybridization and selection at later generations could be followed for genetic improvement of these traits. These mineral elements had no association with pod yield indicating the possibility of selecting genotypes with high yield and higher concentrations of P, K, Zn and Fe in kernels.

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Response of Indian mustard (*Brassica juncea* L.) hybrids to different spacings on aridisols

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ABSTRACT

The field experiments on the performance of four hybrids/varieties *viz.,* three newly released hybrids DMH 1, PAC 432 and NRCHB 506 and one best check variety of Indian mustard (*Brassica juncea* L.) with five crop geometries (30 cm x 10 cm, 30 cm x 15 cm, 45 cm x 10 cm, 45 cm x 15 cm and 60 cm x 10 cm) were conducted on Typic Ustochrept soil at Bawal, Haryana during *rabi* season for two consecutive years (2009-10 and 2010-11) under irrigated conditions. The experiment was laid out in split plot design with four replications. The pooled results of the study revealed that planting of Indian mustard hybrids *viz.,* DMH 1, PAC 432 and NRCHB 506 at wider crop geometry of 45 cm x 15 cm recorded highest seed yield of 2578, 2308 and 2023 kg/ha; and fetched maximum profits (₹ 36714, ₹ 30784 and ₹ 24584) and benefit: cost ratio (2.80, 2.51 and 2.21), respectively than with other spacings. However, check variety Kranti proved superior with respect to seed yield (1807 kg/ha), net returns (₹ 19820/ha) and benefit: cost ratio (1.98) at a spacing of 30 cm x 15 cm. Among all hybrids tested, hybrid DMH1 was found significantly superior to others in respect of plant height (218 cm), primary branches/plant (8.79), siliquae/plant (408) and seeds/siliqua (16.18) except 1,000-seed weight (3.41 g). This hybrid also recorded 12.7, 29.7 and 50.9; 5.9, 24.0 and 36.7; 12.9, 29.4 and 55.7; and 23.0, 60.6 and 121.8 per cent higher seed yield, production efficiency, oil production and net returns over PAC 432, NRCHB 506 and Kranti, respectively.

Keywords: Hybrid Indian mustard, Production efficiency, Profitability, Spatial management technologies

India is the world's second largest edible oil consumer after China, meeting more than half of its annual requirement through imports. During 2013-14, the country imported about 11.06 mt of vegetable oils costing around ₹ 56,906 crores. At the current rate of population growth in India, the edible oilseeds requirement by 2020 would be around 58 mt (Kushwaha *et al.,* 2012) as compared to production level of 29.38 mt during 2013-14. The proportion of import has increased from a meagre three per cent in 1970-71 to about 53 per cent in 2013-14.

Oilseed *Brassicas* (Rapeseed-Mustard) are the most important source of edible oil after groundnut in India and commonly grown in arid and semi-arid regions of the country consisting of soils of aridisol. (Meena *et al.,* 2013). To bridge the gap between demand and supply, recently breeders have evolved and released few hybrids of Indian mustard (*Brassica juncea* L.) for the first time in India to break-through long standing yield stagnation barriers in Indian mustard. Hybrids of Indian mustard are likely to be preferred over traditional varieties of Indian mustard as they have maximum production potential (Sodhi *et al.,* 2006; Patel *et al.,* 2014; Meena *et al.,* 2014) and appears to be the suitable alternative. Therefore, there is urgent need to exploit the genetic production potential by selecting suitable new hybrids in comparison to existing varieties of Indian mustard through agronomic testing and further standardizing their agro-technologies particularly optimum crop geometry appropriate inter-row and intra-row plant spacing for rationale use of other resources (Sudhakara Babu, 2011). The degree of interference between plants tends to increase as the distance between them decreases and may influence performance of neighbours by changing the environment. Meagre information is available in the literature till now on production potential and optimum crop spacing of recently released hybrids of Indian mustard under arid and semi-arid climatic conditions of India. Therefore, the present investigation was carried out to assess growth, productivity and profitability of various newly released hybrids with different crop geometries under specific edapho-ecological conditions.

MATERIALS AND METHODS

The field experiments were conducted for two consecutive years (2009-10 and 2010-11) on aridisols at Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Regional Research Station, Bawal, Rewari (situated at 28°4' N latitude and 76°35' E longitude at an altitude of 266 m above mean sea level), Haryana, India under AICRP on Rapeseed-Mustard during winter seasons. Annual potential evaporation exceeds precipitation. The location has a typical semi-arid climate with an average rainfall of around 300-550 mm; and most of it (about 85%) is received during rainy season (July to September). The soil

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of the experimental field classified as a Typic Ustochrept was loamy sand in texture with low moisture retention capacity, slightly alkaline in reaction (pH 8.3), low in organic carbon (0.23 %), available nitrogen (165 kg N/ha) and sulphur (12 kg S/ha); and medium in available phosphorus (16 kg P/ha) and high in available potash (321 kg K/ha). Treatments comprised of five crop geometries *viz.,* 30 cm x 10 cm, 30 cm x 15 cm, 45 cm x 10 cm, 45 cm x 15 cm and 60 cm x 10 cm as main plot and three newly released hybrids (DMH 1, PAC 432 and NRCHB 506) and one released best check variety Kranti of Indian mustard (*Brassica juncea* L.) as sub plot treatments. The experiment was laid out in a split plot design with four replications. The crop was sown on 20th October, 2009 and 23rd October 2010 during 2009-10 and 2010-11, respectively. A seed rate of 5.0, 3.3, 3.3, 2.2 and 2.5 kg/ha was used to maintain 3.33, 2.22, 2.22, 1.48 and 1.66 lakh plants/ha under crop geometries of 30 cm x 10 cm, 30 cm x 15 cm, 45 cm x 10 cm, 45 cm x 15 cm and 60 cm x 10 cm, respectively. Crop was fertilized with 80 kg N: 30 kg P_2O_5: 40 kg S/ha. Uniform full dose of phosphorus and sulphur; and half dose of nitrogen was drilled below the seed before sowing. Remaining half nitrogen was top dressed at 50% flowering stage after first irrigation. Rest of the recommended package of practices were followed to raise the crop. A total rainfall of 30 and 79.8 mm was received during crop season of 2009-10 and 2010-11, respectively. Weather conditions were favourable during 2010-11 due to congenial temperature, better rainfall and more sunshine hours in the crop season as compared to 2009-10.

At physiological maturity, five plants were selected randomly from each net plot to measure growth parameters (plant height and primary branches/plant) and yield components (siliquae/plant and seeds). 1000-seeds were counted from the produce of each of net plot harvested and weighed. The difference in variable cost under different treatments was due to differential cost of seed of hybrids and variety of Indian mustard; and use of different seed rates under varying crop geometries. The costs for other inputs and operations from sowing to threshing were considered as common cost of cultivation.

RESULTS AND DISCUSSION

Effect of spatial management techniques:A perusal of data in Table 1 indicated that, significantly taller plants (211 cm) were observed when crop was grown at ultra narrow spacing of 30 cm x 10 cm over other spacings under study. While reverse trend was observed with respect to number of primary branches/plant. Wider spacing (45 cm x 15 cm) produced 1.4, 8.6, 14.9 and 38.6 per cent more number of primary branches/plant over other spacings of 60 cm x 10 cm, 45 cm x 10 cm, 30 cm x 15 cm and 30 cm x 10 cm, respectively (Table 1). It could be ascribed to less space for lateral growth and inter plant competition for sunlight, moisture and nutrients under narrow spacing compared to wider spacing. The results exhibited that crop geometries *viz*., 30 cm x 10 cm, 30 cm x 15 cm, 45 cm x 10 cm and 60 cm x 10 cm favoured more vertical growth of the plant, while crop spacing of 45 cm x 15 cm was more favourable for lateral plant growth. The results are in consonance with that of Kumar *et al.* (2004). Crop sown at a spacing of 45 cm x 15 cm took more days to maturity (141 days) than that sown at other spacings (Table 1).

Amongst the yield attributing characters *viz.,* siliquae/plant (375) and 1000-seed weight (4.07g) were significantly superior under wider plant spacing (45 x 15 cm) which were higher by 8.7, 12.6, 13.3 and 23.4 per cent; and 3.8, 6.5, 7.1 and 10.0 per cent over closer spacing of 60 cm x 10 cm, 45 cm x 10 cm, 30 cm x 15 cm and 30 cm x 10 cm, respectively (Table 1). Reduction in number of siliquae/plant under narrow spacing (30 cm x10 cm, 30 cm x 15 cm, 45 cm x 10 cm and 60 cm x 10 cm) might be due to lesser number of primary branches/plant in comparison to wider spacing (45 cm x 15 cm). Similarly 1000-seed weight also decreased probably because of more competition for source photosynthates at the time of seed formation and development under closer spacing. The differences with respect to seeds/siliqua were found to be non-significant within crop geometries. Corroborative finding has also been reported by Chaniyara *et al.* (2002). Seed yield also followed the trend of yield attributes (Table 2). Overall, crop sown at wider spacing (45 cm x 15 cm) produced 17.7, 15.3, 4.7 and 3.2 per cent higher seed yield over narrow spacing of 30 cm x 10 cm, 60 cm x 10 cm, 30 cm x 15 cm and 45 cm x 10 cm, respectively. Production efficiency (14.7 kg seed/ha/day) was also better under wide spacing (45 cm x 15cm) compared to narrow spacings. Wider spacing (45 cm x 15 cm) out yielded narrow spacings despite the lowest plant population density per unit area (1.48 lakh plants/ha) than that of closer spacing of 30 cm x 10 cm (3.33 lakh plants/ha), 30 cm x 15 cm (2.22 lakh plants/ha), 45 cm x 10 cm (2.22 lakh plants/ha) and 60 cm x 10 cm (1.66 lakh plants/ha) because the loss in plant population counteracted by the effect of higher number of siliquae/plant, seeds/siliqua and 1000-seed weight, thereby resulted in highest seed yield. Increase in seed yield as a result of remarkable improvement in yield components due to adoption of different crop geometries has also been reported by Anal *et al.* (2002) and Kumar *et al.* (2004).

Effect of Hybrids/Variety: Growth characters, days to maturity, yield components, seed yield (kg/ha), production efficiency, oil content and its production (Table 1 and 2) differed significantly within hybrids, and between hybrids and variety of Indian mustard. Hybrid DMH 1 recorded 5.3, 11.2 and 12.4 per cent; and 7.6, 10.6 and 57.8 per cent more plant height and number of primary branches per plant over PAC 432, NRCHB 506 and Kranti, respectively. Similarly, hybrids (DMH 1, PAC 432 and NRCHB 506) took significantly more days to maturity (ranged between 137 to 145 days) than Kranti (132 days). Hybrids matured late owing to their requirements of more heat units for completion of their life cycle than variety. Thus, the longer vegetative and reproductive phase of hybrids resulted in better vegetative and reproductive growth and ultimately higher seed yield compared to Kranti. Similar variation in respect of growth, days to maturity and yield components; and seed yield within genotypes of Indian mustard have also been reported by Kumar (2002) and Kumar *et al.* (2004).

Table 1 Growth and yield attributes of Indian mustard hybrids/variety as influenced by varying crop geometries (pooled data of 2009-10 and 2010-11)

Treatments	Plant height (cm)	Primary branches/ plant	Days to maturity (days)	No. of siliquae/ plant	No. of seeds/ siliqua	1000- seed weight (g)
Crop geometry						
30 cm x 10 cm	211	6.11	135	304	14.21	3.70
30 cm x 15 cm	205	7.37	138	331	14.26	3.80
45 cm x 10 cm	203	7.80	138	333	14.32	3.82
45 cm x 15 cm	199	8.47	141	375	14.39	4.07
60 cm x 10 cm	201	8.35	139	345	14.36	3.92
SEm±	1.8	0.20	0.9	12	0.21	0.04
CD (P=0.05)	5.0	0.61	3.0	36	NS	0.13
Hybrids/Variety						
DMH 1	218	8.79	145	408	16.18	3.41
PAC 432	207	8.17	137	363	14.23	3.58
NRCHB 506	197	7.95	139	321	13.51	4.01
Kranti	194	5.57	132	257	13.31	4.46
SEm±	1.2	0.16	1.3	9.3	0.18	0.06
CD(P=0.05)	4.0	0.54	4.0	29.0	0.56	0.21

Table 2 Seed and oil production of Indian mustard hybrids/variety as affected by varying crop geometries (pooled data of 2009-10 and 2010-11)

Treatments	Seed yield (kg/ha)			Oil content (%)	Oil yield (kg/ha)	Production efficiency (kg seed/ha/day)
	2009-10	2010-11	Pooled			
Crop geometry						
30 cm x 10 cm	1434	2100	1767	41.10	725	13.1
30 cm x 15 cm	1654	2319	1987	40.60	806	14.4
45 cm x 10 cm	1672	2358	2015	40.70	819	14.6
45 cm x 15 cm	1728	2432	2080	39.75	826	14.7
60 cm x 10 cm	1458	2151	1804	40.05	722	13.0
SEm±	32	35	38	0.08	23	0.3
CD (P=0.05)	99	110	116	0.28	72	0.8
Hybrids/Variety						
DMH 1	2325	1995	2657	40.74	945	16.0
PAC 432	2063	1718	2408	40.69	837	15.1
NRCHB 506	1793	1408	2179	40.83	730	12.9
Kranti	1541	1239	1844	39.51	607	11.7
SEm±	33	37	34	0.15	29	0.3
CD (P=0.05)	98	112	102	0.46	87	1.1

Seed yield and its contributing characters were significantly better in hybrids than variety except 1000-seed weight. However, the difference between NRCHB 506 and Kranti with regards to seeds/siliqua was non significant (Table 1 and 2). Hybrid DMH 1 registered 12.4, 27.1 and 58.7 per cent; 13.7, 19.8 and 21.6 per cent; 12.7, 29.7 and 50.9 per cent; and 6.0, 24.0 and 36.7 per cent higher number of siliquae/plant, seeds/siliqua, seed yield and production efficiency in comparison to PAC 432, NRCHB 506 and Kranti, respectively. Although variety Kranti recorded significantly higher 1000-seed weight (4.46 g) than hybrids DMH1 (3.41 g), PAC 432 (3.58 g) and NRCHB-506 (4.01 g), yet Hybrid DMH 1 out yielded other hybrids and variety Kranti due to its better yield components *viz*., number of primary branches/plant, number of siliquae/plant and seeds/siliqua except 1000-seed weight (lowest) which was compensated by the effect of higher number of siliquae/plant and seeds/siliqua and ultimately resulted into highest seed yield. Further, the variation in growth, yield components and seed yield within hybrids; and between hybrids and variety of Indian mustard might be attributed to their genetic constitution. Corroborative findings have also been reported by Sodhi *et al.* (2006), Razzaque *et al.* (2007) and Dehghani *et al.* (2008).

Oil content and its yield varied significantly within hybrids; and between hybrid and variety of Indian mustard (Table 2). Hybrid NRCHB 506 had higher oil content (40.83%) followed by DMH 1 (40.74%), PAC 432 (40.69%) and Kranti (39.51%) in descending order. While hybrid DMH 1 produced significantly higher oil yield (945 kg/ha) over other hybrids and variety which was higher to the tune of 12.9, 29.4 and 55.7 per cent than PAC 432, NRCHB 506 and Kranti, respectively. Kumar *et al.* (2004) also observed variation in oil content and its production within varieties of Indian mustard.

Interaction effect of crop geometry x hybrids/ variety on siliquae/plant: Pooled data given in Table 3 indicated that all hybrids (DMH 1, PAC 432 and NRCHB 506) recorded significantly higher number of siliquae/plant over variety Kranti at all levels of crop geometries. Among the hybrids, DMH 1 proved superior in respect of number of siliquae/plant (378 to 415) to PAC 432 (333 to 367) and NRCHB 506 (292 to 330) in descending order under different levels of plant rectangularity. The corresponding values of siliquae/plant for variety Kranti ranged from 213 to 269 under varying crop geometries.

Interaction effect of crop geometry x hybrids/variety on seed yield: Overall, interaction effect between crop geometry and hybrids/variety (Table 3) revealed that sowing of Indian mustard hybrids at a wider crop spacing of 45 cm x 15 cm gave significantly higher seed yield [DMH 1 (2578 kg/ha), PAC 432 (2308 kg/ha) and NRCHB 506 (2023kg/ha)] over other spacings. While variety Kranti proved better at a spacing of 30 cm x 15 cm (yield) than other spacings. Hybrid DMH 1 produced 11.7 and 27.4 per cent higher seed yield over PAC 432 and NRCHB 506, respectively, at a crop geometry of 45 cm x 15 cm. It yielded 42.7 per cent higher than Kranti sown at spacing of 30 cm x 15 cm. The variability in optimum requirement of crop geometry of mustard hybrids (45 cm x 15 cm) and variety (30 cm x 15 cm) for optimum yield may be due to their differential genetic growth behaviour and architecture of plant ideotype.

The data pertaining to oil content and its yield (Table 2) revealed that seeds of crop grown under narrow crop geometry (30 cm x 10 cm) had significantly higher oil content (41.10%) compared to seeds of crop grown at widely spaced geometries (30 cm x 15 cm, 45 cm x 10 cm, 45 cm x 15 cm and 60 cm x 10 cm). Almost reverse trend was observed with respect to oil production. Plant rectangularity of 45 cm x 15 cm produced 14.4, 13.9, 2.5 and 0.8 per cent higher oil yield over 60 cm x 10 cm, 30 cm x 10 cm, 30 cm x 15 cm and 45 cm x 10 cm, respectively as oil yield is the resultant product of oil percent and seed yield. These findings are in close conformity with that of Singh and Prasad (2003).

Economics of treatment combinations: It is evident from the data given in Table 4 that the net profit (₹/ha) and benefit: cost ratio (B:C ratio) from all the hybrids of Indian mustard (DMH 1, PAC 432 and NRCHB 506) were highest at a spacing of 45 cm x 15 cm as compared to other spacings. On the other hand, variety Kranti gave higher net returns and B:C ratio at a closer spacing of 30 cm x 15 cm.

Table 3 Interaction effect of crop geometry with Indian mustard hybrids/variety on number of siliquae/plant and seed yield (pooled data of 2009-10 and 2010-11)

Crop geometry	Number of siliquae /plant				Seed yield (kg/ha)			
	DMH 1	PAC 432	NRCHB506	Kranti	DMH 1	PAC 432	NRCHB 506	Kranti
30 cm x 10 cm	378	333	292	213	2124	1881	1623	1440
30 cm x 15 cm	396	353	308	267	2311	2047	1782	1807
45 cm x 10 cm	400	360	312	262	2384	2108	1832	1737
45 cm x 15 cm	452	406	366	276	2578	2308	2023	1410
60 cm x 10 cm	415	367	330	269	2230	1969	1706	1313
SEm±	21				64			
#CD (P=0.05)	NS				188			
SEm±	14				52			
$CD (P=0.05) for hybrids/variety x crop geometry	39				153			

#=CD (P=0.05) for crop geometry x hybrids/variety; $=CD (P=0.05) for hybrids/variety x crop geometry; NS=Non-significant

Among the various hybrids/variety, hybrid DMH 1 sown at 45 cm x 15 cm spacing gave highest net monetary returns and benefit: cost ratio (₹ 36714/ha and 2.80) followed by PAC 432 (₹ 30784/ha and 2.51) and NRCHB 506 (₹ 24584/ha and 2.21), whereas, variety Kranti fetched maximum net returns and benefit: cost ratio (₹ 19820/ha and 1.98) with crop geometry of 30 cm x 15 cm followed by 45 cm x 10 cm (₹ 18261/ha and 1.90), 30 cm x 10 cm (₹11700/ha and 1.58), 45 cm x 15 cm (₹ 11128/ha and 1.55) and 60 cm x 10 cm (₹ 8984/ha and 1.44) in diminishing order, respectively.

Based on the results of two years study, it can be concluded that hybrids (DMH 1 and PAC 432) of Indian mustard were proved to be superior to best check variety (Kranti) and these should be sown at a spacing of 45 cm x 15 cm for obtaining higher seed and oil yield as well as net returns and B:C ratio.

