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Research Papers

Short Communications

Genetic variability, character association and path coefficient analysis for pod yield and drought tolerance in groundnut (*Arachis hypogaea* L.)

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ABSTRACT

A field experiment was conducted at Oilseeds Research station, Latur during *rabi* 2017-18 to evaluate twenty four genotypes of groundnut for genetic variability, character association and path analysis for ten characters under both stress and non stress conditions. Results revealed high phenotypic correlation coefficients (PCV) and genotypic correlation coefficients (GCV) for kernel yield and pod yield per plant and GCV were higher than PCV suggesting strong inherent association under both conditions. High heritability accompanied with high genetic advance as per cent of mean was recorded for kernel yield and pod yield per plant under non stress condition and kernel yield, pod yield, number of pods per plant and SCMR under stress condition. Pod yield exhibited highest positive and significant association with number of pods per plant, number of seeds per pod, kernel yield per plant, test weight, harvest index and SPAD Chlorophyll Meter Reading (SCMR) at both genotypic and phenotypic level under non stress condition. Path coefficients among the characters showed that kernel yield per plant, number of seeds per pod and harvest index exerted highest positive direct effect on pod yield per plant under non stress and stress conditions.

Keywords: Character association, Drought tolerance, Groundnut, Heritability, Path analysis, Pod yield

Groundnut (*Arachis hypogaea* L.) is an annual legume cum oilseed crop which is also known as peanut, earthnut, monkeynut and *moongfali* (hindi). It is the 13th most important food crop and 4th most important oilseed crop of the world. It belongs to the family Fabaceae, native to South America (Brazil), and grown throughout the tropical, sub-tropical and warm temperate regions of the world. It is a segmental allotetraploid (2n=40) and self-pollinating annual legume. Groundnut kernel contains 40-55 per cent oil, 22-30 per cent protein and 10-20 per cent carbohydrate (Narendra Kumar *et al.,* 2017).

As the crop is grown in marginal lands with poor management, yield in rainfed areas is limited by drought stress due to reduction in crop growth and pod yield (Pimratch *et al.,* 2008, Nautiyal *et al.,* 2002, Reddy *et al.,* 2003; Nigam *et al.,* 2005; Bhargavi *et al.,* 2016; Divyadarshini *et al.,* 2016). Yield loss has been estimated to be 56-85 per cent (Nageswararao *et al.,* 1989), depending on crop growth stages at which the crop gets exposed to drought (Reddy *et al.,* 2003; Amar *et al.,* 2018), its intensity and duration (Nautiyal *et al.,* 2002; Nigam *et al.,* 2005). Even in irrigated areas, crop experiences drought stress as the water is not sufficient for growth. Limited water availability, especially, during flowering and peg penetration stages appears to be one of the important constraints to harness complete genetic potential of improved cultivars for yield.

The basic key to bring about the genetic upgrading of a crop is to utilize the available genetic variability (Ajay *et al.,* 2018). The variability in the population is largely due to genetic cause with least environment effect. The possibility of selecting superior genotype is a prerequisite for obtaining higher yield, which is the ultimate expression of various yield contributing characters. Harnessing the variability present among the available genotypes helps in selecting the superior genotypes for different traits and situations.

The present investigation was carried out with an objective to estimate the variability, character association and path analysis for yield and its component traits in selected groundnut genotypes under both moisture stress and non stress conditions to select the genotypes for future breeding programs.

