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Short Communications

Inheritance and allelic relationship of white rust resistance gene in the crosses of exotic and indigenous germplasm lines of Indian mustard [*Brassica juncea* (L.) Czern. and Coss.]

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ABSTRACT

White rust caused by *Albugo candida* (Pers. ex Lev.) Kuntze is a destructive disease in many important *Brassica* species including *Brassica juncea* in India. It leads to massive yield losses with maximum damage upto 89.8 per cent under late sown conditions due to staghead formation. Identification of diverse sources of resistance is a prerequisite for proper cost effective and eco-friendly management of white rust in Indian mustard. Here, a combination of both exotic and indigenous sources of *B. juncea* was taken to study the genetics of white rust resistance. Five resistant genotypes *viz.,* BEC144, BEC286, EC399299, Heera and BioYSR were crossed to Bio 902 (Pusa Jaikisan) an otherwise high-yielding popular variety of Indian mustard but susceptible to white rust. The F_1s of the ten crosses including reciprocals were resistant indicating the dominance nature of white rust resistance in Indian mustard. Segregation of 3 resistant: 1 susceptible plants in F_2 generation showed the monogenic inheritance of white rust resistance. Further, backcross generations revealed segregation of 1 resistant: 1 susceptible plants confirming that white rust resistance is governed by a single dominant gene which can easily be transferred through backcrossing from a resistant donor to high yielding, well adapted susceptible genotypes. Crosses among the resistant donors have also been attempted to study the allelic relationship among the five resistant sources; and F_2 population of all possible twenty crosses including reciprocals showed complete resistance indicating the genes for white rust resistance in these resistant sources were allelic to each other.

Keywords: Allelic relationship, *Brassica juncea*, Inheritance, Resistance, White rust

White rust caused by *Albugo candida* (Pers. ex Lev.) Kuntze is a highly destructive disease of Indian mustard (*Brassica juncea*). Both the vegetative and reproductive phases of the plants are affected by this fungal pathogen. This leads to massive yield losses in *Brassica* crops (Saharan and Verma, 1992), with the maximum damage (89.8%) occurring due to staghead formation (Lakra and Saharan, 1989). Infection at the vegetative phase results in the appearance of white pustules, predominantly on cotyledons and the abaxial surface of leaves. The pathogen can spread systemically and cause severe malformation of the inflorescence through hypertrophy and hyperplasia resulting in staghead formation (Punjabi *et al*., 2010). At least 13 races of *A. candida* have been identified on the basis of their specificity to different crucifer species (Verma *et al*., 1999) of which race 2 predominantly infects *B. juncea* (Petrie, 1988; Rimmer *et al*., 2000). However, this species-specific race pathogenicity is not absolute. Most races can also infect related *Brassica* species, especially those sharing their genome with the hosts from which they were originally collected.

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Almost all the Indian cultivars of *B. juncea* being grown commercially are susceptible to white rust. Though, chemical control has been recommended in the form of seed treatment and foliar spray for field management of this disease, but it is not so effective due to unawareness of farmers about disease initiation and non-availability of effective chemicals. Moreover, spray of chemical pesticides pollutes the environment besides increasing the input cost. Hence, to overcome these shortcomings, breeding varieties resistance to white rust is the pre-requisite. Developing resistant cultivars also offers sustainable and long term solution for management of diseases. For any effective resistance breeding programme availability of effective resistant donors, nature of inheritance of the trait and the allelic relationship among the existing donor sources is highly important.

In the past number of resistant sources for white rust resistance have been reported in *B. juncea* and differing reports of inheritance have been published. Genetic analysis of available white rust resistance has elucidated a digenic mode of inheritance with duplicate gene action in *B. napus* (Fan *et al*., 1983; Verma and Bhowmik, 1989) and monogenic dominant resistance in *B. juncea* (Bansal *et al*., 1999; Sachan *et al*., 2000; Chauhan and Sharma, 2001; Vignesh *et al*., 2011) as well as in *B. rapa, B. carinata* and

B. nigra (Delwiche and Williams, 1974). Vignesh *et al*. (2009) has reported that white rust resistance is governed by a single dominant gene in an indigenously developed white rust resistant donor BioYSR. In another study involving exotic (BEC144, BEC286 and EC399301) and indigenous (BioYSR, JM1, JM2) sources of resistance in *B. juncea*. Yadava *et al*. (2012) reported the control of white rust resistance by a single dominant gene and the resistance gene(s) were allelic to each other in BEC144 and Bio-YSR. Punjabi *et al*. (2010) have reported two independent loci in the east European donors which need to be characterized along with other donor sources being used in the white rust breeding programme. It is necessary to breed for durable resistance for white rust, as dynamic changes in race composition of pathogen have often resulted in short lived efficiency of host resistance in the improved varieties. Hence, the present study was undertaken to study the inheritance of white rust resistance gene(s) in different reported donors and the allelic relationship among different exotic and indigenous sources of white rust resistance in Indian mustard for their use in the future *Brassica* improvement programme.

MATERIALS AND METHODS

Genetic materials: The five white rust resistant donors *viz.,* BEC144 and BEC286 (exotic resistant lines from Poland), EC399299 (an exotic resistant line from UK), Heera (derived from East European germplasm line by Department of Botany, Nagpur University, Nagpur and Dhara Vegetable Oil and Foods Co. Ltd., Vadodara) and BioYSR [a somaclone of *B. juncea* developed by ICAR-National Research Centre on Plant Biotechnology (NRCPB), New Delhi and registered with NBPGR INGR No. 04099] were included in the present study to understand the nature of white rust resistance genes these possess. Bio902 (Pusa Jaikisan) a popular somaclonal variant of widely grown variety Varuna of *B. juncea* was used as the susceptible parent. The inheritance and the allelic relationship studies were undertaken using F_2 and BC_1 populations.

Development of segregating populations: Crosses among the susceptible parent and resistant donors were attempted at the Experimental Farm of ICAR-Indian Agricultural Research Institute (IARI), New Delhi during *rabi* 2012-13 to study the inheritance of white rusts resistance in different donors (susceptible × resistant) and for studying the allelic relationship between different resistance genes available in the donors (resistant × resistant). During *kharif* 2013 (Offseason at IARI-Regional Station, Wellington, Tamil Nadu), F_1s of all the crosses were grown and F_2s were obtained through selfing of each F_1. Backcrossing to both the parents for each cross was done to generate BC_1P_1 (backcrossed to susceptible parent, P_1) and BC_1P_2 (backcrossed to resistant parent, P_2).

Phenotyping for white rust

Sporangial spray inoculation technique: The inoculum was prepared by collecting white rust spore from the infected leaves from highly infested areas. Fresh zoosporangia were collected by scraping the fungus from infected leaves with a spatula into Petri-plates containing sterile distilled water. The zoosporangia suspension was kept for four hours at 4°C to allow germination of fungal spores. The zoospore concentration was adjusted to approximately 1×10^4 spores per ml. The prepared inoculum was sprayed on the foliage with a hand automizer until runoff; and was repeated three to four times. Dark conditions were maintained for 24 hrs after the spray for development of the disease by covering the entire plot with light blocking PVC sheet. To maintain high humidity, which is congenial for the disease development, experimental plot was irrigated frequently and water was kept standing in channels surrounding the plots during the period of inoculation (Vignesh *et al*., 2011). All the plants were tagged at seedling stage itself and observations were recorded on individual plants until the stage of staghead formation. Two weeks after inoculation, the plants were rated for white rust reaction. Observations for white rust infection were recorded on a minimum of 20 plants each from the parental genotypes (P_1 and P_2) as well as the F_1 generation. Around 130-245 plants of F_2 and 39-94 plants from back cross generations were phenotyped to record the manifestation of the disease in all the crosses. Likewise for allelic relationship studies, phenotyping for disease manifestation of 113 - 167 plants of F_2 from 20 crosses *viz*., Heera × BEC144, Heera × BEC286, Heera × EC399299, Heera × BioYSR, BEC144 × Heera, BEC144 × BEC286, BEC144 × EC399299, BEC144 × BioYSR, BEC286 × Heera, BEC286 × BEC144, BEC286 × EC399299, BEC286 × BioYSR, EC399299 × Heera, EC399299 × BEC144, EC399299 × BEC286, EC399299 × BioYSR, BioYSR × Heera, BioYSR × BEC144, BioYSR × BEC286, BioYSR × EC399299 was done. Ratio of the susceptible to the resistant plants was recorded for understanding the mode of inheritance and allelic relationship of the genes responsible for the white rust resistance.

Disease scoring: Disease reactions were observed and scored using a rating scale 0 to 9, where, 0 - no symptoms on either cotyledon surface; 1- necrotic fleck/none to few necrotic flecks; 3- few, minute pustules/none to very few pustules; 5- few to many small pustules/ few small pustules; 7- many to few small pustules/many large pustules; 9- very few to no pustules/large coalescing pustules (Williams, 1985). Cotyledons that showed no symptoms or small necrotic flecks on the adaxial surface without sporulation were scored as 0 or 1 and were considered resistant, whereas, those showing scattered or coalescing pustules on the abaxial or adaxial surfaces were scored as 7 or 9 and were

considered susceptible. Intermediate scores (3 and 5) were rarely observed.

Statistical analysis: Data for inheritance studies and allelic relationship were analyzed by using chi-square test to fit appropriate genetic ratios in F_2 and BC_1F_1 generation obtained from all crosses.

RESULTS AND DISCUSSION

Inheritance of white rust resistance in different resistant donors: The F_1 progenies of all the crosses between susceptible × resistant and their reciprocals showed resistant to white rust revealing complete dominance of gene(s) transferred from the resistant parents (BEC144, BEC286, EC399299, Heera and BioYSR). Segregation in F_2 population of all the crosses showed perfect fit into the 3 resistant : 1 susceptible ratio (Table 1). In BC_1P_2 (backcross with the resistant parent), all the plants were found to be resistant. However, in BC_1P_1 (backcross with the susceptible parent), segregation into resistant and susceptible plants was found in almost equal frequencies of 1 resistant : 1 susceptible plants showing the monogenic inheritance of white rust resistance in these crosses (Table 1). From the data and observations on F_1, F_2, BC_1P_1 and BC_1P_2 it was confirmed that the resistance to white rust is controlled by single gene with complete dominance in all the resistant sources. These results were in confirmation with the earlier findings reported on monogenic dominant inheritance of white rust resistance in Indian mustard (Vignesh *et al*., 2009; 2011).

Table 1 Segregation pattern for white rust resistance in crosses between susceptible parents and resistant donors

Cross	Generation	Segregation ratio (R:S)	Total no. of plants screened	No. of Resistant plants	No. of Susceptible plants	Chi-square value	P-value
Bio 902 × Heera	BC_1P_1	1:1	42	19	23	0.38	0.9 to 0.5
	F_2	3:1	146	104	42	3.38	0.1 to 0.05
Bio 902 × BEC 144	BC_1P_1	1:1	39	17	22	0.64	0.5 to 0.1
	F_2	3:1	135	94	41	2.08	0.5 to 0.1
Bio 902 × BEC 286	BC_1P_1	1:1	39	21	18	0.23	0.9 to 0.5
	F_2	3:1	130	92	38	1.24	0.5 to 0.1
Bio 902 × EC399299	BC_1P_1	1:1	43	26	17	1.88	0.5 to 0.1
	F_2	3:1	197	154	43	0.26	0.9 to 0.5
Bio 902 × Bio-YSR	BC_1P_1	1:1	44	23	21	0.09	0.9 to 0.5
	F_2	3:1	163	115	48	1.72	0.5 to 0.1
Heera × Bio 902	BC_1P_1	1:1	54	23	31	1.18	0.5 to 0.1
	F_2	3:1	133	103	30	0.42	0.9 to 0.5
BEC 144 × Bio 902	BC_1P_1	1:1	44	23	21	0.09	0.9 to 0.5
	F_2	3:1	201	154	47	0.28	0.9 to 0.5
BEC 286 × Bio 902	BC_1P_1	1:1	42	19	23	0.38	0.9 to 0.5
	F_2	3:1	171	117	54	3.27	0.1 to 0.05
EC399299 × Bio 902	BC_1P_1	1:1	39	17	22	0.64	0.5 to 0.01
	F_2	3:1	233	160	73	4.90	0.05 to 0.025
Bio-YSR × Bio 902	BC_1P_1	1:1	94	49	45	0.17	0.9 to 0.5
	F_2	3:1	245	187	58	0.22	0.9 to 0.5

Monogenic dominant nature of white rust resistance can successfully be exploited in the breeding programme as the resistance gene can easily be transferred to otherwise susceptible high yielding genotypes through backcross breeding. With the advent of molecular marker technologies, it will be further easier to accelerate the breeding process by employing the linked markers reported for white rust resistance genes in marker-assisted selection (MAS).

Allelic relationship among different donors for white rust resistance: F_2 population of the crosses among the resistant parents and their reciprocal crosses showed complete resistance to white rust and no segregation was observed at all. This clearly indicates that the white rust resistance gene present in these sources *viz*., BEC144, BEC286, EC399299, Heera and BioYSR were allelic to each other. Hence, the same gene is governing the resistance to white rust in all the resistant donors being used and same alleles are harbored by these resistant sources (Yadava *et al*., 2012). Hence, highly adapted and agronomically well performing donor genotype among the five donors can be used in the breeding programme to save resources and also to avoid any possible linkage drag while backcrossing. This result also clearly indicates the narrow diversity of white rust resistance sources available for the breeding programme; and this may lead to large scale disease outbreak when the resistance breaks down. Therefore, it necessitates the large scale characterization of existing germplasm for reaction to white rust so as to identify new sources of resistance. The donor genotypes once identified can be used in the breeding programme after testing for its allelism with the available sources of resistance.

The present study clearly demonstrated that the white rust resistance is governed by single dominant gene having allelic relationship in both exotic as well as indigenous germplasm. This gene can be easily transferred to high yielding, locally adapted susceptible cultivars through backcross breeding method. The study also reveals the emphasis on identifying new sources of resistance to diversify the Indian mustard germplasm.

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Response of contrasting root genotypes of castor (*Ricinus communis* L.) to water stress

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ABSTRACT

Two contrasting genotypes for root biomass i.e. RG-111 with good root, RG-1520 with poor root were studied for root, shoot growth till 90 DAS in root structures and also in field for seed yield by imposing water stress (30-90 DAS) during late *rabi* (2011-12). The reduction in root length was less due to stress. But root volume, dry weight and shoot growth reduced with stress and the per cent reduction was less in poorer root genotype (RG-1520) compared to good root genotype (RG-111). With drought stress in field, the growth before relieving stress, seed yield of different order branches and total seed yield reduced significantly in both genotypes. RG-1520 showed adaptation to survive drought stress in root structure and in field by increasing chlorophyll content (SCMR), less reduction in relative water content (RWC), decrease in specific leaf area (SLA) and increase in bloom content as that of good root genotype RG-111. But, seed yield reduction was more in poor root genotype (RG-1520) and also recorded high drought susceptibility index (DSI) as its photo assimilates were spent for its survival in stress and assimilate translocation was less for seed growth. Hence good root is important for crop survival, growth and seed yield especially in drought conditions.

Keywords: Castor, Root, Seed yield, Water stress

Roots are the essential plant organ for nutrient and water uptake associated with drought avoidance. Root traits have been claimed to be critical for increasing yield under soil-related stresses (Lynch, 2007). Roots are largely neglected in scientific experiments and in crop management. Occasional improvements in root characteristics achieved in breeding programs is due to indirect selection rather than intentional selection for root traits. The vigorous root system of castor plants is often referred to as a positive characteristic (Weiss, 2000). But, a vigorous root growth requires an increased biomass allocation also. Though castor is considered as drought hardy crop, there are genotypic differences in response to water stress (Lakshmamma *et al.*, 2015; Ramesh *et al.*, 2016) and mainly above ground dry matter, and seed yield was studied. So far, the response of root to drought stress was not studied in castor. Hence, an experiment was conducted with two contrasting genotypes for root growth for their response to drought stress in root structure and field.

MATERIALS AND METHODS

Root studies were conducted by growing plants in specially constructed raised structures on the ground. The height of the structure varies with the crop and depends on the depth to which the roots of the crop can penetrate. Castor genotypes were screened in 30 x 2.4 x 1.5 m (L x B x H) root structure which can accommodate 33 castor genotypes on either side. During *kharif* 2009-10 and 2010-11, 120 germplasm accessions were screened by growing them in root structures in two replications and were allowed to grow for 90-100 days which coincide with the maximum root growth. Various root and shoot characters were recorded and genotypes were ranked using principal component analysis. Based on this data, two contrasting genotypes, RG-111 (with good root), RG-1520 (with poor root) were grown in root structure during late *rabi* 2011-12 by withholding irrigation from 30-90 DAS in one set along with irrigated control in six replications. Same genotypes were also sown under field conditions during the same time to see their field performance with water stress (30-90 DAS). Data on shoot observations *viz*., plant height, leaf number, stem girth, total dry matter (TDM), and physiological traits like SPAD chlorophyll content (SCMR), specific leaf area (SLA), leaf area index (LAI), relative water content (RWC), bloom content and excised leaf water retention capacity (ELWRC) expressed as excised leaf water loss (ELWL) etc. were recorded at 90 DAS in root structures and in field before relieving stress. Root traits *viz*., length, volume and dry weight was recorded at 90 DAS by dismantling root structures. Data on yield components and yield of different spike orders were recorded in field.

RESULTS AND DISCUSSION

The genotypes for this study were selected based on the data generated in root structures during 2009-10 and 2010-11 (DOR, 2011; 2012). Root growth differences of these two contrasting genotypes are presented in Table 1. Root characters *viz*., length, volume, dry weight and total dry matter was comparatively higher in RG-111 than RG-1520

(Table 1). Root volume and root dry weight showed significant correlation with TDM, stem girth and plant height (> 0.80) while root length did not show significant correlation with shoot characters and TDM (Lakshmamma *et al*., 2014). Hence, these two genotypes, one with good root growth (RG-111) and one with poor root growth (RG-1520) were studied in root structure for root and shoot growth by imposing stress from 30-90 DAS during late *rabi* (2011-12).

Table 1 Root growth of selected germplasm lines (per plant) in root structure with irrigation

Characters (per plant)	RG-111	RG-1520
Year of study	2010-11	2009-10
Root length (cm)	215	125
Root volume (cm3)	404	59
Root dry weight (g)	68.4	8
TDM (g)	503	111

Crop performance in root structures grown in late *rabi* (November 1st week) was found to be poor compared to the growth during *kharif* season in root structures. In general, there was reduction in crop growth with water stress in both the genotypes, but, the per cent reduction in leaf number, secondary branch production, and stem girth in RG-1520 with water stress was less than RG-111. No secondaries and tertiaries were produced in stress in RG-111 but branch production of these two orders is seen in RG-1520 in stress. Number of days taken for initiation and 50% flowering was reduced under stress in RG-1520. Root length reduction was not much due to stress and even the poor root genotype (RG-1520) also increased its root length in search of moisture. Though, root volume, dry weight and shoot growth (stem, leaf, spike dry weight) reduced with stress, the per cent reduction was less in poor root genotype (RG-1520) compared to good root genotype (RG-111) (Table 2). Reduction in total dry matter was 55 per cent in RG- 1520 compared to 64% in RG-111. TDM reduction with drought stress in field was also reported in other studies in castor (Lakshmamma and Lakshmi, 2006). SLA decreased and SCMR increased in poor root trait accession which is desirable to reduce leaf area there by reducing the evaporative surface and increasing chlorophyll content to improve photosynthetic efficiency (Nageshwar Rao *et al.*, 2001). Reduction in per cent relative water content (RWC) was similar in both genotypes. Bloom content increased with water stress which is an adaptive feature to avoid drought stress (Vakharia *et al.*, 1997) and the per cent increase was more in poor root RG-1520.

The data recorded on growth and seed yield of these two genotypes in field during the same time by imposing drought stress from 30-90 DAS is presented in Tables 3, 4 and 5. Crop growth in terms of plant height, leaf number, branch production, dry matter reduced significantly with water stress from 30-90 DAS in both the genotypes (Table 3). The reduction in plant height, node number, branch production was less and leaf number, stem girth, LAI, TDM was more with drought stress in RG-1520 over RG-111. The poor root type RG-1520 tried to survive by increasing SCMR, RWC, bloom and decreasing SLA compared to RG-111. Leaf water loss with excision was more in irrigated plots at different time intervals and in RG-1520 than RG-111. Per cent water loss in stress was on par in both genotypes.

During stress, in RG-111, no secondary branch production was observed but in RG-1520, secondaries and few tertiaries were produced in irrigated plots also. After relieving stress, crop recovered by producing secondaries in stress and also tertiary, quarternary branches in both treatments in RG-111, tertiaries in stress, quarternaries in irrigated plots in RG-1520 (Table 4). There was significant reduction in spike length, effective spike length (ESL), capsule number, seed yield and test weight under stress in both genotypes up to secondary order branches. Tertiary and quarternary seed yield reduction was not significant with drought stress in both genotypes. Reduction in seed yield of different order branches is more in RG-1520 compared to RG-111. RG-111 performed better than RG-1520 in spike characters.

Total dry matter (TDM) and seed yield at harvest are presented in Table 5. Stem weight, leaf weight, spike weight of all order branches and TDM at harvest showed significant reduction in stress and reduction was more in poor root accession RG-1520 than good root accession RG-111.

Total seed yield recorded 22.7 per cent reduction in stress in RG-111 compared to reduction of 56.8 per cent in RG-1520. Growth and seed yield reduction with drought stress in castor was also reported by Lakshmamma *et al.* (2006). But harvest index (HI) data clearly shows the increased stem reserve mobilization in both genotypes by increasing HI in stress. Among the two, more partitioning is seen in poor root genotype RG-1520 (44%) compared to good root RG-111 (24%). RG-111 recorded low drought susceptibility index (DSI) and high drought tolerance efficiency (DTE) compared to RG-1520.

Thus, two contrasting genotypes for root growth, when studied in root structure and under field conditions for drought tolerance by imposing stress from 30-90 DAS, the poor root genotype (RG-1520) showed less reduction in crop growth in terms of plant height, branch production and

physiological traits of drought tolerance *viz*., SCMR, SLA, RWC, bloom etc. in stress compared to control than good root genotype (RG-111). But, TDM, seed yield reduced in both genotypes and reduction was less in RG-111 and it also showed low DSI. RG-1520 increased stem reserve mobilization in stress as shown by more increase in HI compared to RG-111. Poor root RG-1520 showed less reduction in crop growth in stress and also tried to survive by showing adaptive traits for drought (SPAD, RWC, SLA). Due to its poor root growth the assimilates produced were spent for its survival and could not be translated to reproductive growth resulting in poor seed yield compared to good root RG-111.