Table 4 Economic viability of various treatment combinations (Mean of 2009-10 and 2010-11)

Treatments (crop geometry x hybrids/variety)	Seed yield (kg/ha)	Gross returns (₹/ha)	Cost of cultivation (₹/ha)	Net returns (₹/ha)	Benefit: Cost ratio
30 cm x 10 cm with DMH 1	2124	47040	20625	26415	2.28
30 cm x 10 cm with PAC 432	1881	41714	20625	21089	2.03
30 cm x 10 cm with NRCHB 506	1623	36083	20625	15458	1.75
30 cm x 10 cm with Kranti	1440	32000	20300	11700	1.58
30 cm x 15 cm with DMH 1	2311	51169	20455	30714	2.50
30 cm x 15 cm with PAC 432	2047	45369	20455	24914	2.22
30 cm x 15 cm with NRCHB 506	1782	39586	20455	19131	1.93
30 cm x 15 cm with Kranti	1807	40060	20240	19820	1.98
45 cm x 10 cm with DMH 1	2384	52783	20455	32328	2.58
45 cm x 10 cm with PAC 432	2108	46733	20455	26278	2.28
45 cm x 10 cm with NRCHB 506	1832	40706	20455	20251	1.99
45 cm x 10 cm with Kranti	1737	38501	20240	18261	1.90
45 cm x 15 cm with DMH 1	2578	57059	20345	36714	2.80
45 cm x 15 cm with PAC 432	2308	51129	20345	30784	2.51
45 cm x 15 cm with NRCHB 506	2023	44929	20345	24584	2.21
45 cm x 15 cm with Kranti	1410	31330	20202	11128	1.55
60 cm x 10 cm with DMH 1	2330	49430	20375	29055	2.43
60 cm x 10 cm with PAC 432	1969	43677	20375	23302	2.14
60 cm x 10 cm with NRCHB-506	1706	37899	20375	17524	1.86
60 cm x 10 cm with Kranti	1313	29196	20212	8984	1.44

Market price of produce (seed of hybrids/variety): ₹ 21/- and ₹ 23/- per kg during 2009-10 and 2010-11, respectively.

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Production potential of castor (*Ricinus communis* L.) intercropping with soybean (*Glycine max* L.) under irrigated conditions

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ABSTRACT

A field experiment was conducted consecutively for three years during rainy seasons of 2010-11 to 2012-13 at the Main Oilseeds Research station, Junagadh Agricultural University, Junagadh on intercropping castor in soybean with an objective to find out suitable intercropping ratio for achieving higher productivity and profitability. The experiment was conducted on medium clay soil under irrigated conditions. It consisted of eight treatments including sole castor, sole soybean, combinations of intercropping of castor (cv. GCH 7) with soybean (cv. Gujarat soy. 1) in row proportion 1:1 and 1:2 with sowing period of castor 15, 30 and 45 days after sowing of soybean. The results revealed that sowing of castor at 30 days after sowing of soybean in 1:2 ratio recorded significantly higher castor equivalent yield (2806 kg/ha) and land equivalent ratio (LER: 1.72) besides higher net returns (Rs. 69289/ha) and B:C ratio (2.86).

Keywords: Castor, Castor equivalent yield, Intercropping, Land equivalent ratio, Soybean

Castor (*Ricinus communis* L.) is an important non edible and industrial oilseed crop grown under rainfed and irrigated conditions. Among the various agronomic factors, planting method and ratio are important for enhancing the yields of intercropping systems (Venkattakumar *et al.,* 2014). Castor being a long duration and widely spaced crop with comparatively less plant density as compared to other close spaced field crops provides ample scope for growing intercrop in order to increase production from unit area of land. Intercropping is popular in tropical and sub-tropical country as it acts as insurance against crop failure, creates favourable micro-climate, reduces pest and disease incidence and enhances productivity and profitability (Aggarwal *et al.,* 1992; Fininsa, 1996; Iswar Singh *et al.,* 2013). Osiru (1983) reported that pulses had a complementary effect and cereals had a competitive effect when they were grown as intercrops with castor. The yield advantages due to intercropping are especially important because they are achieved not by means of costly inputs, but the simple expedient of growing crop together. The suggested benefits of legumes as an intercrop are the increased growth of roots and shoots, better root stratification and utilization of soil nutrients and nitrogen fixation which allows the legumes to become independent of soil nitrogen and making some nitrogen available to associate to non-legume. This availability to non-legume was attributed through soluble root exudes and/or decay of nodules. The soil structure also improved due to legume intercrop by aggregation around roots involving the adherence of fine soil particles to living root hairs (Latif *et al*., 1992; Karlen *et al*., 1994) with improvement in water holding and buffering capacity of soil with incorporation of legume residues (Buresh and Dutta, 1991). For achieving maximum yield potential of any crop, it is necessary to provide congenial environmental conditions for its optimum growth and development. In Saurashtra region of Gujarat, groundnut castor intercropping is popular among farmers due to higher system productivity besides drought resistance capacity. Further, soybean is grown widely under rainfed condition in Saurashtra region and was found to be a suitable crop in intercropping system with castor. After harvesting soybean crop, productivity of castor can be increased by two to three folds by giving 3-4 supplementary irrigations. However, information on optimum time of sowing castor in intercropping with soybean and also the ratio in which these two crops have to be sown is not known. Therefore, present investigation was carried out with different rows ratio and sowing times.

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MATERIALS AND METHODS

The experiment was conducted during rainy (*kharif*) seasons of 2010-11, 2011-12 and 2012-13 at Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh, Gujarat under irrigated conditions. The soil of the experimental plot was clayey in texture and slightly alkaline in reaction. The soil has an organic carbon content of 0.69 per cent and was low in available nitrogen (207 kg/ha) and phosphorus (27.0 kg/ha) and high in potash (314 kg/ha). The moisture content of the experimental plot at field capacity and permanent wilting point were 28.4 and 14.8 per cent, respectively, while the bulk density was 1.34 g/cm3. The experiment was laid out in randomized block design with three replications. There were eight treatments consisting of sole castor, sole soybean and combinations of intercropping castor (cv. GCH 7) with soybean (cv. Gujarat soy. 1) in row proportion 1:1 and 1:2 with sowing period of castor 15, 30 and 45 days after sowing of soybean. A recommended dose of fertilizers and seed rate to both the crops were applied based on the proportion of planting density of the intercrops. Both the crops were sown and grown using rainfall, but after cessation of monsoon, five irrigations each of 50 mm depth were given to castor crop at an interval of 15 days. Pest and disease control measures were taken as and when required. Soybean was harvested in 90 days and picking of castor was done at 120, 150 and 180 days after sowing. The rainfall received during the crop growing season of 2010-11, 2011-12 and 2012-13 was 962 mm, 525 mm and 1520 mm, respectively. Land and equivalent ratio was calculated as follows: LER crop A = YAi / YAs, YAi is intercrop yield of Crop A; YAs is sole crop yield of crop A. If LER ≥ meant that intercropping was more beneficial than sole cropping; LER ≤ meant sole cropping was more productive while LER=1 meant no significant difference in either intercropping or sole cropping (Teixeira *et al.,* 2012).

RESULTS AND DISCUSSION

Seed yield of castor: The result revealed that seed yield of castor was significantly influenced by different treatments (Table 1). The maximum seed yield of castor (2635 kg/ha and 2425 kg/ha, respectively) was recorded by sole castor treatments (T1) during the year 2012-13 and in pooled, which was at par with castor + soybean (1:1) with castor sown at 15 DAS (T3), castor + soybean (1:1) with castor sown at 30 DAS (T4) and castor + soybean (1:2) with castor sown at 30 DAS (T7) in respect of pooled data. No significant differences were found in yield during the years 2010-11 and 2011-12. Growth and yield attributing characters of castor *viz.,* plant height, number of spikes, number of internodes, length of main spike and capsules per spike were found significantly higher in sole castor (T1) as compared to rest of the treatments (Table 3). Enhanced yield attributes which contributed favourably to photosynthetic efficiency might be on account of higher nitrogen status of soil because of additional advantage of nitrogen fixation by soybean root nodules. These results are in agreement with those of Sharma (2002), Satish (2009) and Honnali and Chittapur (2014).

Seed yield of soybean: Significant differences were found in seed yield of soybean during the years 2010-11, 2011-12 and in pooled results (Table 1). Significantly higher seed yield (1490, 1008 and 1345 kg/ha, respectively) was recorded with sole soybean (T2) during 2010-11, 2011-12 and in pooled results as compared to soybean in all intercropping treatments. The magnitude of reduction in seed yield of soybean due to intercropping was less in 1:2 row ratio followed by 1:1 row ratios. The reduction in the yield of soybean in intercropped treatments was mainly due to loss in area (rows) for the crop which was occupied by castor. These results are in agreement with the findings of Lingaraju and Babalad (2007).

Seed equivalent yield of castor: The seed equivalent yield of castor was found significant during all individual years and in pooled results (Table 4). Significantly higher seed equivalent yield of castor (2917 kg/ha) was recorded in year 2010-11 by castor + soybean (1:1) with castor sown at 45 DAS (T5) intercropping system, while, during 2011-12, 2012-13 and in pooled results significantly higher seed equivalent yield of castor was recorded (2597 kg/ha, 2997 kg/ha and 2806 kg/ha, respectively) in castor + soybean (1:2) intercropping with castor sown at 30 DAS (T7). Based on pooled results castor + soybean (1:2) with castor sown at 30 DAS (T7) was found to be the best intercropping system, but, it remained on par with castor + soybean (1:1) with castor sown at 15 DAS (T3), castor + soybean (1:1) with castor sown at 30 DAS (T4), castor + soybean (1:1) with castor sown at 45 DAS (T5) and castor + soybean (1:2) with castor sown at 15 DAS (T6). The higher equivalent yield with these treatments was due to higher yield of component crops in the system. The results are in agreement with the findings of Sharma (2002), Patel *et al.* (2007) and Kalaghatagi and Guggari (2010).

Land Equivalent Ratio (LER): The values of LER indicated better land use in all intercrop treatments in all years and in pooled results (Table 2). Yield advantage of 66 per cent (LER = 1.66) in castor + soybean (1:2) castor sown at 45 DAS treatment (T8), 81 per cent (LER = 1.81), 71 per cent (LER=1.71) and 72 per cent (LER=1.72) in castor + soybean (1:2) with castor sown at 30 DAS treatment (T7) were registered in 2010-11, 2011-12, 2012-13 and in pooled results, respectively. Castor + soybean (1:2) with castor sown at 30 DAS (T7) had a well-balanced yield compensation for both the crops, the vegetative and reproductive phases of the component crops did not coincide, which translated into reasonably good yield for both of them; and hence best land use efficiency. The results of this study showed that soybean and castor could be intercropped. Intercropping of castor + soybean (1:2) with castor sown at 30 DAS (T7) was much more efficient in utilizing the available resources (Rafael *et al.,* 2014) than sole cropping as indicated by the high LER values in pooled results (LER=1.72). The results obtained here for LER agree with other researches where the cultivation of castor intercropped with other species proved to be more efficient than monoculture (Lingaraju and Babalad, 2007; Kalaghatagi and Guggari, 2010; Kumar *et al.,* 2010; Teixeira *et al.,* 2012).

Economics: Monetary returns for the relay cropping system are presented in Table 3. Gross realization, cost of cultivation, net realization and B:C ratio of different treatments were worked out on the basis of current market prices of castor and soybean inputs used. The results indicated that system economics, gross realization (₹ 106639/ha), net return (₹ 69289/ha) and B:C ratio (2.86) were higher in intercropping castor + soybean (1:2) with castor sown at 30 DAS treatment (T7) as compared to sole and other intercropping treatments in pooled results. Similar experimental results have been reported by Gupta and Rathore (1993), Banik *et al.* (2006) and Lingaraju and Babalad (2007).

It was concluded from the present study that intercropping system castor and soybean in 1:2 row proportion with castor sown at 30 day after sowing of soybean was more productive and remunerative than sloe crop of castor and soybean under irrigated conditions.

Table 1 Effect of intercropping on seed yield of castor and soybean

Treatment	Seed yield of castor (kg/ha)			Pooled (kg/ha)	Seed yield of soybean (kg/ha)			Pooled (kg/ha)
	2010-11	2011-12	2012-13		2010-11	2011-12	2012-13	
Sole Castor	2451	2189	2635	2425	0	0	0	0
Sole Soybean	0	0	0	0	1490	1008	1537	1345
Castor + soybean (1:1) castor sown at 15 DAS	2099	2084	2235	2139	1010	509	1074	864
Castor + soybean (1:1) castor sown at 30 DAS	2144	2176	2301	2207	992	502	1166	886
Castor + soybean (1:1) castor sown at 45 DAS	2341	2082	1690	2038	995	578	1081	885
Castor + soybean (1:2) castor sown at 15 DAS	1875	2042	2021	1979	1145	825	1202	1057
Castor + soybean (1:2) castor sown at 30 DAS	2181	2102	2277	2187	1112	856	1244	1071
Castor + soybean (1:2) castor sown at 45 DAS	2116	1852	1589	1852	1222	895	1060	1059
SEm.(±)	145	94	102	115	51	52	119	47
CD(P=0.05)	NS	NS	315	355	156	160	NS	134

Table 2 Effect of intercropping on castor seed equivalent yield and land equivalent ratio

Treatment	Seed equivalent yield of castor (kg/ha)			Pooled (kg/ha)	Land Equivalent Ratio (LER)			Pooled
	2010-11	2011-12	2012-13		2010-11	2011-12	2012-13	
Sole Castor	2451	2189	2635	2425	1.00	1.00	1.00	1.00
Sole Soybean	862	584	890	779	1.00	1.00	1.00	1.00
Castor + soybean (1:1) castor sown at 15 DAS	2683	2379	2857	2640	1.54	1.45	1.60	1.53
Castor + soybean (1:1) castor sown at 30 DAS	2718	2466	2976	2720	1.54	1.50	1.67	1.57
Castor + soybean (1:1) castor sown at 45 DAS	2917	2417	2316	2550	1.62	1.53	1.39	1.52
Castor + soybean (1:2) castor sown at 15 DAS	2538	2520	2716	2591	1.54	1.75	1.59	1.63
Castor + soybean (1:2) castor sown at 30 DAS	2825	2597	2997	2806	1.65	1.81	1.71	1.72
Castor + soybean (1:2) castor sown at 45 DAS	2823	2370	2203	2465	1.66	1.74	1.32	1.57
SEm(±)	147	92	110	111	0.07	0.06	0.08	0.06
CD(P=0.05)	447	280	332	338	0.22	0.18	0.24	0.20

Table 3 Effect of intercropping on growth, yield attributing characters and economics of castor (3 years pooled data)

Treatment	Height at harvest (cm)	No of branches /plant	No. of spikes/ plant	No. of internodes/plant	Length of main spike (cm)	No. of capsules/spike	System economics			
							Gross income (Rs/ha)	Total cost of production (Rs/ha)	Net realization (Rs/ha)	B:C ratio
Sole Castor	71.22	5.75	9.70	19.30	43.67	69.64	92150	32500	59650	2.84
Sole Soybean	0.00	0.00	0.00	0.00	0.00	0.00	29590	11500	18090	2.57
Castor + soybean (1:1) castor sown at 15 DAS	60.47	5.33	8.00	18.55	42.44	64.11	100314	35150	65164	2.85
Castor + soybean (1:1) castor sown at 30 DAS	60.09	5.22	7.44	18.18	39.52	66.48	103357	36550	66807	2.83
Castor + soybean (1:1) castor sown at 45 DAS	69.31	5.07	7.00	18.37	43.85	66.15	96901	36150	60751	2.68
Castor + soybean (1:2) castor sown at 15 DAS	64.65	5.44	8.63	18.26	39.70	62.04	98472	36850	61622	2.67
Castor + soybean (1:2) castor sown at 30 DAS	64.68	5.63	8.55	18.33	43.63	67.77	106639	37350	69289	2.86
Castor + soybean (1:2) castor sown at 45 DAS	69.50	5.37	7.33	16.89	39.59	65.28	93686	37860	55826	2.47
SEm.(±)	0.22	0.22	0.22	0.32	0.33	0.72	-	-	-	-
CD(P=0.05)	0.67	NS	0.67	0.99	1.03	2.23	-	-	-	-

Market price: Castor seed - Rs.38/kg; Soybean seed - Rs. 22/kg ; Cost of inputs : Urea - Rs. 5.84/kg; DAP- Rs. 25.18/kg

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Influence of integrated nutrient management practices on productivity and economics of soybean-safflower cropping system on vertisols of Marathwada region

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ABSTRACT

An experiment on soybean-safflower cropping system consisting of four main treatments for soybean viz., 100% recommended dose of fertilizer (RDF), 50% RDF + 3.5 t/ha safflower residues, 50% RDF + 2.5 t/ha FYM + 3.5 t/ha safflower residues and 5 t FYM/ha + 3.5 t/ha safflower along and five sub plot treatments for safflower viz., 100% RDF, 50% RDF + 6 t FYM/ha, 50% RDF + 3 t/ha soybean residues/ha, 50% RDF + 3 t FYM/ha + 3 t soybean residues/ha and 6 t FYM/ha+ 3 t soybean residues/ha was conducted at research farm of AICRP on Safflower, VNMKV, Parbhani during kharif and rabi seasons of 2010-11 to 2013-14. The results showed that application of 100% RDF and 50% RDF + 2.5 t FYM/ha + 3.5 t safflower/ha residues to soybean were at par and recorded significantly higher safflower equivalent yield, gross monetary returns and net monetary returns than other treatments. Further, application of 100% NPK was found to have given significantly safflower equivalent yield, gross monetary returns and net monetary returns besides B:C ratio. Next best treatment was application 50% NPK + 3t/ha FYM + 3t/ha soybean residues to soybean.

Keywords: Cropping system, Economics, Integrated nutrient management, Safflower, Soybean

Safflower (*Carthamus tinctorius* L.) is one of the oldest crops with Mexico and India as the leading producers which contribute 54 per cent of the total safflower production in the world. Safflower is a multipurpose crop and is grown for use as edible oil (linoleic rich types), industrial oil (oleic acid types), cake, animal meal and safflower dye while it is predominantly cultivated in China for flowers for use in traditional medicines. Safflower oil is rich in poly unsaturated fatty acid (75% linoleic) is known to reduce blood cholesterol level and demands a premium price among edible oils and is competitive from health point of view with canola and olive oil (Singh *et al*., 2013; Indu and Singh, 2014). Safflower is grown as rainfed crop on residual soil moisture with least fertilizer or no fertilizer under vertisols to conserve and optimize the use of natural resources with profitability as guiding factors of sustainability under rainfed situation. Soybean-safflower is one of the most popular cropping sequences followed by traditional safflower growing tracts. Hence the productivity of safflower and system returns is assessed in crop sequences.

The area under safflower crop is increasing but the productivity is not keeping with its yield potential. Among several reasons attributed to low productivity, the inadequate and imbalanced nutrition including almost all the essential nutrients, can be considered as major one. Fertilizer is the major input through which the productivity can be increased by exploiting the varietal potential. As the cost of nutrients/chemical fertilizers is increasing on one hand, inherent fertility of soil has been declining on the other hand, inorganic fertilizer and organic manures have to be used judiciously in an integrated manner. Integrated plant nutrient supply system is a concept aimed at maintenance of soil fertility and plant nutrient supply at an optimum level for sustaining the productivity through optimization of the benefit from all possible sources of plant nutrients in an integrated manner (Singh and Kamath, 1990). Adequate and balanced fertilization is the key to sustain productivity of soybean-safflower cropping system. Integration of chemical, organic and biological sources and their efficient management has shown promise in not only sustaining the productivity and soil health but also in meeting a part of chemical fertilizer requirement of different crops and cropping systems (Hegde, 1998). Hence integrated nutrient management is more emphasized not only to boost the production but also to preserve the ecosystem (Raju *et al.,* 2013). The present study was carried out with an objective to find out optimum integrated nutrient management for better soil microbial activity of safflower based cropping systems.

MATERIALS AND METHODS

A field experiment was conducted during 2010-11 to 2013-14 at research farm of AICRP on Safflower, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra. Soybean variety JS-335 and safflower variety PBNS-12 were grown during *kharif* and *rabi* seasons, respectively. Experiment was designed in split plot with three replications. The treatments consisted of M1 - 100% recommended dose of fertilizer (RDF), M2 - 50% RDF + 3.5t/ha safflower residues, M3 - 50% RDF+2.5t/ha FYM + 3.5t/ha safflower and M4 - 5t FYM/ha + 3.5t/ha safflower residues to soybean as main plots and S1 - 100% NPK, S2 - 50% NPK + 6t/ha FYM, S3 - 50% NPK + 3t/ha soybean residues, S4 - 50% NPK + 3t/ha FYM + 3t/ha soybean residues and S5 - 6t FYM/ha + 3t/ha soybean residues to safflower as sub plots. The 30:60:30 and 60:40:0 NPK kg/ha were used as recommended fertilizer doses for soybean and safflower, respectively. Appropriate cultural practices and timely plant protection measures were adopted. Production potential and system economics were studied.

RESULTS AND DISCUSSION

Table 1 indicated that there is significant influence of crop residues as a component of INM on production potential and system economics in soybean-safflower cropping system.

Soybean: Pooled analysis indicated that application of 100% RDF to soybean recorded significantly higher seed yield of soybean than other treatments, however, it was on par with application of 50% RDF+2.5t/ha FYM+3.5t/ha safflower residues. Residual effect of applied fertilizers to preceding safflower was not observed on soybean.

Safflower: Pooled analysis indicated that residual effect of applied fertilizers to preceding soybean was not observed on safflower crop grown in succession. Application of 100% RDF and 50% RDF+3/ha FYM+3 t/ha soybean residues to safflower produced similar seed yields of safflower (yield), which were significantly superior over rest of the treatments. Residual effect of application of different treatments on soybean was found non-significant.