MATERIALS AND METHODS

The experiment was conducted during *rabi* 2017-18 at Oilseeds Research Station, Latur with 24 groundnut genotypes sown in Randomized Block Design with two replications at a spacing of 30 x 10 cm under both stress and non stress condition by dibbling. Non- stress condition was maintained by irrigating the plots as per the crop requirement. Moisture stress condition was created by withholding irrigation after flowering initiation. Observations on ten different yield contributing and drought tolerance characters *viz.,* number of pods per plant, number of seeds per pod, pod yield per plant, kernel yield per plant, shelling per cent, test weight, harvest index, oil content, SCMR and specific leaf area (SLA) were recorded with five selected plants from each genotypes of both replications and under both moisture stress and non stress conditions. Analysis of variance was carried out as per the method suggested by Panse and sukhatme (1985). Phenotypic and genotypic coefficient of variation (GCV and PCV) was computed as

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per Burton (1952), heritability (broad sense) and genetic advance as per cent of mean (GAM) as per Allard (1960). The genotypic and phenotypic coefficients of correlation were calculated using the method given by Johnson *et al.* (1955). Path coefficient analysis was carried out by using phenotypic and genotypic correlation coefficients as per the method suggested by De way and Lu (1959).

RESULTS AND DISCUSSION

Analysis of variance for all characters indicated that the mean sum of squares due to genotypes were highly significant for all the characters indicating the presence of sufficient amount of variability in the studied genotypes under both stress and non stress condition (Table 1). The estimates of genetic parameters (Table 2) revealed that there were closer correspondences between GCV and PCV for all the characters except number of pods per plant and harvest index under both non stress and stress conditions. Thus, the results indicated that most of the characters were largely under genetic control. The GCV and PCV estimates were relatively high for kernel yield per plant and pod yield per plant under both conditions. These findings were in accordance with the reports of Ramana *et al.* (2015), Thirumala Rao (2016), Hampannavar *et al.* (2018) and Wadikar *et al.* (2018). The moderate GCV and PCV values were observed for number of pods per plant, SCMR, number of seeds per pod and harvest index. Similar findings have been reported by Injeti *et al.* (2008), Vasanthi *et al.* (2015) and Bhargavi *et al.* (2016) for number of pods per plant and harvest index. The lowest GCV and PCV values were recorded for test weight, SLA, shelling per cent and oil content under both the situations and this observation is in line with the earlier reports by Bhargavi *et al.* (2016) and Hampannavar *et al.* (2018) for shelling per cent and oil content, by Pradhan and Patra (2011), Ramana *et al.* (2015), Vasanthi *et al.* (2015) for shelling per cent and by Srivalli and Nadaf (2016) for SLA.

High heritability coupled with high genetic advance as per cent of mean has been noticed for kernel yield per plant and pod yield per plant under non stress situations and kernel yield per plant, pod yield per plant, number of pods per plant and SCMR under stress condition indicating lesser influence of environment and prevalence of additive gene action in their expression. Thus selection for improvement of those characters would be more effective. The highest heritability in broad sense was recorded for kernel yield per plant (88.86%) followed by pod yield per plant (85.41%) and SCMR (78.91%) under non stress condition. Under stress condition, kernel yield per plant (89.41%), pod yield per plant (88.13%), number of pods per plant (76.04%) and SCMR (74.88%) showed higher variability (Table 2). The results were in accordance with Injeti *et al.* (2008), Thirumala Rao *et al.* (2014), Bhargavi *et al.* (2017), Chavadhari *et al.* (2017), Hampannavar *et al.* (2018) and Wadikar *et al.* (2018) for kernel yield per plant, pod yield per plant and number of pods per plant. Moderate heritability coupled with moderate to low genetic advance as per cent of mean recorded by SCMR, test weight, harvest index, number of pods per plant, oil content, number of seeds per pod, shelling per cent and SLA under non stress condition and test weight, harvest index, oil content, number of seeds per pod, shelling per cent and SLA under stress condition indicated the presence of non additive gene action and influence of environment on the expression of these characters and thus the selection would be less effective under both situations (Table 2). Similar findings were reported by Patil *et al.* (2014) for test weight, shelling per cent and harvest index, Ramana *et al.* (2015) for test weight, Shrivalli and Nadaf (2016) for SCMR and SLA and Bhargavi *et al.* (2017) for SCMR and oil content.