Table 2 Root and shoot growth of RG-111 and RG-1520 genotypes in control and stress treatments in root structure

Growth characters (per plant)	RG-111		RG-1520		Per cent reduction	
	Control	Stress	Control	Stress	RG-111	RG-1520
Plant height (cm)	61	38	58	38	37.7	33.9
Leaf (No.)	18	9	16	9	50.0	40.9
Nodes on primary stem	16	16	13	14	1.0	-3.8
No.of secondary branches	3	0	3	1	90.0	52.9
No.of tertiary branches	0	0	0	1	100	0
Days to 1st flowering	69	78	63	55	-13.5	13.0
Days to 50% flowering	72	80	68	58	-10.7	15.0
Stem girth (cm)	6.1	4.6	5.3	4.6	24	14
Leaf area (dm^2)	102.5	40.4	92.2	36.8	60.5	60.1
LAI	2.05	0.81	1.84	0.74	61	60
SCMR	46.9	51.1	49.8	54.2	-8.9	-8.8
SLA (dm^2/g)	1.68	1.80	1.41	1.26	-7.2	11.0
Root length (cm)	154	158	155	149	-4.0	3.9
Root volume(cm^3)	88	33	75	34	63	54
Root dry weight (g)	12.2	5.6	10.1	7.2	54	28
Stem dry weight (g)	43.9	14.0	42.5	14.6	68.0	65.7
Leaf dry weight (g)	61.5	25.0	64.8	29.1	59.4	55.1
Spike dry weight (g)	10.1	1.5	7.3	5.2	85	29
TDM (g)	128	46	125	56	64	55
RWC (%)	93.4	90.6	94.4	91.9	2.9	2.6
Bloom (wax) content ($\mu g/cm^2$)	65	85	56	80	-30.8	-43

Table 3 Crop growth of RG-111 and RG-1520 genotypes in control and stress treatments before relieving stress in field

Growth characters (per plant)	Before relieving stress				Per cent reduction	
	RG-111		RG-1520		RG-111	RG-1520
	Control	Stress	Control	Stress		
Plant height (cm)	106	44.3	55	35	58.2	36.4
Leaf (No.)	40	8	30	5	80.0	83.3
Nodes on primary stem	14	9	8	7	35.7	12.5
No. of secondary branches	4	0	2	2	100	0
Length of secondary branches	28.2	0	58.7	5.4	100	90.8
No. of tertiary branches	0	0	3	0	-	100
Length of tertiary branches	0	0	22.7	0	-	100
Days to 1st flowering	43	43	39	38	0.0	2.6
Stem girth (cm)	6.3	4.8	6.2	4.1	23.8	33.9
LAI	1.65	0.66	1.59	0.52	60.0	67.3
SCMR	46.8	54.3	52.9	64.7	-16.0	-22.3
SLA (dm^2/g)	1.49	1.25	1.61	1.23	16.1	23.6
Stem dry weight (g)	84.5	18.3	55	5.6	78.3	89.8
Leaf dry weight (g)	61.4	29.5	54.8	23.5	52.0	57.1
Spike dry weight (g)	14.6	5.9	32.2	4	59.6	87.6
TDM (g)	161	53.7	142	33.1	66.6	76.7
RWC (%)	92.4	88.2	93.3	90.3	4.6	3.2
Bloom content ($\mu g/cm^2$)	42.4	101.3	41.4	109.7	-139	-165
ELWL (%)						
After 2.0 hrs	9.1	5.3	13.4	5.2		
After 4.0 hrs	17.9	10.1	26.3	11.9		
After 6.0 hrs	24.0	14.3	33.9	13.2		
After 24 hrs	51.5	45.4	57.0	39.6		

Table 4 Yield and yield components of different spike orders in RG-111 and RG-1520 genotypes in control and stress treatments (per plant)

Genotype	Spike number		ESL (cm)		Capsule number		Spike weight (g)		Seed weight (g)		Reduction in seed yield (%)
	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress	
Primary spike characters											
RG 111	-	-	35.7	17.6	51	24	64.2	30.3	32.9	15.8	51.9
RG 1520	-	-	20.2	10.4	23	15	35.4	15.1	18.3	6.9	62.5
Secondary spike characters											
RG 111	4	2	18.1	13.4	21	18	111.6	48.3	59.7	30.1	49.6
RG 1520	2	4	17.8	9.2	21	12	52.8	38.2	39.1	18.5	52.8
Tertiary spike characters											
RG 111	5	5	8.3	13.2	9	14	30.7	80.9	11.8	36.2	-207.0
RG 1520	3	4	12.5	9.5	12	13	53.0	55.1	27.2	23.8	12.5
Quarternars spike characters											
RG 111	6	7	10.2	9.7	9	9	79.9	61.5	37.0	27.3	26.3
RG 1520	4	0	9.3	0.0	9	0	59.4	0	29.0	0.0	100.0

Table 5 TDM and seed yield at harvest in field

Growth characters at harvest (per plant)	Before relieving stress				Per cent reduction	
	RG-111		RG-1520		RG-111	RG-1520
	Control	Stress	Control	Stress		
Stem weight (g)	145.0	75.8	223.3	56.0	47.7	74.9
Leaf weight (g)	24.5	8.1	55.2	5.3	66.9	90.4
Total spike weight (g)	430	275	422	146	36.0	65.4
Total dry matter (TDM) (g)	599	359	700	207	40.1	70.4
Total seed yield (g)	141.4	109.3	113.6	49.1	22.7	56.8
Harvest Index (HI) %	24.6	30.6	16.7	24.1	-24.4	-44.3
Drought susceptibility index (DSI)	0.65		1.63			
Drought tolerance efficiency (DTE) %	77.3		43.2			

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Nutrient composition of selected cultivars of safflower (*Carthamus tinctorius* L.) leaves during different crop growth stages

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ABSTRACT

The changes in nutrient composition of four cultivars of safflower (*Carthamus tinctorius* L.) leaves (Annigeri-1, Manjira, TSF-1 and NARI-6) were estimated at three different crop growth stages *viz.,* 30th (rosette stage), 50th (elongation stage) and 70th day (flower initiation stage). The results indicate that the moisture content in leaves was higher during the earlier stages (30th day) as compared to 50th and 70th days in all the four cultivars. The carbohydrate content was higher during 30th day as compared to 50th and 70th days in Annigeri-1, TSF-1 and NARI-6 varieties. Protein content varied between 2.51 to 4.04g/100g during various stages of maturity, while fat content was found to increase from 30th day (2.46g/100g) to 70th day (9.51g/100g) in all four cultivars. The crude fiber content ranged from 8.77 to 9.58g/100g, while ash content of safflower leaves ranged between 13.68 to 17.36 per cent during various stages of maturity in the four cultivars. Energy values of safflower ranged between 58.82 to 111.44 kcal/100g. Results indicated that safflower leaves were found to be rich sources of both iron (3.42 to 5.33mg/100g) and calcium (240 to 333.33mg/100g) during various stages of maturity in all the four cultivars. The results show that consumption of safflower leaves would contribute to very good content of carbohydrates, proteins, fiber, iron and calcium during all the stages of maturity though the content varies during various crop growth stages.

Keywords: Green leafy vegetable, Growth stages, Nutrient composition, Safflower leaves

Micronutrient deficiencies have become a serious global problem, especially in areas where the diets lack variety (Kennedy *et al.,* 2003). It has been observed that diets in many developing countries are not optimal (Johns and Sthapit, 2004) and that globalization and modernization in agriculture has resulted in simplification of diets and reliance on few staple crops (Flyman and Afolayan, 2006). Diversified diets, based on a range of crop species, are essential for nutritional security and reduction of micronutrient deficiencies. Vegetables, especially green leafy vegetables (GLV) are an excellent source of macronutrients and micronutrients which could make an important contribution to combat micronutrient malnutrition as well as providing food security. Hence their promotion as well as integration into diets has been promoted as the most practical and sustainable way to achieve optimal dietary requirements to combat micronutrient deficiencies.

Many underutilized GLV's have high levels of micronutrients and could significantly contribute to nutritional security if eaten as part of the daily diet. Despite the importance of underutilized GLV's in combating malnutrition and poverty, and despite the wealth of traditional knowledge about these species, many are still poorly studied and understood by the scientific community. Neglected and underutilized plant food resources constitute the bedrock of the diversity in traditional food systems to achieve food security. The general belief that there is a lack of reliable information and evidence to justify promoting their use as dependable nutrient-rich food resources has hindered attempts to integrate them into contemporary food systems thus engendering the main streaming of their use in dietary habits. In view of this, underutilized GLV's are receiving renewed attention, with the recognition that they could become useful as potential vehicles for improved nutrition and increased food supply (Olorode, 2006; Padulosi *et al*., 2002).

In India various types of underutilized foods are available seasonally but are not utilized to the extent they should be in spite of their higher nutritive value. Looking into the prevalence of high level of micronutrient malnutrition among the vulnerable sections, utilization of underutilized foods can be explored to overcome nutritional disorders (Misra *et al*., 2008). The nutritional value of underutilized GLV's is higher (Orech *et al*., 2007) than several known common vegetables. Most of these underutilized GLV's have a potential for income generation but fail to compete with exotic vegetables at present due to lack of awareness (Maikhuri *et al*., 2004). Despite these advantages, most underutilized plant foods are generally uncultivated and underutilized (Jansen *et al*., 2004). One among such kind underutilized GLV's is safflower leaves.

Safflower (*Carthamus tinctorius* L.), an oilseed crop is a member of the family Compositae or Asteraceae, which has been grown for centuries in India for the orange-red dye (carthamin) extracted from its brilliantly colored flowers and for its quality oil rich in polyunsaturated fatty acids. The

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tender leaves, shoots, and thinning of safflower are used as pot herb, green leafy vegetable and salad. They are rich in vitamin A, iron, phosphorus, and calcium. Bundles of young plants are commonly sold as a green vegetable in markets in India and some neighboring countries (Nimbkar, 2002). The thinned out plants are harvested during thinning and are consumed as leafy vegetable in areas where the crop is grown. As the crop matures, the bottom leaves are also consumed during various stages till the completion of flowering stage. Suneel Kumar *et al.* (2015) reported that fresh safflower leaves from non-spiny varieties can be consumed up to 90 days, where as spiny varieties of safflower leaves can be well acceptable up to 50 days. Safflower leaves or powder from any stage of maturity and any cultivar adds variety in the diet and also has good overall acceptability.

Some scientific studies on various foods, have reported changes in chemical composition at different stages of development of fruits, vegetables and leaves (Polyana *et al.,* 2014; Oliveira *et al.,* 2011; Celli *et al.,* 2011; Leite *et al.,* 2011; Peiretti *et al.,* 2013; Suneel Kumar *et al.,* 2016). However, there are no studies that address the nutritional composition during different stages of development of safflower leaves (30^{th} day - Rosette stage; 50^{th} day - Elongation stage; 70^{th} day - Flowering initiation stage). Most research on safflower has been concentrated on seeds and petals, while the leaves of safflower have to a large extent been ignored and are underutilized as GLV. Leaves are reportedly inexpensive and easy to cook. They are known as potential sources of minerals and vitamins (Richard *et al.,* 2007). The nutritional contribution of safflower leaves has not been widely exploited. Nutritional information on safflower leaves at different growth stages will be useful for the nutritional education of the public as a means to improve the nutritional status of the population. Hence, the present study was taken up to evaluate the nutrient composition in various cultivars of safflower leaves during different crop growth stages.

MATERIALS AND METHODS

Sample procurement for analysis: Safflower leaves of three spiny cultivars Annigeri-1, Manjira, TSF-1 and one non spiny cultivar NARI-6, during different stages of development (30^{th} day - Rosette stage; 50^{th} day - Elongation stage and 70^{th} day - Flower initiation stage) were procured from the farms of IIOR-ICRSAT, Pantancheru, Hyderabad and Regional Agricultural Research Station (RARS) Tandur, Ranga Reddy district, Telangana.

Sorting: Fresh, green, undamaged, non-insect infested, bruised, discoloured, decayed and wilted leaves were discarded before washing the leaves, as decayed and wilted leaves give a bad flavour to the whole batch. Besides, decayed and wilted leaves can lead to loss of nutrients (Pallavi and Dipika, 2010). Fresh leaves after cleaning were used for further studies.

Washing, blanching and tray drying: The safflower plants (30^{th} day) and leaves (50^{th} and 70^{th} days) were washed gently under running water to remove the adhering mud particles followed by double glass-distilled water and drained completely. The plants (30^{th} day) and leaves (50^{th} day and 70^{th} day) were then chopped into the sizes of 0.5cm×5cm approximately. To inhibit enzymatic browning reactions, the safflower leaves were blanched in hot water at 90±2°C for 2min with the ratio of safflower leaf residues to water of 1:7. The chopped and blanched safflower leaves were then immediately cooled in cold water at 4°C (AOAC, 1995). The leaves were drained after cooling and the residual moisture was evaporated at room temperature, on a clean paper with constant turning over to avert fungal growth (Gupta and Prakash, 2011). The leaves were then spread on stainless steel trays for drying at 60°C for 6-8h in a pre-heated (60°C) tray drier. The dried leaf sample was ground to fine powder using a grinder (Waring Commercial Blender, WCG75, Torrington, CT) at a medium speed for 2 min. The powder was then sieved using a sieve analyzer (Retsch, AS200 basic, Hann, Germany). The powder with particle size in the range of 150-430 µm was vacuum packed in an HDPE package until further analysis.

Proximates analysis: Moisture content of the fresh safflower leaves was determined using procedure given by Association of Official Analytical Chemists (AOAC, 2005). Protein content was estimated from the crude nitrogen content of the sample determined by the Micro Kjeldhal method (N × 6.25) (AOAC, 1990). Fat content was estimated as crude ether extract of the dry material using automatic Gerhardt Soxtherm extraction unit. Crude fiber content of the samples was determined by the procedure given by AOAC (2005). Similarly total ash was determined using procedure given by AOAC (2005). Energy and carbohydrate content was calculated by difference method. Iron and calcium content of the samples were determined by methods given by Jamaluddin and Ahmed (2009) and AOAC (2000) respectively. Moisture was analysed on a fresh basis and the rest of the nutrients were estimated on dry matter basis in triplicates. Experimental results were subjected to analysis of variance (ANOVA).

RESULTS AND DISCUSSION

The results of proximate analysis are given in Table 1. The results of moisture estimation indicate that the moisture content was higher at earlier stages (30^{th} day) as compared to 50^{th} and 70^{th} day in all the four cultivars. The results show that there was a constant reduction in the moisture content in

all the varieties as the plant matured. Similar results were found by Gopalan *et al.* (2004) in safflower leaves and Ravindran and Ravindran (1988) in Cassava (*Manihot esculenta* Crantz) leaves during different stages of maturity.

From the results of carbohydrate estimation, it was observed that the carbohydrates decreased from 30th day to 70th day in Annigeri-1, TSF-1 and NARI-6, whereas an increase in carbohydrates was observed in Manjira variety. Carbohydrates are the most abundant biochemical constituents in plants, representing 50-80% of the total dry weight. They function as forms of stored energy reserves and make up much of the structural frame work of the cells. A study by Ravindran and Ravindran (1988) in Cassava (*M. esculenta*) leaves during different stages of maturity reported a decrease in carbohydrate content from 45.8g to 43.6g to 38.2g in very young, young and mature leaves, respectively.

Protein content varied between 2.51 to 4.04g/100g during all stages of maturity in all the four cultivars studied. The results of protein estimation among cultivars show that Annigeri-1, TSF - 1 and NARI-6 had similar protein content (2.51 to 2.89g/100g), whereas Manjira had higher protein content with 3.35g/100g. The protein content was similar in all four cultivars on 50th day. Protein content on 70th day was highest in Annigeri-1 (4.04±0.53) followed by NARI-6 (3.21±0.10), Manjira (2.60±0.42) and TSF-1 (2.32±0.10). Based on the results of protein content, it is evident that, not only tender leaves during 30th day, even the mature leaves of safflower plants during 50th and 70th day could be used as a potential protein source in the diet.

The fat content in the safflower leaves was found to increase in all four cultivars from 30th day to 50th day to 70th day. This could be due to the fact that safflower being an oilseed crop, the oil component increases in the leaves also, as the plant matures. Fat content was lowest in Annigeri-1 (2.46±1.04) on 30th day as compared to Manjira, TSF-1 and NARI-6. On the contrary fat content was highest in Annigeri-1 (8.32±4.15) on 50th day compared to Manjira, TSF-1 and NARI-6. It was observed that there was no significant ($P>0.05$) difference in the fat content among all four cultivars on 70th day. Gopalan *et al*. (2004) reported 1g/100g fat content in safflower leaves which is not in correlation with the present findings. This could be due to agro-climatic variations and difference in cultivars.

The results of crude fiber analysis indicate that safflower leaves are a very rich source of fiber ranging from 8.77 to 9.29g/100g during various stages of maturity in the four cultivars and can be used as an excellent source of fiber rich green leafy vegetable. A significant increase in total dietary fiber and insoluble dietary fiber was also found in amaranth, basella, hibiscus, rumex, spinach and kachnar buds and flowers in their tender, mature and coarse stage (Punna and Rao, 2004; Verma *et al.,* 2012). The ash content of safflower leaves ranged between 13.68 to 17.36 per cent which indicates that safflower leaves are a rich source of minerals, which if included in regular diet, can enhance the mineral content. Among all the cultivars, NARI-6 had the highest ash content during all the maturity stages from 30th day to 70th day indicating that NARI-6 consumed as green leafy vegetable can contribute to good amount of minerals in the diet.

The results also indicate that during all the stages of maturity, there is no significant difference in the energy content within the cultivars indicating consumption of Annigeri-1 or Manjira or TSF-1 or NARI-6 provides the same energy levels when consumed. The energy values of safflower ranged between 58.82 to 111.44kcal/100g. As per the analysis done by Gopalan *et al*. (2004), safflower leaves had an energy value of 33kcal/100g, which is not in correlation with our study. Studies by Castro *et al.* (2002); Serradilla *et al.* (2011); Kalt *et al.* (1993) and Tahir *et al.* (2012) reported that production practices *viz.,*sowing time, harvesting time, soil type, irrigation, the type and quantity of fertilizer application, plant maturity at harvest and other practices can affect the water and nutrient supply to the plant and therefore also the plant composition and quality.

The results of the calcium and iron analysis are given in Table 2. The results indicate that there is no significant difference in calcium and iron content between the cultivars indicating consumption of leaves at any maturity stage and any cultivar might provide similar iron and calcium content in the diet. Results of iron and calcium estimation show that safflower leaves are rich sources of both iron (3.42 to 5.33 mg/100g) and calcium (240 to 333.33 mg/100g) during various stages of maturity in all the four cultivars. Manjira variety had highest calcium content during 50th day (333.33 mg/100g) while Annigeri-1 had lowest calcium content during 30th day (240 mg/100g). The results of iron content showed that Manjira variety had highest iron content at 30th day (5.33 mg/100g) while the same variety had lowest content during 50th day (3.42 mg/100g) among all cultivars and during all maturity stages. However, the differences in the calcium and iron content were not statistically significant, indicating that consumption of safflower leaves at any stage from any cultivar would give almost similar calcium and iron content.

The gross composition of plant tissues varies quite considerably during various growth stages. The period of maturity varies from plant to plant and the maturation process is accompanied by extensive biochemical changes. The results of the study show that, the optimum period to harvest safflower leaves to be consumed as vegetable, can be done during any crop growth stage from 30, 50 and 70 days in all the four cultivars studied. However, leaf harvesting at various growth stages on seed yield need to be ascertained. There is a very good distribution of carbohydrates, proteins, fiber, iron and calcium during all the crop growth stages,

though the content varies during the stages of maturity. Hence, harvesting age is not very crucial in case of safflower leaves to be consumed as a green leafy vegetable and the leaves (from rosette stage to flower initiation stage) can be popularized as a green leafy vegetable for attainment of nutritional security.

Table 1 Proximate composition of the safflower leaves during different stages of maturity (per 100g)

Parameters	Days of maturity	Cultivars				SE values
		Annigeri-1	Manjira	TSF-1	NARI-6	
	30th day	91.11±0.46^{a1}	89.65±1.12^{a2}	89.20±0.18^{a2}	90.24±0.52^{a1}	
Moisture (%)	50th day	88.29±1.17^{b1}	88.84±0.46^{a1}	88.52±0.46^{a1}	89.73±2.29^{a1}	0.386
	70th day	83.44±0.60^{c2}	85.12±2.52^{b2}	89.03±0.28^{a1}	84.59±0.49^{b2}	
SE value	0.335					
	30th day	10.49±0.40^{a1}	1.99±0.49^{c3}	4.77±0.44^{a2}	2.89±0.53^{b3}	
Carbhohydrates (g)	50th day	5.91±0.50^{b1}	2.46±0.56^{b3}	3.41±0.25^{b2}	1.46±0.48^{c3}	0.139
	70th day	2.08±0.52^{c2}	3.41±0.61^{a1}	3.23±0.16^{b1}	1.18±0.07^{c2}	
SE value	0.120					
	30th day	2.51±0.006^{b2}	3.35±0.65^{a1}	2.89±0.10^{b1}	2.58±0.26^{c2}	
Protein (g)	50th day	3.21±0.34^{a1}	3.08±0.23^{a1}	3.01±0.44^{a1}	2.89±0.72^{c1}	0.132
	70th day	4.04±0.53^{a1}	2.60±0.42^{b3}	2.32±0.10^{c3}	3.21±0.10^{b2}	
SE value	0.114					
	30th day	2.46±1.04^{b2}	5.19±3.91^{b1}	3.19±1.65^{c1}	5.33±4.94^{c1}	
Fat (g)	50th day	8.32±4.15^{a1}	5.72±0.61^{b2}	6.02±0.78^{b1}	5.27±0.23^{c2}	0.860
	70th day	7.07±2.38^{a1}	8.15±1.33^{a1}	8.08±1.20^{a1}	9.51±3.00^{a1}	
SE value	0.744					
	30th day	9.27±0.05^{a1}	9.29±0.06^{a1}	9.20±0.05^{a1}	9.16±0.02^{c2}	
Crude Fiber (g)	50th day	9.16±0.04^{b1}	9.18±0.01^{b1}	9.10±0.10^{b2}	9.14±0.04^{c1}	0.026
	70th day	8.77±0.06^{c3}	9.08±0.17^{c2}	9.10±0.04^{b2}	9.24±0.10^{b1}	
SE value	0.022					
	30th day	13.68±0.16^{b1}	17.06±0.06^{c2}	13.46±0.04^{a1}	17.36±0.07^{b2}	
Ash (g)	50th day	15.40±0.14^{c2}	15.16±0.08^{a2}	14.73±0.07^{b1}	17.10±0.02^{b3}	0.109
	70th day	13.05±0.10^{a1}	16.43±0.14^{b2}	16.93±0.04^{c2}	17.30±0.02^{b3}	
SE value	0.094					
	30th day	74.10±3.16^{a1}	68.17±9.19^{a1}	58.82±4.37^{a1}	83.28±0.30^{a1}	
Energy (k cal)	50th day	111.44±10.86^{b1}	76.14±0.86^{a1}	83.28±0.30^{b1}	84.65±8.55^{a1}	6.88
	70th day	88.20±5.80^{a1}	97.50±3.54^{b1}	88.29±3.30^{b1}	103.26±7.99^{a1}	
SE value	5.960					

Values are expressed as mean ± standard deviation of three replicates;
Mean values with similar superscripts within a column (alphabets) and row (numerical) do not differ significantly (P=0.05)

Table 2 Calcium and iron content in safflower leaves during different stages of maturity (mg/100g)

Parameters	Days of maturity	Cultivars				SE values
		Annigeri-1	Manjira	TSF-1	NARI-6	
	30th day	240±11.55^{a1}	286.67±12.02^{a1}	293.33±6.67^{a1}	266.67±8.82^{a1}	
Calcium	50th day	306.67±12.02^{a1}	333.33±14.53^{a1}	340±5.77^{b1}	313.33±14.53^{a1}	12.957
	70th day	286.66±12.02^{a1}	306.67±14.53^{a1}	306.67±8.82^{a1}	306.67±8.82^{a1}	
SE values	11.221					
	30th day	3.75±0.42^{a1}	5.33±0.12^{a1}	4.74±0.27^{a1}	4.69±0.08^{a1}	
Iron	50th day	4.17±0.11^{a1}	3.42±0.11^{a1}	3.90±0.38^{a1}	3.86±0.42^{a1}	0.327
	70th day	3.58±0.04^{a1}	4.12±0.04^{a1}	3.86±0.38^{a1}	3.90±0.43^{a1}	
SE values	0.283					

Values are expressed as mean ± standard deviation of three replicates;
Mean values with similar superscripts within a column (alphabets) and row (numerical) do not differ significantly (P=0.05)

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Studies on relative fitness and off-season activity of castor capsule borer, *Conogethes punctiferalis* Guenee (Lepidoptera : Crambidae)

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ABSTRACT

Castor capsule borer, *Conogethes punctiferalis* Guenee is a key pest of economic importance in the rainfed castor belts of Telangana, Andhra Pradesh and Karnataka. The polyphagous pest was found to infest 36 crop plants in India. In the recent years, occurrence of host races or cryptic species have been reported in different host-associated populations of *C. punctiferalis.* In the present study, oviposition responses and relative fitness of *C. punctiferalis* on five economically important hosts *viz.,* castor, ginger, turmeric, maize and guava was studied under laboratory conditions. Among five hosts, *C. punctiferalis* preferred castor and maize for oviposition, while there was no oviposition was recorded on ginger, turmeric and guava. The fecundity, per cent hatching, pupation and adult emergence was 23.6 and 18.6 eggs, 64.4 and 60.2 per cent, 87.7 and 87.3 per cent and 94.9 and 93.0 per cent on castor and maize, respectively. The average larval and pupal periods were 17.15 and 8.27 days on castor, while it was 18.1 and 8.76 days on maize. Field survey was conducted to study off-season activity and carry-over of castor capsule borer, *C. punctiferalis* during March to July, 2014 and 2015. Among 12 alternate hosts surveyed, off-season multiplication of *C. punctiferalis* was recorded on perennial castor, guava fruits and mango inflorescence in both the years. Laboratory rearing of the larvae and pupae of *C. punctiferalis* collected on the alternate hosts revealed that there was no diapause in any stage of its life cycle during the off-season. The present results provide informative data on relative fitness and off-season activity of *C. punctiferalis* on alternate hosts will be useful in developing strategies for the management of this pest.