On system basis, application of 100% RDF to soybean significantly improved the safflower equivalent yield (3441 kg/ha) which was on par with that of 50% RDF + 2.5 t/ha FYM + safflower residues to soybean (3372 kg/ha). Similarly, application of 100% RDF to safflower significantly improved the safflower equivalent yield (3352 kg/ha) which was on par with that of 50% RDF + 2.5 t/ha FYM + soybean residues (3067 kg/ha). System gross and net monetary returns and B:C ratio followed the similar trend set by seed yield. Interaction between main and sub plots was found to be non significant. Similar results were reported by Chikshe *et al.* (2013) and Arbad *et al.* (2014).

Table 1 Crop residue management as a component of INM in soybean-safflower cropping system (Pooled mean of 2010-11 to 2013-14)

Treatment	Seed yield (kg/ha)		SEY (kg/ha)	System Economics		
	Soybean	Safflower		GMR (Rs/ha)	NMR (Rs/ha)	B:C ratio
A) Main plot (Soybean)						
M1 – 100% recommended NPK	1850	1745	3441	92115	59902	2.9
M2 – 50% NPK + 3.5t/ha safflower residues	1470	1634	2981	80066	50416	2.7
M3 – 50% NPK+2.5t/ha FYM + 3.5t/ha safflower residues	1764	1755	3372	90188	58725	2.959
M4 – 5t FYM/ha + 3.5t/ha safflower residues	1274	1638	2805	75042	43017	2.427
SEm±	27	42.00	59	1563.97	1563.97	0.054
CD (P=0.05)	80	NS	173	4573	4573	0.163
B) Sub plot (Safflower)						
S1 – 100% NPK	1593	1892	3352	89846	59720	3.086
S2 – 50% NPK + 6t/ha FYM	1573	1597	3038	81336	47811	2.500
S3 – 50% NPK + 3t/ha soybean residues	1583	1585	3035	81413	52276	2.900
S4 – 50% NPK + 3t/ha FYM + 3t/ha soybean residues	1613	1888	3367	90255	58893	2.972
S5 – 6t FYM/ha + 3t/ha soybean residues	1587	1503	2957	78914	46376	2.499
SEm±	30.43	35.00	96	1237.40	1237.40	0.042
CD (P=0.05)	NS	94.00	290	3727.07	3727.07	0.127
C) Interaction						
SEm±	60.86	69.26	209.10	2476.96	2476.96	0.084
CD (P=0.05)	NS	NS	NS	NS	NS	NS
G. Mean	1589.8	1693	3149.8	84352.8	53015.2	2.7914

Market rate of safflower and soybean, cost of fertilizer and manures taken

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Influence of irrigation depth and interval under drip irrigation method on productivity of *rabi* groundnut (*Arachis hypogaea* L.) in water scarce regions

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ABSTRACT

Due to depletion of underground water, the farmers have been facing many problems in irrigating the crops by traditional methods. In such situations, the drip method of irrigation proved efficient. However, to identify optimum irrigation depth and suitable irrigation interval under drip method of irrigation to *rabi* groundnut, field experiments were conducted during *rabi* 2006-07 to 2007-08 with two irrigation depths *viz.,* 10 mm and 15 mm each scheduled at 3 intervals i.e. on 2nd day, 3rd day and 4th day and were compared with traditional check-basin method. In both the years, significantly higher pod yield was recorded with 10 mm depth of irrigation, scheduled on every third day which was at par with 15 mm depth given on 3rd day and 15 mm depth of irrigation on 2nd day. Significantly lowest groundnut pod yield was with check basin method at IW/CPE 1.0, which was 187% and 21% lower than that of 10 mm depth scheduled on 3rd day during 2006-07 and 2007-08, respectively. Highest field water use efficiency was with 10 mm depth of irrigation scheduled on 3rd day during 2006-07 (7.7 kg/hamm) and 10 mm depth scheduled on 4th day during 2007-08 (5.0 kg/hamm). When the quantity of irrigation water available is equal to that of check basin method, irrigations could be scheduled with 10 mm depth of water on every 4th day so that 136 times additional area could be brought under similar set of irrigation treatment. Thus, the reduction in pod and haulm yields with this treatment could be compensated by bringing additional area through diverting the saved water.

Keywords: Drip irrigation, Filed water use efficiency, Groundnut, Irrigation depth and interval

Irrigation water shortage is one of the main constraints for overall development in arid and semi-arid areas. Due to depletion of underground water, farmers face many problems in irrigating the crops by traditional methods (Bheemappa and Patil, 2013). Hence, innovations are needed to increase the use efficiency of water that is available for which there are several possible approaches. One way is changing the irrigating methods from surface methods which are traditional and less efficient to pressurized methods like using drip and sprinkler methods which were proved efficient in saving water (Rathod and Trivedi, 2011). The other way of increasing the water use efficiency is applying deficit water which eliminates the irrigations that have little impact on yield. Thus, the resulting yield reduction may be small compared with the benefits gained through diverting the saved water to irrigate additional area.

Drip irrigation method allows for more uniform distribution as well as more precise control on the amount of water to be applied (Phene *et al.,* 1994), leading to saving of water (Darusman *et al.,* 1997). However, the method can result in water saving if the correct management procedures are applied for which it is necessary to know the crop yield responses to water applications. Frequency of water application is one of the most important factors in drip irrigation management (Assou line, 2002; Wang *et al.,* 2006). Depletion of groundwater is one of the main constraints in groundnut cultivation during *rabi* season since nearly 600-700 mm of irrigation water is required in Alfisols of Anantapur district to irrigate the crop during the crop season by traditional check-basin method (Hruday Ranjan *et al*., 2014). Scheduling of irrigation to meet the crop needs with minimum adverse effect on pod yields is an important aspect of water economy in groundnut production (Padmalatha *et al.,* 2001). Hence, there is every need to find out the methods which save the quantity of irrigation water without reducing the yield, besides improving the irrigation water use efficiency. Micro irrigation methods using sprinkler and drip methods proved efficient in saving water and improving the irrigation water use efficiency. The recommendations for drip irrigation methods are mostly made for horticultural crops and some field crops which are more scientific and irrigations are to be given daily based on evaporation of preceding day which are not feasible at farmer's level. Hence, there is a need to evaluate irrigation depth and interval with drip method of irrigation for its easy adaptation in groundnut crop production.

MATERIALS AND METHODS

Field experiments were carried out for two years (2006-07 and 2007-08) during *rabi* season at Agricultural Research Station, Reddipalli (14°41'N, 77°0' E and 350 m altitude above mean sea level) in scarce rainfall zone of Andhra Pradesh. Soil of the experimental field is shallow in depth (20-25 cm), sandy loam in texture, slightly alkaline in reaction (7.5 pH), low in available nitrogen (110.0 kg/ha), medium in available phosphorus (16.0 kg/ha) and potassium (177 kg/ha) with a bulk density of 1.45 g/cm^3. The filed capacity and permanent wilting point of soil are 10.6 and 3.7 per cent, respectively.

The experiment was laid out in a randomized block design with seven irrigation treatments replicated thrice. The treatments included two depths of irrigation (10 mm and 15 mm depths / irrigation) and each depth scheduled at 2nd day, 3rd day and 4th day using drip irrigation method and these six treatments were compared with check basin method of irrigation (control). Each plot had 4 laterals of 16 mm spaced at 1.0 m apart with 30 m length and having on-line drippers (4 lph) fixed at 1.0 m apart. The radius of wetted surface of each dripper in the experimental area having red sandy loam soils was 60 cm and hence drippers were fixed at 1.0 m apart to have overlapping of wetted areas. The inlet of each lateral (drip line) was fitted with individual valve which is in turn connected to sub main through 16 mm grommet take off. Thus, the laterals and drippers which were fixed were emitting 4 mm depth of water/hour. The required depth of irrigation could be controlled by the individual valves which were fixed to each lateral.

In the treatments where 10 mm depth of irrigation was given, this depth of irrigation was maintained upto 75 days after sowing (DAS) and from 75 DAS to maturity 15 mm depth of irrigation was provided since water requirement of the crop as well as evapo-traspiration losses were increased. Similarly, in the treatments where 15 mm depth of irrigation was given, the same depth was maintained upto 75 days after sowing and lateron, 22.5 mm depth of irrigation was given upto maturity. The test variety was Spanish bunch Kadiri-6 with a duration of 100-110 days during *rabi*. The weekly weather parameters which prevailed during the crop seasons of 2006-07 and 2007-08 are given in table 1.The crop was sown on 23rd December and 7th December and harvested on 10th April and 4th April during 2006-07 and 2007-08, respectively. No rainfall was received during the crop season of 2006-07. During the crop season of 2007-08, only 8.4 mm of rainfall was received in 4 rainfall events which was not considered for calculating the total water applied. Though rainfall of 48.8 mm was received in four rainy days from 22-31st December during 2007-08, it was not considered for calculating the total water applied since the crop attained maturity by 20th March itself. Recommended package of practices were followed and care was taken against biotic stresses. The biometric observations, yield attributes and pod yield as well as haulm yield were recorded and analysed statistically to know the crop responses to water applications. Total quantity of irrigation water applied and field water use efficiency for each treatment were calculated and discussed.

Table 1 Mean weekly weather parameters prevailed during crop seasons of *rabi* 2006-07 and 2007-08

Standard week	Maximum temperature (°C)		Minimum temperature (°C)		Relative humidity-I (%)		Relative humidity-II (%)		Sunshine hours		Rainfall (mm)	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
48	32.0	30.6	18.1	14.2	90	60	40	35	9.0	8.8	0	0
49	30.8	29.4	15.6	16.9	89	72	40	46	8.4	5.0	0	0
50	30.7	30.2	17.5	18.2	84	84	41	47	7.4	6.5	0	0
51	29.9	28.7	144	17.9	92	83	44	54	7.7	5.3	0	5.2
52	30.4	33.2	14.7	15.5	91	82	39	39	7.7	9.7	0	0
1	31.0	30.6	13.8	15.4	91	83	36	40	9.6	8.9	0	0
2	30.5	31.2	15.5	13.7	88	81	38	30	9.6	9.6	0	0
3	32.5	32.3	15.5	13.6	84	82	33	21	9.5	10.0	0	0
4	33.4	33.2	16.6	17.5	83	87	33	31	9.7	9.2	0	0
5	33.3	33.1	16.5	19.0	84	85	32	36	10.0	8.3	0	0
6	34.1	33.0	17.0	22.1	81	84	31	37	9.9	5.9	0	1.8
7	34.1	31.4	20.4	20.6	74	88	32	47	9.4	5.7	0	1.4
8	33.4	35.3	16.5	19.5	84	74	33	30	10.3	9.8	0	0
9	36.2	34.7	19.6	17.4	77	67	27	25	10.5	10.3	0	0
10	37.5	36.4	23.6	16.7	65	67	26	22	9.6	9.7	0	0
11	37.2	35.3	21.5	21.5	74	78	27	46	10.4	7.0	0	8.6
12	39.7	35.0	23.3	22.2	68	83	22	45	9.9	5.7	0	46.2
13	40.2	35.2	23.2	23.1	68	83	23	46	10.0	9.2	0	2.6
14	40.2	36.3	23.8	24.2	67	68	23	32	10.2	10.8	0	0

Table 2 Biometric observations at harvest as influenced by depth of irrigation and its schedule through drip method

Treatment	*Rabi* 2006-07	*Rabi* 2006-07	DMP (g/m^2)			Pod number (per m^2)		
	Plant height (cm)	No. of branches/plant	*Rabi* 2006-07	*Rabi* 2007-08	Pooled	*Rabi* 2006-07	*Rabi* 2007-08	Pooled
10 mm of irrigation on 2nd day	17.9	4.6	190.7	106.6	148.3	330	282	306
10 mm of irrigation on 3rd day	15.1	4.3	168.7	131.5	151.9	302	277	287
10 mm of irrigation on 4th day	15.5	4.3	143.0	103.9	123.5	300	276	288
15 mm of irrigation on 2nd day	19.0	4.4	198.7	120.3	159.5	318	269	294
15 mm of irrigation on 3rd day	19.9	4.0	214.7	115.0	164.8	285	302	294
15 mm of irrigation on 4th day	17.1	4.7	157.0	107.9	132.5	287	294	291
Check basin method (IW/CPE1.0)	10.9	4.0	202.7	89.3	89.2	199	225	292
SEm±	1.0	--	15.6	--	9.6	9.98	22.3	8.7
CD 5%	3.1	NS	48.8	NS	28.7	31.1	69	25
CV%	14.8	8.2	16.3	16.5	--	6.0	14.1	--

Table 3 Yield attributes and yield of groundnut as influenced by depth of irrigation and its schedule through drip method

Treatment	Shelling percentage			Test weight (g)			Pod yield (kg/ha)			Haulm yield (kg/ha)		
	Rabi 2006-07	*Rabi* 2007-08	Pooled	*Rabi* 2006-07	*Rabi* 2007-08	Pooled	*Rabi* 2006-07	*Rabi* 2007-08	Pooled	*Rabi* 2006-07	*Rabi* 2007-08	Pooled
10 mm of irrigation on 2nd day	64.1	72.1	68.1	34.5	35.9	35.2	2363	1100	1731	3746	2141	2944
10 mm of irrigation on 3rd day	61.6	67.2	64.4	31.5	34.4	33.0	2965	1407	2186	4261	1919	3090
10 mm of irrigation on 4th day	64.9	68.2	66.6	34.6	33.5	34.1	2318	1270	1794	3448	2230	2839
15 mm of irrigation on 2nd day	64.1	70.9	67.5	33.9	33.8	33.9	2662	1007	1835	3270	1696	2483
15 mm of irrigation on 3rd day	61.8	72.5	67.1	34.8	31.8	33.3	2742	1400	2071	4133	1928	3032
15 mm of irrigation on 4th day	61.8	69.7	65.7	34.1	32.4	33.3	2454	1321	1888	3514	2092	2803
Check basin method (IW/CPE1.0)	61.7	61.1	61.4	28.1	28.2	28.2	1032	1220	1126	1813	1017	1415
SEm±	3.16	1.9	1.9	1.1	1.4	0.9	149.5	114.3	95	315.8	152.5	170
CD 5%	NS	6.2	NS	3.5	4.3	2.6	466	351	277	984	471	494
CV %	8.8	5.0	--	5.8	7.4	--	10.9	15.8	--	15.8	14.2	--

Table 4 Field water use efficiency as influenced by irrigation depth and interval through surface drip irrigation

Treatment	*Rabi* 2006-07		*Rabi* 2006-07	
	Depth of irrigation (mm)	Field water use efficiency (kg/hamm)	Depth of irrigation (mm)	Field water use efficiency (kg/hamm)
10 mm of irrigation on 2nd day	525	4.50	485	2.3
10 mm of irrigation on 3rd day	385	7.70	330	4.3
10 mm of irrigation on 4th day	300	7.73	250	5.0
15 mm of irrigation on 2nd day	757.5	3.51	717	1.4
15 mm of irrigation on 3rd day	547.5	5.00	485	2.9
15 mm of irrigation on 4th day	420	5.84	365	3.6
Check basin method (IW/CPE1.0)	700	1.47	600	1.9

Table 5 Additional advantage with drip method of irrigation under different irrigation depths and schedules

Irrigation depth and interval	Mean depth of irrigation (mm)	Additional area over check basin (times)	Additional pod yield kg/ha	Additional haulm yield over check basin
T1:10 mm of irrigation on 2nd day	505	0.29	502	854
T2:10 mm of irrigation on 3rd day	358	0.82	1793	2534
T3:10 mm of irrigation on 4th day	275	1.36	2440	3861
T4:15 mm of irrigation on 2nd day	738	-0.12	-220	-298
T5:15 mm of irrigation on 3rd day	517	0.26	538	788
T6:15 mm of irrigation on 4th day	393	0.65	1227	1822
T7:Check basin	650	-	-	

RESULTS AND DISCUSSION

Plant height and dry matter production (Table 2) were significantly influenced by the treatments, while, number of branches was non-significant. Significantly taller plants were observed with 15 mm irrigation, given on every 3rd day through drip method. This treatment was at par with same depth at other irrigation schedules. Check basin method produced significantly shortest plants compared to drip method. Similarly, significantly higher dry matter was with 15 mm irrigation given an every 3rd day during *rabi* 2006-07. Significantly lowest dry matter was recorded with irrigation scheduled on every 4th day in both irrigation depths (10 mm and 15 mm).

During *rabi* 2006-07, significantly highest pod number per unit area (Table 2) was with 10 mm depth on every 2nd day, which was at par with same depth on other schedules and also 15 mm depth on every 2nd day. During *rabi* 2007-08, it was significantly higher with 15mm depth on every 3rd day, but comparable with other treatments except check basin method. During both the years, significantly lowest pod number was with check basin method of irrigation.

Yield attributes like shelling percentage and test weight (Table 3) were not significantly influenced by the treatments during *rabi* 2006-07. However, during *rabi* 2007-08, though they were significant, all drip irrigation treatments were at par and superior to check basin.

During *rabi,* 2006-07, significantly higher pod yield (Table 3) was with 10 mm depth of irrigation at 3rd day which was in turn at par with 15 mm depth given on 3rd day and 15 mm depth on 2nd day. Significantly lowest groundnut pod yield was with check basin method which was 187 per cent lower than 10 mm depth given on 3rd day. During *rabi* 2007-08, significantly highest pod yield was with 10 mm depth given on 3rd day, followed by 15 mm depth, given on 3rd day, which were in turn comparable with all drip irrigation treatments, except 15 mm depth given on every 2nd day. High relative humidity and low minimum temperatures prevailed during pod filling phase of 2007-08 crop might have contributed to lesser pod yield (Table 1). The haulm yield (Table 3) almost followed the similar trend set by pod yield during 2006-07. While, during 2007-08, significantly higher haulm yield was with 10 mm depth of irrigation scheduled on 4th day and this treatment was comparable with all treatments under drip method except 15 mm depth of irrigation scheduled on 2nd day. During both the years, significantly lowest haulm yield was with check basin method of irrigation.

During *rabi* 2006-07, higher field water use efficiency of 7.7 kg ha/mm (Table 4) was with 10 mm depth of irrigation given through surface drip method on every third day. Total quantity of irrigation given in this treatment was 385 mm. Similarly, during *rabi* 2007-08, it was highest with 10 mm depth on 4th day (5.0 kg ha/mm) followed by 10 mm depth on 3rd day (4.3 kg ha/mm) which received the total quantities of irrigations of 250 and 330 mm, respectively. Irrigation water given during *rabi* 2006-07 was higher since one additional irrigation of 30 mm irrigation water was given on 5th day after sowing for uniform germination. Moreover, during 2006-07, crop duration was more by 5 days and uniform irrigations were started from 25 days after sowing. While, during *rabi* 2007-08, only with one pre-sowing irrigation, satisfactory germination was observed. Besides this, uniform irrigations were started from 30 DAS. Hence, the quantity of irrigation water given during *rabi* 2007-08 was less.

Similar results were obtained by Firake and Shinde (2000) and they stated that to obtain maximum yields of dry pod, kernel, haulm and oil from summer groundnut, drip irrigation should be scheduled at 2 days interval @ 70 per cent CPE. Water use efficiency was found more in 2 days irrigation interval by 9.97 per cent over 3 days irrigation interval and by 19.13 per cent over four days irrigation interval. The experiments conducted under AICRP on water management at TNAU (2010) also revealed saving of 144 mm of irrigation water, accounting for 19.2 per cent by micro irrigation over surface irrigation method (Anonymous, 2010).

El-Boraie *et al.* (2009) stated that yield, water consumptive and water use efficiency by groundnut plants increased as irrigation water amount increased and irrigation intervals decreased under drip irrigation. Among drip irrigation treatments, the lower performance of high frequency irrigation (irrigating 2nd day) in terms of pod yield and field water use efficiency with 10 mm depth during 2006-07 and with both depths during 2007-08 might be attributed to low water retentive capacity of red sandy loams and poor aeration in the pod zone which were in conformity with the findings of EL-Hendawy *et al.* (2008). Therefore, these results suggest that it is important to determine the accurate irrigation frequency for specific locations under the drip irrigation method. For groundnut of red sandy loams, the optimal water requirement was found as 330 mm (2007-08) to 385 mm (2006-07), giving maximized pod yield of 1407 kg/ha and 2965 kg/ha, respectively during 2007-08 and 2006-07. When irrigation water is limited, irrigations could be given on every third day with 10 mm depth of water for higher pod as well as haulm yields and higher field water use efficiency. When the quantity of irrigation water available is equal to that of check basin method, irrigations could be scheduled with 10 mm depth of water on every fourth day such that 1.36 times additional area could be brought (Table 6) under similar set of irrigation treatment. Thus, the reduction in pod and haulm yields with this treatment could be compensated by bringing additional area through diverting the saved water.