In the present study, the genotypic correlation coefficients were higher than the phenotypic correlation coefficients suggesting strong inherent association among the characters studied under both non stress and stress conditions. Pod yield exhibited highest positive and significant association with harvest index, kernel yield per plant, SCMR, number of pods per plant, number of seeds per pod and test weight at both genotypic and phenotypic level under non stress condition (Table 3a) and positive significant association with kernel yield per plant, harvest index, test weight, SCMR, number of pods per plant and number of seeds per pod at both genotypic and phenotypic level under stress condition (Table 3b). This indicated that correlation coefficients were stable across both (stress and non-stress) conditions. Similar associations have also been reported by Bhargavi *et al.* (2015) and Rathod *et al.* (2015) for number of pods per plant, kernel yield per plant, test weight, SCMR, Harvest index and Wadikar *et al.* (2018) for number of pods per plant, number of seeds per pod, kernel yield per plant, test weight and harvest index.

The pod yield exhibited highest negative and significant association with Specific leaf area (SLA) under both conditions. Similar findings were reported by Suvarna *et al.* (2004), Upadhyaya (2005), Injeti *et al.* (2008) and Janila *et al.* (2015). The interrelationships were positive and highly significant among yield components and drought tolerance related characters like SCMR with number of seeds per pod, kernel yield per plant, number of pods per plant, harvest index and test weight; test weight with harvest index, number of seeds per pod, kernel yield per plant and shelling per cent; number of pods per plant with kernel yield per plant and harvest index; number of seeds per pod with harvest index, kernel yield per plant and shelling per cent; shelling per cent with kernel yield per plant and harvest index; and harvest index with kernel yield per plant under moisture non stress condition. The interrelationships were positive and highly significant among yield components and drought tolerance

related characters like SCMR with kernel yield per plant, number of seeds per pod, test weight, shelling per cent, number of pods per plant and harvest index; test weight with kernel yield per plant, harvest index, number of seeds per pod, number of pods per plant and shelling per cent; number of pods per plant with kernel yield per plant, harvest index and shelling per cent; number of seeds per pod with shelling per cent and kernel yield per plant; shelling percent with kernel yield per plant and harvest index; harvest index with kernel yield per plant under moisture stress condition. These observations are in line with the results reported by Painawadee *et al.* (2009) for SCMR with number of pods per plant, for SCMR with test weight Dandu *et al.* (2012), Babariya and Dobariya (2012) for number of pods per plant with kernel yield per plant, Kadam *et al.* (2009) and Wadikar *et al.* (2018) for test weight with harvest index and kernel yield per plant.

Path coefficient among the characters showed kernel yield per plant, number of seeds per pod and harvest index exerted the highest positive direct effect on pod yield per plant under non stress condition (Table 4a, Fig. 1). Whereas, the kernel yield per plant exhibited highest positive direct effect on pod yield under stress condition (Table 4b, Fig. 2). Similar results were observed by Babariya and Dobariya (2012), Dandu *et al.* (2012), Kahate *et al.* (2014), Gupta *et al.* (2015) and Raghuwanshi *et al.* (2015) for pod yield with kernel yield per plant and harvest index.

In the present study, SCMR exerted highest negative direct effect on pod yield per plant under non stress. Whereas, shelling per cent exerted highest negative direct effect on pod yield per plant under stress condition. Similar results were found by Bhargavi *et al.* (2015) for pod yield with SCMR and shelling per cent, Thirumala Rao (2016) for pod yield with SCMR and Dandu *et al.* (2012), Thirumala Rao *et al.* (2014), Patil *et al.* (2015), Raghuwanshi *et al.* (2015) and Hampannavar *et al.* (2018) for pod yield with shelling per cent.