Keywords: Alternate hosts, Castor, *Conogethes punctiferalis,* Off-season biology, Relative fitness

Castor (*Ricinus communis* L.) is an industrially important oilseed crop in India cultivated in an area of 11.05 lakh hectares with a production of 17.33 lakh tonnes. One of the major constraints in the production of castor is the excessive damage caused by insect pests, the major ones being capsule borer, *Conogethes punctiferalis* Guenee (Lepidoptera : Crambidae). The larva bores into the capsules and damages inner contents causing a direct loss to potential yield. The magnitude of the capsule borer problem is quite high in Southern India where castor is grown mainly as rainfed crop resulting in lower seed yields (Duraimurugan and Lakshminarayana, 2015). In India it has been reported to attack over 36 crop plants belonging to 23 families and production losses of about 20-30 per cent were reported in castor and cardamom (Thyagaraj, 2003). In the recent years, DNA barcoding reveals the occurrence of cryptic species in host-associated population of *C. punctiferalis* and showed genetic divergence between host-associated populations (Shashank *et al.,* 2014). Development of effective management strategies requires a thorough understanding about the biological relationships of pest with various host plants. A very important aspect of such relationship is that of host preference for oviposition but the knowledge on this with respect to *C. punctiferalis* is limited (Thyagaraj *et al.,* 2003; Shashank *et al.,* 2014). Similarly, there is a lack of systematic information on off-season activity and carry-over of castor capsule borer which is one of the prerequisites for the integrated management of the pest. The objectives of our study are to evaluate the oviposition preference and relative fitness of castor capsule borer, *C. punctiferalis* on selected economically important crop plants and to study the off-season biology of the pest. Our study will provide information which may prove to be valuable in developing strategies for the management of this pest.

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MATERIALS AND METHODS

Relative fitness of castor capsule borer, *Conogethes punctiferalis* on different hosts: Laboratory culture of *C. punctiferalis* was established from the larvae collected from castor fields at Research Farm, ICAR-Indian Institute of Oilseeds Research, Rajendranagar, Hyderabad during October and November, 2012. The larvae were reared on fresh castor capsules (cv. DCS-9) in Insect Breeding Dish (90 x 40 mm with ventilation hole size of 40mm, HiMedia, Mumbai). The larvae were provided with fresh capsules once in 3-4 days. After pupation, pupae were transferred to specimen tubes (25 x 100 mm, Borosil, Mumbai) for adult emergence. Both male and female were sexed based on pupal marking at posterior abdominal segment. Emerged adults were used for further studies. The relative fitness of *C.*

punctiferalis on five economically important and reported as hosts of *C. punctiferalis viz.,* castor, ginger, turmeric, maize and guava was studied under laboratory conditions using no-choice test. Castor inflorescence (raceme) with immature capsules, immature rhizomes of ginger and turmeric, immature cobs of maize and immature fruits of guava was used for the experiment. Each host was kept individually in a transparent plastic jar (25 cm × 10 cm, height x diameter) and a single pair of freshly emerged adults were released for mating and oviposition. Cotton pads soaked with 10% sugar solution were given as adult food and the mouth of the jar was covered with muslin cloth. After four days, the moths were removed from the plastic jar and the number of eggs laid on the hosts was assessed. Freshly hatched first instar larvae were transferred with camel hair brush to individual plastic jars containing respective immature hosts and reared. The jars were covered with muslin cloth for adequate aeration and rubber bands to prevent the escape of larvae. New hosts were given as feed once in 3-4 days i.e. when dried or eaten by the larvae. The experiment and mass rearing were carried out under ambient (27 ± 2°C, 60 - 70% RH) conditions with natural photoperiod (12:12 L:D). Observations on the number of eggs laid, per cent hatching, larval period, pupal period, per cent pupation and adult emergence were recorded. Each set up was replicated fifteen times and mean and standard error were calculated using MS-Excel software.

Off-season biology of castor capsule borer, *Conogethes punctiferalis*: Field survey was conducted to study off-season activity of castor capsule borer, *C. punctiferalis* during March to July, 2014 and 2015. To observe survival of *C. punctiferalis* during off-season (March to July), one km radius around the Research farms of ICAR-Indian Institute of Oilseeds Research at Rajendranagar (latitude 17.53°N, longitude 78.27°E, altitude 545 m a.s.l.) and Narkhoda (latitude 17.25°N, longitude 78.33°E, altitude 563 m a.s.l.) were considered for the study. After harvest of castor from the fields during March to till onset of regular monsoon (July), twelve reported alternate hosts of *C. punctiferalis* (Thyagaraj *et al.,* 2003) *viz.,* sorghum (*Sorghum bicolor* L.), maize (*Zea mays* L.), perennial castor (*Ricinus communis* L.), sunflower (*Helianthus annuus* L.), cotton (*Gossypium hirsutum* L.), brinjal (*Solanum melongena* L.), mango (*Mangifera indica* L.), guava (*Psidium guajava* L.), grape (*Vitis vinifera* L.), pomegranate (*Punica granatum* L.), citrus (*Citrus aurantifolia*) and ber (*Ziziphus mauritiana* Lam.) were examined every fortnight for the presence of life stages of capsule borer. For this, ten randomly selected plants of each host were sampled for the incidence of *C. punctiferalis.* In case of field crops, the whole plants were examined and number of larvae per plant was worked out, while four fruits or inflorescence (one from each cardinal directions) were sampled from each of the ten randomly selected trees and number of larvae/fruit/tree or larvae/inflorescence/tree was worked out in case of horticultural crops. As and when the incidence was noticed, the larvae were collected from the respective host plants and fed with the same food material and reared under laboratory conditions to know diapauses, if any and also to confirm the species.

RESULTS AND DISCUSSION

Relative fitness of castor capsule borer, *Conogethes punctiferalis* on different hosts: Laboratory experiment was conducted to study the oviposition response and relative fitness of *C. punctiferalis* on five hosts (castor, ginger, turmeric, maize and guava). Among five hosts, *C. punctiferalis* preferred castor and maize for oviposition. More number of 23.6 eggs was laid on castor as compared to 18.6 eggs on maize. No oviposition of *C. punctiferalis* was recorded on ginger, turmeric and guava. Larvae of *C. punctiferalis* reared on castor and maize gave comparable results in growth and development as measured by several biological parameters (Fig. 1 and Fig. 2). The larval and pupal period was 17.15 and 8.27 days on castor, while it was 18.1 and 8.76 days on maize. The number of days taken by a neonate larva to become adult was 25.42 days in castor and 26.86 days in maize. The per cent hatching, pupation and adult emergence was 64.4 and 60.2 per cent, 87.7 and 87.3 per cent and 94.9 and 93.0 per cent on castor and maize, respectively. The preference of oviposition of *C. punctiferalis* observed in the present study was in close agreement with the findings of Honda *et al.* (1986) and Shashank *et al.* (2014) who reported oviposition preferences of the *C. punctiferalis* for different plant hosts. The total larval duration observed in the present investigation on castor and maize is comparable with the report of Thyagaraj (2003). Longer larval duration of 21 to 25 days reported by Stanley *et al.* (2009) could be due to the difference in host plant and change in the micro environment. The pupal periods which lasted from 8.27 to 8.76 days overlaps the findings of Gour and Sriramulu (1992) and Stanley *et al.* (2009) on grape (7-10 days) and cardamom (7.9 days), respectively. Insect traits that govern the use of different host plant species can be subject to selection at a variety of spatial scales, leading to changes in oviposition behavior and larval performance on different plant species (Forister, 2004; Ballabeni *et al.,* 2003). The modification in feeding preference by polyphagous larvae could result in their progeny restricting their preference to one or a few host plants and a change of preference by a larval population could stimulate genetic differences (Ladner and Sonia, 2005). It is concluded that different hosts have effects on egg laying behaviour of *C. punctiferalis.* Among five host plants evaluated in the present investigation, *C. punctiferalis* accepted maize and castor as hosts and its biology was found comparable on both the hosts under laboratory conditions.

The information on preference of host plants for oviposition and developmental periods of the stages of *C. punctiferalis* will be useful in understanding the population dynamics and developing strategies for the management of this pest.

Off-season biology of castor capsule borer, *Conogethes punctiferalis*: Fortnightly survey was conducted on 12 reported alternate hosts of *C. punctiferalis* to study the off-season survival and multiplication of castor capsule borer during March - July, 2014 and 2015. In both the years, off-season multiplication of *C. punctiferalis* was recorded on shoot and capsules of perennial castor, guava fruits and mango inflorescence (Fig. 3 and 4). Regular incidence of *C. punctiferalis* was recorded during off-season (March - July) on perennial castor and the population ranged from 0.1 to 1.3 larvae/plant and 0.5 to 3.0 larvae/plant during 2014 and 2015, respectively. The incidence of *C. puctiferalis* was more during March to May with higher number of 1.3 and 3.0 larvae/plant was recorded during first fortnight of May during 2014 and 2015, respectively. Off-season survival and multiplication of *C. puctiferalis* was also observed on guava fruits and mango inflorescence during March to July and March to June, respectively. The incidence of *C. puctiferalis* on guava ranged from 0.03 to 0.19 and 0.02 to 0.47 larva/fruit/tree, while it was 0.025 to 0.15 and 0.03 to 0.35 larva/inflorescence/tree on mango during 2014 and 2015, respectively. Higher number of 0.19 and 0.47 larva/fruit/tree on guava was recorded during second fortnight of March and first fortnight of April, while it was 0.15 and 0.35 larva/inflorescence/tree on mango during first fortnight of April and May in 2014 and 2015, respectively. Laboratory rearing of the larvae and pupae of *C. punctiferalis* collected on the alternate hosts revealed that there was no diapause in any stage of its life cycle during the off-season. David *et al.* (1964) reported off-season occurrence of *C. punctiferalis* on sorghum feeding on the grains. Contrarily, off-season multiplication of *C. punctiferalis* was not recorded on sorghum in the present investigation. During the off-season, it was occurred on perennial castor, guava fruits and mango inflorescence. This finding was in confirmation with the report of Mishra and Teotia (1965) who reported the off-season occurrence of *C. punctiferalis* on castor. In contrary to the report of Kuang *et al.* (2009) who stated larval diapause in *C. punctiferalis,* there was no diapause in any stage of its life cycle was observed in the present investigation. *C. punctiferalis* population maintained on alternate hosts during off-season may contribute for the buildup of the pest on castor during *kharif* season. The off-season alternate hosts of *C. punctiferalis* identified in the present study may be valuable in developing strategies for the management of the pest in castor. Observations on non-acceptance of guava for oviposition under laboratory conditions and off-season multiplication on guava under field found in the present investigation necessitates studies on the effect of host shift on biology of *C. punctiferalis* involving populations from castor on cardamom and *vice versa*.

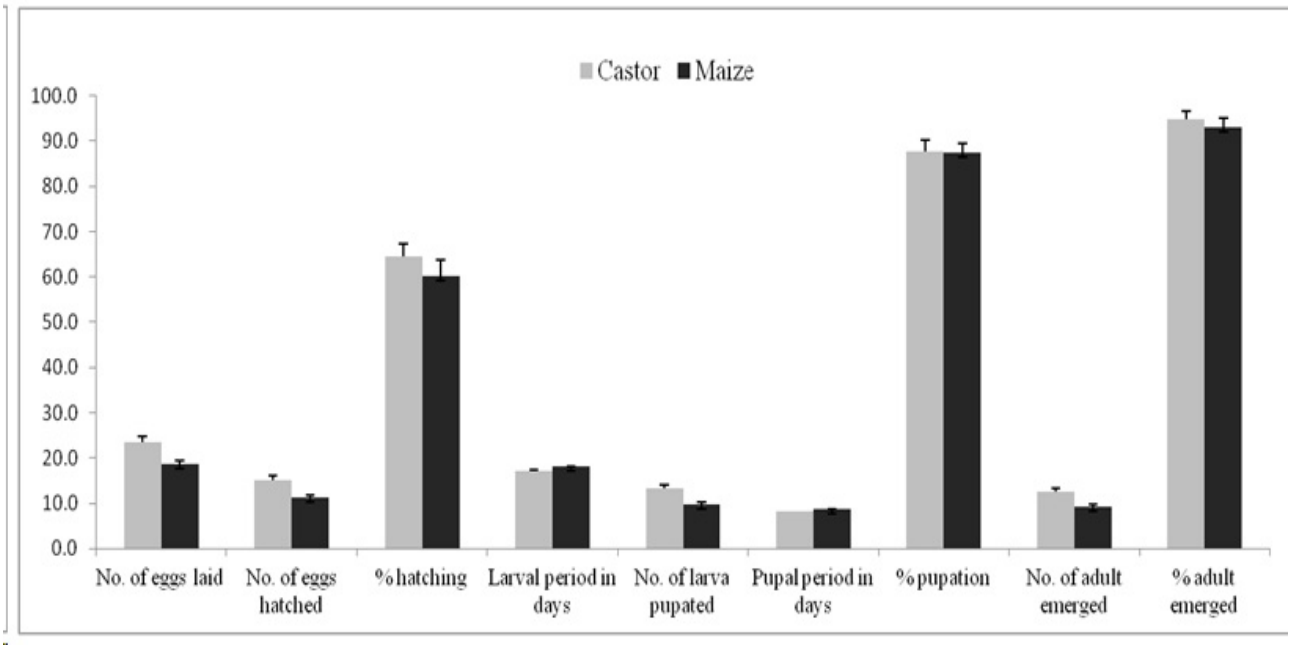

Fig. 1. Ovipositional response, larval and pupal development of *Conogethes punctiferalis* on castor and maize under laboratory conditions (Mean ± SE)

Fig. 2. Multiplication of *Conogethes punctiferalis* on maize cob under laboratory conditions

Fig. 3. Off-season multiplication of *Conogethes punctiferalis* on guava, mango and perennial castor

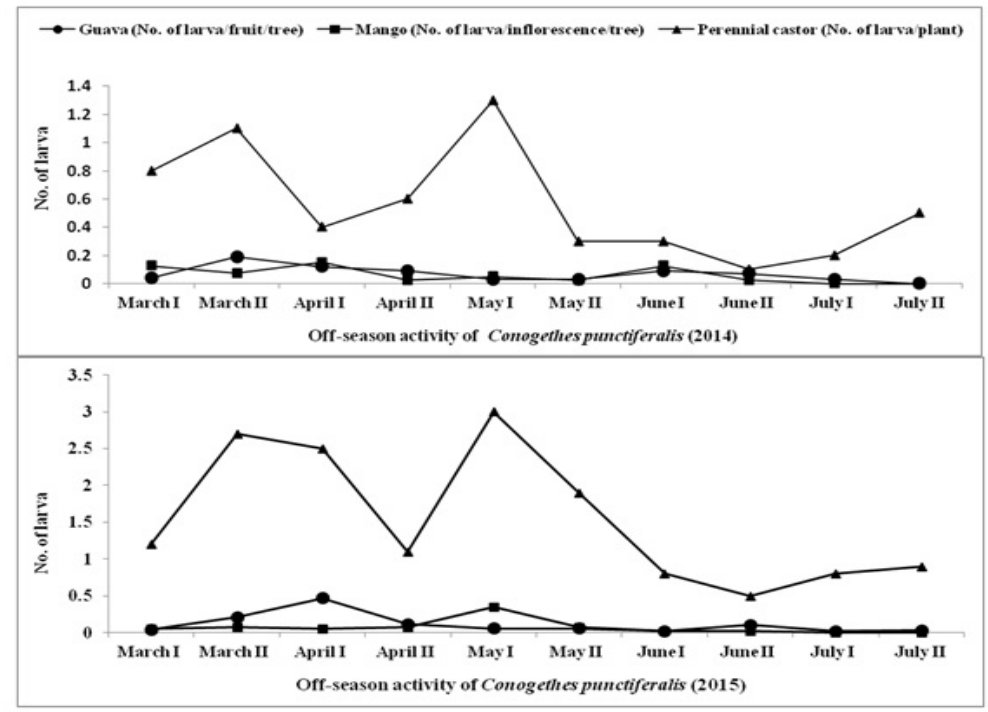

Fig. 4. Off-season activity of *Conogethes punctiferalis* on guava, mango and perennial castor (2014 and 2015)

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Impact of improved groundnut (*Arachis hypogaea* L.) production technologies on knowledge and adoption of farmers

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ABSTRACT

Groundnut is an important oilseed crop in Karimnagar district, Telangana state. The KVK, Karimnagar has disseminated improved groundnut production technologies to the farmers of the district through village adoption, technology assessment, refinement, demonstrations and farmer field schools. Further, the KVK has used various modes of communication such as electronic and print media for popularization of technologies. An impact assessment was done in 15 adopted villages with 60 farmers and 15 non-adopted villages with 30 farmers to assess the increase in knowledge and adoption of groundnut technologies. An *Ex-post* facto research designed was used for impact assessment. The results indicated significant differences in level of knowledge and extent of adoption between farmers of KVK-adopted villages and non-adopted villages. The knowledge scores were high in 48 per cent of farmers from adopted villages whereas high knowledge scores were observed in 23 per cent of farmers from non-adopted villages. The extent of adoption was high in 45 per cent of farmers from adopted villages, whereas it was 27 per cent from non-adopted villages. Farmers from adopted and non-adopted villages possessed knowledge of improved varieties such as K6 and application of gypsum. Deep ploughing and irrigating the crop at regular intervals were adopted by majority of the farmers in non-adopted villages.

Keywords: Extent of adoption, Groundnut, Knowledge mapping, Production technologies

Groundnut is an important oilseed crop grown during *rabi* season in Karimnagar district, Telangana state. It is grown over an area of 20,000 ha with a productivity of 1600 kg/ha. KVKs are district level institutes for technology transfer in agriculture. The KVK, Karimnagar has adopted 15 villages in Karimnagar and transferred improved groundnut production technologies to improve the production and productivity through Integrated Crop Management (ICM). Various approaches like technology assessment, refinement, demonstrations and farmer field schools were conducted by the KVK for technology transfer. The KVK also acted as resource centre for technologies and facilitated in transfer of technologies to the farmers. The objectives of the present study is to understand the personal, psychological, socio-economic and situational characteristics of farmers adopted by the KVK and assess the level of knowledge and extent of adoption of groundnut technologies by these farmers.

MATERIALS AND METHODS

An *Ex-post* facto research design was used for the study. The KVK, Karimnagar was selected purposively as it was recognized as the best KVK for the year 2006-07 by the ICAR at the National level. KVK adopted 15 villages during the period 1993-2008 and all these were selected for the study. In the study, respondents were divided in two categories i.e., farmers adopting KVK technologies and farmers not adopting KVK technologies. This paper presents the result drawn from the survey of a total of 60 adopting farmers and 30 non-adopting farmers growing groundnut crop from 15 selected villages. Four farmers from each adopted villages, who were adopting the KVK technologies in groundnut for the last five years were selected randomly. Correspondingly from each adopted village, 2 farmers growing groundnut crop who are not adopting the technologies disseminated by the KVK were selected randomly. The knowledge level and extent of adoption were assessed with the help of a test and scale developed respectively for the study. Frequencies, percentages and Z-test were used for analysis of the data.

RESULTS AND DISCUSSION

Profile of the groundnut farmers: Most of the farmers adopting KVK technologies belonged to middle age, high level of mass media exposure, extension contact, innovativeness, scientific orientation and economic orientation. In case of non-adopting farmers, the majority belonged to middle age group, medium to low level of mass media exposure, extension contact, innovativeness, scientific orientation and economic orientation. Majority of the KVK adopted farmers were found better in almost all the profile characteristics than the not adopting farmers. It could be understand that high level of social participation, mass media exposure driven the farmers to have high level of extension contacts. Under normal circumstances the young and middle age individuals are attracted easily to experiment new technology due to their more innovativeness and risk orientation.

Level of knowledge of farmers on technologies imparted through KVK: The levels of knowledge of the adopted and non-adopted farmers of groundnut technologies disseminated by KVK are presented in Table 1. It is evident from the table 1 that calculated 'Z' value (3.20) was greater than table 'Z' value at 0.01 level of probability, indicating significant difference between mean scores of KVK adopted and non-adopted farmers.

It was observed from Table 2 that majority (48.33%) of the KVK adopted farmers had high level of knowledge followed by medium (35.00%) and low (16.67%) whereas, majority (40.00%) of the non-adopted farmers had medium level of knowledge followed by low (36.67%) and high (23.33%). These findings are in tune with the results of Ingle (1997) and Sharma and Sharma (1999).

Table 1 Knowledge level of KVK adopted and non-adopted groundnut farmers

Respondent category	Size of sample (n)	Mean	SD	'Z' value
KVK adopted farmers	60	46.56	2.13	3.20*
Non adopted farmers	30	30.73	2.80	

*Significant at 0.01 level of probability

Table 2. Distribution of respondents according to their level of knowledge of groundnut production technologies

	KVK adopted groundnut farmers (n=60)			Non-adopted groundnut farmers (n=30)		
Category	Low (24 -32)	Medium (33-41)	High (42-48)	Low (24 -32)	Medium (33-41)	High (42-48)
Frequency	10	21	29	11	12	7
Percentage	16.67	35.00	48.33	36.67	40.00	23.33

The technologies on which the respondents had high level of knowledge are application of gypsum, usage of K-6 variety and deep summer ploughing ranked 1st followed by weed management with recommended herbicides , providing irrigations at critical stages (2nd), usage of suitable *rabi* varieties, usage of optimum seed rate (3rd), optimum time of sowing, use of rhizobium biofertilizer (4th), soil test based fertilizer application, seed treatment (5th), usage of recommended dose of fertilizers (6th) respectively, whereas adopted farmers had lowest level of knowledge on usage of biological pesticides. The non-adopted KVK farmers had high knowledge on practices like usage of K-6 variety and poison bait effectively control the spodoptera ranked 1st followed by using sprinkler irrigation and sowing of JCG-88 variety, usage of optimum seed rate, application of gypsum (2nd), optimum time of sowing, usage of suitable varieties (3rd), seed treatment, usage of post emergence herbicides and usage of biological pesticides (4th), usage of rhizobium bio fertilizer (5th), soil test based fertilizer application, providing irrigation at critical stages and spraying of post emergence herbicides (6th) (Table 3).

The high level of knowledge on application of gypsum to increasing the shelling percentage and use of K-6 improved variety in place of TMV-2, was due to the efforts of KVK, which promoted seed village concept and taken up seed production of K-6 and provided gypsum to all the adopted farmers on subsidy basis with the help of Department of Agriculture. The adopted farmers also had high knowledge on deep summer ploughing, weed management with herbicides, usage of suitable varieties, usage of optimum seed rate, optimum time and spacing, soil test based fertilizer application etc., the possible reasons for high level of knowledge on the above technologies could be the KVK scientists assessed and refined the several technologies in adopted villages followed by conducting more number of demonstrations and extension activities with the help of electronic and print media, where as adopted farmers had lowest level of knowledge on usage of biological pesticides due to non availability of quality inputs in the local market. Whereas non-adopted groundnut farmers had high level of knowledge on usage of K-6 variety, poison bait for spodoptera control, sprinkler irrigation, usage of optimum seed rate, application of gypsum, seed treatment, weed management etc. The reasons for high knowledge was due to the efforts of KVK in giving several programmes in electronic media and print media on groundnut cultivation, which helped non-adopted farmers to get higher knowledge on the above technologies.

Extent of adoption of technologies disseminated through KVK by farmers: The extent of adoption of groundnut technologies by the KVK adopted farmers and non-adopted farmers are presented in Table 5. It is evident from the table that, calculated 'Z' Value (2.15) was greater than table 'Z' value at 0.01 level of probability, indicating significant differences between mean scores of KVK adopted and non-adopted farmers.

It was observed from Table 6 that, majority (45.00%) of the KVK adopted groundnut farmers had high extent of adoption followed by medium (33.33%) and low (21.67%) whereas, majority (40.00%) of the KVK non-adopted farmers had low extent of adoption followed by medium (33.33%) and high (26.67%). These results are in tune with the findings of Deshmukh *et al.* (1997), Veeraiah *et al.* (1998) and Sreenivasulu *et al.* (1998), Sreenivasulu *et al.* (2015) and Sonawane *et al.* (2016).

The technologies on which the respondents had high adoption are application of gypsum and usage of K-6 variety are ranked 1st followed by harvesting of groundnut (2nd), seed treatment (3rd), providing irrigation at critical stages (4th), usage of optimum seed rate, frequency of irrigating the crop (5th), use of recommended fertilizers (6th) respectively, where as adopted farmers had lowest extent of adoption on usage of biological pesticides. Most of the non-adopted KVK farmers practices like frequency of irrigating the crop is ranked 1st followed by deep summer ploughing (2nd), providing irrigations at critical stages (3rd), application of gypsum (4th), usage of K-6 variety and JCG 88 variety (5th), sprinkler irrigation, usage of optimum seed rate and optimum spacing (6th) (Table 7).