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Seed attributes characterization and exploration of fatty acid composition in *Calophyllum inophyllum* L.

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ABSTRACT

Thirty progenies of *Calophyllum inophyllum* L. commonly known as 'Undi' or 'Alexandrian laurel' were studied for seed, oil quality as well as fatty acid profile. Among the progenies, only one progeny *viz.,* FCRICI 14 consistently expressed superiority in all seed characteristics *viz.,* pod length (3.95 cm), pod width (3.42 cm), seed length (2.71 cm), seed width (2.35 cm), 100-seed weight (536.26 g), germination per cent (73.00%), germination value (5.11), peak value (3.06) and oil content (55.60%). Three progenies *viz.,* FCRICI 14 (Honnavara, Karnataka), FCRICI 2 (Nagapattinam, Tamil Nadu) and FCRICI 17 (Bhatkal, Karnataka) recorded higher oil content of 55.60, 52.33 and 51.43 per cent, respectively. The analysis of fatty acid composition revealed that the major fatty acid was oleic acid (56.42-68.25%) followed by palmitic acid (8.23-18.42%) and stearic acid (6.23 - 8.23%).

Keywords: *Calophyllum inophyllum,* Fatty acid composition, Oil quality, *Undi*

India is heavily dependent on imported fuels to meet its energy needs. During 2012-13, the country imported 184.8 MMT of crude oil and 10.91 MMT LNG against 171.7 MMT and 11.63 MMT, respectively during 2011-12. This accounts for nearly 77 per cent on its consumption and is met through imports as a result crude oil constitutes the major item in India's import bill (Nielson, 2013). In the recent past, research has been directed to explore plant based biofuel sources as a supplement or substitute of fossil fuel. Under Indian conditions, only such plant sources can be considered for bio-diesel, which produce non-edible oil in appreciable quantity and can be grown in large scale on non-crop marginal and wastelands. It has been recorded that fatty oils derived from *Jatropha curcas, Pongamia pinnata* and *Calophyllum inophyllum* are excellent feed stock for bio-diesel production (Srinivas *et al.,* 2001).

Calophyllum inophyllum L. (Family: Clusiaceae) is a littoral tree of the tropics, occurring above the high-tide mark along sea coasts and commonly seen on sandy beaches of seashore. It generally grows on the detritus brought down by rivers and on the sand and shingles banked up by wind and waves. The tree is native of East Africa to Southeast Asia, Philippines and Australia. In India, species is distributed along the Western and Eastern coasts of Kerala, Karnataka, Maharashtra, Tamil Nadu, Andhra Pradesh and Odisha (Friday and Okano, 2006). *Undi* an ideal source for making biodiesel since it is non-edible, has high kernel oil (65%), fruits profusely (3,000-10,000 seeds/tree/year) and requires little maintenance (Azam *et al.,* 2005; Sahoo *et al.,* 2006; Hathurusingha and Ashwath, 2007). Geo-climatic variations may influence plastic changes in plant performance. Varietal development is a key issue which demand continuous improvement programme to screen and improve varieties with high oil content and higher productivity. Though research attempts for improving *C. inophyllum* have taken place here and there but still demand continuous and decentralized approach to improve the *C. inophyllum* genetic resources towards higher oil content coupled with increased productivity. Against this backdrop, the current study has been planned to improve the variety through systematic tree improvement programme.

MATERIALS AND METHODS

Three states of Southern India *viz.,* Tamil Nadu, Karnataka and Kerala were surveyed and a total number of 30 trees were selected. These selected trees were given with the accession numbers. The details of actual locations and growth attributes of the selected 30 trees were furnished in the Table 1.

The experimental materials for the study consisted of 30 progenies in *Calophyllum inophyllum.* Nursery experiments were carried out at Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam, Tamil Nadu (11°19'N, 76°56'E, 300 m.s.l., 800 mm, pH 7.1) during 2013-2015. Seed from the 30 progenies were raised and used as source of propagules for raising progeny evaluation trial. The characteristics of the pod of each of the progenies were evaluated as detailed below with 10 pods of three replications in each of the sources. The pods were extracted for seeds adopting dry extraction technique using manual method (breaking using hard surface). From the extracted pods, 10 seeds in three replications were randomly selected and the following observations were recorded.

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Table 1 Location details of superior progenies of *Calophyllum inophyllum*

State	Location	Latitude	Longitude	Altitude (m)	Name of the CPTs
Tamil Nadu	Vedaranyam	10°22'N	79°51'E	12	FCRICI 1
Tamil Nadu	Nagapattinam	10°45'N	79°49'E	10	FCRICI 2
Tamil Nadu	Velankanni	10°41'N	79°50'E	8	FCRICI 3
Tamil Nadu	Thiruvarur	10°45'N	79°37'E	12	FCRICI 4
Puducherry	Puducherry	11°54'N	79°47'E	9	FCRICI 5
Tamil Nadu	Tindivanam	12°13'N	79°39'E	43	FCRICI 6
Tamil Nadu	Cuddalore	11°44'N	79°42'E	11	FCRICI 7
Tamil Nadu	Nagercoil	08°09'N	77°22'E	48	FCRICI 8
Tamil Nadu	Pechiparai	08°26'N	77°18'E	101	FCRICI 9
Tamil Nadu	Mettupalayam	11°19'N	76°58'E	316	FCRICI 10
Tamil Nadu	Thiruchencode	11°22'N	77°53'E	428	FCRICI 11
Tamil Nadu	Coimbatore I	10°59'N	76°54'E	398	FCRICI 12
Tamil Nadu	Coimbatore II	10°57'N	76°55'E	419	FCRICI 13
Karnataka	Honnavara	14°15'N	74°26'E	14	FCRICI 14
Karnataka	Hubli	15°22'N	75°04'E	648	FCRICI 15
Karnataka	Sirsi	14°39'N	74°52'E	624	FCRICI 16
Karnataka	Bhatkal	13°59'N	74°31'E	16	FCRICI 17
Karnataka	Kumta	14°26'N	74°23'E	35	FCRICI 18
Karnataka	Udupi	13°20'N	74°43'E	15	FCRICI 19
Karnataka	Mangalore	12°54'N	74°51'E	25	FCRICI 20
Karnataka	Talugoppa	14°12'N	74°54'E	598	FCRICI 21
Karnataka	Shimoga	13°53'N	75°33'E	585	FCRICI 22
Karnataka	Sagar	14°09'N	75°00'E	604	FCRICI 23
Karnataka	Tumkur	13°20'N	76°09'E	815	FCRICI 24
Karnataka	Mandiya	12°29'N	76°54'E	673	FCRICI 25
Karnataka	Hiregutti	14°34'N	74°23'E	54	FCRICI 26
Kerala	Trivandrum	08°29'N	76°59'E	25	FCRICI 27
Kerala	Thrissur	10°29'N	76°17'E	50	FCRICI 28
Kerala	Kottayam	09°33'N	76°32'E	14	FCRICI 29
Kerala	Upala	12°41'N	79°54'E	10	FCRICI 30

Pod length (cm): The distance between the stalk end to stylar end of the pod was measured using a digital Vernier caliper and the mean expressed in centimeter.

Pod width (cm): The distance between the two rims of the pod at its maximum width was measured using digital Vernier caliper and the mean values were expressed in centimeter.

Seed length (cm): The length of seed from the micropyler end to the anti-polar end was measured using verniercaliper and expressed in cm.

Seed width (cm): The breadth at the middle of seed was measured using Vernier caliper and the mean values were expressed in cm.

100-seed weight (g): Three replicates of 100 seeds were weighed in a top pan balance as per ISTA (1999) and the mean values were expressed in g.

Estimation of oil content: For estimating oil, the seeds were depulped, the kernels dried at 50°C for 16 hrs and allowed to cool in a desiccator. Five grams of seeds were pulverized to a fine powder in a porcelain mortar. Ground samples were placed in a filter paper and fastened in such a way to prevent escape of the meal and then carefully transferred to an extraction thimble. The thimble was then placed in a Soxhlet extractor to which sufficient quantity of solvent petroleum ether (40-60°C) was added and heated until eleven siphonings were completed. The oil content was recorded by evaporating the petroleum ether at 60°C. The entire extraction process was carried out in Soxhlet extractor. The percentage of oil content was then calculated by using the formula.

$$\text{Oil per cent} = \frac{\text{Oil weight (g)}}{\text{Sample weight (g)}} \times 100$$

Fatty acid composition: The fatty acid composition was determined following the ISO standard ISO 5509:2000. In brief, one drop of the oil was dissolved in 1mL of n-heptane, 50µg of sodium methylate was added, and the closed tube was agitated vigorously for 1 min at room temperature. After addition of 100 µL of water, the tube was centrifuged at 4500g for 10 min and the lower aqueous phase was removed. Then 50µL of HCl (1 mol with methyl orange) was added, the solution was shortly mixed, and the lower aqueous phase was rejected. About 20 mg of sodium hydrogen sulphate (monohydrate, extra pure; Merck, Darmstadt, Germany) was added, and after centrifugation at 4500g for 10 min, the top n-heptane phase was transferred to a vial and injected in a Varian 5890 gas chromatography with a capillary column, CP-Sil 88 (100 m long, 0.25 mm ID, film thickness 0.2 µm). The temperature program was as follows: from 155ºC; heated to 220°C (1.5ºC/min), 10 min isotherm; injector 250°C, detector 250ºC; carrier gas 36 cm/s hydrogen; split ratio 1:50; detector gas 30 mL/minhydrogen; 300 mL/min air and 30mL/min nitrogen; manual injection volume less than 1µL. The peak areas were computed by the integration software, and percentages of fatty acid methyl esters (FAME) were obtained as weight per cent by direct internal normalization.

Experimental design and treatment: The nursery experimental trial was laid out using a Completely Randomized Block Design with 30 progenies from each species with 3 replications. Observation with respect to germination per cent, germination value, plant height, collar diameter, number of leaves and root length were taken at every one month interval till the end of experiment.

Influence of progenies on seed germination attributes

Germination (%): Survival of seedlings was calculated and expressed as percentage

$$\text{Germination percentage (\%)} = \frac{\text{No. of survived seedling}}{\text{No. of seedlings planted in nursery}} \times 100$$

Germination value (GV): Germination value was estimated by following method prescribed by Czabator (1962).

Germination value = MDG x PV

Whereas,

MDG - Mean daily germination (ISTA 1999).

PV - Peak value

$$\text{Peak value} = \frac{\text{Total germination per cent}}{\text{The number of days}}$$

$$\text{Mean daily germination} = \frac{\text{Final germination per cent}}{\text{No. of days took to reach the peak germination}}$$

Determination of oil quality of superior progenies (GC-MS analysis): Based on the seed oil content superior progenies were screened. Accordingly three progenies of *C. inophyllum viz.,* FCRICI 14, FCRICI 2 and FCRICI 17 were screened as a potential progenies with higher oil content. These superior genetic resources were analyzed by GC-MS Thermo GC - Trace Ultra Ver: 5.0, Thermo MS DSQ II; DB 5-MS, Capillary standard non-polar column (30 Mts, ID: 0.25 mm, FILM: 0.25 µm), column temperature / oven temp 800 C raised to 2600 C AT 50 C /min; carrier gas, He, flow: 1.0 ML/Min. Injection volume 1 micro liter. The percentage composition of the seed oil (g per 100 g) was computed by the normalization method from the GC peak areas, using nonane as internal standard and the response factors are reported.

Identification of the fatty acid composition: Fatty acid profile identification was done by comparing the NIST library data of the peaks with those reported in literature, mass spectra of the peaks with literature data and on computer search using digital libraries of mass spectral data (15-18) percentage composition was computed from GC peak areas with DB-5 ms column without applying correction factors.

RESULTS AND DISCUSSION

In *C. inophyllum,* seed variability and genetic analysis have been carried out for 30 progenies to identify the promising genetic resource for adoption in afforestation and reforestation and to inculcate in the second generation breeding programme. Significant variations were observed among 30 progenies of *C. inophyllum* for all the seed parameters *viz.,* pod length, pod width, seed length, seed width, hundred seed weight, germination per cent, germination value, mean daily germination, peak value and seed oil content. Only one progeny *viz.,* FCRICI 14 showed high values for all the seed parameter consistently. A plethora of workers have reported such seed variability due to progenies or seed sources or provenances in several species like *Pongamia pinnata* (Divakara *et al.,* 2010; Sunil *et al.,* 2012).

Among the seed characters, the 100-seed weight and germination per cent coupled with oil content are considered very effective in practical tree improvement and utilization programme. In the current study, 100-seed weight varied between 536.26 g and 442.44 g in *C. inophyllum.* Seed oil content is an essential parameter which decides the commercial viability. All progenies in *C. inophyllum* differed significantly due to oil content. The oil content ranged between 55.60 per cent and 35.67 per cent. Similar variation in oil content was observed due to various accessions of *Pongamia pinnata* (Sunil *et al.,* 2012). This study found that variation in oil content among accessions was due to altitudinal differences. The study found that lower altitude recorded 34 per cent oil content and higher altitude recorded low oil content. In the current study, the higher oil content was recorded by the progeny collected from Honnavara (altitude 15 m).

The variability among the 'Undi' progenies were in the order of 3.95 cm, 3.42 cm, 2.71 cm, 2.35 cm and 536.26 g, respectively for pod length, pod width, seed length, seed width and 100-seed weight characteristics of seeds (Table 2). Seed germination attributes were in the order of 73.00 per cent, 5.11, 3.06 and 55.60 per cent, respectively in the evaluated germination percent, germination value, peak value and seed oil content (Table 3). Among the seed characters the highest values were obtained with Honnavara (FCRICI 14) progenies. Similar variation on physical characteristics of seed were observed by Gairola *et al.* (2011) in *Jatropha curcas;* Sanjeev Kumar and Sanjay Singh (2014) in *J. curcas;* Wani and Wani (2013) in *Madhuca indica;* Mihiri and Jagath (2015) in *Madhuca longifolia* which were focused largely to the variations in ecological factors observed with the place of collection (mother land) of the source material. The seed source variations were reported in many tree species (Mishra and Banerjee, 1995; Thapliyal and Dhiman, 1997) and were controlled by environmental and edaphic factors. Variations due to altitude (Barnett and Farmer, 1978) or region of collection (Bonner, 1984) were also documented. In the present investigation, one progeny in *C. inophyllum* (FCRICI 14) exhibited superiority with respect to seed physical and germination attributes.

Table 2 Seed physical attributes of *Calophyllum inophyllum* progenies

Name of the Progeny	Seed Physical Attributes				
	Pod length (cm)	Pod width (cm)	Seed length (cm)	Seed width (cm)	100-seed weight (g)
FCRICI 1	2.91	2.23	1.95	1.87	485.52
FCRICI 2	3.43*	2.51	2.13	2.06**	499.51
FCRICI 3	3.06	2.69	1.91	1.75	442.44
FCRICI 4	2.49	2.56	2.13	2.03**	480.40
FCRICI 5	3.02	2.40	2.19	1.96*	485.46
FCRICI 6	2.98	2.56	2.09	1.47	490.19
FCRICI 7	2.97	2.45	2.13	1.51	482.31
FCRICI 8	2.93	2.50	2.08	1.38	434.29
FCRICI 9	3.37*	2.33	2.04	1.79	439.44
FCRICI 10	2.95	2.20	2.15	1.49	504.46*
FCRICI 11	2.43	2.43	2.00	1.45	476.58
FCRICI 12	2.89	2.38	2.03	1.32	485.31
FCRICI 13	2.75	2.59	2.00	1.42	472.51
FCRICI 14	3.95**	3.42**	2.71**	2.35**	536.26*
FCRICI 15	2.50	2.56	1.87	1.33	474.26
FCRICI 16	2.65	2.40	1.89	1.43	500.32
FCRICI 17	2.86	2.40	1.77	1.24	470.27
FCRICI 18	3.07	2.52	2.19	1.34	495.48
FCRICI 19	2.83	2.31	2.17	1.50	506.27*
FCRICI 20	2.62	2.91*	2.14	1.28	480.34
FCRICI 21	2.76	2.50	2.00	1.28	487.52
FCRICI 22	2.84	2.40	2.09	1.41	444.19
FCRICI 23	3.46*	2.30	2.13	1.28	501.18*
FCRICI 24	3.33*	2.83*	2.22	2.14**	495.62
FCRICI 25	2.99	2.68	2.52*	2.19**	450.38
FCRICI 26	2.77	2.70	2.31	1.50	510.35**
FCRICI 27	2.69	2.56	2.16	1.44	469.57
FCRICI 28	3.41*	2.46	2.07	1.48	468.37
FCRICI 29	2.90	2.57	1.88	1.42	522.21**
FCRICI 30	2.53	2.58	2.21	1.55	523.42**
Mean	2.94	2.53	2.11	1.59	483.81
SEd±	0.19	0.15	0.15	0.16	8.67
CD (0.05)	0.39	0.30	0.31	0.32	17.35
CD (0.01)	0.52	0.40	0.41	0.43	23.08

** Significant at 1% level; * Significant at 5% level

Table 3 Seed germination attributes of *Calophyllum inophyllum* progenies

Name of the Progeny	Seed Germination Attributes				
	Germination per cent	Germination value	Peak value	Mean daily germination	Oil content (%)
FCRICI 1	58.00	4.41	2.30	1.92	44.90
FCRICI 2	63.00	4.71*	2.85*	1.69	52.33**
FCRICI 3	56.67	3.68	1.92	1.93	47.77
FCRICI 4	51.00	3.87	2.18	1.79	42.60
FCRICI 5	53.00	3.32	2.09	1.59	49.63**
FCRICI 6	53.00	3.32	1.98	1.67	41.00
FCRICI 7	54.33	3.07	1.93	1.59	38.23
FCRICI 8	63.33	3.80	2.17	1.74	46.37
FCRICI 9	59.00	4.45	2.55	1.56	51.43**
FCRICI 10	54.67	3.10	1.97	1.57	45.83
FCRICI 11	49.00	3.64	2.06	1.77	44.40
FCRICI 12	59.67	3.50	2.04	1.70	43.67
FCRICI 13	53.33	3.48	2.20	1.57	50.57**
FCRICI 14	73.00**	5.11**	3.06**	1.79	55.60**
FCRICI 15	51.00	3.64	2.31	1.56	39.30
FCRICI 16	48.00	3.63	1.99	1.83	44.77
FCRICI 17	49.67	3.25	1.92	1.68	51.43**
FCRICI 18	54.00	3.48	2.02	1.73	45.50
FCRICI 19	50.67	2.88	1.98	1.43	43.53
FCRICI 20	41.67	2.54	1.77	1.44	43.00
FCRICI 21	49.67	2.53	1.68	1.51	43.63
FCRICI 22	47.33	3.26	1.89	1.72	46.33
FCRICI 23	51.00	3.62	1.98	1.82	48.17
FCRICI 24	51.00	2.63	1.68	1.73	37.86
FCRICI 25	47.00	2.96	1.87	1.66	48.33
FCRICI 26	50.67	2.90	2.09	1.40	35.67
FCRICI 27	52.33	2.24	1.70	1.33	47.70
FCRICI 28	49.67	2.72	1.98	1.52	44.45
FCRICI 29	52.33	2.63	1.74	1.53	44.70
FCRICI 30	49.33	3.29	2.06	1.58	46.30
Mean	53.21	3.39	2.06	1.64	45.50
SEd±	6.54	0.60	0.31	0.40	1.46
CD (0.05)	13.0	1.20	0.62	NS	2.93
CD (0.01)	17.4	1.59	0.82	NS	3.89

** Significant at 1% level; * Significant at 5% level

Estimation of seed oil content and quality of the identified genetic resources: Fatty acids are the products of seed cotyledon metabolism, which takes sucrose derived from photosynthesis and converts it into three major storage components, namely protein, starch and fatty acids. Fatty acids are synthesised by a well-defined pathway involving two carbon elongation and bond desaturation. Oleic acid is viewed as an optimal fatty acid for biodiesel production as it generates a low cloud-point fuel. Palmitic and stearic acids increase the cloud point, as these molecules have less mobility. More unsaturated C18 acids (C18:2 and C18:3) are less desirable as oxidation occurs (Paul *et al.,* 2008). The *C. inophyllum* shall have on impact most significantly through the extraction of seed oil for use in the manufacture of biodiesel. The fatty acid composition is the function of quality of oil. The current study identified the presence of following fatty acid *viz.,* palmitic, stearic, oleic, heptadecanoic, eicosenoic, docosadienoic, myristic, docosanoic, margaric and linoleic fatty acid compositions in *C. inophyllum* genetic resources. The seeds of *C. inophyllum* contained the seed oil content ranged between 55.60 per cent and 35.67 per cent (Table 3). The oil contains predominantly the oleic acid which ranged between 68.25 per cent and 56.42 per cent among the screened progenies (Tables 4 to 6). The oil contained predominantly oleic group of fatty acid which ranged between 12.39 per cent and 12.02 per cent among the screened progenies. Chavan Sangram and Keerthika (2013) reported the presence of 34 per cent oleic acid in *C. inophyllum* followed by other fatty acid which supports the findings of current investigation. The oleic acid is the mono unsaturated fatty acid which is very essential for biodiesel production (Gaurav Dwivedi *et al.,* 2011) and the predominant of oleic group of fatty acid identified in the current investigation will be useful for commercial biofuel production.