Table 1 Analysis of variances for yield, yield contributing and drought tolerance related characters

Sources of variation/character	Mean sum of squares					
	Replications		Genotypes		Error	
	NS	S	NS	S	NS	S
D.F.	1	1	23	23	23	23
No. of pods/ plant	9.18	0.65	26.61**	8.75**	3.40	1.19
No. of seeds/ pod	0.003	0.001	0.036**	0.084**	0.017	0.022
Pod yield/plant (g)	2.43	0.01	15.03**	5.39**	1.18	0.34
Kernel yield/plant(g)	0.04	0.002	6.41**	1.77**	0.37	0.09
Shelling (%)	8.92	0.24	27.01**	30.93**	13.07	14.63
Test weight (g)	2.34	2.29	17.34**	13.22**	4.59	4.08
Harvest index (%)	8.60	2.27	31.05**	18.81**	11.98	7.52
Oil content (%)	0.15	0.28	4.81**	3.97**	1.14	1.03
SCMR	5.50	17.92	70.85**	81.40**	8.35	11.69
SLA	1.63	23.53	144.68**	151.04**	68.88	69.15

NS = Non Stress; S = Stress; **Significant (at p=0.01)

Table 2 Parameters of genetic variability for yield and yield contributing and drought tolerance characters in groundnut.

Parameters	Range		Mean		GV (δ^2g)		PV (δ^2p)		GCV (%)		PCV (%)		Heritability (BS) (%)		Genetic advances		GAM (%)	
	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S
Number of pods/plant	10.10 to 24.00	6.50 to 14.30	17.05	9.83	5.94	3.78	15.01	4.98	14.30	19.78	22.73	22.69	39.58	76.04	3.16	3.49	18.53	35.53
Number of seeds/pod	1.55 to 2.10	0.95 to 1.70	1.86	1.35	0.01	0.03	0.03	0.05	5.26	13.02	8.81	17.13	35.68	57.72	0.12	0.28	6.48	20.37
Pod yield/plant (g)	4.40 to 16.00	3.00 to 9.80	8.81	5.29	6.92	2.53	8.11	2.87	29.87	30.03	32.33	31.99	85.41	88.13	5.01	3.07	56.87	58.08
Kernel yield/plant (g)	2.60 to 10.10	1.40 to 5.30	5.60	2.74	3.02	0.84	3.40	0.94	31.05	33.37	32.93	35.29	88.86	89.41	3.37	1.78	60.29	65.00
Shelling (%)	57.00 to 71.45	42.46 to 57.42	63.22	51.44	6.97	8.15	20.05	22.79	4.18	5.55	7.10	9.28	34.77	35.76	3.21	3.52	5.07	6.84
Test weight (g)	26.60 to 38.10	21.35 to 31.25	32.34	26.55	6.37	4.57	10.97	8.66	7.81	8.05	10.24	11.10	58.08	52.79	3.96	3.20	12.25	12.05
Harvest index (%)	22.50 to 41.02	18.32 to 30.29	32.01	23.39	9.54	5.65	21.52	13.17	9.65	10.16	14.49	15.52	44.33	42.87	4.24	3.21	13.23	13.71
Oil content (%)	45.80 to 51.70	41.26 to 47.25	48.30	44.18	1.84	1.47	2.98	2.51	2.81	2.75	3.58	3.58	61.64	58.75	2.19	1.92	4.54	4.34
SCMR	25.40 to 46.82	21.00 to 44.51	34.72	31.26	31.25	34.86	39.60	46.55	16.10	18.89	18.12	21.83	78.91	74.88	10.23	10.52	29.46	33.67
SLA	92.51 to 124.28	88.22 to 115.10	107.27	100.51	37.90	40.95	106.78	110.10	5.74	6.37	9.63	10.44	35.49	37.19	7.56	8.04	7.04	7.99

GV-Genotypic variance; PV-Phenotypic variance; GCV-Genotypic coefficient variation; PCV-Phenotypic coefficient variation; GAM-Genetic advance as % of mean;
NS = Non Stress; S = Stress

Table 3a Estimates of genotypic and phenotypic correlation coefficient among yield, yield contributing and drought tolerance related characters in groundnut under moisture non stress conditions