Table 3 Item wise analysis of adopted farmers on level of knowledge of groundnut production technologies in Karimnagar district (n=60)

Groundnut production technologies	Level of knowledge		Total score	Mean score	Rank
	Yes	No			
	F (%)	F (%)			
Soil samples collected up to 15-20 cm depth in V shape for soil testing	52 (86.6)	8 (13.4)	112	1.86	V
Soil test based fertilizer application is economical	52 (86.6)	8 (13.4)	112	1.86	V
Optimum time of sowing for *rabi* September 15th - October 15th	54 (90.0)	6 (10.0)	114	1.90	VI
Suitable varieties for *rabi* ; Kadiri-6, JCG- 88, TAG -24, Greeshama	56 (93.3)	4 (6.7)	116	1.93	III
Optimum seed rate for *rabi* 60-75 kg/acre	56 (93.3)	4 (6.7)	116	1.93	III
Seed treatment with mancozeb @ 3 g/kg seed + chlorpyriphos @ 6.5 ml/kg reduces the incidence of insect pests and diseases in the initial stages of crop growth	52 (86.6)	8 (13.4)	112	1.86	V
Optimum spacing in *rabi* 22.5 x 10 cm	52 (86.6)	8 (13.4)	112	1.86	V
Optimum dose of fertilizer for *rabi* : NPK : 12-16-20 kg/acre	51 (85.0)	9 (15.0)	111	1.85	VI
Use of rhizobium bio fertilizer decreases the usage of nitrogenous fertilizer	54 (90.0)	6 (10.0)	114	1.90	IV
Application of gypsum improves the shelling percentage	60 (100.0)	0 (0.0)	120	2.00	I
The frequency of irrigating the groundnut crop (12-15 days)	58 (96.7)	2 (3.3)	118	1.96	II
Providing irrigation at critical stages of crop growth is important for achieving higher yield	58 (96.7)	2 (3.3)	118	1.96	II
K-6 variety which gives higher yields with lesser duration than TMV-2	60 (100.0)	0 0.0	120	2.00	I
Spraying of pre emergence herbicide pendimethalin @ 1.0 lt /acre or oxyflourfen @ 200 ml /acre will effectively controls the weeds	58 (96.7)	2 (3.3)	118	1.96	II
Spraying of quizolofop ethyl @ 400 ml/acre after 20 DAS as post emergence herbicide will reduce the weeds effectively	58 (96.7)	2 (3.3)	118	1.96	II
JCG-88 variety which is tolerant for leaf spot gives higher yield than TMV-2	56 (93.3)	4 (6.7)	116	1.93	III
Giving irrigation with sprinklers will save 25-30% water	56 (93.3)	4 (6.7)	116	1.93	III
Deep ploughing during summer reduces the incidence of soil borne diseases	60 (100.0)	0 (0.0)	120	2.00	I
Installation of pheromone traps helps to monitor insects pests	46 (76.7)	14 (23.3)	106	1.76	
Application of biological pesticides is economical and control insects pests and diseases	30 (50.0)	30 (50.0)	90	1.35	
Poison bait is effective for spodoptera control	44 (73.3)	16 (26.6)	104	1.73	
Application of chemical pesticides ‘as and when’ symptoms are observed is economical and gives good control of insect pests / diseases	44 (73.3)	16 (26.6)	104	1.73	
Application of pesticides based on ETL levels is economical and gives good control of insects pests and diseases	50 (83.3)	10 (16.7)	110	1.83	
Harvesting of groundnut should be done when the pods develop black netting	44 (73.3)	16 (26.6)	104	1.73	

Table 4 Item wise analysis of non-adopted farmers on level of knowledge of groundnut production technologies in Karimnagar district (n=30)

Groundnut production technologies	Level of knowledge		Total score	Mean score	Rank
	Yes	No			
	F (%)	F (%)			
Soil samples collected up to 15-20cm depth in V shape for soil testing	20 (66.7)	10 (33.3)	50	1.66	VI
Soil test based fertilizer application is economical	20 (66.7)	10 (33.3)	50	1.66	VI
Optimum time of sowing for *rabi* September 15th - October 15th	24 (80.0)	6 (20.0)	54	1.77	III
Suitable varieties for *rabi* ; Kadiri-6, JCG- 88, TAG -24, Greeshama	24 (80.0)	6 (20.0)	54	1.77	III
Optimum seed rate for *rabi* 60-75 kgs/acre	25 (83.3)	5 (16.7)	55	1.83	II
Seed treatment with mancozeb @3 g/kg seed + chlorpyriphos @6.5 ml/kg reduces the incidence of insect pests and diseases in the initial stages of crop growth	22 (73.3)	8 (26.6)	52	1.73	IV
Optimum spacing in *rabi* 22.5 x 10 cm	25 (83.3)	5 (16.7)	55	1.83	II
Optimum dose of fertilizer for *rabi* : NPK : 12-16-20 kg/acre	15 (50.0)	15 (50.0)	45	1.50	
Use of rhizobium biofertilizer decreases the usage of nitrogenous fertilizer	22 (73.3)	8 (26.6)	52	1.72	V
Application of gypsum improves the shelling percentage	25 (83.3)	5 (16.7)	55	1.83	II
The frequency of irrigating the groundnut crop (12-15 days)	25 (83.3)	5 (16.7)	55	1.83	II
Providing irrigation at critical stages of crop growth is important for achieving higher yield	20 (66.7)	10 (33.3)	50	1.66	VI
K-6 variety which gives higher yields with lesser duration than TMV-2	28 (93.3)	2 (6.7)	58	1.93	I
Spraying of pre-emergence herbicide pendimethalin @ 1.0l/acre or oxyflourfen @ 200 ml/acre will effectively controls the weeds	20 (66.6)	10 (33.4)	50	1.66	VI
Spraying of quizolofop ethyl @ 400 ml/acre after 20 DAS as post emergence herbicide will reduce the weeds effectively	22 (73.3)	8 (26.7)	52	1.73	IV
JCG-88 variety which is tolerant for leaf spot gives higher yield than TMV-2	25 (83.3)	5 (16.7)	55	1.83	II
Giving irrigation with sprinklers will save 25-30% water	25 (83.3)	5 (16.7)	55	1.83	II
Deep ploughing during summer reduces the incidence of soil borne diseases	11 (36.7)	19 (63.3)	41	1.36	
Installation of pheromone traps helps to monitor insects pests	16 (53.3)	14 (46.7)	46	1.53	
Application of biological pesticides is economical and control insects pests and diseases	22 (73.3)	8 (26.7)	52	1.73	IV
Poison bait is effective for spodoptera control	28 (93.3)	2 (6.7)	58	1.93	I
Application of chemical pesticides 'as and when' symptoms are observed is economical and gives good control of insect pests / diseases	14(46.7)	16 (53.3)	44	1.46	
Application of pesticides based on ETL levels is economical and gives good control of insects pests and diseases	16 (53.3)	14 (46.7)	46	1.53	
Harvesting of groundnut should be done when the pods develop black netting	25 (83.3)	5 (16.7)	55	1.83	II

Table 5 Adoption level of KVK adopted and non-adopted groundnut farmers

Respondent category	Size of the sample (n)	Mean	SD	'Z' value
KVK adopted farmers	60	57.11	8.30	2.15*
Non-adopted farmers	30	30.50	4.05	

*Significant at 0.01 level of probability

Table 6 Distribution of respondents according to their extent of adoption of groundnut production technologies

Category	KVK adopted groundnut farmers (n=60)			Non-adopted groundnut farmers (n=30)		
	Low (33-55)	Medium (56-78)	High (79-100)	Low (33-55)	Medium (56-78)	High (79-100)
Frequency	13	20	27	12	10	8
Percentage	21.67	33.33	45.00	40.00	33.33	26.67

It is noticed from Table 8 that the KVK adopted farmers had high extent of adoption than the non-adopted farmers. The KVK adopted farmers had high extent of adoption on application of gypsum to increase the shelling percentage and usage of K-6 variety due to KVK scientists were formed the village groups in adopted villages and taken up the seed production through seed village concept. During the seed production KVK scientists facilitated and provided the gypsum to adopted farmers on subsidy basis with the help of Department of Agriculture. After harvesting the village groups were procured the entire seed and supplied to other farmers on cost basis. With these reasons the extent of adoption is high on the above technologies. The adopted farmers also has high adoption on seed treatment, providing irrigation on critical stages, usage of optimum seed rate,

frequency of the irrigating crop, use of recommended fertilizers etc. The reasons could be the KVK scientists conducted several demonstrations in the farmer fields of adopted villages with practical approach. KVK also focused on extension activities especially airing documentaries in TV at critical stages of crop helped the farmers to increase the adoption rate. The adopted farmers had lowest extent of adoption on usage of biological pesticides due to non availability of quality in puts in local market. Whereas non-adopted farmers had high extent of adoption on deep summer ploughing, providing irrigation at critical stages, application of gypsum, usage of K-6 variety, sprinkler irrigation, use of optimum seed rate etc. The reasons could be they were influenced and inspired by the performance of the above technologies in adopted farmers fields. They were also participated in extension activities and learnt the performance of new technologies from the rich experience of the adopted farmers. The farmers of KVK-adopted villages have high level of knowledge and high extent of adoption of groundnut production technologies as compared to farmers of non-adopted villages. Further, the every five years, the adopted villages have to be changed and the impact has to be assessed.

Table 7 Item wise analysis of adopted farmers on extent of adoption of groundnut production technologies in Karimnagar district (n=60)

Groundnut production technologies	Extent of adoption			Total score	Mean score	Rank
	Fully adopted	Partially adopted	Not adopted			
	F (%)	F (%)	F (%)			
Soil samples collected up to 15-20cm depth in V shape for soil testing	30 (50.0)	20 (33.3)	10 (16.7)	140	2.33	
Soil test based fertilizer application is economical	30 (50.0)	20 (33.3)	10 (16.7)	140	2.33	
Optimum time of sowing for *rabi* September 15th – October 15th	42 (68.3)	14 (23.3)	5 (8.4)	156	2.60	
Suitable varieties for *rabi* ; Kadiri-6, JCG- 88, TAG -24, Greeshama	42 (70.0)	13 (21.7)	5 (8.3)	157	2.61	
Optimum seed rate for *rabi* 60-75 kgs/acre	52 (86.7)	8 (13.3)	0 (0.0)	172	2.83	V
Seed treatment with mancozeb @3 g/kg seed + chloropyriphos @6.5 ml/kg reduces the incidence of insect pests and diseases in the initial stages of crop growth	53 (88.3)	7 (11.7)	0 (0.0)	173	2.88	III
Optimum spacing in *rabi* 22.5 x 10 cm	50 (83.3)	10 (16.7)	0 (0.0)	160	2.66	
Optimum dose of fertilizer for *rabi* : NPK : 12-16-20 kg/acre	49 (81.7)	11 (18.3)	0 (0.0)	169	2.81	VI
Use of rhizobium biofertilizer decreases the usage of nitrogenous fertilizer	34 (56.6)	16 (26.6)	10 (16.8)	144	2.40	
Application of gypsum improves the shelling percentage	60 (100.0)	0 (0.0)	0 (0.0)	180	3.00	I
The frequency of irrigating the groundnut crop (12-15 days)	52 (86.7)	8 (13.3)	0 (0.0)	172	2.83	V
Providing irrigation at critical stages of crop growth is important for achieving higher yield	53 (88.3)	7 (11.7)	0 (0.0)	173	2.84	IV
K-6 variety which gives higher yields with lesser duration than TMV-2	60 (100.0)	0 (0.0)	0 (0.0)	180	3.00	I
Spraying of pre-emergence herbicide pendimethalin @ 1.0 lt /acre or oxyflourfen @ 200 ml /acre will effectively controls the weeds	50 (83.3)	10 (16.7)	0 (0.0)	160	2.66	
Spraying of quizolofop ethyl @ 400 ml/acre after 20 DAS as post emergence herbicide will reduce the weeds effectively	40 (66.6)	10 (16.7)	10 (16.7)	150	2.50	
JCG-88 variety which is tolerant for leaf spot gives higher yield than TMV-2	40 (66.6)	10 (16.7)	10 (16.7)	150	2.50	
Giving irrigation with sprinklers will save 25-30% water	40 (66.6)	10 (16.7)	10 (16.7)	150	2.50	
Deep ploughing during summer reduces the incidence of soil borne diseases	40 (66.6)	10 (16.7)	10 (16.7)	150	2.50	
Installation of pheromone traps helps to monitor insects pests	10 (16.6)	0 (0.0)	50 (83.4)	80	1.33	
Application of biological pesticides is economical and control insects pests and diseases	28 (46.7)	0 (0.0)	32 (53.3)	116	1.93	
Poison bait is effective for spodoptera control	46 (76.6)	10 (16.6)	4 (6.6)	162	2.70	
Application of chemical pesticides 'as and when' symptoms are observed is economical and gives good control of insect pests / diseases	20 (33.3)	12 (20.0)	28 (46.6)	112	1.83	
Application of pesticides based on ETL levels is economical and gives good control of insects pests and diseases	43 (71.6)	7 (28.3)	0 (0.0)	163	2.71	
Harvesting of groundnut should be done when the pods develop black netting	58 (96.6)	0 (0.0)	2 (3.4)	176	2.93	II

Table 8 Item wise analysis of non-adopted farmers on extent of adoption of groundnut production technologies in Karimnagar district (n=30)

Groundnut production technologies	Extent of adoption			Total score	Mean score	Rank
	Fully adopted	Partially adopted	Not adopted			
	F (%)	F (%)	F (%)			
Soil samples collected up to 15-20cm depth in V shape for soil testing	0 (0.0)	14 (46.7)	16 (53.3)	44	1.46	
Soil test based fertilizer application is economical	0 (0.0)	14 (46.7)	16 (53.3)	44	1.46	
Optimum time of sowing for *rabi* September 15th October 15th	12 (40.0)	12 (40.0)	6 (20.0)	66	2.20	
Suitable varieties for *rabi* ; Kadiri-6, JCG- 88, TAG -24, Greeshama	20 (66.7)	0 (0.0)	10 (33.3)	70	2.33	VI
Optimum seed rate for *rabi* 60-75 kgs/acre	20 (66.7)	0 (0.0)	10 (33.3)	70	2.33	VI
Seed treatment with mancozeb @3 g/kg seed + chlorpyriphos @6.5 ml/kg reduces the incidence of insect pests and diseases in the initial stages of crop growth	20 (66.7)	0 (0.0)	10 (33.3)	70	2.33	VI
Optimum spacing in *rabi* 22.5 x 10 cm	20 (66.7)	0 (0.0)	10 (33.3)	70	2.33	VI
Optimum dose of fertilizer for *rabi*: NPK:12-16-20 kg/acre	15 (50.0)	0 (0.0)	15 (50.0)	60	2.00	
Use of rhizobium biofertilizer decreases the usage of nitrogenous fertilizer	12 (40.0)	0 (0.0)	18 (60.0)	54	1.80	
Application of gypsum improves the shelling percentage	20 (66.7)	10 (33.3)	0 (0.0)	80	2.66	IV
The frequency of irrigating the groundnut crop (12-15 days)	26 (86.7)	4 (13.3)	0 (0.0)	86	2.86	I
Providing irrigation at critical stages of crop growth is important for achieving higher yield	21(70.0)	9 (30.0)	0 (0.0)	84	2.80	III
K-6 variety which gives higher yields with lesser duration than TMV-2	22 (73.3)	0 (0.0)	8 (26.7)	74	2.46	V
Spraying of pre-emergence herbicide pendimethalin @ 1.0 l/acre or oxyflourfen @ 200 ml/acre will effectively controls the weeds	22 (73.3)	0 (0.0)	8 (26.7)	74	2.46	V
Spraying of quizolofop ethyl @ 400 ml/acre after 20 DAS as post emergence herbicide will reduce the weeds effectively	13 (43.3)	0 (0.0)	17 (56.7)	56	1.86	
JCG-88 variety which is tolerant for leaf spot gives higher yield than TMV-2	22 (73.3)	0 (0.0)	8 (26.7)	74	2.46	V
Giving irrigation with sprinklers will save 25-30% water	20 (66.7)	0 (0.0)	10 (33.3)	70	2.33	VI
Deep ploughing during summer reduces the incidence of soil borne diseases	25 (83.3)	5 (16.7)	0 (0.0)	85	2.83	II
Installation of pheromone traps helps to monitor insects pests	0 (0.0)	0 (0.0)	30 (100.0)	30	1.00	
Application of biological pesticides is economical and control insects pests and diseases	0 (0.0)	10 (33.3)	20 (66.7)	40	1.33	
Poison bait is effective for spodoptera control	0 (0.0)	10 (33.3)	20 (66.7)	40	1.33	
Application of chemical pesticides 'as and when' symptoms are observed is economical and gives good control of insect pests / diseases	10 (33.4)	10 (33.3)	10 (33.3)	30	1.00	
Application of pesticides based on ETL levels is economical and gives good control of insects pests and diseases	10 (33.4)	10 (33.3)	10 (33.3)	30	1.00	
Harvesting of groundnut should be done when the pods develop black netting	22 (73.3)	8 (26.7)	0 (0.0)	82	2.23	

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Variation of oil content and fatty acid composition of *Millettia pinnata* (L.) progenies in Tamil Nadu

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ABSTRACT

Thirty progenies of Millettia pinnata commonly known as 'Pungam' were studied for seed, oil quality as well as fatty acid profile. Among the progenies, only one progeny *viz.,* FCRIMP 2 consistently expressed superiority in all seed characteristics *viz.,* pod length (5.56 cm), pod width (2.98 cm), seed length (2.81 cm), seed width (2.20 cm), 100-seed weight (129.63 g), germination per cent (89.67%), germination value (11.07), peak value (3.45) and oil content (37.50 %). Among the thirty progenies, only nine progenies *viz.,* FCRIMP 2 (37.50%), FCRIMP 3 (33.50%), FCRIMP 4 (37.50%), FCRIMP 6 (33.50%), FCRIMP 12 (34.50%), FCRIMP 15 (35.50%), FCRIMP 22 (34.50%), FCRIMP 24 (33.50%) and FCRIMP 25 (35.50%) recorded higher oil content. The analysis of fatty acid composition revealed that the major fatty acid was oleic acid (12.02 to 12.39%) followed by palmitic acid (1.30-2.65%) and stearic acid (0.12-0.68%).

Keywords: Fatty acid, Growth parameters, *Millettia pinnata,* Oil content

Millettia pinnata (L.) Pierre (family: Leguminosae, sub-family: Fabaceae) is one of the commercially important multi-purpose tree species of India and is popularly known as 'Karanj' or 'Pungam'. In Latin "pinnata' means 'feathered' and glabra' means without hairs. It is native to humid and subtropical environments along the coasts and riverbanks in India especially in Western Ghats and Myanmar and will thrive in areas having an annual rainfall ranging from 500-2500 mm (Bringi, 1987). Pungam can grow on most soil types ranging from sandy to clayey. It does not do well on dry sands. It is highly tolerant of salinity. It is common along waterways or seashores, with its roots in fresh or salt water. Oil is the most important product of the pungam tree and vast amounts of seeds are collected in India for commercial processing of industrial uses. It has been found that the seed contains 27-40 per cent of thick, yellow or reddish-brown oil and that 2 kg of mature pods will yield about 1 kg of husked kernels. Extracted oil amounts to 13.4 per cent of the whole seed pod, 26.97 per cent of the kernels. The oil has a bitter taste, a disagreeable aroma and a specific gravity of 0.93 at 150°C. It is used as a lubricant, varnish, water-paint binder and in soap making. It is one of the few nitrogen-fixing trees to produce seeds containing oil.

Geo-climatic variations may influence plastic changes in plant performance. 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 *M. pinnata* have taken place here and there but still demand continuous and decentralized approach to improve the *M. pinnata* genetic resources towards higher oil content coupled with increased productivity. Against this backdrop, the current work has been planned to improve the variety through systematic tree improvement programme.

MATERIALS AND METHODS

Sixteen districts namely Dharmapuri, Krishnagiri, Dindigul, Madurai, Theni, Thanjavur, Pudukkottai, Coimbatore, Tiruppur, Nagapattinam, Villupuram, Thiruvallur, Cuddalore, Tiruvarur, Sivaganga, Kanyakumari in Tamil Nadu and one from Puducherry in U.T. of Puducherry were surveyed and total number of 30 candidate plus trees (CPTs) was selected. These selected CPTs 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 *Millettia pinnata.* 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.

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.

Table 1 Location details of superior progenies of *Millettia pinnata*

State	Location	Latitude	Longitude	Altitude (m)	Name of the CPTs
Tamil Nadu	Anjetti	12°19'N	77°45'E	554	FCRIMP 1
Tamil Nadu	Denkanikottai	12°31'N	77°46'E	890	FCRIMP 2
Tamil Nadu	Hosur	12°43'N	77°49'E	883	FCRIMP 3
Tamil Nadu	Krishnagiri	12°30'N	78°12'E	497	FCRIMP 4
Tamil Nadu	Pennagaram	12°07'N	77°53'E	520	FCRIMP 5
Tamil Nadu	Dharmapuri	12°05'N	78°05'E	482	FCRIMP 6
Tamil Nadu	Harur	12°02'N	78°28'E	357	FCRIMP 7
Tamil Nadu	Palacodu	12°17'N	78°04'E	521	FCRIMP 8
Tamil Nadu	Chinnalapatti	10°16'N	77°55'E	312	FCRIMP 9
Tamil Nadu	Thirumangalam	09°49'N	77°59'E	123	FCRIMP 10
Tamil Nadu	Theni	09°59'N	77°27'E	334	FCRIMP 11
Tamil Nadu	Cumbum	09°43'N	77°16'E	446	FCRIMP 12
Tamil Nadu	Bodi	10°01'N	77°21'E	337	FCRIMP 13
Tamil Nadu	Orathanadu	10°38'N	79°15'E	36	FCRIMP 14
Tamil Nadu	Tanjavur	10°50'N	79°07'E	47	FCRIMP 15
Tamil Nadu	Pattukottai	10°25'N	79°19'E	24	FCRIMP 16
Tamil Nadu	Mettupalayam	11°17'N	76°57'E	256	FCRIMP 17
Tamil Nadu	Sirumugai	11°19'N	77°01'E	302	FCRIMP 18
Tamil Nadu	Dharapuram	10°43'N	77°31'E	807	FCRIMP 19
Tamil Nadu	Vedaranyam	10°22'N	79°49'E	15	FCRIMP 20
Tamil Nadu	Arakkonam	13°06'N	79°40'E	245	FCRIMP 21
Tamil Nadu	Thiruvallur	13°15'N	80°00'E	36	FCRIMP 22
Tamil Nadu	Villuppuram	11°55'N	79°30'E	41	FCRIMP 23
Tamil Nadu	Tindivanam	12°13'N	79°37'E	46	FCRIMP 24
Tamil Nadu	Mannargudi	10°41'N	79°25'E	19	FCRIMP 25
Tamil Nadu	Perundurai	11°15'N	77°36'E	277	FCRIMP 26
Tamil Nadu	Sivaganga	09°51'N	78°30'E	97	FCRIMP 27
Tamil Nadu	Manamadurai	09°40'N	78°26'E	75	FCRIMP 28
Tamil Nadu	Nagercoil	08°11'N	77°23'E	20	FCRIMP 29
Puducherry	Puducherry	11°54'N	79°47'E	554	FCRIMP 30

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 Vernier caliper 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, 50mg of sodium methylate was added, and the closed tube was agitated vigorously for 1 min at room temperature. After addition of 100 mL of water, the tube was centrifuged at 4500g for 10 min and the lower aqueous phase was removed. Then 50mL 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 mm). 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 1mL. The peak areas were computed by the integration software, and percentages of fatty acid methyl esters (FAME) were obtained as weight percent 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 percentage (%): 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 (GC-MS analysis): Based on the seed oil content superior progenies were screened. Accordingly three progenies of *M. pinnata viz.,* FCRIMP 2, FCRIMP 4 and FCRIMP 25 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 mm), column temperature / oven temp 800 °C raised to 2600°C AT 50°C /min; carrier gas, He, flow: 1.0 ML/Min. Injection volume 1µl. 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 *M. pinnata*, 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 *M. pinnata* 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.,* FCRIMP 2 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 *M. pinnata* and *Calophyllum inophyllum* (Divakara *et al.,* 2010; Sunil *et al.,* 2012; Palanikumaran *et al.,* 2016). 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 129.63 g (FCRIMP 2) and 96.50 g (FCRIMP 17). Seed oil content is an essential parameter which decides the commercial viability. All progenies in *M. pinnata* differed significantly due to oil content. The oil content ranged between 37.50 per cent (FCRIMP 2) and 27.50 per

cent. Similar variation in oil content was observed due to various accessions of *M. pinnata* (Sunil *et al.,* 2012). This study found that variation in oil content among accessions was due to altitudinal differences.