In conclusion, thirty progenies in *C. inophyllum* have been selected from the predominant growing areas in South India. The trees were identified based on morphometric traits *viz.,* tree height, girth at breast height (GBH) and crown diameter. From these trees, seeds were collected and deployed for seed characterization and progeny evaluation. Seed attributes expressed wider variability and one progeny in *C. inophyllum viz.,* FCRICI 14 registered superior seed characteristics. The oil quality analysis indicated the presence of oleic, palmitic and stearic acid groups and witnessed their suitability for biofuel utility.

Table 4 Fatty acid composition of *Calophyllum inophyllum* seed oil (FCRICI 14)

RT	Name of the compound	Molecular formula	MW	Peak Area %
879	Palmitic acid	C16H32O2	256	8.23
800	Stearic Acid	C18H36O2	284	8.23
739	Oleic Acid	C18H34O2	282	59.75
947	Heptadecanoic acid	C17H34O2	270	1.41
751	Eicosenoic Acid	C20H38O2	310	0.57
775	2,4 Docosadienoic acid	C22H40O2	336	17.66
953	Margaric acid	C17H34O2	270	1.41
787	Linoleic acid	C18H32O2	280	0.57

Table 5 Fatty acid composition of *Calophyllum inophyllum* seed oil (FCRICI 02)

RT	Name of the compound	Molecular formula	MW	Peak Area %
897	Palmitic acid	C16H32O2	256	18.42
876	Stearic Acid	C18H36O2	284	6.83
922	Oleic Acid	C18H34O2	282	68.25
947	Heptadecanoic acid	C17H34O2	270	0.46
751	Eicosenoic Acid	C20H38O2	310	0.08
953	Margaric acid	C17H34O2	270	0.46

Table 6 Fatty acid composition of *Calophyllum inophyllum* seed oil (FCRICI 17)

RT	Name of the compound	Molecular formula	MW	Peak Area %
796	Palmitic acid	C16H32O2	256	16.20
885	Stearic Acid	C18H36O2	284	6.23
920	Oleic Acid	C18H34O2	282	56.42
962	Heptadecanoic acid	C17H34O2	270	0.41
874	Eicosenoic Acid	C20H38O2	310	0.43
932	Margaric acid	C17H34O2	270	0.85

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GIS mapping and survey for powdery mildew severity on linseed (*Linum usitatissimum* L.) in Northern Karnataka

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ABSTRACT

Powdery mildew of linseed caused by *Leveillula taurica* (Lev.) Arn. is one of the economically important disease causing yield loss up to 60 per cent. Survey conducted in Northern Karnataka to assess the severity of linseed powdery mildew during *rabi* of 2014-15 revealed that mean maximum powdery mildew was observed in Raichur (98.00) followed by Bellari (32.50), Bidar (19.00), Vijayapura (17.66), Koppal (14.00), Yadgir (13.00) and least per cent disease index was observed in Kalaburgi (11.85). During the survey it was observed that the incidence of the disease was maximum in Raichur district, this may be due to the fact that crop coincides with the favourable weather factors such as cold temperature at night and warm days, no rainfall during crop growth period, continuous cultivation of linseed crop in the same area might have provided the primary source of inoculum.

Keywords: GIS, *Leveillula taurica,* Linseed, Powdery Mildew, Survey

Linseed (*Linum usitatissimum* L.) is a member of the family Linaceae, an important oilseed crop grown in temperate and tropical zone for its seed as well as fibre, further used in the manufacture of linen. Linseed occupies a greater importance among oilseeds owing to its various uses and special qualities. In India, it is grown mainly for seeds, used for extraction of oil. The oil content of the seed varies from 33 to 47 per cent. Linseed oil is an excellent drying oil used in the manufacturing of paints and varnishes, cloths, waterproof fabrics, pad ink, printed ink and linoleum and also as an edible oil in some areas. Linseed cake is a very good manure and animal feed hence priced 50 per cent higher than rapeseed-mustard cake. Linseed straw produces fibre of good quality and it will be used in making of paper and plastics. Linseed is globally cultivated for its fibres and is also called flax.

In India, Madhya Pradesh leads in yield and acreage, followed by Uttar Pradesh and Maharashtra. Madhya Pradesh and Uttar Pradesh together contribute to the national linseed production to the extent of about 70 per cent. In Bihar, Rajasthan, Karnataka and West Bengal also linseed is grown in large areas. In Karnataka the crop is grown in area of 11,000 ha with production of 4000 tonnes. Vijayapura leads with maximum area and production followed by Bagalkot, Koppal, Belgavi and Gadag (Anonymous, 2013).

Among the various diseases, the powdery mildew of linseed caused by *Leveillula taurica* (Lev.) Arn. is one of the economically important diseases that causes loss up to 60 per cent (Srivastava *et al.,* 1997). The disease usually covers host leaf surface and capsule hence reducing the photosynthetic area and activity. The disease occurs in severe form in *rabi* season, the main season for linseed cultivation, particularly when temperature is low (20-25°C) and humidity is high (80-90%). The major sign of the disease is appearance of whitish superficial colonies of pathogen. It causes white minute spots on the upper surface of the lower leaves, then spreads to younger leaves covering all parts of the plant. In severe cases, powdery mass also occurs on capsules, stems, resulting in withering and drying of leaves. Heavy infection may cause shrivelling of seed. The fungus has very wide host range and is present in nature throughout the year. In view of this survey was conducted to assess the severity of the disease in linseed growing districts of Karnataka.

MATERIALS AND METHODS

Survey for assessment of powdery mildew: A roving survey was conducted during January 2015 to know the severity of linseed powdery mildew in the farmers fields of different villages belonging to Raichur, Yadgir, Kalaburgi, Bidar, Ballari, Vijayapura and Koppal districts of Karnataka. Randomly linseed fields were selected in a village. In each field, 10 plants were randomly selected and powdery mildew severity was recorded by following 0-5 scale (Som Prakash and Saharan, 1999).

Disease scale:

Score	Infection	Disease reaction
0	0 per cent (Free from infection)	Immune
1	0.1 to 10 per cent plant parts infected	Resistant
2	10.1-25 per cent plant parts infected	Moderately resistant
3	25.1-50 per cent plants parts infected	Moderately susceptible
4	50.1-75 per cent plant parts infected	Susceptible
5	>75 per cent plant parts infected	Highly susceptible

Later Per cent Disease Index (PDI) was calculated by using the following formula proposed by Wheeler (1969).

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$$\text{Per cent disease index (PDI)} = \frac{\text{Sum of all the individual disease ratings}}{\text{Number of plants observed} \times \text{Maximum disease grade}} \times 100$$

At the same time work coordinates of the plots were recorded by using Global Positioning System (GPS) mobile and later the incidence was mapped by Geographic Information System (GIS) software.

Generation of spatial GIS maps for powdery mildew of linseed: Powdery mildew of linseed was assessed in seven districts of Northern parts of Karnataka with ground data by field survey. The methodology for generation of spatial GIS maps for assessing and distribution of linseed powdery mildew is given below.

a) Data collection: The collection of data at different places in *rabi* 2014-15 was planned to assess the spatial variability of powdery mildew of linseed. The survey was carried out by using Differential Global Positioning System (DGPS) (Trimble MAK - Geo XH), where the co-ordinates (latitudes and longitudes) were collected at each sampling point to map the spatial distribution of the disease. Each site was geo referenced in the Universal Transverse Mercator (UTM) co-ordinate system with a GPS for spatial analysis.

b) DGPS data import: The collected sample locations from DGPS were imported using path finder software. Since the projection system of collected locations were pre-defined in the DGPS, the imported sample points were found within the respective villages administrative boundary, when imported in the GIS environment.

c) Data attachment and mapping: The field observations of linseed powdery mildew were fed in excel sheet with proper labelling for each observation made. The unique ID was added and the physical ID was created along with the sample locations imported in the Arc GIS environment. Further the collected field data were attached to the respective GPS location points using ID 121 relationships in Arc GIS 2010. The disease incidence was displayed through unique symbol to understand the spatial distribution. The maps for spatial distribution of linseed powdery mildew were developed in surveyed districts *viz.,* Raichur, Yadgir, Kalaburgi, Bidar, Ballari, Vijayapura and Koppal. The DGPS used in study is the latest version (GEO-XH) from Trimble, which was enabled to receive the satellite signals to give more accurate location reading.

d) Computer software: Arc GIS 10 software from Precision Agriculture Research Laboratory, Department of Plant Pathology, College of Agriculture, Raichur was used for processing and analysis of the data.

RESULTS AND DISCUSSION

Survey for the powdery mildew of linseed was carried out in seven districts of Northern Karnataka during *rabi* 2014-15 to find out incidence and severity of the disease and the results revealed that powdery mildew was observed in all the surveyed fields with variation in the severity (Table 1). The spatial variability among the districts is shown in Fig. 1 to Fig. 6 which will be helpful in further assessment of the disease.

Maximum mean per cent disease index (PDI) of powdery mildew was observed in Raichur (98.00) followed by Ballari (32.50), Bidar (19.00), Vijayapura (17.66) and least PDI was observed in Kalaburgi (11.85). In Raichur district maximum powdery mildew was recorded on crop at flowering stage at MARS, Raichur (100), whereas in Ballari district, Hadagali has recorded maximum powdery mildew disease (37.00). Survey conducted in Kalaburgi district revealed that maximum powdery mildew was observed in Kamalapura village (20.00) followed by Mahagaon (18.00) and Kadagunchi (15.00) but least disease was observed in Nandikur (4.00).

In Bidar district, maximum PDI (28.00) was observed in Budhera village of Aurad taluk at flowering stage followed by Rajgira village (22.00) and least PDI was found in Mangalagi (12.00), whereas in Humnabad taluk, Bhangura village recorded maximum PDI (21.00) and least PDI was recorded in Mindhoola (15.00).

Survey data in Yadgir district showed that linseed powdery mildew was also observed in Agricultural College, Bheemrayanagudi (13.00) of Shahpur taluk. Among the two taluk surveyed in Vijayapura district, maximum powdery mildew PDI was observed in Indi village (21.00) followed by Thamba village (17.00) of Indi taluk. In Ballari district maximum PDI of powdery mildew was observed in Hadagali (37.00). In general powdery mildew severity was more during full flowering and it indicated that pre-flowering stage was more prone for infection (Dinesh *et al.,* 2009).

The variation of disease severity in various localities is mainly attributed to the climatic factors like temperature, relative humidity and distribution and amount of rainfall followed by cultural practices like intercropping, date of sowing, sanitation and other suitable management practices. The age of the crop (pre flowering and flowering) and cool nights and dry weather situation are more favourable for the powdery mildew disease to attain severity (Ajithkumar *et al.,* 2014).

When the age of the crop coincides with favourable weather conditions disease aggravates and cause severe loss. Symptoms were observed at all stages of crop but it was more when flowering stage of the crop coincides with favourable weather parameters which aggravates powdery mildew and become severe (Arjunan *et al.,* 1976; Sivaprakasam *et al.,* 1981). When there was less rain, cooler nights and high day temperatures, which were enough for dew formation and wide variation (13-15°C) in the maximum and minimum temperature and day and night relative humidity (39.9 - 51.7%) increased powdery mildew intensity in black gram (Anand Singh and Anil Sirohi, 2003). The highest severity of powdery mildew was attributed to temperature and relative humidity prevailed during crop period which was favourable for the chilli powdery mildew development and spread (Ashtaputre *et al.,* 2007).

Table 1 Severity of powdery mildew of linseed in Northern Karnataka during *rabi* 2014-15

District	Taluk	Village	Per cent disease index (PDI)	District mean PDI	Latitude	Longitude
Raichur	Raichur	MARS, Raichur	96.00	98.00		
		MARS, Raichur	100.00		77.33256	16.27663
Kalaburgi	Kalaburgi	Kalaburgi	12.00	11.85	76.82438	17.48678
		Nadisannur	06.00		76.99319	17.28387
		Nandikur	04.00		76.81516	17.2752
		Sulatanpur	08.00		76.81658	17.39809
		Kamalapura	20.00		76.98143	17.57167
		Mahagoan	18.00		76.91459	17.52096
		Kadagunchi	15.00		76.65934	17.44385
Yadagir	Shahapur	Bheemarayangudi	13.00	13.00	76.79235	16.73876
Koppal	Koppal	Gabbur	14.00	14.00	76.26226	15.36686
Bidar	Bidar	Satholi	17.00	19.00	77.47302	17.78786
		Rajgira	22.00		77.86588	17.86669
		Mangalagi	12.00		77.30089	17.75349
	Aurad	Budhera	28.00		76.89729	17.44446
		Muthangi	18.00		77.32169	17.65808
	Humnabad	Bhangura	21.00		77.44293	17.69144
		Mindhoola	15.00		77.48571	17.71745
Ballari	Hadagali	Hadagali - Field 1	37.00	32.50	75.01111	15.01726
		Hadagali - Field 2	28.00		75.93862	15.01676
Vijayapura	Sindagi	Hipparagi	15.00	17.66	76.11041	16.52756
	Indi	Indi	21.00		77.95541	17.17819
		Thamba	17.00		75.98834	17.03434

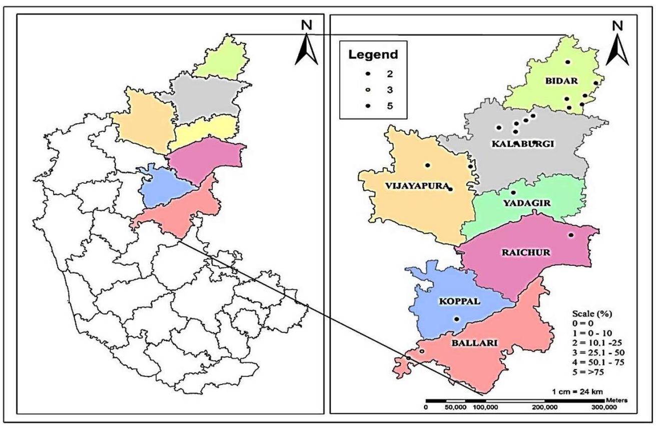

Fig. 1. Location map of selected districts of survey in Northern Karnataka during *rabi* 2014-15

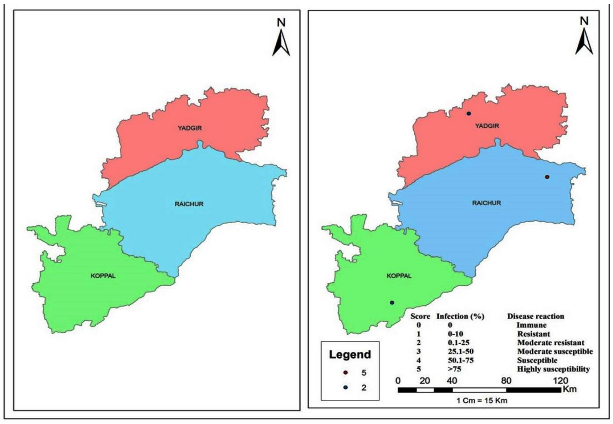

Fig. 2. Spatial variability of linseed powdery mildew in Yadgir, Raichur and Koppal district during rabi 2014-15

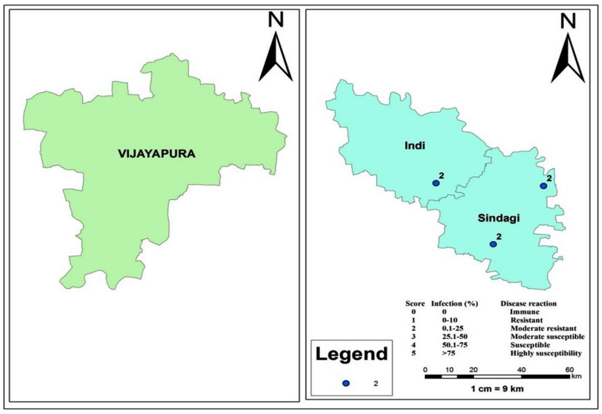

Fig. 3. Spatial variability of linseed powdery mildew in Vijayapura district during *rabi* 2014-15

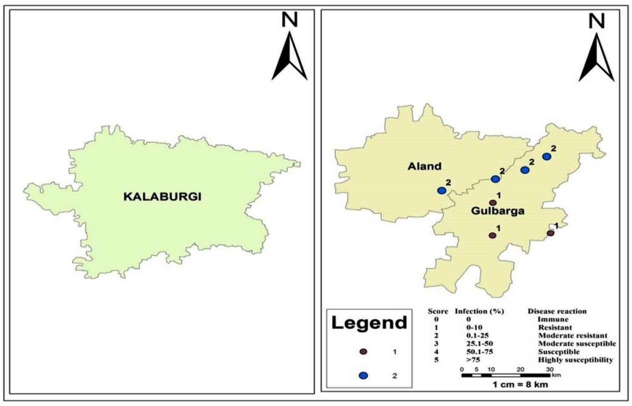

Fig. 4. Spatial variability of linseed powdery mildew in Kalaburgi district during *rabi* 2014-15

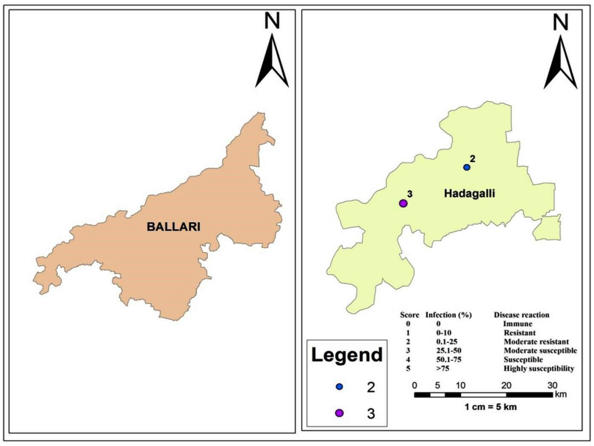

Fig. 5. Spatial variability of linseed powdery mildew in Bellari district during *rabi* 2014-15

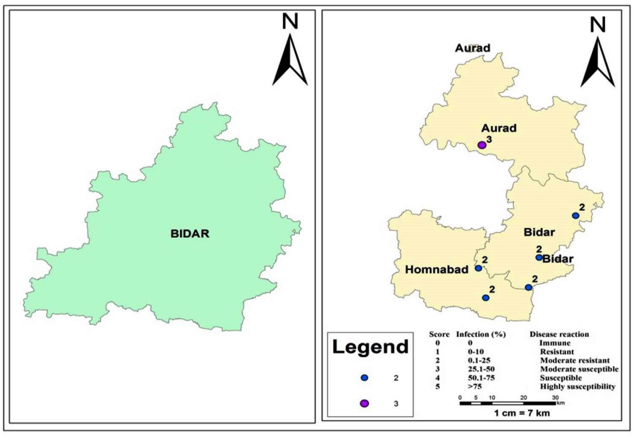

Fig. 6. Spatial variability of linseed powdery mildew in Bidar district during *rabi* 2014-15

The microclimate builds up due to close spacing and heavy crop canopy also helps in pathogen multiplication (Akhileshwari *et al.,* 2011). Less disease severity depends on factors such as location, cultural practices, susceptible cultivars grown, microclimate congenial for disease progress and meteorological factors such as temperature, relative humidity and rain. The higher incidence of powdery mildew was attributed to the temperature 27.8°C and minimum temperature 17°C with morning relative humidity of 66.30 per cent and evening relative humidity of 37.80 per cent prevailing during the crop period which were favourable for the disease development and spread (Ashtaputre *et al.,* 2007; Patil *et al.,* 2012).

In Raichur district maximum incidence was recorded (98.00%) during *rabi* 2014-15. This may be due to favourable temperature (28.6°C to 32.7°C) and relative humidity (56 to 96%) prevailing during the crop period. Moreover different genotypes of linseed were taken up for screening during the season in which susceptible lines helped for the build up of inoculum causing maximum disease severity of powdery mildew.

The disease was widely distributed in Northern parts of Karnataka and during *rabi* 2014-15 the average disease severity was more in Raichur district followed by Ballari and least was in Kalaburgi. Among the seven districts surveyed Raichur was identified to be the "hot spot" for powdery mildew of linseed. GIS mapping will help in further allocation, for the assessment of the disease with respect to temporal and spatial variability.