Characters		Oil content	SCMR	SLA	Test weight	No. of pods/ plant	No. of seeds/pod	Shelling per cent	Harvest index	Kernel yield/plant	Pod yield/ plant
Oil content	G	1.0000	-0.1303	-0.1097	-0.2316	0.2469	-0.4011**	-0.5296**	0.0518	-0.1150	-0.0639
	P	1.0000	0.0155	-0.2237	-0.0821	0.0356	-0.1255	-0.1409	-0.0663	-0.1075	-0.0667
SCMR	G		1.0000	-0.8210**	0.5899**	0.7439**	1.0656**	0.2541	0.7406**	0.8719**	0.8676**
	P		1.0000	-0.4503**	0.3132*	0.3935**	0.6278**	0.2789	0.4717**	0.7323**	0.7225**
SLA	G			1.0000	-0.1072	-1.3585**	-0.2480	0.0287	-0.9172**	-0.9888**	-0.9506**
	P			1.0000	-0.1496	-0.5408**	-0.1991	-0.1165	-0.2168	-0.4677**	-0.5196**
Test weight	G				1.0000	-0.2104	0.6139**	0.4716**	0.9643**	0.5681**	0.4838**
	P				1.0000	0.1018	0.3345*	0.1966	0.1936	0.4091**	0.4092**
No. of pods/plant	G					1.0000	-0.0760	0.2261	0.7797**	0.8303**	0.7555**
	P					1.0000	0.0876	-0.0799	0.3180*	0.6164**	0.6931**
No. of seeds/pod	G						1.0000	0.5302**	0.8379**	0.7399**	0.6763**
	P						1.0000	0.1674	0.3208*	0.4149**	0.4237**
Shelling per cent	G							1.0000	0.5003**	0.5021**	0.3110*
	P							1.0000	0.1218	0.1964	0.0865
Harvest index	G								1.0000	1.0334**	1.0406**
	P								1.0000	0.6565**	0.6536**
Kernel yield/plant	G									1.0000	1.0158**
	P									1.0000	0.9662**

G - Genotypic correlation coefficient; P - Phenotypic correlation coefficient; *5 per cent significance level; ** 1per cent significance level

Table 3b Estimates of genotypic and phenotypic correlation coefficient among yield, yield contributing and drought tolerance related characters in groundnut under moisture stress condition

Characters		Oil content	SCMR	SLA	Test weight	No. of pods/ plant	No. of seeds/pod	Shelling per cent	Harvest index	Kernel yield/plant	Pod yield/ plant
Oil content	G	1.0000	0.2838	-0.3918**	-0.1089	0.1983	0.0619	0.1386	0.0400	0.0205	0.0229
	P	1.0000	0.0760	-0.1109	-0.0196	0.1323	-0.0995	0.0849	0.0106	0.0272	0.0230
SCMR	G		1.0000	-0.5540**	0.7994**	0.6872**	0.8592**	0.7844**	0.5586**	0.8731**	0.8512**
	P		1.0000	-0.2830	0.5114**	0.5985**	0.5419**	0.3451*	0.4231**	0.7714**	0.7576**
SLA	G			1.0000	-0.1661	-0.5731**	0.0613	0.2058	-0.4357**	-0.3127*	-0.3829**
	P			1.0000	0.0095	-0.2983*	-0.0108	-0.0893	-0.1784	-0.2397	-0.2459
Test weight	G				1.0000	0.5242**	0.6335**	0.4364**	0.6661**	0.8569**	0.8693**
	P				1.0000	0.1702	0.2056	0.1844	0.2947*	0.6039**	0.6038**
No. of pods/plant	G					1.0000	0.1107	0.5136**	0.7360**	0.7970**	0.8118**
	P					1.0000	0.1475	0.3235*	0.4734**	0.7308**	0.7314**
No. of seeds/pod	G						1.0000	0.5322**	0.1043	0.4952**	0.4422**
	P						1.0000	0.1299	0.1715	0.3762**	0.3776**
Shelling per cent	G							1.0000	0.6588**	0.7336**	0.6285**
	P							1.0000	-0.1625	0.4925**	0.2803
Harvest index	G								1.0000	0.8933**	0.8982**
	P								1.0000	0.5343**	0.6349**
Kernel yield/plant	G									1.0000	0.9879**
	P									1.0000	0.9708**