The variability among the 'Pungam' progenies were in the order of 5.56 cm, 2.98 cm, 2.81 cm, 2.20 cm and 129.63 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 89.67 per cent, 11.07, 3.45 and 37.50 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 Denkanikottai (FCRIMP 2) 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 *M. pinnata* (FCRIMP 2) exhibited superiority with respect to seed physical and germination attributes.

Table 2 Seed physical attributes of Millettia pinnata progenies

Name of the Progeny	Seed Physical Attributes				
	Pod length (cm)	Pod width (cm)	Seed length (cm)	Seed width (cm)	100-seed weight (g)
FCRIMP 1	4.28	2.18	1.88	1.34	102.65
FCRIMP 2	5.56**	2.98**	2.81**	2.20**	129.63**
FCRIMP 3	4.00	1.99	1.77	1.33	107.50
FCRIMP 4	4.65	2.45	2.42*	2.07*	121.27**
FCRIMP 5	4.23	2.00	1.78	1.23	100.37
FCRIMP 6	4.18	3.01**	1.90	1.56	108.76
FCRIMP 7	3.88	2.04	1.97	1.35	116.53**
FCRIMP 8	4.41	2.18	2.21	1.75	111.46
FCRIMP 9	3.93	2.07	1.70	1.35	96.65
FCRIMP 10	4.22	2.09	1.96	1.62	103.35
FCRIMP 11	4.33	2.28	2.07	1.45	114.66*
FCRIMP 12	4.12	2.31	1.74	1.51	128.71**
FCRIMP 13	3.58	1.57	1.77	1.15	98.82
FCRIMP 14	4.27	2.08	1.95	1.61	111.34
FCRIMP 15	3.85	1.68	1.64	1.33	115.56**
FCRIMP 16	3.98	1.81	1.86	1.65	125.51**
FCRIMP 17	3.48	1.97	1.88	1.24	96.50
FCRIMP 18	4.05	2.45	2.23	1.53	106.30
FCRIMP 19	4.66	2.36	2.36	1.71	120.19**
FCRIMP 20	4.59	2.42	2.05	1.28	115.47**
FCRIMP 21	4.03	2.16	2.10	1.67	117.47**
FCRIMP 22	3.34	2.38	2.33	1.41	99.21
FCRIMP 23	4.76	1.81	2.30	1.56	120.38**
FCRIMP 24	4.22	2.00	2.11	1.32	115.39**
FCRIMP 25	5.05*	2.12	2.11	1.61	120.66**
FCRIMP 26	4.31	2.21	2.28	1.21	116.49**
FCRIMP 27	4.63	1.93	1.99	1.50	119.69**
FCRIMP 28	3.60	2.25	2.27	1.38	121.40**
FCRIMP 29	4.74	1.85	1.90	1.75	116.52**
FCRIMP 30	4.23	2.14	2.12	1.39	113.38
Mean	4.24	2.16	2.05	1.50	113.06
SEd	0.41	0.28	0.18	0.23	0.77
CD (P=0.05)	0.81	0.57	0.37	0.47	1.54
CD (P=0.01)	1.09	0.75	0.50	0.63	2.05

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

Table 3 Seed germination attributes of *Millettia pinnata* progenies

Name of the Progeny	Seed Germination Attributes				
	Germination per cent	Germination value	Peak value	Mean daily germination	Oil content (%)
FCRIMP 1	78.00**	7.04	2.80	2.51	32.50
FCRIMP 2	89.67**	11.07**	3.45**	3.45**	37.50**
FCRIMP 3	77.00**	7.33	2.84	2.55	33.50*
FCRIMP 4	68.67	7.23	2.84	2.55	37.50**
FCRIMP 5	75.67	5.25	2.42	2.19	31.50
FCRIMP 6	72.33	5.29	2.43	2.20	33.50*
FCRIMP 7	65.33	4.79	2.31	2.10	31.50
FCRIMP 8	75.00	6.32	2.62	2.35	32.50
FCRIMP 9	69.00	4.30	2.17	1.99	27.50
FCRIMP 10	68.33	5.02	2.37	2.14	30.00
FCRIMP 11	73.00	6.71	2.72	2.45	28.50
FCRIMP 12	87.67**	6.08	2.61	2.36	34.50**
FCRIMP 13	71.67	4.80	2.31	2.06	27.50
FCRIMP 14	78.00**	5.57	2.48	2.24	31.00
FCRIMP 15	71.33	5.03	2.34	2.13	35.50**
FCRIMP 16	84.00**	6.67	2.72	2.45	32.00
FCRIMP 17	75.33	6.45	2.66	2.40	33.00
FCRIMP 18	81.00**	6.57	2.70	2.43	27.50
FCRIMP 19	64.67	3.83	2.03	1.84	29.00
FCRIMP 20	61.33	3.82	2.03	1.88	32.00
FCRIMP 21	69.00	4.78	2.30	2.09	28.50
FCRIMP 22	77.33**	6.36	2.59	2.33	34.50**
FCRIMP 23	69.33	6.54	2.69	2.42	28.50
FCRIMP 24	76.00*	5.73	2.53	2.29	33.50*
FCRIMP 25	70.67	5.42	2.43	2.18	35.50**
FCRIMP 26	63.00	3.76	2.07	1.88	28.50
FCRIMP 27	55.33	3.22	1.92	1.76	31.00
FCRIMP 28	67.67	4.46	2.23	2.03	32.50
FCRIMP 29	66.33	4.97	2.29	2.08	29.00
FCRIMP 30	74.33	5.66	2.57	2.31	32.00
Mean	72.53	5.67	2.48	2.25	31.72
SEd	1.68	1.59	0.26	0.23	0.81
CD (P=0.05)	3.37	3.19	0.53	0.47	1.63
CD (P=0.01)	4.49	4.25	0.71	0.62	2.17

** 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 synthesized 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 *M. pinnata* 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 *M. pinnata* genetic resources. The seeds of *M. pinnata* contained the seed oil content ranged between 37.50 per cent (FCRIMP 2) and 27.50 per cent (Table 3). The oil contains predominantly the oleic acid which ranged between 12.02 per cent and 12.39 per cent among the screened progenies (Tables 4 to 6). 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.

Table 4 Fatty acid composition of *Millettia pinnata* seed oil (FCRIMP 2)

RT	Name of the compound	Molecular formula	MW	Peak Area %
902	Palmitic acid	C16H32O2	256	2.65
862	Stearic Acid	C18H36O2	284	0.88
913	Oleic Acid	C18H34O2	282	12.39
919	Heptadecanoic acid	C17H34O2	270	0.42
670	Myristic acid	C14H28O2	228	0.52
625	Docosanoic acid	C22H44O2	340	0.12

Table 5 Fatty acid composition of *Millettia pinnata* seed oil (FCRIMP 4)

RT	Name of the compound	Molecular formula	MW	Peak Area %
941	Palmitic acid	C16H32O2	256	1.30
896	Stearic Acid	C18H36O2	284	0.88
913	Oleic Acid	C18H34O2	282	12.11
947	Heptadecanoic acid	C17H34O2	270	3.57
920	Myristic acid	C14H28O2	228	0.32
912	Docosanoic acid	C22H44O2	340	0.44

Table 6 Fatty acid composition of *Millettia pinnata* seed oil (FCRIMP 25)

RT	Name of the compound	Molecular formula	MW	Peak Area %
865	Palmitic acid	C16H32O2	256	1.96
963	Stearic Acid	C18H36O2	284	0.45
756	Oleic Acid	C18H34O2	282	12.02
891	Heptadecanoic acid	C17H34O2	270	2.56
917	Myristic acid	C14H28O2	228	0.41
966	Docosanoic acid	C22H44O2	340	0.68

In conclusion, thirty progenies in *M. pinnata* have been selected from the predominant growing areas in Tamil Nadu. 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 *M. pinnata viz.,* FCRIMP 2 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.

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Character association and path coefficient analysis in groundnut (*Arachis hypogaea* L.)

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ABSTRACT

In groundnut, correlation and path coefficient analysis was carried out to identify the suitable selection indices in F_3 generation of four crosses *viz.,* CO 7 × VRI Gn 6, TMV 2 × VRI Gn 6, TMV Gn 13 × VRI Gn 6 and VRI 2 × VRI Gn 6. Correlation analysis revealed that the traits *viz.,* number of pods per plant, 100-pod weight (g), 100-kernel weight (g), shelling (%) and pod yield per plant (g) were positively associated with kernel yield per plant (g). Inter-correlation among these traits also recorded significantly positive association in most of the crosses studied. Hence these characters may be considered as the important yield attributing characters and due importance should be given while breeding for high pod and kernel yield per plant (g) in groundnut. The association between sound mature kernel per cent, late leaf spot and rust scores with other yield component traits varies with the populations. Hence, these characters may also be considered as selection indices with caution. Moreover in path analysis, the trait pod yield per plant (g) exhibited high positive direct effect on kernel yield per plant (g). It also possessed significant and positive association with kernel yield per plant (g). Hence, pod yield per plant (g) plays a major role in determining the kernel yield per plant (g). The traits *viz.,* number of pods per plant, 100-pod weight (g), 100-kernel weight (g) and shelling (%) recorded moderate to high indirect effect through pod yield per plant (g) on kernel yield per plant (g). Hence due emphasis should be placed on these traits for yield improvement in groundnut.

Keywords: Groundnut, Path analysis, Selection indices, Yield

Groundnut (*Arachis hypogaea* L.) is one of the most important legume crops of the world which is native to Brazil in South America. It is cultivated for cheap source of vegetable oil, good quality feedstuff, improvement of soil health through nitrogen fixation as well as a source of fuel for the rural population. Besides, it is consumed and utilized in diverse ways due to its nutritional and medicinal values (Bhargavi *et al.,* 2016). Groundnut yield is constrained due to two foliar fungal diseases *viz.,* late leaf spot [*Phaeoisariopsis personata* (Berk. and Curt.) Deighton] and rust (*Puccinia arachidis* Speg.) and is capable of causing considerable yield loss in most areas of the world. Yield is a complex entity associated with many characters, which are themselves inter-related. In any plant breeding program, it is essential to know the association among yield and yield related traits in the material generated for effectual selection. Selection based on simply inherited and highly heritable yield attributes is most effective and reliable approach as compared to direct selection on yield itself. Understanding the nature and extent of association of different yield components with yield and inter relationship among themselves is an essential pre requisite for the formulation of breeding procedure for effective improvement of yield (Prabhu *et al.,* 2016). The correlation coefficients between any two characters would not give a complete picture of a complex situation like yield of plant which is jointly determined by a number of traits either directly or indirectly. In such situations, path coefficient analysis would be useful, as it permits the separation of direct effect from indirect effects through other related traits. Hence, an attempt was made in the present study to understand the direction and extent of character association, and the direct and indirect effect of other component traits on kernel yield in groundnut.

The present experimental material comprised of four crosses *viz.,* CO 7 × VRI Gn 6, TMV 2 × VRI Gn 6, TMV Gn 13 × VRI Gn 6 and VRI 2 × VRI Gn, in groundnut. The parents CO 7, TMV 2, TMV Gn 13 and VRI 2 are susceptible to foliar fungal diseases such as late leaf spot and rust. In order to incorporate resistance to these diseases, resistant donor VRI Gn 6 was used in crossing programme and the resultants were selfed to evolve F_3's in respective crosses. These four crosses in F_3 generation were used to investigate the relationship among yield and yield component characters in groundnut. The crop was raised during *kharif,* 2014 at the Oilseeds farm, Centre for Plant Breeding and Genetics (CPBG), Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. Recommended agronomic practices were followed under irrigated condition. Observations were recorded in each cross for nine characters *viz.,* number of pods per plant, 100-pod weight (g), 100-kernel weight (g), shelling (%), sound mature kernel (SMK) (%), late leaf spot (LLS) score, rust score, pod yield per plant (g) and kernel yield per plant (g). Simple correlation coefficient analysis for yield and yield

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components were carried out employing the formula propounded by Al-jibouri *et al.* (1985). Path analysis was adopted to partition the correlation coefficient into direct and indirect effects and the path coefficients were ranked on the scales given by Lenka and Misra (1973).

The aim of correlation studies is primarily to know the suitability of various characters for indirect selection (Prabhu *et al.,* 2015). Correlation studies provide information on the nature and extent of association between any two metric traits and it will be possible to bring about genetic upgradation in one trait by selection of the other of a pair. The association of yield with different yield components in four F_3 population *viz.,* CO 7 × VRI Gn 6, TMV 2 × VRI Gn 6, TMV Gn 13 × VRI Gn 6 and VRI 2 × VRI Gn 6 were estimated and presented in Table 1. Taking all the nine characters into consideration, kernel yield per plant (g) expressed significant and positive relationship with number of pods per plant, 100-pod weight (g), 100-kernel weight (g), shelling (%) and pod yield per plant in all the four crosses under study. In crosses CO 7 × VRI Gn 6 and VRI 2 × VRI Gn 6, it showed significant and positive association with sound mature kernel (%). Kernel yield per plant (g) recorded significant and negative association with late leaf spot and rust score in the cross VRI 2 × VRI Gn 6. Hence it might be inferred that these traits could be considered as most important yield contributing traits in groundnut. This is in accordance with the findings of Kwaga (2014 a) and Pawankumar *et al.* (2014).

Among the nine characters studied, pod yield per plant (g) recorded significant and positive correlation with number of pods per plant, 100-pod weight (g), 100-kernel weight (g) and shelling (%) in the all the four F_3 crosses in groundnut. In the crosses CO 7 × VRI Gn 6 and VRI 2 × VRI Gn 6, pod yield per plant (g) showed significant and positive association with sound mature kernel (%) whereas, it expressed significant and negative association with late leaf spot and rust score in VRI 2 × VRI Gn 6. These results are confirmative with findings of Thirumala *et al.* (2014), Anitha (2013) and Pavithradevi (2013).

Number of pods per plant recorded significant and positive correlation with shelling (%) in all the four crosses taken for the study. It recorded significant and positive association with 100-pod weight (g) in all the crosses except TMV Gn 13 × VRI Gn 6. In TMV 2 × VRI Gn 6, VRI 2 × VRI Gn 6 and CO 7 × VRI Gn 6, VRI 2 × VRI Gn 6 crosses, the number of pods per plant showed significant and positive association with 100-kernel weight (g) and sound mature kernel (%) respectively. Significant and positive association was exhibited with rust score in VRI 2 × VRI Gn 6 whereas; it recorded significant and negative association with late leaf spot score in VRI 2 × VRI Gn 6. These findings were also reported earlier by Shoba *et al.* (2010) and Anitha (2013).

All the four crosses expressed significant and positive association with 100-kernel weight (g), shelling (%) and sound mature kernel (%). Significant and positive association of 100-pod weight (g) with late leaf spot score was observed in the cross CO 7 × VRI Gn 6 whereas, it exhibited significant and negative association with rust score in the cross VRI 2 × VRI Gn 6. Similar results were reported by Prabhu *et al.* (2014). The character 100-kernel weight (g) exhibited significant and positive correlation with shelling (%) in all the four crosses, and also with sound mature kernel (%) in TMV Gn 13 × VRI Gn 6. In addition to these characters, 100-kernel weight (g) showed significant and negative association with late leaf spot score in VRI 2 × VRI Gn 6. Pavithradevi (2013) and Anitha (2013) also observed similar associations with one or more characters for the trait 100-kernel weight (g). Shelling (%) possessed significant and positive association with sound mature kernel (%) in two crosses *viz.,* CO 7 × VRI Gn 6 and VRI 2 × VRI Gn 6. However, sound mature kernel (%) recorded significant and negative association with late leaf spot score in the cross TMV Gn 13 × VRI Gn 6. Babariya and Dobariya (2012) noticed significant and positive association between shelling (%) and sound mature kernel (%).

The character late leaf spot score exhibited significant and positive association with rust score in the cross CO 7 × VRI Gn 6 and VRI 2 × VRI Gn 6. Similar findings were reported earlier by Prabhu *et al.* (2014). Association of late leaf spot and rust score with various traits especially kernel yield and pod yield per plant (g) showed variation among crosses. Late leaf spot and rust disease scores recorded significant and negative correlation with kernel yield per plant (g) and pod yield per plant (g) in the cross VRI 2 × VRI Gn 6. The negative association as shown by VRI 2 × VRI Gn 6 can be effectively exploited for simultaneous improvement on yield and less disease score. In crosses with no association between disease score and yield traits, selection needs to be made for both yield traits and disease score.

A path coefficient is simply a standardized partial regression coefficient and it measures the direct influence of one trait upon another. In the present study, direct and indirect effects of yield contributing components on seed yield were worked out and presented in Table 2. The estimate of residual effect ranges from 0.078 to 0.101, which indicated the adequacy of the characters chosen for the study. Number of pods per plant exhibited negative moderate direct effect on kernel yield per plant (g) in the cross CO 7 × VRI Gn 6 and TMV Gn 13 × VRI Gn 6 while, the remaining crosses recorded low and negligible direct effects. Similar results were reported by Thirumala *et al.* (2014). Similarly, the trait number of pods per plant recorded very high positive indirect effect via pod yield per plant (g) in the crosses CO 7 × VRI Gn 6, TMV 2 × VRI Gn 6 and TMV Gn 13 × VRI Gn 6 and high positive indirect effect *via* pod yield per plant (g) in the cross VRI 2 × VRI Gn 6. While via rest of the traits it exhibited low to negligible indirect effect on kernel yield

per plant (g). Shoba *et al.* (2012), Kwaga (2014 b) and Thirumala *et al.* (2014) also reported similar results. In all the crosses studied, 100-pod weight (g) recorded low and negligible direct effect on kernel yield per plant (g), while it possessed high positive indirect effect *via* pod yield per plant (g). Low to negligible indirect effects were observed through other traits on kernel yield per plant (g). Hundred kernel weight (g) exhibited low to negligible direct effect in all the crosses studied whereas, it recorded high positive indirect effect via pod yield per plant (g) in the crosses CO 7 × VRI Gn 6, TMV 2 × VRI Gn 6, TMV Gn 13 × VRI Gn 6 and VRI 2 × VRI Gn 6. Through other traits it possessed low to negligible indirect effect on kernel yield per plant (g). This is in accordance with the findings of Shoba *et al.* (2012), Kwaga (2014 b), Pavankumar *et al.* (2014) and Thirumala *et al.* (2014).

Shelling (%) recorded low to negligible direct effect in all the crosses studied. It exhibited high positive indirect effect via pod yield per plant (g) in all the crosses studied. Pavankumar *et al.* (2014) noticed similar findings. While through other traits it recorded low to negligible indirect effect on kernel yield per plant (g). Concomitant results were reported by Kwaga (2014 b) and Thirumala *et al.* (2014) also reported similar results. Sound mature kernel (%) possessed high positive direct effect in the cross VRI 2 ×VRI Gn 6 and negligible direct effect in all the other crosses. Negligible direct effect was reported earlier by Pavankumar *et al.* (2014). Similarly, high positive indirect effect *via* pod yield per plant (g) were noticed in the cross CO 7 × VRI Gn 6 and TMV 2 × VRI Gn 6 and moderate positive indirect effect *via* pod yield per plant (g) in the cross TMV Gn 13 × VRI Gn 6 and VRI 2 × VRI Gn 6. Pavankumar *et al.* (2014) reported similar findings. Through other traits it recorded low to negligible indirect effect on kernel yield per plant (g).

Table 1 Simple correlation among yield and yield attributes in F_3 generation of groundnut

Character	Cross	Number of pods per plant	100-pod weight (g)	100-kernel weight (g)	Shelling (%)	SMK (%)	LLS score	Rust score	Pod yield per plant (g)
100-pod weight (g)	C1	0.46**							
	C2	0.69**							
	C3	0.27							
	C4	0.34**							
100-kernel weight (g)	C1	0.25	0.70**						
	C2	0.81**	0.81**						
	C3	0.09	0.92 **						
	C4	0.29**	0.85**						
Shelling (%)	C1	0.57**	0.49**	0.46**					
	C2	0.72**	0.59*	0.82**					
	C3	0.65**	0.56**	0.48**					
	C4	0.56**	0.29**	0.32**					
SMK (%)	C1	0.33**	0.39**	0.02	0.37**				
	C2	0.27	0.69**	0.53	0.50				
	C3	0.06	0.55**	0.68**	0.29				
	C4	0.27**	0.39**	0.09	0.36**				
LLS score	C1	0.05	0.30*	0.23	0.22	0.09			
	C2	-0.16	0.04	0.02	-0.03	0.46			
	C3	0.08	-0.08	0.15	0.12	-0.40*			
	C4	-0.39**	-0.24*	-0.24*	-0.17	-0.12			
Rust score	C1	-0.04	0.09	-0.04	0.07	0.06	0.42**		
	C2	0.17	-0.12	0.08	0.12	0.10	0.55		
	C3	-0.02	0.02	0.06	0.00	0.07	-0.11		
	C4	0.29**	-0.15	-0.15	-0.12	-0.05	0.66**		
Pod yield per plant (g)	C1	0.94**	0.67**	0.44**	0.59**	0.38**	0.17	0.01	
	C2	0.95**	0.86**	0.85**	0.70**	0.42	-0.17	0.03	
	C3	0.94**	0.55**	0.35*	0.71**	0.23	0.03	0.03	
	C4	0.94**	0.56**	0.50**	0.55**	0.30**	-0.42**	-0.30**	
Kernel yield per plant (g)	C1	0.92**	0.66**	0.48**	0.65**	0.40**	0.17	0.00	0.99**
	C2	0.94**	0.87**	0.88**	0.75**	0.47	-0.12	0.06	0.99**
	C3	0.92**	0.56**	0.38*	0.75**	0.24	0.07	0.06	0.99**
	C4	0.93**	0.55**	0.51**	0.59**	0.33**	-0.41**	-0.29**	0.99**

C1 - CO 7 × VRI Gn 6 C2 - TMV 2 × VRI Gn 6 C3 - TMV Gn 13 × VRI Gn 6 C4 - VRI 2 × VRI Gn 6
*,** Significant @ 5% and 1% level of probability, respectively

Table 2 Direct and indirect effect of yield components on kernel yield in F_3 generation of groundnut

Character	Cross	Number of pods per plant	100-pod weight (g)	100-kernel weight (g)	Shelling percentage	SMK (%)	LLS score	Rust score	Pod yield per plant (g)	Simple correlation with kernel yield per plant (g)
Number of pods per plant	C1	-0.231	-0.049	0.007	0.067	0.007	-0.001	0.001	1.122	0.923**
	C2	-0.145	0.004	-0.011	0.084	-0.001	-0.004	0.004	1.013	0.944**
	C3	-0.253	-0.054	0.010	0.052	0.000	0.004	-0.001	1.166	0.924**
	C4	0.008	-0.043	0.035	0.019	0.018	-0.003	-0.001	0.899	0.932**
100-pod weight (g)	C1	-0.106	-0.106	0.020	0.057	0.009	-0.005	-0.001	0.796	0.664**
	C2	-0.099	0.006	-0.011	0.068	-0.002	0.001	-0.003	0.910	0.871**
	C3	-0.069	-0.198	0.101	0.045	0.002	-0.004	0.001	0.681	0.559**
	C4	0.003	-0.125	0.102	0.010	0.026	-0.002	0.000	0.538	0.552**
100-kernel weight (g)	C1	-0.058	-0.074	0.028	0.054	0.000	-0.004	0.000	0.528	0.475**
	C2	-0.117	0.005	-0.013	0.095	-0.001	0.001	0.002	0.906	0.878**
	C3	-0.022	-0.182	0.110	0.039	0.002	-0.009	0.001	0.440	0.378**
	C4	0.002	-0.106	0.120	0.011	0.006	-0.002	0.000	0.476	0.507**
Shelling (%)	C1	-0.133	-0.052	0.013	0.117	0.008	-0.004	-0.001	0.698	0.647**
	C2	-0.105	0.004	-0.011	0.116	-0.001	-0.001	0.003	0.746	0.751**
	C3	-0.164	-0.111	0.053	0.080	0.001	0.005	0.000	0.881	0.745**
	C4	0.004	-0.036	0.039	0.034	0.024	-0.001	0.000	0.529	0.593**
SMK (%)	C1	-0.077	-0.041	0.001	0.043	0.022	-0.002	-0.001	0.455	0.401**
	C2	-0.040	0.004	-0.007	0.058	-0.003	0.012	0.002	0.446	0.473
	C3	-0.016	-0.109	0.074	0.023	0.004	-0.017	0.002	0.284	0.245
	C4	0.002	-0.048	0.010	0.012	0.068	-0.001	0.000	0.285	0.328**
LLS score	C1	-0.013	-0.032	0.007	0.026	0.002	-0.016	-0.005	0.203	0.172
	C2	0.023	0.000	0.000	-0.004	-0.001	0.027	0.012	-0.179	-0.123
	C3	-0.020	0.016	-0.023	0.010	-0.001	0.044	-0.003	0.043	0.065
	C4	-0.003	0.031	-0.028	-0.006	-0.008	0.008	0.001	-0.406	-0.412**
Rust score	C1	0.010	-0.010	-0.001	0.008	0.001	-0.007	-0.012	0.008	-0.002
	C2	-0.025	-0.001	-0.001	0.014	0.000	0.015	0.022	0.035	0.059
	C3	0.005	-0.004	0.004	0.000	0.000	-0.005	0.027	0.033	0.060
	C4	-0.002	0.018	-0.018	-0.004	-0.004	0.005	0.002	-0.288	-0.290**
Pod yield per plant (g)	C1	-0.218	-0.071	0.013	0.069	0.009	-0.003	0.000	1.191	0.989**
	C2	-0.138	0.005	-0.011	0.082	-0.001	-0.005	0.001	1.061	0.993**
	C3	-0.238	-0.109	0.039	0.057	0.001	0.002	0.001	1.240	0.992**
	C4	0.007	-0.070	0.060	0.019	0.020	-0.003	-0.001	0.960	0.992**

Residual effects: C1 - CO 7 × VRI Gn 6 (0.101); C2 - TMV 2 × VRI Gn 6 (0.078); C3 - TMV Gn 13 × VRI Gn 6 (0.090); C4 - VRI 2 × VRI Gn 6 (0.095); * bold figures denote direct effect; ** Significant @ 1% level of probability

In all the crosses studied, late leaf spot score exhibited negligible positive direct effect. High negative indirect effect *via* pod yield per plant (g) were noticed for late leaf spot score in the cross VRI 2 × VRI Gn 6, while moderate positive indirect effect *via* pod yield per plant (g) were recorded in the cross CO 7 × VRI Gn 6. In rest of the crosses late leaf spot score revealed low to negligible indirect effect *via* pod yield per plant (g) on kernel yield per plant (g). The results are in accordance with the findings of Shoba *et al.* (2012). Low to negligible positive direct effect was recorded for rust score in all the crosses studied. It exhibited moderate negative indirect effect *via* pod yield per plant (g) in the cross VRI 2 × VRI Gn 6 and low to negligible indirect effect *via* pod yield per plant (g) in rest of the crosses. Through other traits rust score recorded negligible indirect effect on kernel yield per plant (g).