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Impact of improved production technology of groundnut (*Arachis hypogaea* L.) on farm productivity and income in Western Maharashtra

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ABSTRACT

Groundnut (*Arachis hypogaea* L.) is an important leguminous oilseed crop grown in India occupies an area of 5.49 million ha. The groundnut grown in Western Maharashtra was selected for the study with the objectives to study the employment, income and expenditure pattern, effects of improved production technology on per hectare resource use structure, costs and returns, constraints in adoption of improved technologies, input use gap and yield gap. The study was carried out in 15 tahsils, 30 groundnut growers were selected randomly i.e., 10 from each of the category of small, medium and large size farms. Thus, in all 450 groundnut growers (150 from each size group) were selected. The annual average employment of groundnut sample family was found to be 409.60 days. The total employment of a female worker of sample families was 90.33 days. The average annual gross income of the sample families at the overall level was ₹ 5,49,380. The crop production alone accounts near about half of the annual expenditure in all adoption groups. There exists an excessive gap (from 12 to 76%) in the use of manures. The gap in seed use was 32.79 per cent. The ICBR indicates that the high adopter farmers were in profit with 2.02. It clearly indicates that the farmers should adopt the improved technologies of groundnut to the fuller extent for maximizing returns and minimizing per unit cost. The yield gap was ranged between 68 to 88 and 43 to 78 per cent, respectively. The nine independent variables have jointly explained the 45 per cent variation in output for groundnut. The variables *viz.,* human labour, phosphorus, plant protection and number of irrigation were highly significant indicating that these are the important variables for which the output is responsive.

Keywords: Groundnut, Farm productivity, Impact, Improved production technology

Groundnut (*Arachis hypogaea* L.) is an important leguminous oilseed crop grown in India. It occupies an area of 5.49 million ha with productivity of around 1730 kg/ha (2012-13). It is grown in semi-arid regions of India, especially in the states of Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra. Among the total oilseed crops in Maharashtra, groundnut occupied an area of 277 thousand ha (2012-13). The crop is mainly grown under three situations *viz., kharif, rabi*/summer and residual moisture conditions on riverbeds (Satish Kumar *et al.,* 2004). Govindaraj (2010) stated that in recent years the utilization propositions have altered in India due to changes in trade and tariff policy after liberalization, availability of cheaper oils like soybean, sunflower and palm, and also due to urbanization induced as well as consumption shift.

The Government of India has launched the new scheme, "Integrated Scheme of Oilseeds, Pulses, Oil palm and Maize (ISOPOM)" which provides flexibility to states to implement the scheme based on a regionally differentiated approach for promoting crop diversification. In order to achieve the required production level of groundnut through higher productivity, in depth analysis of groundnut production methods and adoption pattern of technology is necessary (Hruday Ranjan *et al.,* 2014). Therefore, the pooled analysis on impact of improved production technology of groundnut on farm productivity and income in Western Maharashtra was undertaken for three years i.e., 2011-12, 2012-13 and 2013-14. The major oilseed crop groundnut grown in Western Maharashtra was considered for the study with the objectives to study the employment, income and expenditure pattern among the different adoption groups; to study the effects of improved groundnut production technology on per hectare resource use structure, costs and returns; to study the resource use productivities of major inputs of groundnut; to estimate the input use gap and yield gap of groundnut and to ascertain the constraints in adoption of improved groundnut production technologies.

MATERIALS AND METHODS

The three stage stratified random sampling design was adopted with tahsil as a primary unit, villages as the secondary unit and the oilseed grower as an ultimate unit of sampling. The study was conducted in 15 tahsils, which were selected on the basis of crop complex approach i.e. the proportionate area under groundnut crop, from 10 districts of Western Maharashtra. From each selected tahsil, a village (in case of non availability of required sample size, cluster approach was employed) having the highest area under groundnut was selected.

On the basis of operational holding, 30 groundnut growers were selected randomly i.e., 10 from each of the category of small (up to 2.00 ha.), medium (2.01 to 4.00 ha.) and large size farms (4.01 ha and above.). Thus, in all 450 groundnut growers (150 from each size group) were selected for the study.

Technology adoption index:

Extent of adoption of all technologies together was estimated by calculating Technology Adoption Index (TAI) as per Ranjitkumar's formulae as below:

TAI=

$$\frac{1}{K}\left[\frac{A_{X1}}{R_{X1}} + \frac{A_{X2}}{R_{X2}} + - + ---- + \frac{A_{Xn}}{R_{Xn}}\right] \quad x100$$

Where,

TAI = Technology Adoption Index (%)
K = No. of technology
A_{Xn} = Actual score of selected technology
R_{Xn} = Recommended score of selected technology

The selected farmers were grouped as low, medium and high adopters according to the mean and standard deviation of the calculated Technology Adoption Index as follows

Low adopters = Mean - SD
Medium adopters = Mean - SD to Mean + SD
High adopters = Mean + SD

Functional analysis

Resource productivity: The functional analysis was carried out by using Cobb-Douglas type of production function

$$Y = a\, X_1^{b1}\, X_2^{b2}\, X_3^{b3}\, X_4^{b4}\, X_5^{b5}\, X_6^{b6}\, X_7^{b7}\, X_8^{b8}\, X_9^{b9}\, e^u$$

Where,
Y= Output (q/ha)
X_1 = Human labour (mandays/ha)
X_2 = Bullock labour (pair days/ha)
X_3 = Manures (q/ha)
X_4 = Nitrogenous fertilizers (kg/ha)
X_5 = Phosphatic fertilizers (kg/ha)
X_6 = Potassic fertilizers (kg/ha)
X_7 = Plant protection (Rs./ha)
X_8 = No. of irrigations
X_9 = Technology adoption index (%)
a = Constant
u = Error term
bi's = Regression coefficients

Input use and yield gap: The yield gap was estimated by using the methodology developed by International Rice Research Institute (IRRI), Manila, Philippines. The methodologies for estimation of different types of yield gaps are:

Yield Gap I = Y_P - Y_a

Where,
Y_P = Potential Farm Yield (Yield realized on demonstration plots)
Y_a = Actual Yield (Yield realized on sample farm)

Yield Gap II = Y_d - Y_a

Where,
Y_d = Demonstration yield (Yield realized at research station)
Y_a = Actual yield (Yield realized on sample farms)

RESULTS AND DISCUSSION

Distribution of sample cultivators: The selected sample cultivators were grouped as low, medium and high adopters on the basis of estimated Technology Adoption Index (TAI) and shown in Table 1. The sample cultivators on technology adoption index were grouped as low, medium, high adopters. The per cent contributed by low adopters was 17.36, medium adopters 67.91 and high adopters 14.74. The technology adoption index ranged between 53 to 76 per cent for low to high adopters. The medium technology adoption farmers were more among three groups.

Employment, income and expenditure pattern: The average annual employment of farm families of the sample groundnut growers is given in Table 2. The annual average employment of groundnut sample family was found to be 409.60 days at the overall level. The annual average employment available on their own farm including crop production and livestock activity was observed to the tune of 69.13 per cent while crop production alone provided 47.75 per cent of total employment. The wage earning and services or business contributed for 9.13 and 15.64 per cent of total employment, respectively. The total annual employment of family worker was 384.71 days, 393.68 days and 482.89 days for low, medium and high adoption groups, respectively.

Annual employment of male worker: The average annual employment of male workers of the sample groundnut growers is given in Table 3.

The average annual employment of a male worker was the highest for high adoption group (375.91 days) followed by low adoption group (303.59 days) and medium adoption group (303.31 days) with an average of 319.26 days at the overall level. The own farm employment was estimated to 65.60 per cent of total employment at the overall level. It was the highest for low adoption group (69.41 per cent) followed by medium (67.73 per cent) and high (60.22 per cent) adoption group. The wage earning and services and other contributed 6.95, 20.07 and 7.38 per cent of total employment at the overall level. The off farm employment was highest (39.78%) in high adoption group and was followed by medium (32.27%) and low (30.59%) adoption group, respectively.

Annual employment of a female worker: The average annual employment of female workers of the sample growers is given in Table 4.

The total employment of a female worker of sample families was 90.33 days at the overall level. The share of own farm and off farm employment worked out to be 81.60 per cent and 18.41 per cent, respectively. The total employment of female worker was found to be highest for high (106.98 days) followed by medium (90.37 days) and low (81.11 days) adoption group. The highest own farm employment was observed for high (89.27%) followed by medium (81.36%) and low (75.21%) adoption group. The wage earning (20.31 days) contributed largely off-farm employment in the low adoption group of sample households. The wage earning was larger in low adoption group.

Table 1 Distribution of sample cultivators on technology adoption index

	Sample cultivators	TAI (%)	Number
Level of adoption	Low	Below 53.21	126 (17.36)
	Medium	53.22 – 76.19	493 (67.91)
	High	Above 76.20	107 (14.74)
	Total	726 (100.00)	726 (100.00)

Figures in the parentheses indicated percentages to respective total

Table 2 Annual employment of farm families (days/farm)

Particulars	Adoption group			
	Low	Medium	High	Overall
A. Own farm employment				
Crop production	190.93 (49.63)	194.38 (49.38)	212.63 (44.03)	195.59 (47.75)
Livestock activity	80.80 (21.00)	84.56 (21.48)	109.26 (22.63)	87.55 (21.37)
B. Off-farm employment				
Wage earnings	42.41 (11.02)	35.70 (9.07)	39.35 (8.15)	37.40 (9.13)
Service/Business	37.93 (9.86)	61.34 (15.58)	72.05 (14.92)	64.06 (15.64)
Others	32.63 (4.22)	17.69 (6.18)	49.60 (11.50)	24.99 (7.06)
Total employment	384.71 (100.00)	393.68 (100.00)	482.89 (100.00)	409.60 (100.00)

Figures in the parentheses are the percentages to the total employment

Table 3 Annual employment of male worker (days/farm)

Particulars	Adoption group			
	Low	Medium	High	Overall
A. Own farm employment				
Crop production	152.38 (50.19)	145.42 (47.94)	147.19 (39.16)	146.89 (46.01)
Livestock activity	58.35 (19.22)	60.00 (19.78)	79.20 (21.07)	62.54 (19.59)
B. Off-farm employment				
Wage earnings	25.94 (8.54)	20.01 (6.60)	27.88 (7.42)	22.20 (6.95)
Service/Business	37.93 (12.49)	61.34 (20.22)	72.05 (19.17)	64.06 (20.07)
Others	28.99 (9.55)	16.53 (5.45)	49.60 (13.19)	23.57 (7.38)
Total employment	303.59 (100.00)	303.31 (100.00)	375.91 (100.00)	319.26 (100.00)

Figures in the parentheses are the percentages to the total employment

Table 4 Annual employment of female workers (days/farm)

Particulars	Adoption group			
	Low	Medium	High	Overall
A. Own farm employment				
Crop production	38.55 (47.53)	48.96 (54.18)	65.44 (61.17)	48.70 (53.92)
Livestock activity	22.45 (27.68)	24.56 (27.17)	30.06 (28.1)	25.00 (27.68)
B. Off-farm employment				
Wage earnings	16.47 (20.31)	15.69 (17.36)	11.47 (10.73)	15.20 (16.83)
Service/Business	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Others	3.64 (4.49)	1.16 (1.29)	0.00 (0.00)	1.42 (1.57)
Total employment	81.11 (100.00)	90.37 (100.00)	106.98 (100.00)	90.33 (100.00)

Figures in the parentheses are the percentages to the total employment

Annual income of sample families: The per farm source wise annual gross income of sample farm families was depicted in Table 5. The average annual gross income of the sample families at the overall level was ₹ 5,49,380 and it ranged from ₹ 5,47,177 (low) to ₹ 5,49,886 (medium). The share of income received from crop production was 66.56 per cent followed by livestock (12.14%), service (8.53%), loan taken (5.34%), wages (5.16%) and business (2.27%) at the overall level. The income received from crop production was the highest for low adoption group (₹ 3,75,851) followed by medium (₹ 3,68,505) and high (₹ 3,40,642) adoption groups.

The income received from livestock production amounted to ₹ 66,692 at the overall level and it ranged from ₹ 61,862 (medium) to ₹ 83,318 (high) adoption groups. The income from wage earning and business was the highest in high adoption group.

Annual expenditure pattern of sample farm families: The per farm average annual expenditure of sample farm families is depicted in Table 6. The per family annual expenditure ranged between ₹ 2,80,189 (medium) to ₹ 3,42,651 (high) with an average of ₹ 2,95,800 at overall level. The crop production alone accounts near about half of the annual expenditure in all adoption groups. The cash expenses include purchased inputs like seed, fertilizer, plant protection chemicals and hired human, bullock, machine charges and they together accounted for more than that of expenses for imputed resources (own human, bullock, machine charges, rental value of land). The livestock activity constitute next important item of expenditure and it was ₹54,986 at the overall level.

As such, near about 8 per cent of the total expenditure was incurred for maintenance of family. The per family expenditure on food consumption incurred was ₹ 12,525 at the overall level and it ranged from ₹ 11,267 (low) to ₹ 12,824 (medium). The repayment of loan was the important item of expenditure ranged between 5.03 to 9.71 per cent related with loan used for farm and family. The investment in business was ₹ 1395 for low adoption group, ₹ 628 for medium with an average of ₹ 975 at the overall level.

Impact of improved technology of groundnut production

Resource use gap: The information on input use and input gap for technology adoption levels of the groundnut is shown in Table 7. Overall, there exists an excessive gap (from 12 to 76%) in the use of manures. The per cent gap in seed use was 32.79 and the use of chemical fertilizers showed that 'N' and 'K' were used at higher levels. This is due to the use of mixed fertilizers instead of straight fertilizers by the sample cultivators. Jadhav *et al.* (1993) studied the resource productivity in summer groundnut production in Sindhudurg district of Maharashtra in 1989-90. They found that there was excessive use of inputs and there was need to organize the allocation of resources.

Costs and returns structure: The information on costs and returns of groundnut is depicted through Table 8. The per hectare cost, returns and net profit is compared as per the adoption level of the oilseed technologies. It is revealed from the Table 9 that the per hectare yield is increased as farmers adopted more improved technologies of groundnut. The per hectare yield has increased from 5.36 to 14.02 quintal per hectare over the different level of adoption. The added yield was 2.56 q/ha and 6.10 q/ha over the low and medium level of adoption. Thus, for producing this extra yield per hectare costs were also increased from ₹ 5,291.27 to ₹ 8,047.17 and accordingly, the added returns were also increased from ₹ 8,828.97 to ₹ 16,230.50.

The ICBR indicates that the high adopter farmers were in profit with 2.02 ICBR ratio followed by medium adopters (1.67). It clearly indicates that the farmers should adopt the technologies of groundnut to the fuller extent for maximizing returns and minimizing per unit cost. Vanraj (2008) revealed that the average cost of cultivation is worked out as ₹ 15102.15 per hectare while the average yield of groundnut was 10.83 quintal.

Table 5 Annual incomes of sample families (₹/farm)

Particulars	Adoption group			
	Low	Medium	High	Overall
Crop production	375851 (68.69)	368505 (67.01)	340642 (61.98)	365673 (66.56)
Livestock	71475 (13.06)	61862 (11.25)	83318 (15.16)	66692 (12.14)
Wages	28380 (5.19)	27593 (5.02)	31776 (5.78)	28346 (5.16)
Service	31126 (5.69)	49380 (8.98)	53640 (9.76)	46840 (8.53)
Business	22527 (4.12)	9500 (1.73)	14311 (2.60)	12470 (2.27)
Loan taken	17819 (3.26)	33046 (6.01)	25952 (4.72)	29358 (5.34)
Total	5,471,77 (100.00)	5,49,886 (100.00)	5,49,640 (100.00)	5,49,380 (100.00)

Figures in the parentheses are the percentages to the respective total

Table 6 Annual expenditure pattern of sample farm families (₹/farm)

Particulars	Adoption group			
	Low	Medium	High	Overall
Crop production				
a) Cash expenses	124883 (39.60)	113776 (40.61)	128574 (37.52)	117885 (39.85)
b) Imputed resources	18637 (5.91)	18948 (6.76)	16277 (4.75)	18500 (6.25)
Livestock activity	65741 (20.85)	47657 (17.01)	76087 (22.21)	54986 (18.59)
Family expenditure				
a) Food consumption	11267 (3.57)	12824 (4.58)	12625 (3.68)	12525 (4.23)
b) Other expenditure	11818 (3.75)	11491 (4.10)	12293 (3.59)	11666 (3.94)
Business expenditure	1395 (0.44)	628 (0.22)	43 (0.01)	975 (0.33)
Loan repayment	15875 (5.03)	27208 (9.71)	20665 (6.03)	24277 (8.21)
Miscellaneous expenditure	65741 (20.85)	47657 (17.01)	76087 (22.21)	54986 (18.59)
Total expenditure	3,15,357 (100.00)	2,80,189 (100.00)	3,42,651 (100.00)	2,95,800 (100.00)

Figures in the parentheses are the percentages to the respective total

Table 7 Input use and gap for different levels of technology adoption in groundnut (per ha)

Resources	Groundnut			
	Adoption group			
	Low	Medium	High	Overall
1. Manure (q)				
Recommended	60	60	60	60
Actual	16.75	13.87	52.43	19.41
% Gap	72.08	76.88	12.62	67.65
2. Seed (kg)				
Recommended	125	125	125	125
Actual	71.61	87.92	83.11	84.01
% Gap	42.71	29.66	33.51	32.79
3. N (kg)				
Recommended	25	25	25	25
Actual	12.66	27.33	71.62	30.07
% Gap	49.36	-9.32	-186.48	-20.28
4. P (kg)				
Recommended	50	50	50	50
Actual	19.21	32.65	72.72	35.09
% Gap	61.58	34.70	-45.44	29.82
5. K (Kg)				
Recommended	0	0	0	0
Actual	5.17	8.41	9.38	7.89
% Gap	-105.17	-108.41	-109.38	-107.89

Note: "- ve" sign indicates excess than recommended levels

Table 8 Cost and returns from groundnut (per ha)

Item	Technology Adoption Level		
	Low	Medium	High
Yield (q)	5.36	7.92	14.02
Added yield (q)	-	2.56	6.10
% increase in yield	-	47.65	77.00
Cost C	27734.91	33026.18	41073.35
Added cost	-	5291.27	8047.17
Cost (₹/q)	5174.42	4169.97	2929.63
Unit cost reduction (₹/q)	-	1004.45	1240.35
% reduction	-	19.41	29.74
Returns ₹	31558.73	40387.70	56618.20
Added returns ₹	-	8828.97	16230.50
ICBR ratio	-	1.67	2.02

Table 9 Yield gap in groundnut production on farms (q)

Particulars	Low	Medium	High
Potential yield	45		
Actual yield	5.36	7.92	14.02
Yield gap I	39.64	37.08	30.98
% gap	88.09	82.4	68.84
Demonstration farm yield	25		
Actual yield	5.36	7.92	14.02
Yield gap II	19.64	17.08	10.98
% gap	78.56	68.32	43.92

Yield gap in groundnut production: The potential yield was 45 quintals/ha whereas the demonstration farm yield was 25 quintals/ha, respectively. However, for groundnut the yield gap ranged between 68 to 88 and 43 to 78 per cent, respectively (Table 9). In general, the yield gap (I and II) was maximum.

Yield gap-I referred to the difference between the potential yield and the actual yield and the difference between demonstration farm yield and the actual yield on the respective farms was referred to as yield gap-II. The similar results were found by Patil and Kunnal (1997). Swain (2013) reported an average potential yield of groundnut as 31.7 quintal per hectare and the average experimental yield as 29.7 q/ha.

Resource use productivity of groundnut production: The resource use productivity of groundnut production was estimated by using Cobb-Douglas production function and the results are presented in Table 10.

The nine independent variables have jointly explained the 45 per cent variation in output for groundnut. The variables *viz.,* human labour (X_1), phosphorus (X_5), plant protection (X_7) and number of irrigation (X_8) were highly significant at 1 per cent level of significance indicating that these are the important variables for which the output is responsive. The variables *viz.,* bullock labour and nitrogen use were negatively significant indicating that there was an excess use of these inputs and need to curtail up to recommendation level for increasing output.

Table 10 Results of Cobb-Douglas production function

Items			Groundnut (N=726)
Constant		(a)	0.5551
Human labour (Man days/ha)		X_1	0.1973*** (0.0314)
Bullock labour (Pair days/ha)		X_2	-0.09538 *** (0.0162)
Manure (q/ha)		X_3	-0.0180 ** (0.0070)
Fertilizers (kg/ha)	N	X_4	-0.0410*** (0.0175)
	P	X_5	0.0501*** (0.0158)
	K	X_6	0.0038 (0.0087)
Plant protection (₹/ha)		X_7	0.0471*** (0.0058)
Irrigation (No.)		X_8	0.0789*** (0.020)
Adoption Index (%)		X_9	0.1254* (0.0757)
R^2			0.45

Figures in the parentheses indicate the standard error of respective regression coefficient; ***, **, & * indicates the 1, 5, & 10 per cent level of significance

Extent of adoption of technology at different levels of adoption: The extent of adoption of improved technologies for groundnut are presented in Table 11. It is revealed that 90 per cent farmers adopted the recommended technology of ploughing followed by land use (76%), variety (80%), seed rate (73%) and seed treatment (57%) for groundnut. 100 per cent farmers were adopted the recommended technology of sowing time, weeding, nitrogen and phosphorous application for groundnut. The extent of adoption of technology *viz.,* thinning, number of irrigation, plant protection was very low using below 50 per cent than recommended technology adoption. Joshi *et al.* (2004) studied the impact assessment of crop and resource management technology in groundnut and reported that farmers partially adopted the concept of crop and resource management research products and modified the technology options according to their needs, convenience and resource endowments. Differential adoption of various components of the technology was observed. The adoption rate for improved varieties was about 84 per cent and for single super phosphate was about 70 per cent.