G -Genotypic correlation coefficient; P- Phenotypic correlation coefficient; *5 per cent significance level; ** 1per cent significance level

Table 4a Estimates of path coefficient analysis among yield, yield contributing and drought tolerance related characters in groundnut for non stress condition

Characters		Oil content	SCMR	SLA	Test weight	No. of pods/plant	No. of seeds/pod	Shelling per cent	Harvest index	Kernel yield/plant	Pod yield/ plant
Oil content	G	-0.0629	0.0082	0.0069	0.0146	-0.0155	0.0252	0.0333	-0.0033	0.0072	-0.0639
	P	-0.0015	0.0000	0.0003	0.0001	-0.0001	0.0002	0.0002	0.0001	0.0002	-0.0667
SCMR	G	0.1615	-1.2397	1.0178	-0.7313	-0.9222	-1.3210	-0.3150	-0.9181	-1.0809	0.8676**
	P	0.0007	0.0426	-0.0192	0.0133	0.0167	0.0267	0.0119	0.0201	0.0312	0.7225**
SLA	G	0.0239	0.1789	-0.2179	0.0233	0.2960	0.0540	-0.0063	0.1998	0.2155	-0.9506**
	P	0.0109	0.0219	-0.0485	0.0073	0.0263	0.0097	0.0057	0.0105	0.0227	-0.5196**
Test weight	G	0.1570	-0.3997	0.0726	-0.6775	0.1426	-0.4160	-0.3196	-0.6534	-0.3849	0.4838**
	P	-0.0047	0.0178	-0.0085	0.0568	0.0058	0.0190	0.0112	0.0110	0.0232	0.4092**
No. of pods/plant	G	-0.1348	-0.4062	0.7419	0.1149	-0.5461	0.0415	-0.1235	-0.4258	-0.4534	0.7555**
	P	0.0051	0.0565	-0.0777	0.0146	0.1436	0.0126	-0.0115	0.0457	0.0885	0.6931**
No. of seeds/pod	G	-0.3074	0.8166	-0.1901	0.4705	-0.0582	0.7663	0.4063	0.6421	0.5670	0.6763**
	P	-0.0043	0.0214	-0.0068	0.0114	0.0030	0.0341	0.0057	0.0109	0.0142	0.4237**
Shelling per cent	G	0.3072	-0.1474	-0.0166	-0.2735	-0.1311	-0.3075	-0.5800	-0.2902	-0.2912	0.3110*
	P	0.0133	-0.0263	0.0110	-0.0185	0.0075	-0.0158	-0.0942	-0.0115	-0.0185	0.0865
Harvest index	G	0.0218	0.3118	-0.3861	0.4059	0.3282	0.3527	0.2106	0.4210	0.4351	1.0406**
	P	-0.0045	0.0319	-0.0147	0.0131	0.0215	0.0217	0.0082	0.0676	0.0444	0.6536**
Kernel yield/plant	G	-0.2301	1.7451	-1.9791	1.1369	1.6618	1.4810	1.0049	2.0684	2.0015	1.0158**
	P	-0.0817	0.5568	-0.3556	0.3111	0.4687	0.3155	0.1494	0.4992	0.7604	0.9662**

Genotypic residual effect = SQRT (1- 1.2045); Phenotypic residual effect = 0.1896; *5 per cent significance level ; ** 1per cent significance level