Pod yield per plant (g) exhibited very high positive direct effect in the cross CO 7 × VRI Gn 6, TMV 2 × VRI Gn 6 and TMV Gn 13 × VRI Gn 6, while high positive direct effect were noticed in the cross VRI 2 × VRI Gn 6. Shoba *et al.* (2012) and Pavankumar *et al.* (2014) also reported similar results. Similarly, it recorded moderate negative indirect effect *via* number of pods per plant in the cross CO 7 × VRI Gn 6 and TMV Gn 13 × VRI Gn 6. In other crosses, it possessed low to negligible indirect effects via number of pods per plant. Through other traits pod yield per plant (g)

revealed negligible indirect effect on kernel yield per plant (g). Concomitant results were reported by Shoba *et al.* (2012) and Pavankumar *et al.* (2014).

Hence, pod yield per plant (g) alone contributes to kernel yield per plant (g) which reveals the true relationship between these traits and direct selection for this will be rewarding for yield improvement. Similarly, the traits number of pods per plant, 100-pod weight (g), 100-kernel weight (g) and shelling (%) exhibited moderate to high indirect effect through pod yield per plant (g) on kernel yield per plant (g) in groundnut.

Correlation analysis revealed that the traits number of pods per plant, 100-pod weight (g), 100-kernel weight (g), shelling (%) and pod yield per plant (g) were positively associated with kernel yield per plant (g). Inter-correlation among these traits also recorded significantly positive association in most of the crosses studied. Hence these characters may be considered as the important yield attributing characters and due importance should be given while breeding for high pod and kernel yield per plant (g) in groundnut. The association between sound mature kernel per cent, late leaf spot and rust scores with other yield component traits varies with the populations. Hence these characters may also be considered as selection indices with caution. Moreover in path analysis, the trait pod yield per plant (g) exhibited high positive direct effect on kernel yield per plant (g). It also possessed significant and positive association with kernel yield per plant (g). Hence, pod yield per plant (g) plays a major role in determining the kernel yield per plant (g). The traits *viz.,* number of pods per plant, 100-pod weight (g), 100-kernel weight (g) and shelling (%) recorded moderate to high indirect effect through pod yield per plant (g) on kernel yield per plant (g). Hence due emphasis should be placed on these traits for yield improvement in groundnut.

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Genetic diversity in sunflower (*Helianthus annuus* L.)

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ABSTRACT

A study was conducted to determine the diversity among sunflower genotypes using D^2 analysis during *kharif*, 2014. Study of per se performance of genotype, ARM 243B showed superiority for head diameter, 100-seed weight, seed yield per plant, oil yield per plant and with moderate resistance to *Alternaria* leaf spot disease. This was followed by COSF 2B, COSF 7B, CSFI 5019, CSFI 5040, CSFI 5083, CSFI 5213, CSFI 5336 and TNHSF 239-68-1-1-1. These genotypes showed high oil yield per plant and few component traits with moderate resistance to *Alternaria* leaf spot disease. These genotypes can be used for increasing oil yield by hybridization for development of hybrids. Parental divergence study showed that 115 genotypes were grouped into nine clusters. Considering the cluster mean and divergence values, clusters VII and VIII were more diverse followed by clusters II and VIII, I and VIII, III and VIII, V and VIII and VI and VIII suggesting that hybridization between divergent groups may lead to more variability for the characters concerned. Among the diverse clusters, genotypes CSFI 13024 and TNHSF 239-68-1-1-1 of cluster VII and CSFI 13022, CSFI 13023, CSFI 13069 and CSFI 13071 of cluster VIII may be crossed to obtain wider variation in segregating population.

Keywords: *Alternaria* leaf spot, Genetic diversity, Sunflower

Sunflower (*Helianthus annuus* L.) is termed as the "Golden Girl of American Agriculture" planted earlier for aesthetic value and apiary. It has now become the third major source of edible oil in the world after soybean and groundnut. Sunflower competes in the world oilseed complex with other major oilseeds *viz.,* soybean, groundnut and rapeseed. In India, sunflower occupies the fourth place among oilseed crops in terms of acreage and production. At present the crop is grown over an area of 0.69 m. ha with a production and productivity of 0.55 m. tonnes and 791 kg/ha respectively in India (Anonymous, 2015). Choice of parents is of paramount importance in any breeding program. Genetic diversity plays an important role in the choice of parents because hybrids between lines of diverse origin generally display a greater heterosis than those between closely related parents (Bhoite *et al.,* 2015; Chandirakala *et al.,* 2015). The assessment of a large number of inbreds for genetic diversity is of utmost importance. D^2 analysis is a powerful technique for measuring genetic divergence. The D^2 statistics enables one to discriminate between different cultivars according to the diversity present. Although sunflower crop has the yield potential of 2.0 to 2.5 tonnes/ha under favourable conditions, the average productivity level in India is only 791 kg/ha. The lower yield level of sunflower is mainly due to several biotic and abiotic factors. Among these, susceptibility to disease is considered to be one of the major constraints. *Alternaria* leaf blight is known to cause more than 80 per cent of the yield loss under severe epiphytotic conditions (Hiremath *et al.,* 1990). To date no complete resistance against *Alterneria* is available in cultivated sunflower or any related germplasm even though the differences in susceptibility exist. Breeding for resistance to *Alternria* leaf spot faces the challenge of a gene pool containing only moderate levels of resistance. There is a strong need to identify genotypes resistant to *Alternaria* isolates of the geographical region and identify potential hybrid with genes for resistance/tolerance to *Alternaria helianthi.* With this background, the present investigation was undertaken to assess the diversity of 115 genotypes of sunflower.

The seed material of 115 genotypes for the field experiments were obtained from the Sunflower Unit at the Department of Oilseeds, Tamil Nadu Agricultural University (TNAU), Coimbatore. The field experiments were carried out at Department of Oilseeds, TNAU, Coimbatore during *kharif*, 2014. The trial was conducted with two replications in a randomized block design. In each replication, each entry was raised in 4 m row, adopting a spacing of 60 cm between the rows and 30 cm between the plants. Normal agronomic practices were followed under irrigated condition. Data recorded on randomly chosen five plants for nine characters *viz*., days to 50% flowering, plant height (cm), head diameter (cm), 100-seed weight (g), volume weight (g/100 ml), seed yield per plant (g), oil content (%), oil yield per plant (g) and *Alternaria* leaf spot severity. The mean data of each replication were analyzed for diversity analysis. Based on the degree of divergence (D^2 values) between any two genotypes, grouping of genotypes was done by using Tocher's method.

Analysis of variance showed significant differences among genotypes for all the characters indicating the presence of significant variability in the experimental materials. Burli *et al.* (2001) reported significant differences

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among genotypes for days to 50% flowering, days to maturity, plant height, head diameter and seed yield per plant. Significant differences for 100-seed weight and oil content were reported by Ashok *et al.* (2000). Significant differences for days to 50% flowering, days to maturity, plant height, head diameter, 100- kernel weight, hull content, oil content, filled seed per cent and seed yield were reported by Isaacs (2002).

In any breeding programme, the choice of desirable parents determines the success in developing new varieties/hybrids. The yield contributing traits are governed by many genetic factors. Hence, it is necessary to plan and adopt an appropriate strategy to select the potential parents for hybridization. The broad principles governing the choice of the parents are (i) it should possess high *per se* performance (ii) genetically it should have accumulated desirable alleles and (iii) it should possess desirable general combining ability. The mean performances of the 115 genotypes are presented in Table 2.

In sunflower, earliness and dwarf plant types are the desirable plant characteristics for which low mean values are desired and considered as superior mean performance and for rest of the characters high mean values are considered as superior performance. In the present study, among the genotypes studied, 850B, CSFI 5286, CSFI 5287, CSFI 5373, CSFI 13069, CSFI 13071, CSFI 13021, CSFI 13022, CSFI 13023, CSFI 13024, CSFI 13003 and CSFI 13004 showed earliness in days to 50% flowering. While, 1B, 234B, 400B, COSF 3B, CSFI 5205, CSFI 5219, CSFI 5232, CSFI 5287, CSFI 5307, CSFI 5373, IR 3,CSFI 13069, CSFI 13071, CSFI 13021, CSFI 13022, CSFI 13023 and CSFI 13004 were dwarf genotypes.

Likewise, genotypes 17B, ARM 243B, CSFI 5291, CSFI 5330, CSFI 5390 and CSFI 13043 expressed significant and superior values for head diameter over the mean of the genotypes. While, genotypes 17B, ARM 243B, CSFI 5040, CSFI 5083, CSFI 5019, CSFI 5040, CSFI 5083, CSFI 5213, CSFI 5232, CSFI 5260, CSFI 5292, CSFI 5335, CSFI 5336, M 1014-4 and TNHSF 239-68-1-1-1 expressed significant and superior values for resistance to *Alternaria* leaf spot over the mean of the genotypes.

Genotypes *viz.,* 17B, ARM 243B, CSFI 5062, CSFI 5092, CSFI 5152, CSFI 5190, CSFI 5287, CSFI 5288, POP 449-1-2-4, CSFI 13021, CSFI 13022, CSFI 13023 and CSFI 13034 had showed superior mean performance for the 100-seed weight. High order of expression for volume weight was recorded by 86B, COSF 5B, CSFI 5152, CSFI 5219, CSFI 5411, M 1014-4, CSFI 13021 and CSFI 13043. Significantly superior seed yield was registered by 17B, ARM 243B, CO 4, COSF 1B, COSF 2B, COSF 7B, COSFV 5, CSFI 5019, CSFI 5040, CSFI 5083, CSFI 5086, CSFI 5152, CSFI 5213, CSFI 5291, CSFI 5336, CSFI 5401, CSFI 99, CSFI 13024 and TNHSF 239-68-1-1-1.

Table 1 Analysis of variance for various characters

		Mean sum of square								
Source	df	Days to 50% flowering (days)	Plant height (cm)	Head diameter (cm)	*Alternaria* leaf spot (%)	100-seed weight (g)	Volume weight(g/ 100ml)	Seed yield per plant(g)	Oil content (%)	Oil yield per plant(g)
Treatment	114	41.38 **	868.69 **	9.26 **	206.77 **	2.06**	35.42 **	226.89**	11.53**	38.63**
Error	114	4.53	104.00	3.26	49.64	0.41	8.86	28.16	2.90	4.92

Genotypes *viz.,* 1B, COSF 2B, CSFI 5177, CSFI 5213, CSFI 5216, CSFI 5330, CSFI 5341 and M 1014-1 expressed significant and superior values for oil content. High *per se* performance for oil yield per plant was registered by genotypes *viz.,* ARM 243B, CO 4, COSF 1B COSF 2B, COSF 7B, COSFV 5, CSFI 5019, CSFI 5040, CSFI 5075, CSFI 5083, CSFI 5086, CSFI 5152, CSFI 5213, CSFI 5291, CSFI 5336, CSFI 5401, CSFI 99, CSFI 13024 and TNHSF 239-68-1-1-1.

Based on mean performance, genotypes ARM 243B showed superiority for head diameter, 100-seed weight, seed yield per plant, oil yield per plant and with moderate resistance to *Alternaria* leaf spot disease. This was followed by COSF 2B, COSF 7B, CSFI 5019, CSFI 5040, CSFI 5083, CSFI 5213, CSFI 5336 and TNHSF 239-68-1-1-1. These genotypes showed high oil yield per plant and few component traits with moderate resistance to *Alternaria* leaf spot disease.

The knowledge of genetic diversity among the genotypes is essential for selecting parents for hybridization programme, especially in a cross pollinated crop like sunflower. Genetic diversity is considered to be an important tool for realizing heterotic response in F_1 and for a broad spectrum of variability in segregating generations. Mahalanobis D^2 statistics is a good tool for assessing genetic divergence for quantitative traits and is widely being used by many geneticists and breeders for selecting divergent parents based on their distances for effecting crosses.

The D^2 analysis carried out involving 115 genotypes lines for nine characters revealed that altogether nine clusters have been formed. Among the clusters, cluster II had a maximum of 57 genotypes, cluster III with 28 genotypes, cluster I with

15 genotypes, cluster VIII with four genotypes, cluster IX with three genotypes and remaining all clusters with two genotypes each. Based on the inter cluster distances using D^2 values (Table 3), it could be considered that the genotypes belonging to clusters VII and VIII were more diverse (D^2 = 156.01) followed by clusters II and VIII (149.13), I and VIII (140.25), III and VIII (131.04), V and VIII (119.74) and VI and VIII (109.09) suggesting that hybridization between divergent groups may lead to higher magnitude of heterosis for the characters concerned. Hence genotypes CSFI 13024 and TNHSF 239-68-1-1-1 of cluster VII and CSFI 13022, CSFI 13023, CSFI 13069 and CSFI 13071 of cluster VIII may be crossed to obtain wider variation in segregating population. However, many studies are on the record that whenever genotypes with moderate divergence are used in crosses, throws out significant level of desired heterosis (Arunachalam *et al.,* 1984; Singh *et al.,* 1984).

Table 2 Mean performance of the genotypes used in the research

Genotypes	Days to 50 % flowering (days)	Plant height (cm)	Head diameter (cm)	*Alternaria* leaf spot (%)	100-seed weight (g)	Volume weight (g/100ml)	Seed yield per plant (g)	Oil content (%)	Oil yield per plant (g)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
17B	61.00	121.95	15.70*	16.21# (23.72)	6.72*	35.72	37.70*	35.53	13.42
1B	59.50	95.24*	9.73	18.58# (25.43)	3.45	29.09	20.23	44.76*	9.06
207 DS B	55.00	120.37	10.46	73.06 (58.82)	4.01	29.16	18.60	37.66	7.02
207B	58.50	112.42	9.64	42.41 (40.61)	3.38	23.00	19.15	41.98	8.02
234B	58.50	97.29*	9.60	59.17 (50.44)	2.94	25.96	10.31	40.01	4.13
300B	55.50	104.37	7.68	42.51 (40.63)	4.62	31.57	11.52	40.03	4.64
400B	63.00	82.76*	9.81	27.53 (31.12)	3.54	29.26	20.42	38.41	7.93
607B	54.50	103.49	10.15	78.38 (63.34)	3.53	29.49	22.79	38.69	8.87
60B	56.50	127.40	11.05	74.38 (59.73)	2.43	26.18	25.52	39.64	10.11
821B	60.50	113.74	11.86	40.98 (39.67)	4.02	34.56	26.26	38.82	10.15
850B	52.50*	136.55	10.89	60.99 (51.37)	5.08	32.73	33.19	39.73	13.20
852B	58.00	108.10	9.05	42.89 (40.92)	3.84	26.45	14.72	39.80	5.86
86B	55.50	157.80	14.04	33.86 (35.58)	4.44	38.24*	29.00	36.33	10.56
ARM 243B	68.50	167.74	17.74*	14.34# (22.25)	6.91*	35.16	61.33*	41.17	25.42*
CO 4	60.00	126.00	14.01	27.08 (31.21)	4.64	35.10	39.34*	38.68	15.10
COSF 1B	54.50	126.22	11.99	45.16 (42.02)	5.32	33.34	41.94*	40.89	17.17*
COSF 2B	60.50	118.45	13.51	16.94# (24.23)	3.20	37.45	34.60*	44.37*	15.44*
COSF 3B	58.00	97.00*	8.94	16.94# (24.23)	4.15	33.19	28.80	38.40	11.05
COSF 5B	59.00	103.19	8.62	44.00 (41.53)	3.48	38.62*	15.30	39.61	6.06
COSF 6B	56.00	108.95	8.90	63.61 (53.39)	2.74	28.16	15.69	38.38	6.02
COSF 7B	57.50	134.55	12.20	24.09# (29.40)	4.29	34.04	36.89*	41.49	15.30*
COSFV 5	57.50	127.93	13.94	31.60 (33.90)	4.98	36.23	46.78*	40.58	18.99*
CSFI 5019	57.00	132.22	14.02	14.64# (22.49)	5.37	37.04	40.16*	36.83	14.80*
CSFI 5021	66.50	141.40	12.78	28.75 (31.83)	3.63	28.02	20.48	37.08	7.60
CSFI 5040	58.50	115.20	13.57	19.68# (26.31)	3.96	33.41	39.55*	39.35	15.56*
CSFI 5055	55.00	130.70	15.15	47.54 (43.35)	3.98	22.78	27.48	36.81	10.11
CSFI 5062	58.00	123.80	12.92	21.80# (27.79)	5.65*	28.52	27.83	34.46	9.56
CSFI 5075	55.50	130.20	13.99	55.28 (48.04)	4.95	30.51	33.88	40.91	13.86*
CSFI 5078	55.50	113.89	10.20	40.00 (39.04)	4.32	33.31	16.73	36.58	6.11
CSFI 5082	59.50	99.35	10.83	55.65 (48.25)	5.58	27.86	21.79	40.41	8.79
CSFI 5083	62.00	148.32	13.42	19.47# (26.18)	4.36	27.75	35.95*	39.46	14.13*
CSFI 5084	64.50	131.44	12.98	26.00 (30.66)	3.97	27.02	27.78	39.83	11.05
CSFI 5086	60.00	143.68	13.54	26.25 (30.75)	4.89	26.99	36.48*	39.00	14.24*

Contd...

Table 2 (Contd..)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CSFI 5090	57.00	128.15	15.17	32.87 (34.96)	4.09	34.27	21.85	36.92	8.06
CSFI 5092	55.00	115.65	12.70	25.05 (29.65)	5.77*	29.42	27.74	38.40	10.66
CSFI 5124	56.50	113.22	11.24	54.17 (47.47)	4.16	28.91	25.56	38.85	9.94
CSFI 5125	56.50	101.78	12.03	50.66 (45.38)	4.61	32.48	28.24	38.20	10.79
CSFI 5133	61.00	114.70	11.32	32.63 (34.77)	4.15	35.85	13.31	37.50	4.99
CSFI 5140	60.00	103.08	10.80	49.34 (44.61)	2.83	30.10	22.26	38.19	8.50
CSFI 5152	56.00	129.30	11.65	44.17 (41.47)	5.76*	38.23*	43.47*	39.53	17.19*
CSFI 5177	57.50	124.93	11.23	42.89 (46.35)	4.59	35.70	22.79	43.80*	9.87
CSFI 5181	55.50	125.17	8.70	24.32# (29.30)	3.68	26.09	15.70	38.94	6.12
CSFI 5190	55.50	108.82	11.00	46.83 (43.16)	5.64*	34.68	15.47	38.59	5.97
CSFI 5194	59.50	109.49	10.72	22.07# (28.01)	4.71	29.16	23.34	41.27	9.68
CSFI 5205	57.50	88.16*	10.00	21.39# (27.17)	3.99	35.84	16.65	41.08	6.84
CSFI 5210	59.50	115.42	11.19	32.56 (34.61)	4.29	31.01	27.77	41.61	11.47
CSFI 5213	61.00	131.65	15.08	16.44# (23.60)	5.14	36.45	40.95*	44.44*	18.20*
CSFI 5216	61.50	140.24	15.15	23.37# (28.90)	4.51	35.83	22.40	43.80*	10.02
CSFI 5219	60.00	78.15*	11.30	47.72 (43.41)	5.35	40.38*	22.43	38.87	8.74
CSFI 5223	64.50	146.57	13.98	30.39 (33.29)	3.92	32.14	25.47	40.04	10.21
CSFI 5232	59.00	92.85*	11.77	15.71# (22.33)	4.79	28.12	18.74	40.34	7.67
CSFI 5246	60.00	109.78	10.25	26.67 (31.01)	4.16	30.14	22.05	38.85	8.52
CSFI 5254	60.50	137.29	12.40	29.06 (32.61)	3.65	30.90	28.97	40.02	11.60
CSFI 5260	60.50	135.99	13.17	14.27# (22.19)	4.14	24.58	27.79	39.47	10.97
CSFI 5276	58.00	150.49	11.82	24.17 (29.35)	4.04	36.12	21.18	39.49	8.38
CSFI 5286	54.00*	107.54	11.93	45.00 (42.11)	3.57	38.32*	29.13	40.09	11.64
CSFI 5287	51.50*	88.74*	10.83	58.06 (49.76)	6.14*	24.51	15.10	37.29	5.62
CSFI 5288	62.00	118.87	11.74	29.35 (32.81)	6.19*	24.85	13.42	36.04	4.83
CSFI 5291	61.00	133.20	16.95*	25.18 (30.12)	3.87	33.33	40.55*	40.58	16.45*
CSFI 5292	70.50	147.13	14.90	16.26# (23.63)	3.98	30.08	31.31	38.90	12.29
CSFI 5293	71.50	177.49	13.07	38.67 (38.43)	3.21	34.33	16.36	39.75	6.50
CSFI 5298	60.00	126.32	11.25	32.33 (33.46)	4.50	30.91	17.40	36.67	6.38
CSFI 5307	56.50	93.48*	10.63	43.45 (41.24)	3.00	24.57	3.63	37.69	1.37
CSFI 5330	71.00	152.15	15.63*	37.71 (37.83)	3.92	27.53	28.58	43.99*	12.57
CSFI 5331	58.50	101.17	10.15	48.64 (44.22)	4.17	36.56	15.41	38.88	5.98
CSFI 5334	58.00	111.10	12.07	22.61# (27.99)	3.52	35.11	30.47	40.07	12.21
CSFI 5335	60.00	121.24	14.71	15.65# (23.26)	3.37	32.03	31.64	39.38	12.40
CSFI 5336	62.00	116.29	13.25	21.95# (27.84)	4.07	37.23	41.53*	41.76	17.27*
CSFI 5341	60.00	129.99	10.40	36.94 (37.38)	3.66	32.67	24.82	42.74*	10.61
CSFI 5347	57.50	109.15	11.43	51.37 (45.84)	3.41	34.47	11.60	39.17	4.52
CSFI 5373	47.00*	70.18*	8.15	90.12 (71.68)	3.95	26.73	14.04	37.35	5.24
CSFI 5377	59.00	123.15	14.88	43.17 (41.00)	3.96	26.10	26.24	37.18	9.75
CSFI 5381	54.50	124.95	11.54	71.35 (58.86)	5.35	32.33	22.89	37.30	8.55
CSFI 5387	61.00	126.99	13.57	37.89 (37.38)	5.26	31.75	19.59	40.13	7.87
CSFI 5388	54.50	110.40	8.93	67.01 (55.10)	3.66	33.00	7.69	37.26	2.87
CSFI 5389	59.00	109.13	9.28	44.21 (41.48)	4.28	35.94	7.38	39.01	2.88
CSFI 5390	59.50	126.81	16.81*	43.57 (41.31)	4.73	28.90	22.50	38.06	8.58

Contd...