Constraints in adoption of improved production technology: The data for constraints in technology adoption of groundnut is depicted in Table 12. It is revealed that about 82 per cent sample cultivators reported high cost of ploughing followed by irregular electric supply (81%), non availability of chemical fertilizers at proper time (77%), non-availability of human/bullock labour for inter-culturing (77%), high cost of manure (70%) and high cost of chemical fertilizers (69%) of the selected cultivators.

Kamble (1990) revealed that non availability of improved implement, labour, high wage rate of labour, high cost of inputs and non availability of inputs in time and inadequate capital were the major constraints in adoption of improved groundnut production technology in Sakri taluka of Dhule district of Maharashtra state. Timely supply of inputs, making available simple implements and easily available loan facilities were the suggestions of farmers to overcome the constraints.

Table 11 Extent of adoption of technology on sample farm by groundnut growers (Per cent)

Technologies	Groundnut			
	Low	Medium	High	Overall
Land use	61.84	82.30	69.33	76.75
Preparatory Tillage				
Ploughing	86.84	89.84	96.00	90.35
Harrowing	63.16	67.79	79.33	68.91
Manure	13.61	28.12	64.07	31.62
Variety use	52.63	82.90	96.00	80.01
Sowing time	61.84	84.81	100.00	83.48
Seed rate	62.13	76.11	76.87	73.91
Seed treatment	50.00	56.07	73.33	57.89
Inter culturing				
Thinning	--	1.31	--	0.88
Weeding	100.00	100.00	100.00	100.00
Hoeing	26.32	63.77	64.67	57.68
Sowing distance	73.68	92.79	96.00	90.13
Fertilizers				
N	48.86	102.02	286.40	123.49
P	54.58	66.28	159.37	79.64
K	--	--	--	--
No. of Irrigation	35.58	39.62	58.00	41.97
Crop protection	3.95	17.38	13.33	14.47

In conclusion, the per cent contributed by low adopters was 17.36, medium adopters 67.91 and high adopters 14.74. The technology adoption index ranged between 53 to 76 per cent for low to high adopters. The medium technology adoption farmers were more among three groups. The annual average employment of groundnut sample family was found to be 409.60 days. The average annual employment of a male worker was the highest (375.91 days) for high adoption group. The total employment of a female worker of sample families was 90.33 days at the overall level. The average annual gross income of the sample families at the overall level was ₹ 5, 49,380 and it ranged from ₹ 5,47,177 (low) to ₹ 5,49,886 (medium). The per family annual expenditure ranged between ₹ 2,80,189 (medium) to ₹ 3,42,651 (high) with an average of ₹ 2, 95,800 at overall level. The crop production alone accounts near about half of the annual expenditure in all adoption groups. The ICBR ratio indicates that the high adopter farmers were in profit with 2.02 ICBR ratio and followed by medium adopters with ICBR ratio of 1.67. It clearly indicates that, the farmers should adopt the improved technologies of groundnut to the fuller extent for maximizing returns and minimizing per unit cost. The yield gap was ranged between 68 to 88 and 43 to 78 per cent, respectively. The nine independent variables have jointly explained the 45 per cent variation in output for groundnut. The variables *viz.,* human labour (X_1), phosphorus (X_5), plant protection (X_7) and number of irrigation (X_8) are the important variables for which the output is responsive.

Table 12 Constraints in adoption of improved production technology

Constraints	Groundnut (N=726)	
	No.	Per cent
High cost of ploughing	597	82.23
High cost of harrowing	45	6.20
High cost of manure	514	70.80
Non availability of quality manure	151	20.80
High cost of seed	296	40.77
Non-availability of seed at proper time	435	59.92
Non-availability of human/ bullock for interculturing	560	77.13
Costly weedicide	435	59.92
High cost of chemical fertilizers	501	69.01
Non availability of chemical fertilizers at proper time	564	77.69
Non availability of water	256	35.26
Irregular electric supply	591	81.40
Plant protection	280	38.57
Non awareness	75	10.33

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Influence of improved production technologies on productivity and economics of sunflower (*Helianthus annuus* L.) in Nichabanadhi sub-basin of Tamil Nadu

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ABSTRACT

Two hundred and fifteen on-farm demonstrations on improved production technology (IPT) for sunflower were carried out in 175 hectares of farmer's fields in Sankarankovil, Vasudevanallur and Kuruvikulam blocks of Tirunelveli district of Tamil Nadu from 2009-10 to 2011-12. The results revealed that the adoption of improved production technology favorably influenced growth, yield and economics of sunflower. Higher mean net returns of ₹ 34,818/ha with a benefit: cost ratio of 2.66 was obtained with improved production technologies in comparison to farmer's practice (mean net returns of ₹ 19,385/ha and benefit: cost ratio of 2.05). Adoption of IPT gained an additional net profit of ₹ 15,433/ha as compared to traditional method of sunflower cultivation.

Keywords: Economics, Improved production technology, Sunflower, Tamil Nadu

Sunflower (*Helianthus annuus* L.) is one of the most vital edible oilseed crop native to southern parts of USA and Mexico. In India, it is cultivated in an area of 2.0 million ha with the production of 1.46 million tonnes (DAC, 2015). In Tamil Nadu the production is 11,554 tonnes from the area of 8,720 hectares with the productivity of 1325 kg/ha (DES, 2015). Increasing the sunflower productivity by adopting location specific improved production technologies (IPT) become an essential component of sunflower cultivation. The traditional cultivation system comprises conventional method with local varieties, improper management practices and imbalanced application of fertilizers are the important factors limiting sunflower yield. Closer spacing is also one of the main constraints in obtaining high yield under conventional planting. Improved production technology (IPT) a new production technology is found to increase the productivity and profitability of sunflower growers. It has its own components *viz.,* improved/hybrid variety, seed treatment, soil test based balanced or recommended dose of nutrients, proper irrigation at critical stage and herbicide application for weed control (Kumar *et al*., 2013).

Nichabanadhi originates in Vasudevanallur reserve forest on the eastern slopes of Western Ghats in Sivagiri Taluk of Tirunelveli District, Tamil Nadu. Ullatrumottai and Pudumalai Kavu are the other two hills on the other side of Kerala State. This sub basin area is 565 sq.km out of which the hilly area is 62 sq.km. There are 18 anicuts, 15 system tanks and 151 non-system tanks in this sub basin. The command area is 5684 ha. The taluks covered by this sub basin are Sivagiri and Sankarankoil in Tirunelveli District and Sivakasi in Virudhunagar District of Tamil Nadu. The sub basin area is fully benefited by the northeast monsoon and marginally by southeast monsoon. The objective of this study was to adopt location specific improved production technologies (IPT) to get maximum productivity and profitability of sunflower crop. Two hundred and fifteen on-farm demonstrations on sunflower by adopting improved production technologies (IPT) were carried out in 350 ha of farmer's fields in Sankarankovil, Vasudevanallur and Kuruvikulam blocks of Tiruvelveli district of Tamil Nadu from 2009-10 to 2011-12 under Tamil Nadu - Irrigated Agriculture Modernization and Water Bodies Restoration and Management (TN-IAMWARM) project during September to January. The mean annual rainfall of this sub basin was less than 700 mm. Southwest monsoon contribute 150 mm (27%), while north-east monsoon contributes 550 mm (73%). This basin receives a major share on its rainfall during North east monsoon. The mean maximum and minimum temperature ranges from 34-37ºC and 20-23ºC, respectively. Relative Humidity ranges from 65-70 %. The soil types were in combination of Inceptisol, Alfisol and Vertisol. More prominent type was Vertisol. The textural range of the soil was from sandy clay loam to clay. The soil fertility status of the study area was usually low in organic matter, low in available nitrogen, medium in available phosphorus and high in available potassium. The soil reaction was neutral to slightly alkaline. The fertility status of the demonstration fields were estimated by standard procedures. Soil samples were analysed for organic carbon, alkaline permanganate oxidizable N, 0.5 M $NaHCO_3$-extractable P and available potassium by flame photometry. Two methods of sunflower cultivation *viz.,* IPT and conventional were compared by using the improved and hybrid varieties *viz.,* Nuvizeed, Cauverey-50, MSFH1 and BSH1. In IPT, the recommended dose of fertilizer as 60:90:60 kg NPK/ha with split doses of N and K, ridges and furrows formed with the spacing of 60 × 30 cm, 10 packets of *Azospirillum* mixed with 25 kg FYM and 25 kg of soil and applied on the seed line. Nitrogen in the form of urea, phosphorus as single super phosphate and potassium as muriate of potash were applied. Sulphur @ 20 kg/ha, foliar spray of borax 0.2% pointed spray to capitualm at ray floret opening stage, pre emergence herbicide pendimethalin @2 l/ha followed by hand weeding at 45 DAS. The local varieties being practiced by the farmers at adjacent field were considered as conventional method/farmers practice for control. The biometric observation on growth, yield attributes, seed and stover yields was recorded.

Adoption of the improved production technologies (IPT) increased the plant height, seed and stover yield (Table 1). The results on yield attributes revealed that IPT showed a favourable influence on all the growth and yield attributes of sunflower during all the study period. Adoption of IPT recorded maximum of 165.5 cm of plant height which was higher than that of conventional method of sunflower cultivation (126.5 cm). Ali *et al.* (2011) also observed maximum plant height with adoption of improved management practices. The maximum weight (71.6 g) and size of the capitulum (21.5 cm diameter) were observed in the adopted IPT. The minimum weight (53.4 g) and size of the capitulum (13.1 cm diameter) were noted in the fields followed the traditional conventional method (CM) of sunflower cultivation. The maximum number of filled seeds (1047 seeds/capitulum) and maximum test weight (62.6 g) were also recorded in the IPT adopted fields compared to conventional method of cultivation (799 seeds/capitulum and 48.2 g, respectively). Aditya and Krishnamurthi (2015) also obtained similar results.

Table 1. Comparison of improved production technology (IPT) and conventional method (CM) on yield and economic of sunflower

Parameters	Sankarankovil		Vasudevanallur		Kuruvikulam		Pooled Mean	
	IPT	CM	IPT	CM	IPT	CM	IPT	CM
Plant height (cm)	162.8	123.4	165.3	122.7	168.5	133.5	165.5	126.5
Size of capitulum (diameter in cm)	21.2	12.8	20.7	12.2	22.6	14.2	21.5	13.1
Weight of capitulum (g)	71.3	53.7	69.8	51.2	73.6	55.4	71.6	53.4
No. of seeds/capitulum	1035	748	1015	765	1093	883	1047	799
1000-seed of test weight (g)	62.8	47.7	60.4	47.2	64.5	49.8	62.6	48.2
Yield (q/ha)	25.35	17.25	24.48	17.76	26.17	18.35	25.33	17.79
Stover yield (q/ha)	65.3	44.4	63.6	45.8	67.3	51.5	65.46	47.23
Cost of cultivation (₹/ha)	20,875	16,835	20,540	16,475	21,450	17,125	20,955	16,812
Gross returns (₹/ha)	56,200	35,750	50,875	34,670	60,425	38,170	55,833	36,197
Net income (₹/ha)	35,325	17,835	30,335	19,275	38,795	21,045	34,818	19,385
B:C ratio	2.69	2.06	2.47	1.85	2.82	2.23	2.66	2.05

The effect of different improved production technologies in sunflower influenced seed and stover yields in three blocks. The IPT recorded maximum seed yield (25.33 q/ha) and stover yield (65.46 q/ha) in all three blocks over conventional method (17.79 and 47.23 q/ha, respectively. The increased seed yield in IPT was 42.4% over conventional method. Adoption of IPT with hybrid varieties, recommended fertilizer application, proper management practices on irrigation and weeding increased the plant growth, yield attributes and yield of sunflower. These results on higher seed yield in IPT corroborate with the earlier findings of Gajbhiye *et al.* (2013) and Venkattakumar *et al.* (2011). The economic feasibility of both method of sunflower cultivation revealed that the cost of cultivation was comparatively slightly higher in IPT due to efficient use of inputs *viz.,* hybrid seeds and fertilizers than that of conventional method. The mean cost of cultivation over the study period for IPT and conventional method was ₹ 20,955 and ₹ 16,812/ha, respectively (Table 1). The best gross income, net profit and benefit : cost ratio were also associated with IPT than conventional method of sunflower cultivation. Averaging the three years of study, IPT registered a total income of ₹55,833/ha and net profit of ₹34,818/ha as compared to ₹36,197/ha and ₹19,385/ha, respectively under conventional method. Higher BC ratio was also associated with IPT (2.66) than conventional method (2.05). Effective utilization of inputs as cost of cultivation coupled with higher gross and net income under IPT resulted additional economic benefit. Adoption of IPT gained an additional net profit of ₹15,433/ha as compared to traditional method of sunflower cultivation. The economic superiority of IPT as compared to conventional method of sunflower cultivation was also documented by Kadasiddappa *et al.* (2007) and Venkattakumar *et al.* (2011). The present study concluded that the improved production technology (IPT) is effective to maximize the production of sunflower (25.33 q/ha) and to bring better economic benefit (₹34,818/ha) for sunflower growers of Nichabanadhi sub basin of Tamil Nadu.

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Combining ability studies in groundnut (*Arachis hypogaea* L.) genotypes

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ABSTRACT

Combining ability analysis was carried out for 24 hybrids developed through line x tester mating design in groundnut. Non-additive gene action was predominant for all the characters studied. Based on the mean *gca* effects parents *viz.,* JL 777, RG 426 and JDR 66 could be selected for crossing programme to obtain yield improvement. Among the crosses, R 2001-3 x R 2001-2 registered significant *sca* effects. Hence pedigree breeding method could be adopted to isolate desirable recombinants. Crosses *viz.,* JL777 x R 2001-2 and JL777 x RG 426 could be exploited for recombination breeding.

Keywords: Combining ability, Gene action, Groundnut, Pod yield

Groundnut (*Arachis hypogaea* L.) is the major oilseed as well as food legume crop in India accounting for 20% of oilseed area and 23% of oilseed production in the country. Tamil Nadu is one of the leading groundnut producing state with an area, production and yield of 3.85 lakh hectares, 10.61 lakh tonnes and 2751 kg/ha, respectively. Groundnut is grown mostly under the rain-dependent situations during *kharif* (June-September) season and it accounts for 70% of total groundnut area in the state. Though the groundnut productivity of the state is still the highest among the different groundnut growing states in the country, the groundnut yield realized over the years showed fluctuations because of frequent changes in the rainfall pattern and also owing to long spell of drought experienced during the crop growth period. The groundnut plant is drought tolerant and is grown in many areas of the world where most other food legumes fail to produce a crop. However, insufficient water at the time of flowering and fruiting significantly reduces the pod yield in groundnut. Though several agronomic interventions (Wright and Nageswara Rao, 1994) to conserve the soil moisture and enhance the water use efficiency (WUE) (Hebbar *et al.,* 1994) are advocated, identifying groundnut genotypes tolerant to drought offers the best long term and cost effective solution. Various biometrical methods have been successfully employed to assess the genetic makeup of different genotypes for developing suitable breeding methodology. One such method is the line x tester analysis which provides valid information on combining ability effect of phenotypes. Accordingly, the present study was undertaken to estimate the combining ability effects for yield and its component characters in groundnut.

Ten genetically diverse groundnut genotypes were crossed in a line x tester mating fashion to obtain 24 hybrids. The lines *viz.,* JL 777, GPBD 4, PBG 6040, JL 839, R 2001-3, Kadiri 9 and testers identified as donor for drought tolerant genotypes *viz.,* JDR 65, JDR 66, R 2001-2 and RG 426 are involved. The hybrids were evaluated along with their parents in a randomized block design with two replications at Oilseeds Research Station, Tindivanam, Tamil Nadu during *rabi* 2014-15 with a spacing of 30 x 10cm. The recommended package of practices were followed throughout the growth period. Biometrical observations were recorded on plant height, branches per plant, pods per plant, root length, SPAD chlorophyll meter reading, dry matter production, harvest index and single plant yield and the combining ability analysis was carried out.

The analysis of variance revealed significant difference for all the traits studied except for SPAD chlorophyll meter reading (Table1). The magnitude of specific combining ability variance was higher than general combining ability for eight characters studied indicating the influence of non-additive gene action. Non additive gene action for these traits was earlier reported by Mothilal and Ezhil (2010) and Mothilal and Jayaramachandran (2014).

The first criteria for selection of desirable parent is its *per se* performance for the trait of interest. Among the ten parents evaluated in the present study, the parent line, JL 777 recorded significantly superior *per se* performance of branches per plant and single plant yield. Like wise PBG 6040 recorded significantly superior mean performance for harvest index (Table 2). Hence the parent may be chosen as a best parent. The tester parent JDR 66 had significantly higher single plant yield and dry matter production. The tester parent RG 426 recorded significantly higher pods per plant.

In certain cases, high *per se* performing parents may not transmit their superior traits to their offsprings. Hence general combining ability effect is considered as the second criteria of selection of superior parents. The estimate of *gca* effects of parents for different characters are given in Table 3. Among the lines JL 777 has recorded desirable *gca* effects for the flowing characters *viz.,* plant height, branches per plant and single plant yield. It was followed by GPBD 4 which registered favourable *gca* effects for pods per plant and single plant yield.

Perusal of the *per se* performance of 24 crosses revealed that the cross JL 777 x RG 426 registered significantly higher *per se* performance for pod yield/plant, dry matter production and single plant yield. It was followed by the crosses, JL 839 x RG 426, R 2001-3 x R 2001-2 and Kadiri 9 x RG 426 recorded significant *per se* performance for single plant yield (Table 4).

Exploitation of hybrids for heterosis breeding is judged by *sca* effects (Table 5). Among the 24 hybrids R 2001-3 x R 2001-2 recorded high positive *sca* effects for single plant yield. Such cross could be exploited through pedigree breeding which may give superior performing segregants in the later generations. Further the crosses, JL 777 x RG 426, JL 839 x JDR 66, Kadiri 9 x RG 426 and Kadiri 9 x JDR 65 exhibited significant *sca* effects for pod yield/plant. The cross involved parents with poor combiners indicating operation of non additive gene action in controlling these traits. Hence biparental mating followed by selection might be worthwhile for fostering greater recombination in this cross (Francier and Ramalingam, 1999).

Table 1 Analysis of variance for combining ability

	Plant height (cm)	Branches per plant	Pods per plant	Root length (cm)	SPAD meter reading	Dry matter production (g/plant)	Harvest index (%)	Single plant yield (g)
Lines	35.37	7.00**	42.27**	0.99	27.78	21.5	321.3**	50.51**
Testers	61.76**	0.06	4.61	1.72	24.2	12.9	46.3	0.14
Line x Tester	14.82	1.54	8.18	1.92*	26.59	25.2*	103.6	14.09**
gca	0.4	0.03	0.26	-0.009	-0.002	-0.09	1.51	0.23
sca	12.79	0.65	5.32	0.35	5.39	5.61	41.9	9.68
gcs/sca	0.031	0.046	0.049	0.026	0.000	0.016	0.036	0.024
Error	9.06	1.31	5.97	0.9	37.9	9.28	63.3	0.69

*, ** Significance at P = 0.05 and P = 0.01 level, respectively

Table 2 Mean performance of parents

	Plant height (cm)	Branches per plant	Pods per plant	Root length (cm)	Dry matter production (g/plant)	Harvest index (%)	Single plant yield (g)
Lines							
JL 777	27.7	8.7*	11.5	6.3	13.0	38.3	12.0*
GPBD 4	22.5	8.2*	11.0	6.3	16.7*	43.6	9.3
PBG 6040	25.4	6.7	7.0	6.7	7.7	54.7*	6.5
JL 839	29.4	4.5	10.5	6.0	7.7	46.5	9.4
R 2001-3	31.5*	5.7	12.9*	6.2	10.8	47.3	9.3
Kadiri 9	29.4	5.8	10.3	5.7	9.2	50.4	7.8
Mean	27.6	6.6	10.5	6.2	10.8	46.8	9.0
SEd±	1.5	0.6	1.2	0.5	1.5	4.0	0.4
CD (5%)	3.1	1.3	2.4	1.0	3.1	7.0	0.8
Testers							
JDR 65	30.7	6.2	10.2	7.0	15.3	33.5	8.4
JDR 66	28.4	6.0	11.7	7.0	15.5*	35.3	9.2*
R2001-2	32.2	5.5	7.0	6.2	11.7	44.1*	6.9
RG 426	27.3	5.2	12.2*	7.0	9.3	42.3	9.2*
Mean	29.6	5.7	10.3	6.8	13.0	38.8	8.4
SEd±	1.2	0.5	1.0	0.4	1.2	2.2	0.3
CD (5%)	2.5	1.0	2.0	0.8	2.5	4.5	0.7

From the foregoing discussion, it was concluded that the parents *viz.,* JL 777, RG 426 and JDR 66 could be extensively used in the hybridization programme as these genotypes possessed good combiners for pod yield/plant, dry matter production, number of pods/plant and branches/plant. The cross R 2001-3 x R 2001-2 involved parents are good combiners. Hence pedigree breeding method could be adopted to isolate desirable recombinants.