Table 2 (Contd...)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CSFI 5393	60.00	111.65	9.58	58.04 (49.67)	3.45	35.81	13.98	37.24	5.22
CSFI 5398	61.50	112.44	9.93	41.01 (39.82)	2.72	33.13	10.83	37.42	4.04
CSFI 5401	58.00	134.68	12.85	56.37 (49.23)	4.60	37.13	35.45*	41.65	14.87*
CSFI 5406	60.50	143.40	13.57	32.90 (34.97)	3.91	35.41	33.47	39.83	13.33
CSFI 5411	58.50	142.03	12.79	37.87 (37.98)	3.58	38.67*	28.73	38.92	11.16
CSFI 8002	60.50	114.58	11.10	50.58 (45.35)	3.65	33.34	11.05	39.50	4.37
CSFI 99	56.00	127.41	11.78	60.17 (51.01)	4.76	36.44	39.11*	37.74	14.71*
IR3	60.50	89.22*	7.49	49.65 (44.79)	1.98	26.40	5.92	36.70	2.18
M 1014-1	66.50	138.73	10.82	19.81# (26.42)	2.23	37.29	16.84	42.92*	7.24
M 1014-3	60.00	118.32	12.47	30.38 (33.42)	2.55	29.35	19.75	40.48	7.96
M 1014-4	56.50	100.15	14.37	16.10# (23.66)	4.20	41.15*	18.68	39.06	7.37
POP 440-1-2-1	58.50	132.13	12.12	24.44# (29.53)	4.67	30.66	19.52	39.04	7.73
POP 448-3-1-2	57.00	134.40	12.62	58.42 (49.92)	4.45	30.13	23.89	41.69	9.99
POP 449-1-2-1	61.00	118.17	11.95	30.53 (33.49)	4.84	29.64	20.96	40.86	8.60
POP 449-1-2-2	59.00	115.08	11.10	24.80# (29.86)#	5.54	31.99	20.21	37.97	7.67
POP 449-1-2-3	60.00	127.65	11.00	20.20# (26.68)	5.12	27.38	11.60	36.94	4.29
POP 449-1-2-4	65.00	145.15	12.30	23.72# (28.46)	6.04*	33.13	21.18	37.81	8.01
POP 449-2-1-1	60.50	128.30	13.23	24.99# (29.52)	4.44	29.15	30.48	39.98	12.19
POP 449-2-1-2	58.00	133.00	8.77	30.03 (33.19)	4.08	30.95	20.15	41.81	8.43
POP 449-2-1-3	59.50	135.15	11.42	42.43 (40.10)	4.03	27.35	33.45	40.82	13.65
POP 449-2-1-4	59.50	130.73	9.40	37.98 (37.95)	4.08	26.53	29.05	38.53	11.19
CSFI 13021	49.00*	85.75*	6.95	65.75 (54.37)	6.48*	38.65*	7.26	36.88	2.69
CSFI 13022	43.00*	71.43*	10.53	40.65 (39.61)	6.44*	33.65	3.47	33.80	1.17
CSFI 13023	47.50*	73.15*	8.50	67.68 (55.39)	7.79*	37.10	5.31	35.46	1.88
CSFI 13069	48.00*	62.40*	9.10	57.70 (49.45)	4.84	27.53	7.09	29.75	2.12
CSFI 13071	45.50*	66.57*	8.99	37.17 (37.47)	4.42	27.38	4.39	34.03	1.50
CSFI 13024	53.00*	124.81	13.39	27.53 (31.43)	4.43	36.68	47.45*	39.12	18.56*
CSFI 13028	57.00	109.65	10.90	62.29 (52.38)	2.47	30.89	17.51	36.65	6.41
CSFI 13033	59.00	123.69	12.52	37.70 (37.88)	4.71	31.05	24.85	35.79	8.90
CSFI 13034	61.00	121.65	12.00	23.91# (29.27)	5.92*	30.78	16.38	36.38	5.96
CSFI 13035	60.50	133.73	13.19	30.00 (32.74)	3.70	35.94	28.81	39.74	11.44
CSFI 13043	57.50	115.45	15.85*	21.41# (26.93)	5.55	37.78*	11.91	32.26	3.83
CSFI 13001	58.50	104.57	10.19	44.44 (41.73)	4.19	24.35	15.70	36.88	5.78
CSFI 13002	54.50	138.49	11.94	53.58 47.07)	3.34	31.04	22.40	38.04	8.53
CSFI 13003	53.50*	124.07	13.33	41.67 (40.17)	4.67	30.72	18.29	39.55	7.32
CSFI 13004	48.00*	71.65*	9.54	46.75 (43.13)	4.96	33.90	18.92	40.42	7.65
CSFI 13005	58.00	116.32	11.99	54.31 (47.54)	5.09	28.42	16.18	37.98	6.15
TNHSF 239-	56.00	133.66	14.57	18.71# (25.56)	4.65	35.55	39.94*	41.62	16.62*
Mean	58.25	118.58	11.84	38.23 (37.80)	4.35	31.88	23.60	38.99	9.31
S.E.	1.50	7.21	1.28	4.98	0.45	2.11	3.75	1.20	1.57
CD (5%)	4.17	19.99	3.54	13.81	1.25	5.84	10.40	3.34	4.35
CD(1%)	5.49	26.31	4.65	18.18	1.65	7.68	13.69	4.4	5.72

Values in parenthesis indicates the arc sine transformed value; Mean value of superior genotypes; PDI of genotypes showing moderately resistance in field condition

Table 3 Inter and Intra Cluster D^2 Values

Clusters	I	II	III	IV	V	VI	VII	VIII	IX
I	38.63	40.32	39.72	28.53	34.24	29.43	45.42	140.25	61.02
II		39.65	42.12	33.63	31.92	36.02	41.82	149.13	65.16
III			40.64	28.22	30.97	30.25	52.92	131.04	59.10
IV				7.34	14.59	18.78	54.83	96.34	44.11
V					13.59	25.88	47.16	119.74	52.94
VI						14.02	36.63	109.09	46.95
VII							14.48	156.01	70.40
VIII								36.08	90.72
IX									80.37

The per cent contribution of each character towards divergence is presented in Table 4. Considering the contribution of various characters towards total divergence, oil yield per plant recorded highest (25.26 per cent) contribution. The traits like seed yield per plant, oil content and days to 50% flowering were next in the order. Muppidathi *et al.* (1995), reported that seed yield per plant, head diameter and test weight showed more contribution towards genetic divergence. The present result indicated that more variability exist for oil yield per plant, seed yield per plant, oil content and days to 50% flowering.

Table 4 Relative contribution of yield and yield components to genetic diversity in sunflower

Characters	Number of times ranked first	Percentage of contribution
Days to flowering (days)	721	11
Plant height (cm)	401	6.12
Head diameter (cm)	194	2.96
Alternaria leaf spot (%)	537	8.19
100-seed weight (g)	541	8.25
Volume weight (g/ 100ml)	563	8.59
Seed yield per plant (g)	1218	18.58
Oil content (%)	724	11.05
Oil yield per plant (g)	1656	25.26
Total	6555	100.00

The cluster mean with respect to different characters are presented in Table 5. Mean for various characters of genotypes clustered in each cluster were worked out. The results showed that Cluster VII had the superior mean values for head diameter, *Alternaria* leaf spot, volume weight, seed yield per plant, oil content and oil yield per plant. Cluster VIII recorded superior mean for days to 50% flowering, plant height and100-seed weight. Hence for improvement of yield and yield components these clusters should be considered for hybridization programme. Among the diverse clusters, cluster VII and cluster VIII recorded superiority for most of the yield and yield component characters. Hence intercrossing of genotypes of these clusters will throw out more variability for yield and yield component traits.

To conclude, the evaluation of 115 genotypes indicated the presence of significant variability for all the traits observed. Based on mean and divergence values, genotypes CSFI 13024 and TNHSF 239-68-1-1-1 of cluster VII and CSFI 13022, CSFI 13023, CSFI 13069 and CSFI 13071 of cluster VIII may be crossed to obtain wider variation in segregating population.

Table 5 Cluster mean of various characters

Cluster	Characters								
	Days to flowering (days)	Plant height (cm)	Head diameter (cm)	*Alternaria* leaf spot (%)	100-seed weight (g)	Volume weight (g/ 100ml)	Seed yield per plant (g)	Oil content (%)	Oil yield per plant (g)
I	57.97	117.24	11.09	41.94	3.97	30.85	23.44	39.39	9.18
II	59.47	122.02	12.36	34.6	4.36	32.06	26.91	39.57	10.72
III	58.55	120.22	11.33	40.76	4.24	32.11	19.94	38.94	7.83
IV	58.25	110.44	11.09	44.63	4.64	26.38	15.94	37.43	5.97
V	60	122.67	12.26	33.57	5.31	30.92	20.62	36.09	7.43
VI	54	131.28	12.63	43.62	4	30.88	20.34	38.8	7.92
VII	54.5	129.23	13.98	28.49	4.54	36.11	43.7	40.37	17.59
VIII	46	68.39	9.28	45.48	5.87	31.41	5.06	33.26	1.67
IX	54.17	98.92	12.1	40.81	4.33	34.19	16.11	36.44	5.96

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Morphological traits based genetic diversity in safflower germplasm (*Carthamus tinctorius* L.)

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ABSTRACT

The material consisted of one fifty accessions from the Core Subset of Indian Institute of Oilseeds Research, Hyderabad (IIOR), Hyderabad and two popular varieties from IIOR, Hyderabad. The study was carried out to assess the genetic diversity based on morphological traits during *rabi* 2014-15. Thirteen characters were recorded to group the genotypes into twelve clusters based on Mahalonobis D^2 statistics. Maximum number of genotypes were grouped into cluster I followed by cluster VI. Height from ground level to first primary branch contributed to maximum genetic divergence followed by number of effective capitula per plant among the genotypes studied. Genotypes in cluster XI recorded highest mean values for number of effective capitula per plant (61.13) and seed yield per plant (25.52g). GMU 3281 in cluster IV recorded highest oil content of 31.05 per cent. Bold capitula were observed in genotypes belonging to clusters VIII and XII.

Keywords: Genetic divergence, Germplasm, Safflower

Safflower (*Carthamus tinctorius* L.) is a drought tolerant oilseed crop grown under receding soil moisture conditions. The crop is grown not only for its oil but also for petals from which orange-red dye is extracted for its several medicinal properties (Li and Mundel, 1996; Suneel Kumar *et al.,* 2015; 2016). Variability exists among the safflower germplasm accessions for yield contributing traits like number of effective capitula/plant, diameter of the main capitula, 100-seed weight and days to maturity needs to be exploited in breeding high seed yielding cultivars. Determination of genetic diversity is vital importance for crop improvement for selection of parents in the breeding program. Detailed characterization of germplasm and understanding the patterns of genetic diversity could help determine future breeding strategies and facilitate introgression of diverse germplasm into the current genetic base. There was significant phenotypic variation in safflower germplasm collections from Middle East (Jaradat and Shahid, 2006). Safflower landraces growing in various agro-climatic regions of Iran were characterized using agro-morphological and RAPD markers (Amini *et al.,* 2007). Mahalonobis D^2 statistic is widely used for analysis of genetic diversity by many researchers in crop plants. The main objective of this study is to estimate the genetic divergence and cluster means for the agronomic traits existing among the IIOR core subset of safflower germplasm consisting of indigenous and exotic collections. The information will help the plant breeders in the selection of genetically divergent and trait specific germplasm as parents for development of high seed and oil yielding safflower varieties suitable for the state of Telangana.

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Mahalonobis D^2 values classified 150 germplasm accessions and two released varieties into 12 distinct clusters with variable number of germplasm in each group revealing the existence of considerable genetic diversity in the accessions. In hybridization programs selection of genetically diverse parents is important to create a wide array of recombinants and hence the knowledge of genetic diversity among the accessions is necessary. Cluster I comprised of 65 genotypes followed by cluster VI (29) and III (26) while clusters IV, V, VIII, IX, X, and XII are represented by single genotypes (Table 1). The inter-cluster distances between the single genotype cluster and remaining clusters are high indicating that these genotypes are genetically diverse. Among the single genotype clusters GMU 3703 (cluster V), 5848 (VIII) and 4507 (X) are exotic collections while GMU 3281(IV) and GMU 6869 (XII) are indigenous collections. The national check varieties A-1 and PBNS-12 were grouped in cluster VI along with 26 germplasm accessions. The inter-cluster distance was higher than the intra-cluster, indicating wide genetic diversity among the genotypes (Table 2).

The maximum inter cluster distance was between cluster VII and XI (73.13) followed by cluster XI and XII (69.65), while minimum genetic distance was observed between cluster VIII and cluster IX (15.37). Hence genotypes from cluster VII and XI are genetically diverse and can be used as parents in breeding program. Cluster XI recorded highest mean values for number of effective capitula/plant (44.0), plant spread (57.17) and highest seed yield per plant (25.52). Cluster IX recorded highest test weight of 6.10 (Table 3). Genotypes in cluster IV have highest oil content of 31.05 per cent while those in clusters VIII and XII have bold capitula. Hence genotypes in cluster XI and cluster IV can be utilized

for breeding program for high seed and oil yield. Cluster IX genotypes have very less angle of 1st primary branch to main stem (140) and genotypes in cluster VII have greater height from ground level to 1st primary branch. Hence these genotypes can be used for development of varieties for high density planting. Genotypes in cluster XII have comparatively less number of days to maturity while those in cluster XI have high seed yields. Also there exists considerable genetic diversity between these two clusters (69.65) for realizing high seed yields in lesser duration. The earliness in the flowering and maturity is one of the important characters of drought avoidance mechanism. However, earliness in flowering further associated with lower total dry matter and yield (Senapati, 1999). Elite safflower germplasm selection was carried out on the basis of important traits of economic interest such as number of capitula/plant, 100-seed weight and seed yield/plant (Table 4). Variation for agronomic traits in spring safflower genotypes has been carried out by Omidi *et al.* (2009). D^2 statistic indicates the characters contributing to divergence (Table 5).

Table 1 Clustering pattern of safflower germplasm accessions

Cluster	Germplasm
I	GMU 4623, 6252, 473, 593, 878, 2437, 2413, 2594, 3436, 4038, 3189, 3822, 3629, 1409, 671, 3537, 3740, 4972, 6312, 6663, 5923, 5825, 6548, 1047, 5133, 1638, 4223, 1059, 6851, 6424, 3639, 3852, 4966, 3607, 3386, 2985, 2718, 1078, 5239, 330, 774, 5081, 2198, 659, 4646, 6506, 3780, 819, 3095, 5046, 4305, 4420, 2616, 2860, 5668, 5728, 4934, 4688, 5295, 4381, 4429, 6556, 4773, 5841, 1824
II	GMU 1137, 2472, 1871, 1855, 1708, 2240, 1626, 4693, 1765, 2129
III	4400, 5935, 6057, 4066, 4812, 7191, 3491, 2749, 1695, 4201, 1287, 744, 5361, 6119, 2136, 224, 1875, 3929, 765, 6192, 6306, 3968, 4627, 864, 821, 4558
IV	GMU 3281
V	GMU 3703
VI	GMU 2016, 4234, 1354, 2432, 6026, 4502, 599, 216, PBNS-12, 3208, 1603, 1339, 2944, 5170, 2969, 3084, 1185, 1812, 5032, A-1, 5908, 4109, 5163, 599, 1315, 3707, 1485, 5075, 707
VII	GMU 4549, 4696, 1250, 4839, 5335, 5701, 4010
VIII	GMU 5848
IX	GMU 5044
X	GMU 4507
XI	GMU 95, 3047, 2987, 3177, 3617, 40
XII	GMU 6869

Table 2 Average inter and intra cluster distances (D^2) of twelve clusters of safflower germplasm

Cluster	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I	22.91	41.37	31.63	28.24	26.52	31.08	42.84	41.58	43.06	31.09	49.42	40.95
II		23.88	42.29	49.96	47.54	47.66	48.88	29.69	35.85	45.26	61.59	57.99
III			28.05	43.59	43.33	44.55	37.50	51.88	53.71	38.99	64.70	46.50
IV				0.0	19.23	27.20	48.49	39.39	37.86	39.33	40.01	34.25
V					0.0	24.81	52.59	37.84	38.91	30.65	38.49	42.82
VI						30.87	53.22	39.51	39.07	40.20	41.27	48.37
VII							34.69	57.30	55.78	54.39	73.13	46.45
VIII								0.0	15.37	47.37	44.82	57.67
IX									0.0	54.90	41.41	59.64
X										0.0	58.90	40.77
XI											32.86	69.65
XII												0.0

Table 3 Cluster means of thirteen morphological characters in safflower germplasm

Cluster	Rosette period	Days to 50% flowering	Days to maturity	Plant height (cm)	Plant spread	Length of the longest primary branch (cm)	Angle of 1st primary branch to main stem	Height from ground level to 1st primary branch (cm)	Diameter of main capitula (cm)	No. of effective capitula/ plant	100-seed weight (g)	Oil content (%)	Seed yield/ plant (g)
I	30.42	84.94	118.15	87.98	41.05	49.95	38.42	21.25	1.78	31.71	3.91	27.80	14.07
II	27.0	108.2	139.40	78.98	37.96	42.8	41.8	20.30	1.68	25.82	3.97	29.04	12.63
III	30.27	86.23	119.12	86.62	34.71	40.2	41.6	32.85	1.75	23.73	3.79	26.64	10.24
IV	31.0	85.0	119.0	98.20	40.20	65.2	34.0	18.40	1.70	40.0	3.50	31.05	23.71
V	31.0	84.0	117.0	85.6	45.20	67.4	38.0	11.40	1.74	35.80	3.12	27.96	14.55
VI	30.23	86.93	119.63	89.91	47.87	58.77	40.47	14.47	1.78	38.21	4.09	26.85	18.46
VII	33.14	92.86	125.71	99.83	32.69	49.06	39.14	44.04	1.74	19.26	3.51	24.88	7.83
VIII	29.0	110.0	141.0	83.80	42.40	56.80	40.0	8.80	1.9	39.80	4.94	28.65	19.25
IX	26.0	110.0	141.0	91.80	50.40	60.80	42.0	16.40	1.80	44.0	6.10	27.90	17.84
X	28.0	81.0	116.0	70.60	32.80	51.0	26.0	11.0	1.87	24.80	4.46	27.72	12.19
XI	29.50	89.67	123.17	85.37	57.17	65.83	44.93	10.02	1.80	61.13	3.74	26.95	25.52
XII	29.0	84.0	116.0	103.8	25.80	59.8	14.0	23.20	1.90	18.60	3.56	28.56	21.70

Table 4 Promising accessions of safflower identified on the basis of traits of interest for future use

Trait of interest	Range	Accessions identified
No. of capitula/plant	> 50	GMU 40, 95, 599, 3617
100-seed weight	5.0g	GMU 5133, 4972, 5032, 2969, 659, 1287, 1603, 1626, 1638, 2016, 2198
Seed yield/plant	> 25g	GMU 95, 1603, 2016, 2198, 2987, 6026

Table 5 Per cent contribution of characters towards genetic diversity

Characters	Contribution %	Times Ranked 1st
Rosette period	0.15	17
Days to 50% flowering	10.11	1160
Days to maturity	0.31	36
Plant height	13.0	`1492
Plant spread	12.64	1450
Length of the longest primary branch	14.81	1700
Angle of 1st primary branch to main stem	9.05	1039
Height from ground level to 1st primary branch	18.81	2159
Diameter of main capitula	0.0	0
No. of effective capitula/plant	15.01	1722
100-seed weight	0.0	0
Oil content	0.02	2
Seed yield/plant	6.09	699

The information related to genetic diversity and *per se* performance of genotypes can be reliably used in the selection of genetically diverse and agronomically superior genotypes as parents in the hybridization program. The characters contributing the most to genetic divergence are considered for the purpose of effective selection and in choosing the parents for hybridization. In the present study maximum contribution towards genetic divergence is by height from ground level to 1st primary branch (18.81%) followed by number of effective capitula/plant (15.01%) and length of the longest primary branch (14.81%). These characters together recorded for more than 48 per cent of the total divergence in the 152 safflower genotypes studied while diameter of main capitula and oil content contributed the least towards genetic divergence. Whereas earlier studies have reported that seed yield contributed maximum for genetic divergence (Shivani and Sreelakshmi, 2013; Shivani and Sreelakshmi, 2014).

Based on D^2 value height from ground level to 1st primary branch and number of effective capitula/plant were identified as the most important traits contributing towards diversity among the safflower germplasm accessions evaluated. It has been earlier reported that height from ground level to 1st primary branch is significantly negatively correlated with seed yield (Bidgoli *et al.,* 2006). This indicates that it is essential to lay greater emphasis on these characters for the purpose of further selection and choice of parents for hybridization. On the basis of genetic divergence and cluster mean it may be concluded that maximum heterosis and good recombinants would be possible from crosses between the genotypes of clusters VII and XI with inter cluster distance of 73.13 followed by cluster XI and XII (69.65) in varietal improvement of safflower. Therefore safflower accessions GMU 95, 3047, 2987, 3177, 3617, 40 and 6869 were short listed on the basis of higher seed yield for improvement through further selection. The genotypes GMU 95, 3047, 2987, 3177, 3617, 40 (Cluster XI) recorded highest mean values for number of effective capitula/plant (44.0), plant spread (57.17) and highest seed yield/plant (25.52g). The clusters having single genotype were identified for specific traits like GMU 5044 (cluster IX) recorded highest test weight of 6.1, while GMU 3281(cluster IV) recorded highest oil content of 31.05 per cent and GMU 5848 (cluster VIII), GMU 6869 (cluster XII) have bold capitula. The trait specific genotypes identified will be useful to the breeders in the selection of parents for safflower breeding program.

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Growth, yield attributes and seed yield of pre-release genotypes of castor (*Ricinus communis* L.) as influenced by fertilizer levels under rainfed conditions of central dry zone of Karnataka

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ABSTRACT

An experiment was conducted to assess the response of castor genotypes in relation to fertilizer input. Three genotypes of castor (SHB-872, RHC-277 and JC-12) were tried under four fertilizer levels i.e., control (no fertilizer), 50%, 100% and 150% recommended dose of fertilizer (RDF) under rainfed conditions during *kharif* season 2011 on black soils at Zonal Agricultural Research Station, Babbur Farm, Hiriyur, Karnataka. The study revealed that there was a linear response to graded levels of fertilizer. Significantly higher seed yield of castor (2302 kg/ha) was registered at 150% RDF. Among castor genotypes, JC-12 recorded the significantly higher seed yield (2103 kg/ha), however, it was comparable with that of SHB-872 (1981 kg/ha) and RHC-277 (1967 kg/ha). Economic analysis revealed that genotype JC-12 gave higher gross returns (₹ 75718/ha), net returns (₹ 57407/ha) and B:C ratio (4.12). Among fertilizer doses, application of 150% RDF accrued higher gross returns (₹ 82898/ha), net returns (₹63962/ha) and BC ratio (4.63).

Keywords: Castor, Fertilizer, Genotypes, Yield

Castor (*Ricinus communis* L.) is one of the ancient and important industrial and non-edible oil crops of the world. In India, castor is grown in an area of 11.05 lakh ha with a production of 17.33 lakh tonnes and a productivity of 1568 kg/ha during 2014-15. In Karnataka, the crop is cultivated in an area of 0.12 lakh ha with a production of 0.07 lakh tonnes and a productivity of 583 kg/ha (IIOR, 2016). Thus, the productivity of castor in the state is lower than national average and also many states in the country *viz.,* Gujarat (1900 kg/ha), Rajasthan (1481 kg/ha), Bihar (933 kg/ha), Punjab (752 kg/ha), West Bangal (750 kg/ha) and Odisha (639 kg/ha). Main reasons for this phenomenon include cultivation under rainfed conditions which is characterized prolonged dry spell and other aberrations of monsoon, growing castor as an intercrop that too in marginal soils with local varieties. As there are meager chances for horizontal expansion of cultivable area, the only way to sustain the crop and farmers income is to enhance productivity by adopting proper agronomic management (Ramesh *et al.,* 2016). Development and promotion of improved cultivars besides balanced nutrition are the important aspects to be given due importance. Hence, this experiment was conducted with three different pre-release varieties/hybrids of castor (which are in advanced stage of testing) under different levels of fertilizer to assess their productivity potential.