The criteria for the selection of hybrids for recombination breeding is that the parents should have significant *gca* effects and the hybrids with non-additive *sca* effects (Nadarajan, 1986). The segregation of these hybrids will throw additive genes from both the parents. Based on these criteria, the hybrids JL777 x R 2001-2 and JL777 x RG 426 are recommended for recombination breeding for isolation of early segregant in groundnut.

Table 3 General combining ability effects of parent

Genotypes	Plant height (cm)	Branches per plant	Pods per plant	Root length (cm)	Dry matter production(g/plant)	Harvest index (%)	Single plant yield (g)
JL 777	-3.7**	1.59**	1.31	-0.17	1.85	-1.19	1.85**
GPBD 4	0.2	-1.2**	-2.8**	-0.29	-0.65	0.71	-2.93**
PBG 6040	-1.08	-0.49	-3.02**	0.15	-1.49	-6.78	-3.45**
JL 839	1.53	-0.24	1.13	-0.42	1.97	-0.79	1.68**
R 2001-3	1.86	0.115	1.1	0.25	-1.86	8.26**	2.04**
Kadiri 9	1.18	0.029	2.29*	0.49	0.18	5.79*	0.81
SE (gi)	1.5	0.57	1.22	0.48	1.52	3.98	0.42
JDR 65	0.95	0.05	-0.47	0.41	-1.39	-2.13	-0.09
JDR 66	-1.54	0.002	0.19	-0.08	0.58	-0.57	0.16
R 2001-2	2.75*	-0.09	-0.51	0.15	-0.17	2.58	-0.01
RG 426	-2.15*	0.04	0.8	-0.48	0.97	0.12	-0.05
SE (gj)	1.28	0.47	0.99	0.38	1.74	3.25	0.34

*, ** Significance at P = 0.05 and P = 0.01 level, respectively

Table 4 Mean performance of hybrids

Hybrids	Plant height (cm)	Branches per plant	Pods per plant	Root length (cm)	Dry matter production (g/plant)	Harvest index (%)	Single plant yield (g)
JL 777x JDR 65	24.9	6.9	11.0	5.7	5.7	21.7	9.0
JL 777x JDR 66	21.5	7.9	9.7	5.9	14.3	40.2	12.2*
JL 777x R 2001-2	23.7	8.5*	10.2	7.5	15.7	44.4	7.7
JL 777x RG 426	21.7	8.4	12.4*	6.6	20.2*	28.0	14.2*
GPBD 4 x JDR 65	23.5	5.2	7.7	7.5	16.5	46.3	5.2
GPBD 4 x JDR 66	25.5	3.9	7.2	7.4	9.7	35.1	6.0
GPBD 4 x RG 426	34.4*	5.5	6.1	5.8	7.3	45.2	8.0
GPBD 4 x R 2001-2	24.0	5.9	5.9	4.5	12.3	39.4	4.7
PBG 6040 x JDR 65	27.7	5.2	4.5	6.3	8.8	34.7	5.4
PBG 6040x JDR 66	20.4	6.9	6.4	7.0	12.2	30.4	5.7
PBG 6040 x R 2001-2	30.8	4.7	9.0	7.0	9.3	37.8	5.8
PBG 6040 x RG 426	23.3	6.5	6.0	6.6	12.2	33.1	5.0
JL 839 x JDR 65	30.2	6.7	11.7	6.0	11.8	29.7	11.0*
JL 839 x JDR 66	29.0	6.2	11.9	6.2	13.5	45.0	14.0*
JL 839 x R 2001-2	26.9	6.0	8.3	6.4	18.7*	42.9	8.9
JL 839 x RG 426	26.5	5.4	10.7	6.1	12.3	42.3	8.5
Kadiri 9 x JDR 65	29.2	7.7	9.5	7.0	10.2	46.1	14.0*
Kadiri 9 x JDR 66	26.7	6.2	11.5	6.3	12.7	52.8*	8.4
Kadiri 9 x R 2001-2	29.7	6.4	11.5	7.3	8.5	49.6*	8.7
Kadiri 9 x RG 426	28.5	5.2	9.9	6.7	9.7	47.6	12.8*
R 2001-3x JDR 65	30.0	6.5	9.8	9.5	11.3	53.3	8.4
R 2001-3x JDR 66	27.5	6.9	11.5	6.2	13.8	37.7	8.2
R 2001-3x R 2001-2	30.9	6.2	8.8	6.5	12.2	40.3	14.4*
R 2001-3x RG 426	22.8	6.8	17.0	6.1	11.8	55.0*	8.0
Mean	26.6	6.3	9.5	6.6	12.1	40.7	8.9
SEd±	3.0	1.1	2.4	1.0	3.1	8.0	0.8
CD (5%)	6.0	2.3	4.9	1.9	6.2	8.0	1.7

*,** Significant at P=0.05 and P=0.01 level, respectively.

Table 5 Specific combining ability effects of parent

Hybrids	Plant height (cm)	Branches per plant	Pods per plant	Root length (cm)	Dry matter production (g/plant)	Harvest index (%)	Single plant yield (g)
JL 777x JDR 65	0.99	-1.09	0.67	-1.16	-6.9**	-9.72	-1.67
JL 777x JDR 66	0.13	-0.04	-1.29	-0.42	-0.21	7.17	1.28
JL 777x R 2001-2	-2.01	0.71	-0.14	-0.9	1.87**	8.26	-3.05
JL 777x RG 426	0.89	0.42	0.75	0.68	-5.24**	-5.72	3.44*
GPBD 4 x JDR 65	-4.31	0.01	1.43	0.76	6.43**	6.92	-0.68
GPBD 4 x JDR 66	0.18	-1.24	0.28	0.121	-2.38	-5.84	-0.13
GPBD 4 x RG 426	4.79	0.51	-0.08	-0.68	-3.96	1.1	2.04
GPBD 4 x R 2001-2	-0.66	0.72	-1.63	-1.29	-0.09	-2.18	-1.23
PBG 6040 x JDR 65	1.22	-0.65	-1.49	-0.84	-0.4	2.87	-0.02
PBG 6040x JDR 66	-3.65	1.05	-0.3	0.36	0.96	-3.04	0.08
PBG 6040 x R 2001-2	2.52	-1.05	3.05	0.12	-1.13	1.2	0.35
PBG 6040 x RG 426	-0.08	0.66	-1.26	0.36	0.57	-1.03	-0.41
JL 839 x JDR 65	1.12	0.6	1.5	-0.56	-0.86	-8.13	0.51
JL 839 x JDR 66	2.4	0.1	1.05	0.08	-1.17	5.61	3.25*
JL 839 x R 2001-2	-4.03	0.05	-1.08	0.05	4.75*	0.35	-1.73**
JL 839 x RG 426	0.52	-0.74	-0.76	0.43	-2.72	2.17	-2.03**
Kadiri 9 x JDR 65	-0.28	1.26	-0.62	-0.23	1.3	-0.78	3.14**
Kadiri 9 x JDR 66	-0.3	-0.14	0.73	-0.44	1.84	4.36	-2.26**
Kadiri 9 x R 2001-2	-1.58	0.11	1.43	0.32	-1.58	-2.05	-2.29**
Kadiri 9 x RG 426	2.17	-1.23	-1.53	0.36	-1.56	-1.53	1.9**
R 2001-3x JDR 65	1.27	-0.13	-1.5	2.03**	0.43	8.84	-1.28**
R 2001-3x JDR 66	1.25	0.27	-0.46	-0.78	0.96	-8.26	-1.73**
R 2001-3x R 2001-2	0.32	-0.33	-2.46	-0.71	0.04	-8.87	4.69**
R 2001-3x RG 426	-2.83	0.18	4.43*	-0.53	-1.43	8.29	-1.67**
SE(gij)	3.01	1.44	2.44	0.95	3.05	7.95	0.83

*, ** Significance at P = 0.05 and P = 0.01 level, respectively

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Biological and chemical management of diseases of safflower (*Carthamus tinctorius* L.)

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ABSTRACT

An experiment was carried out to evaluate the efficacy of different bio-agents and chemicals against seed and soil borne diseases of safflower. Significantly low per cent disease incidence was recorded in treatments with bio-agents, *Trichoderma harzianum* Th4d SC @ 2ml/kg seed (36.8% for Alternaria leaf spot, 26.4% for wilt and 18.3% for blight) and *Pseudomonas fluorescens* Pf2 WP @5g/kg seed (38.2% for Alternaria leaf spot, 26.4% for wilt and 28.2% for blight), which are on par with chemical treatments. Further, *T. harzianum* and *P. fluorescens* seed treatments resulted in higher seed yields (924 kg/ha and 915 kg/ha, respectively) which are statistically at par with chemical treatment, carbendazim + mancozeb @ 0.2% (932 kg/ha).

Keywords: Management, Safflower, Seed and soil borne diseases

Safflower (*Carthamus tinctorius* L.) is one of the most important oilseed crops of the world valued for its highly nutritious edible oil. It is a multipurpose crop having various uses like source of edible oil, cattle feed, medicinal and industrial products. Safflower is known to suffer from many fungal and bacterial diseases among them seed borne disease *viz.,* Alternaria leaf spot/blight (ALS) caused by *Alternaria carthami* and soil borne diseases *viz.,* wilt (*Fusarium oxysporum* f.sp. *carthami*) and Phytophthora blight (*Phytophthora carthami*) are major and attack at different stages of crop growth (Bhale *et al.,* 1998). Seed/soil borne pathogen particularly fungal pathogens affects directly and indirectly the quality and quantity of the oilseed crops in terms of deterioration and reduction in oil content, germination, viability of seed and potential losses in yields. Foliar diseases deteriorate the petal quality thus leading to reduction of medicinal values. Keeping this in view, the present study was carried out to evaluate the efficacy of bio-agents and chemicals towards management of these pathogens.

The field experiment was conducted at Agricultural Research Station, Tandur, Rangareddy district, Telangana during 2011-12 post rainy season in Randomized Block Design under black soil situation with minimal irrigations. Sowing was done at spacing of 45 m x 20 cm with dibbling method and variety used was Nira. The experiment comprised of eight seed treatments and untreated control with three replications as given in Table 1. Bio-agents were obtained from Directorate of Oilseeds Research, Rajendranagar, Hyderabad. Chemical seed treatment was done in dry seed treatment following the dosage given vide Table 1. SC formulation of *Trichodrma harzianum* Th4d was treated as wet seed treatment @ 2ml/kg seed just before the sowing and dried under shade. WP formulation of *Pseudomonas flourescens Pf2* was coated as dry seed dressing @5g/kg seed. Observations on disease incidence along with seed yield were recorded. The data subjected to statistical analysis using OP-STAT software. Economic analysis on gross and net returns was done and benefit cost ratio was calculated.

Percent Disease Incidence (PDI) levels of seed and soil borne diseases under different treatments revealed that carbendazim + mancozeb seed treatment (T_1) found most effective with least PDI of 33.4% for controlling seed borne ALS followed by carbendazim (T_2) with 36.2% PDI (Fig. 1.). Rajpurohit and Sushma Nema (2013) also reported that foliar sprays of carbendazim combination chemicals were most effective in managing the Alternaria leaf spot in sesame. For soil borne wilt and blight diseases, cymoxanil+mancozeb treatment (T_4) was the most effective (10.8% and 10.3%, respectively) followed by tebuconazole treatment for wilt (14.6%) and Th4d SC for blight (18.3%). Among the two bio-agents, *T. harzianum* Th4d SC formulation @ 2ml/kg seed (T_7) was found superior with lower disease incidence levels which are statistically on par with the best chemical treatment i.e., carbendazim + mancozeb (T_1) for ALS and cymoxanil+mancozeb (T_4) for wilt and blight. These results are in confirmation with Pawar *et al.* (2013) who reported that Th4d SC formulation reduce disease incidence levels to the tune of 41.66% in *Fusarium* sp., 8.33% in *Rhizoctonia* sp., 6.66% in *Phytophthora* sp., 4.33% in Alternaria leaf spot and 3.33% in *Cercospora* leaf spot under Maharashtra conditions. *Pf2* WP@5g/kg seed (T_8) found next best with PDI levels of 38.2%, 26.4% and 28.2% for ALS, wilt and blight, respectively with significant reduction over control. Several workers reported the efficacy of *Trichoderma* and

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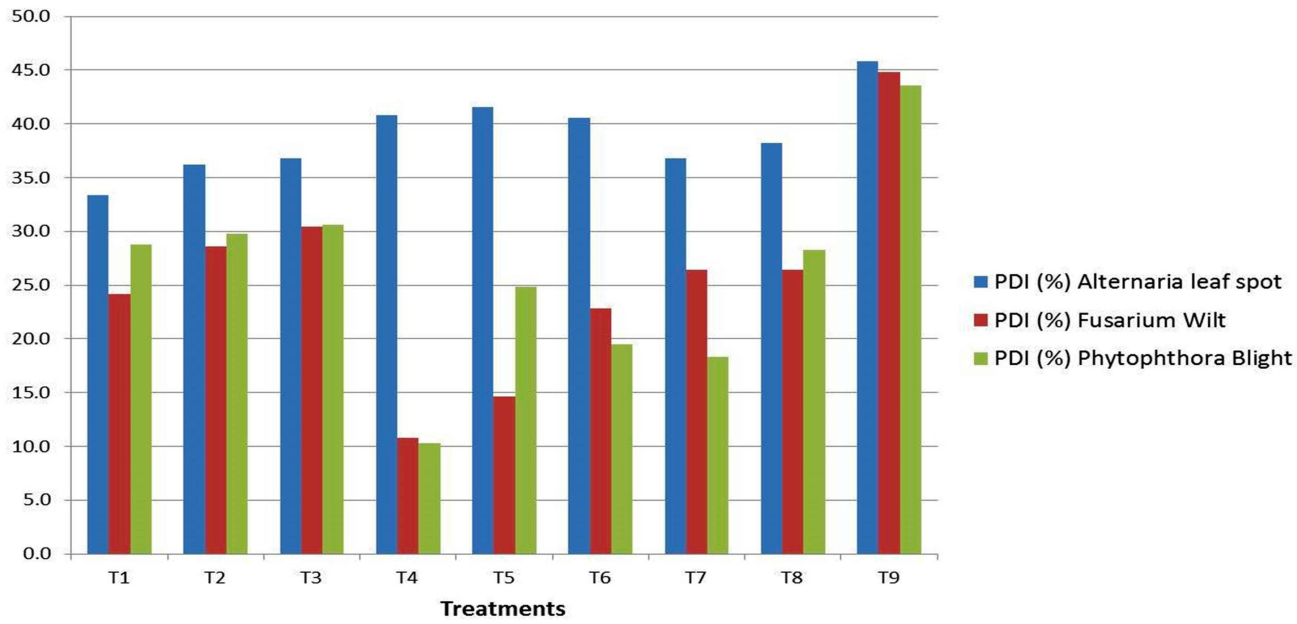
Pseudomonas antagonists for the management of several soil and seed borne diseases of different crops (Suresh *et al.,* 2011; Suresh *et al.,* 2012).

The economic analysis of the data on seed yield, gross and net returns (Table 1) revealed that cymoxanil+mancozeb (T_4) resulted in highest yield (948 kg/ha) followed by carbendazim + mancozeb (T_1) and *T. harzianum* Th4d SC (T_7) which are statistically on par (932 and 924 kg/ha, respectively) emphasizing the efficacy of bio-agents in improving the yields as good as chemicals along with disease control. Cymoxanil+mancozeb treatment (T_4) found highly effective with highest B:C ratio of 4.3 over the other treatments. Further, seed treatments with bio-agents resulted in higher B:C ratios of 4.2 and 4.1 for *T. harzianum* Th4dSC and *P. fluorescens Pf2*WP, respectively. These results confirm the results of earlier works (Pawar *et al.,* 2013; Prasad and Suresh, 2012) that bio-agents can be used for effective management of seed and soil borne diseases without compromising for yield or returns.



T_1 - Carbendazim + Mancozeb @ 0.2%; T_2 - Carbendazim @ 0.2%; T_3 - Captan @ 0.2%; T_4 - Cymoxanil+Mancozeb 64% @ 0.2%; T_5 - Tebuconazole @ 0.1%; T_6 - Metalaxyl + Mancozeb 64% @ 0.2%; T_7 - *Trichoderma harzianum* Th4d SC @ 2 ml; T_8 - *Pseudomonas fluorescens* Pf2 WP@5g; T_9-Check (Water spray)

Fig. 1. Efficacy of chemicals and bio-agents for management of safflower diseases

Table 1 Economics of seed treatments with chemicals and bio-agents for management of safflower diseases

Treatments	Yield (kg/ha)	Gross returns (₹)	Cost of cultivation (₹)	Net returns (₹)	B:C ratio
T_1 - Carbendazim + Mancozeb @ 0.2%	932	20504	4864	15640	4.2
T_2 - Carbendazim @ 0.2%	858	18876	4866	14010	3.9
T_3 - Captan @ 0.2%	786	17292	4864	12428	3.6
T_4 - Cymoxanil+Mancozeb 64% @ 0.2%	948	20856	4888	15968	4.3
T_5 - Tebuconazole @ 0.1%	758	16676	4874	11802	3.4
T_6 - Metalaxyl + Mancozeb 64% @ 0.2%	865	19030	4894	14136	3.9
T_7 - *Trichoderma harzianum* Th4d SC @ 2 ml	924	20328	4860	15468	4.2
T_8 - *Pseudomonas fluorescens* Pf2 WP@5g	915	20130	4858	15273	4.1
T_9 - Check (Water spray)	328	7216	4850	2366	1.5
CD (P=0.05)	46.3	-	-	-	-

Seed treatment chemicals cost: carbendazim + mancozeb @ 0.2% - ₹ 70/100g; carbendazim @ 0.2% - ₹ 80/100g; captan @ 0.2% - ₹ 70/100g; cymoxanil+mancozeb 64% @ 0.2% - ₹ 190/100g; tebuconazole @ 0.1% - ₹ 240/100ml; metalaxyl + mancozeb 64% @ 0.2% - ₹ 220/100g; *Trichoderma harzianum* Th4d SC@ 2 ml – ₹ 50/100ml; *Pseudomonas fluorescens* Pf2 WP@5g – ₹ 15/100g; Market rate of safflower seed – ₹ 22/kg

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JOURNAL OF OILSEEDS RESEARCH

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2. **Short Communication**, not more than 1300 words (total 5 typed pages), which deal with (I) research results that are complete but do not warrant comprehensive treatment, (ii) descriptions of new material or improved techniques or equipment, with supporting data, and (iii) a part of thesis or study. Such notes require no headed sections.
3. **Critical Research Review Articles**, showing lacunae in research and suggesting possible lines of future work. These are mostly invited from eminent scientists.
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6. **Title** should be short, specific and information. It should be phrased to identify the content of the article and include the nature of the study and the technical approach, essential for key-word indexing and information retrieval.
7. **A Short Title** not exceeding 35 letters should also be provided for running headlines.
8. **By-line** should contain, in addition to the names and initials of the authors, the place (organization) where research was conducted. Change of address should be given as a footnote, e-mail ID and correspondence address separately.
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11. Relevant details should be given of the **Materials and Methods** including experimental design and the techniques used. Where the methods are well known, citation of the standard work in sufficient. Mean results with the relevant standard errors should be presented rather than detailed data. The statistical methods used should be clearly indicated.
12. **Results and Discussion** should be combined, to avoid repetition.
13. The results should be supported by brief but adequate tables or graphic or pictorial materials wherever necessary. Self-explanatory tables should be typed on separate sheets, with appropriate titles.
14. The tables should fit in the normal layout of the page in portrait style. All weights and measurement must be in SI (metric) unit. Tables and illustrations (up to 20% of text) should not reproduce the same data.
15. The discussion should relate to the limitations or advantages of the author's experiment in comparison with the work of others. All recent relevant literature should be discussed critically.
16. Line-drawings should be clearly drawn (7 inch or 17 cm width) in black waterproof ink on smooth, tough paper, minor points of style should be noted carefully. Photographs should be large, unmounted, glossy prints of good quality. They should be clear and relevant to the subject. Colour photographs may be sent for better identification and legibility of different parts of the object. All figures should have legends (types). Original artwork should accompany 2 copies. Repetition in graphic and tabular matter should be avoided.
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