A field experiment was conducted at Zonal Agricultural Research Station, Babbur Farm, Hiriyur, University of Agricultural Sciences, Bangalore during *kharif* season of 2011. The treatments comprised of four nutrient levels (No fertilizer and 50, 100, 150% RDF) and three genotypes of castor (SHB-872, RHC-277 and JC-12). The experiment was laid out in a split plot design with three replications. The soil of the experiment block was medium black with pH value 7.68, low in available nitrogen (192.0 kg/ha), medium available P_2O_5 and K_2O of 21.8 and 278.0 kg/ha, respectively. As per the treatments, fertilizers were applied based on the recommended dose (40 kg N, 40 kg P_2O_5 and 20 kg K_2O/ha) in the form of urea, single super phosphate and muriate of potash. One third of nitrogen along with the entire dose of phosphorus and potassium were applied as basal dose at sowing by band placement. Remaining two thirds of nitrogen was applied in two equal split doses each at 45 and 75 days after sowing. The seeds were dibbled at a spacing of 90 cm x 60 cm. The crop was kept free from insect pests and diseases through suitable plant protection measures. The crop was harvested in three pickings manually based on physiological maturity of the capsule. Data pertaining to crop growth, yield attributes and yield were collected at harvest and analyzed statistically, oil content in the seed for each treatment was estimated by nuclear magnetic resonance analysis (Tiwari *et al.,* 1974) and oil yield was calculated by multiplying seed yield and oil content. The economics for various treatments were calculated based on market price. Gross returns were calculated by multiplying seed yield and prevailing market price. Net returns was obtained by deducting cost of cultivation from gross returns. B:C ratio was calculated by dividing the gross returns with cost of cultivation.

Fertilizer levels had a significant effect on number of branches, seed and oil yield of castor. However, plant height, spike length, 100-seed weight and oil content of castor did not differ significantly due to varying levels of fertilizers

(Table 1). Progressive increase in seed and oil yield was observed with successive increase in nutrient levels from no fertilizer to 150% RDF. Maximum seed yield (2302 kg/ha) and oil yield (1163 kg/ha) were obtained due to application of 150% RDF. This was found to be significantly superior to 100% RDF (2041 kg/ha), 50% RDF (1966 kg/ha) and control (1718 kg/ha). The increase in seed yield over control was to the tune of 12.8, 17.1 and 30.9 per cent at 50, 100 and 150% RDF, respectively. Similarly, 12.0 per cent, 16.1 per cent and 28.7 per cent improvement in oil yield was recorded with 50, 100 and 150% RDF over control, respectively. Fertilizer application might provided better nutrition to the crop which in turn helped the plants to boost up their growth. These results are in conformity with the findings of Patel and Patel (2012) and Dodiya *et al.* (2016).

Plant height, number of branches/plant and 100-seed weight were found to be statistically significant among genotypes (Table 1). But spike length, number of capsules/spike, oil content and seed and oil yield of genotypes were not significantly affected. However, JC-12 recorded the highest seed (2103 kg/ha) and oil (1066 kg/ha) yield which was comparable with SHB-872 (1981 kg/ha seed and 1008 kg/ha oil yield) and RHC-277 (1967 and 1006 kg/ha seed and oil yield, respectively). Similar results were reported from AICRP on castor centre, S.K Nagar, Gujarat (Anonymous, 2011). Economic analysis revealed that JC-12 gave higher gross returns (₹ 75718/ha), net returns (₹ 57407/ha) and BC ratio (4.12) as compared to SHB-872 (₹ 53411/ha; 4.00) and RHC-277 (₹ 52689/ha) and BC ratio (3.90). Among fertilizer doses, application of 150% RDF recorded higher gross returns (₹ 82898/ha), net returns (₹ 63962/ha) and B:C ratio (4.63) than other doses of fertilizers (Table 1). The interaction between fertilizer levels and genotypes was not significant. The castor genotype JC-12 and application of 150% RDF (60 kg N, 60 kg P_2O_5, 30 kg K_2O/ha) can be recommended for black soils for achieving higher yields and returns under rainfed conditions of central dry zone of Karnataka State.

Table 1 Growth, yield attributes, seed and oil yield and economics of pre-released genotypes of castor as influenced by nutrient levels (*kharif* , 2011-12)

Treatments	Plant height (cm)	No. of branches/ plant	Spike length (cm)	No. of capsules/ spike	100-seed weight (g)	Seed yield (kg/ha)	Oil content (%)	Oil yield (kg/ ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
Fertilizer levels											
No fertilizer	97.7	5.8	48.8	51.6	33.7	1758	51.4	904	63316	45058	3.46
50% RDF	107.3	6.0	55.1	57.8	32.2	1966	50.9	1001	70816	54023	4.23
100% RDF	91.0	7.1	50.5	50.4	33.1	2041	50.9	1038	73496	54967	3.96
150% RDF	105.9	5.6	52.3	57.7	33.7	2302	50.5	1163	82898	63962	4.36
SEm±	7.6	0.1	2.2	3.0	1.0	65	0.8	18.8	-	-	-
CD(P=0.05)	NS	0.3	NS	NS	NS	193	NS	45.9	-	-	-
Genotypes											
SHB-872	68.5	6.5	50.0	50.7	31.1	1981	50.8	1006	71330	53411	4.00
RHC-277	79.9	7.5	52.2	53.4	31.6	1967	51.2	1008	70847	52689	3.90
JC-12	148.6	4.4	52.9	59.1	36.8	2103	50.7	1066	75718	57407	4.12
SEm±	6.5	0.1	1.9	2.6	0.9	57	0.6	30.4	-	-	-
CD(P=0.05)	19.3	0.4	NS	NS	2.6	NS	NS	NS	-	-	-

100% RDF: 40 kg N, 40 kg P_2O_5 and 20 kg K_2O/ha

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Influence of sowing time on performance of linseed (*Linum usitatissimum* L.) varieties under mid hill conditions of Himachal Pradesh

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ABSTRACT

A field experiment was conducted to evaluate the performance of different linseed varieties (*Binwa, Himani, Baner* and *Nagarkot*) during different time of sowing (last week of October, first week of November and last week of November). Among different times of sowing, the crop sown during first week of November and last week of October being at par with each other had recorded significantly higher plant stand, more plant height and higher number of secondary branches/plant and capsules/plant, which have contributed in getting significantly higher seed yield and economic return over November last week sown crop. The increase of 37.6 and 35.0 per cent in seed yield and ₹ 5110 and 4281/ha in net returns were obtained when sowing was done during first week of November and last week of October, respectively over crop sown on last week of November. Among varieties, *Nagarkot* has recorded significantly highest plant population/ha, which was followed by *Himani* and *Baner* varieties. *Nagarkot* was found to significantly superior for recording higher number of primary and secondary branches and *Himani* for number of capsules/plant, which have resulted higher seed yield of 1062 and 1012 kg/ha and economic parameters (B:C ratio of 1.62 and 1.50) with *Himani* and *Nagarkot* varieties, respectively.

Keywords: Economics, Linseed, Sowing times, Varieties, Yield

Linseed (*Linum usitatissimum* L.) is one of the most important cultivated plants concerning oil (non-edible and edible oil) and fibre. This crop is gaining momentum for manufacturing several items of industrial significance (Yadav and Srivastva, 2002). Linseed is becoming increasingly popular as a nutritional and functional food due to its high content of health promoting substances such as omega 3 fatty acid, soluble and insoluble fibre and lignans (Biradar *et al.,* 2016). Among various factors responsible for low yield of linseed in Himachal Pradesh, sowing time and varietal selection are of primary importance. Sowing time is a non-monetary input, but has noticeable impact on productivity of crop. Planting dates significantly affect growth characters, yield and its component as well as oil yield in flax (Al Doori, 2012; Pankaj Chopra and Badiyala, 2015). The appropriate sowing date is very important since it ensures good seed germination, as well as the timely appearance of seedling and the optimum development of the root system (Casa *et al.,* 1999). Genotypes differ from each others in genetic make up for growth and yield. Fontana *et al.* (1996) tested ten linseed cultivars and observed their variation for seed yield, 1000-seed weight and oil yield. Many high yielding varieties have been evolved and recommended for general cultivation in the past. These varieties are losing their yield potential due to changes in various edaphic and environmental conditions. Optimum planting time range of different cultivars varies with regions depending on growing conditions of a specific tract. These two factors limit linseed productivity because every crop cultivar has its own requirements for particular environmental conditions for maximum growth, which could be facilitated by proper sowing date. Therefore, to ascertain the optimum dates of sowing for linseed genotypes this study was undertaken.

The present study was carried out during two consecutive *rabi* seasons of 2006-07 and 2007-08 at Experimental Farm of Oilseed Section, CSKHPKV, Palampur, Himachal Pradesh. The experiment was conducted in factorial randomized block design keeping 12 treatment combinations, comprising of three times of sowing (last week of October, first week of November and last week of November) and four varieties (*Binwa*, *Himani*, *Baner* and *Nagarkot*) in three replications. The crop was raised with recommended package of practices. The soil of the experiment site was silty clay loam in texture with pH 5.9 and medium in available nitrogen, phosphorus and potassium. The crop was supplied with 50, 40 and 20 kg N, P_2O_5 and K_2O/ha, respectively. The different varieties of linseed were sown at 23 cm apart rows using seed rate of 40 kg/ha at different times as per treatments. For recording plant population in hectare area, the total number of plants present in 1m row length were counted from two randomly selected places in each net plot, averaged and expressed in thousand plants/ha. Plant height, number of primary, secondary branches and capsules/plant were recorded from the selected five plants in each net plot. After maturity, the crop was harvested from the net plot area, sun dried, threshed with wooden mallet and the seed yield obtained was expressed in kg/ha. Economics of the treatments was computed based on prevalent market prices.

Time of sowing and varieties have significant influence on plant stand and plant height of linseed (Table 1). The crop sown during last week of October being at par with November first week sown crop had registered significantly higher plant stand. Significantly tallest plants were found in crop sown during last week of October and was followed by the crop sown on November first week. Among varieties, *Nagarkot* had recorded significantly highest plant population/ha. However, *Himani* and *Baner* being at par to each other were significantly superior to *Binwa* in this regard. Variety *Nagarkot* was proved to be significantly superior in recording more plant height followed by *Baner.* Significantly less plant height was recorded with *Binwa* variety (Table 1).

All the yield attributes except number of primary branches/plant and seeds/capsule were significantly influenced by different times of sowing (Table 1). Significantly more number of secondary branches and capsules/plant were recorded in crop sown during first week of November. However, the crop sown during last week of October behaved statistically similar to it for recording significantly higher number of capsules/plant and next best for higher number of secondary branches/plant. Numerically, highest number of primary branches was found in crop sown during last week of October. More plant stand with higher number of yield attributes contributed in getting significantly higher seed yield of linseed when crop was sown either during last week of October or first week of November. These two sowing time behaved statistically similar to each other for recording significantly higher seed yield of linseed which was 35.0 to 37.6 per cent higher than the crop sown during last week of November (Table 2). The higher values of vegetative characters, yield attributes and seed yield were obtained when this crop was sown from last week of October to first week of November due to favourable weather conditions such as temperature and precipitation, which were in the range of optimum degree for good plant stand, vegetative and reproductive stages and have resulted in higher photosynthetic products accumulation in the source (leaves) through better transportation to the sink (seeds). Chauhan *et al.* (2008) reported better yields of linseed when crop was sown during October. Similarly, Mahapatra *et al.* (2009) also proved the superiority of 30th October sowing with respect to different growth, yield attributes and seed yield in this crop. The sowing of flax crop on first November gave the highest number of capsules per plant, number of seeds per capsule, weight of thousand seed, seed and oil yield than crop sown during mid October and mid November (Al Doori, 2012). The inferiority of delayed sowing to last week of November may be attributed to less plant population (due to poor germination because of low temperature) and the short period for vegetative and reproductive growth.

Different varieties have significant influence on all the yield attributes except seeds/capsule. *Nagarkot* variety had recorded significantly higher values for all the yield attributes except number of capsules/plant, for which *Himani* was significantly superior over rest of other varieties (Table 1). Variety *Baner* being at par with *Nagarkot* had recorded significantly higher number of capsules/plant and was next best for recording significantly higher number of primary branches/plant. Significantly lowest number of secondary branches and capsules/plant were found in *Binwa* variety. However, *Himani* and *Binwa* behaved statistically similar to each other with respect to number of primary branches/plant. Variety *Himani* being at par with *Nagarkot* had recorded significantly higher seed yield of linseed (Table 2). This was due to higher plant stand with better yield attributes especially capsules/plant with *Himani* and other yield attributes with *Nagarkot* over other tested varieties. Superiority of *Nagarkot* for yield was also narrated by Husain *et al.* (2009). Respective increase in the seed yield of linseed due to *Himani* and *Nagarkot* was 70.7 and 62.7 per cent over *Binwa.*

Table 1 Effect of treatments on growth and yield attributes of linseed (Pooled data of two years)

Treatments	Plant stand (000'/ha)	Plant height (cm)	No. of primary branches/ plant	No. of secondary branches/ plant	No. of capsules/ Plant	Seeds/ capsule
Time of sowing						
Last week of October	1104	68.9	4.95	2.37	36.82	7.45
First week of November	1199	65.7	4.64	2.59	37.12	7.55
Last week of November	1050	62.6	4.65	2.23	32.33	7.52
CD (P=0.05)	101	2.3	NS	0.06	2.10	NS
Varieties						
Binwa	893	58.2	4.38	2.46	30.15	7.43
Himani	1146	65.0	4.39	2.14	40.44	7.54
Baner	1117	67.0	4.74	2.37	35.15	7.33
Nagarkot	1318	72.7	5.47	2.63	35.86	7.73
CD (P=0.05)	96	1.9	0.14	0.04	1.31	NS

Table 2 Effect of treatments on seed yield and economics of linseed (pooled data of two years)

Treatments	Seed yield (kg/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	Net returns per rupee invested
Time of sowing				
Last week of October	976	19425	11053	1.30
First week of November	995	19890	11882	1.49
Last week of November	723	14460	6772	0.87
CD (P=0.05)	38	1156	1191	0.19
Varieties				
Binwa	622	12327	4492	0.55
Himani	1062	21230	13164	1.62
Baner	896	17913	9846	1.21
Nagarkot	1012	20230	12106	1.50
CD (P=0.05)	37	1127	1108	0.13

The crop sown either during last week of October or first week of November had recorded significantly higher values of gross, net returns and benefit cost ratio. Sowing during these times of sowing had registered an increase of ₹ 4965 and 5430/ha in gross returns and ₹ 4281 and 5110/ha in net returns, respectively over November last week sown crop. The benefit cost ratio achieved with sowing on these respective times was 1.30 and 1.49 (Table 2).

Varieties *Himani* and *Nagarkot,* which were statistically at par to each other had recorded significantly higher values for all economic parameters *viz*., gross, net returns and B:C ratio. *Himani* variety had increased the gross and net returns to the tune of ₹ 8903 and 8672/ha, respectively as compared to *Binwa* variety, while, the corresponding increase with *Nagarkot* variety was ₹ 7903 and 7614/ha. Benefit cost ratio achieved with *Himani* and *Nagarkot* varieties was 1.62 and 1.50, respectively. The *Binwa* variety was proved to be significantly inferior with respect to all these economic parameters because of involvement of higher cost of cultivation and less production (Table 2). Therefore, sowing of *Himani* or *Nagarkot* variety of linseed upto first week of November is best for achieving higher production with better economic returns.

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Efficacy of newer insecticides against sucking insect pests of groundnut (*Arachis hypogaea* L.)

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ABSTRACT

A field study was conducted at Regional Agricultural Research Station, Polasa, Jagtial, Karimnagar district, Telangana State during *rabi*/summer season of 2010-11 and 2011-12 to evaluate the efficacy of newer insecticides along with conventional insecticides against sucking pests *viz.,* thrips and leafhoppers in groundnut. The results revealed that buprofezin 25SC @ 500 ml/ha and fipronil 5SC 1000 ml/ha were found to be effective and recorded lowest mean per cent leaf damage due to the sucking pests in groundnut as compared to untreated control. The insecticides were also recorded higher dry pod yield as compared to other insecticides and untreated control.

Keywords: Efficacy, Groundnut, Newer insecticides, Sucking pests

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop grown in India and is the largest producer of groundnut pods in the World. The major groundnut growing states in India are Gujarat, Maharashtra, Karnataka, Tamil Nadu, Odisha, Rajasthan, Andhra Pradesh and Telangana. The insect pests is a main reason for low productivity of groundnut in India (Venkataiah *et al.,* 2015). In Southern India, it is mainly cultivated in *kharif* in Andhra and Rajayalseema regions of Andhra Pradesh and in *rabi*/summer as a irrigated dry (ID) crop in Telangana districts of Telangana State. The annual losses from major insect pests in groundnut have been estimated to be approximately 150 crores (Amin, 1984). The loss in yield due to leafhopper (*Empaosca kerri*) and thrips (*Scirothrips dorsalis*, *Caliothrips indicus, Frankliniella schultzei* and *Thrips palmi*) in groundnut was estimated to be 48-50 per cent in Tamil Nadu (Sivasubramaniam and Palanisamy, 1986). Further, thrips have become serious as vectors of viral diseases, besides direct injury by feeding (Sreekanth, 2002). Insecticides of a new group *viz.,* neonicotinoids have emerged as most promising with their specific action. Seed dressers and formulations of many insecticides of this group have been widely accepted in agriculture and found promising against sucking pests (Patil *et al.,* 2004; Vastrad, 2003). Considering the seriousness of the sucking pests on groundnut an experiment was conducted with newer insecticides against thrips and leafhoppers on groundnut.

A field experiment was conducted at Regional Agricultural Research Station, Polasa, Jagtial, Karimnagar District, Telangana state during *rabi*/summer season of 2010-11 and 2011-12 to study the efficacy of newer insecticides along with conventional insecticides against sucking pests *viz.,* thrips and leafhoppers in groundnut. The popular groundnut variety, Kadiri 6 was sown in plots of 5.0 m x 4.0 m with the spacing of 30x10 cm. The experiments were conducted in a randomized block design with nine treatments and replicated trice. The treatments were imposed twice as foliar sprays as a first spray at 20 and second spray at 35 days after first spraying (DAS). The observations on per cent leaf damage due to thrips and leafhoppers were recorded at 25 and 40 DAS as suggested by Amin (1983). For thrips, the per cent damaged leaflets per 25 leaf lets collected from 5 plants randomly. In case of leafhoppers, per cent yellowing of foliage on 10 leaves randomly collected from main branch of the plant/5 plants were observed. Data were recorded on dry pod yield of groundnut at harvest.

The results of the trial conducted during *rabi*/summer 2010-11 revealed that all the insecticides were found significantly superior to untreated control in minimizing the mean per cent leaf damage due to thrips and leafhoppers in groundnut (Table 1). Foliar spraying of buprofezin 25SC @ 500 ml/ha was recorded the lowest mean per cent leaf damage due to thrips and leaf hoppers with 13.83 and 17.50 per cent as against 53.50 and 63.17 per cent recorded in untreated control followed by fipronil 5SC @ 1000 ml/ha against thirps and leafhoppers (19.00% and 26.3%, respectively). Thee treatments, buprofezin 25 SC @ 500 ml/ha fipronil 5 SC @ 1000 ml/ha recorded high dry pod yield (2318 and 2266 kg/ha, respectively) as compared to untreated control (1700 kg/ha).

The results of the second year experiment during *rabi*/ summer 2011-12 season revealed that (Table 1), the treatment, buprofezin 25 SC @ 500 ml/ha recorded lower mean per cent leaf damage due to thrips (16.66%), leaf hoppers (8.33%) followed by fipronil 5 SC @ 1000 ml/ha with 20 per cent leaf damage due to thrips and thiamethoxam 25 WG @ 200 g/ha and acephate 75 SP @ 500 g/ha against leafhoppers (16.66% leaf damage) as compared to untreated control against thrips and leafhoppers (71.66% and 53.33%), respectively. Also, the treatments, buprofezin 25 SC @ 500 ml/ha recorded high dry pod yield (2050 kg/ha) followed by fipronil 5 SC @ 1000 ml/ha (1942 kg/ha) as compared to

untreated control (1292 kg/ha). The results of the experiments conducted on sucking pests (thrips and leafhoppers) of groundnut also revealed that the insecticides *viz.,* buprofezin 25 SC @ 500 ml/ha and fipronil 5 SC @ 1000 ml/ha were effective and recorded lower leaf damage due to thrips and leafhoppers at 20 DAS and 35 DAS (Anonymous, 2012-13).

In the present study, thaimethoxam 25 WG was also found effective against thrips and leafhoppers compared to other treatments against sucking pests of groundnut.. The results are in conformity with the studies of Rao *et al.,* (2007) in blackgram against thirps and leafhoppers and Nakat *et al.* (2002) in greengram. Also similar results reported by Dandale *et al.,* (2001) and Mohapatra *et al*. (2005) against sucking pests in cotton.

Table 1 Efficacy of newer insecticides against sucking pests of groundnut (*rabi*/summer, 2010-11 and 2011-12)

Treatment	Per cent leaf damage due to thirps				Per cent leaf damage due to leafhopper				Dry pod yield (kg/ha)		C:B ratio	
	2010-11		2011-12		2010-11		2011-12					
	Before Spray	7 days after spray	Before Spray	7 days after spray	Before Spray	7 days after spray	Before Spray	7 days after spray	2010-11	2011-12	2010-11	2011-12
Imidacloprid 200 SL @ 125 ml/ha	49.67	37.67 (37.86)*	75.00	37.50 (37.74)	58.3	40.17 (39.33)*	21.66	21.67 (27.68)	1816	1767	1:1.6	1:1.84
Acetamiprid 20 SP @ 100 g/ha	48.67	25.33 (30.21)	73.33	24.17 (29.40)	59.6	33.67 (35.46)	25.00	17.17 (24.45)	1883	1908	1:1.7	1:2.10
Thiamethoxam 25 WG @ 200 g/ha	50.33	24.67 (29.76)	75.00	20.83 (27.10)	60.3	30.67 (33.62)	25.00	15.00 (22.70)	2133	1925	1:1.9	1:2.06
Thiacloprid 480 SC @ 150 ml/ha	48.67	19.00 (25.84)	73.33	37.50 (37.74)	59.3	28.67 (32.32)	23.33	27.50 (31.57)	2200	1733	1:2.1	1:1.80
Buprofezin 25 SC @ 500 ml/ha	48.33	13.83 (21.82)	75.00	15.00 (22.74)	58.6	17.50 (24.72)	20.00	7.50 (15.75)	2318	2050	1:2.3	1:2.27
Fipronil 5 SC @ 1000 ml/ha	48.00	17.00 (24.34)	75.00	18.33 (25.30)	56.0	22.17 (28.06)	26.66	14.17 (22.04)	2266	1942	1:2.2	1:2.06
Triazophos 25 EC @ 1000 ml/ha	47.67	27.17 (31.42)	73.33	29.17 (32.59)	58.6	41.33 (40.01)	23.33	25.50 (30.23)	2250	1625	1:2.2	1:1.59
Acephate 75 SP @ 500 g/ha	49.33	24.17 (29.42)	78.33	20.83 (26.99)	58.3	31.67 (34.24)	28.33	14.17 (21.97)	2150	1925	1:2.1	1:2.11
Control	47.33	53.50 (47.01)	76.66	62.50 (52.30)	58.6	63.17 (52.64)	25.00	47.50 (43.56)	1700	1292		
SEm (±)		0.79		1.91		0.95		1.72	98.88	78.11		
CD (P= 0.05)		2.38		5.76		2.86		5.20	298.98	236.19		
CV (%)	4.42			10.17		4.60		11.16	8.24	7.53		

* Figures in parentheses are angular transformed values

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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.
17. For citing **References** a recent issue or the present journal may be referred, ensuring that all the references cited in the text are referred in the end under References section of the article. Each citation should have the name(s) of the author(s), initials (without full stops, but comma after each full name), year of publication (with full stop), full title of the article (with full stop), name of the journal (in italics with comma but without abbreviations), volume number (in bold), preferably the issue (within parentheses and colon) and complete page range (not merely the first page and full stop). Complete name of publisher and place of publication of books should be given in case of books. For proceedings or other publications complete details should be given.
18. All articles are sent to referees for scrutiny and authors should meet criticism by improving the article, indicating the modifications made (in separate sheet, 2 copies).
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