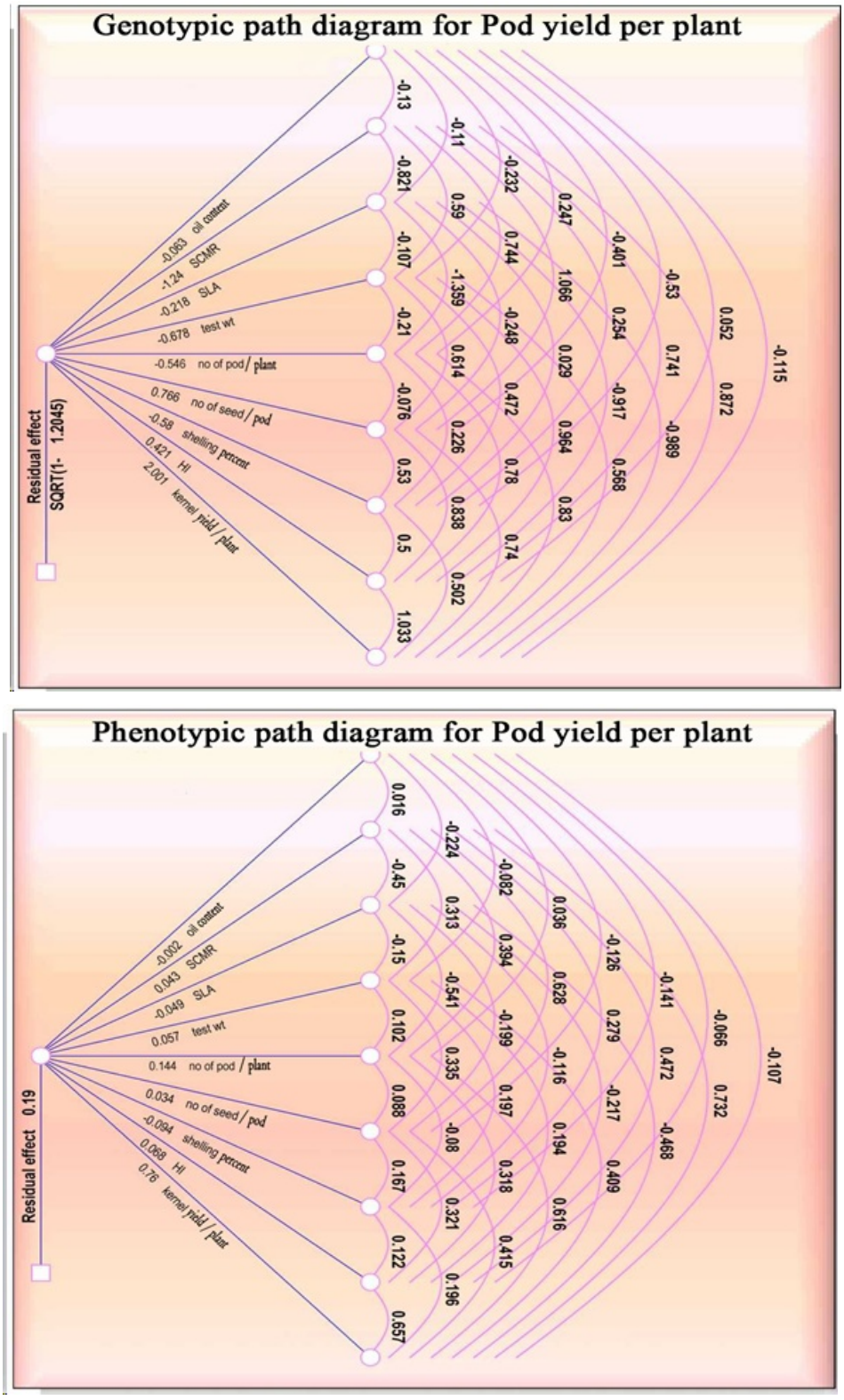

Fig. 1. Graphical representation of genotypic and phenotypic path diagram for pod yield per plant under non stress condition

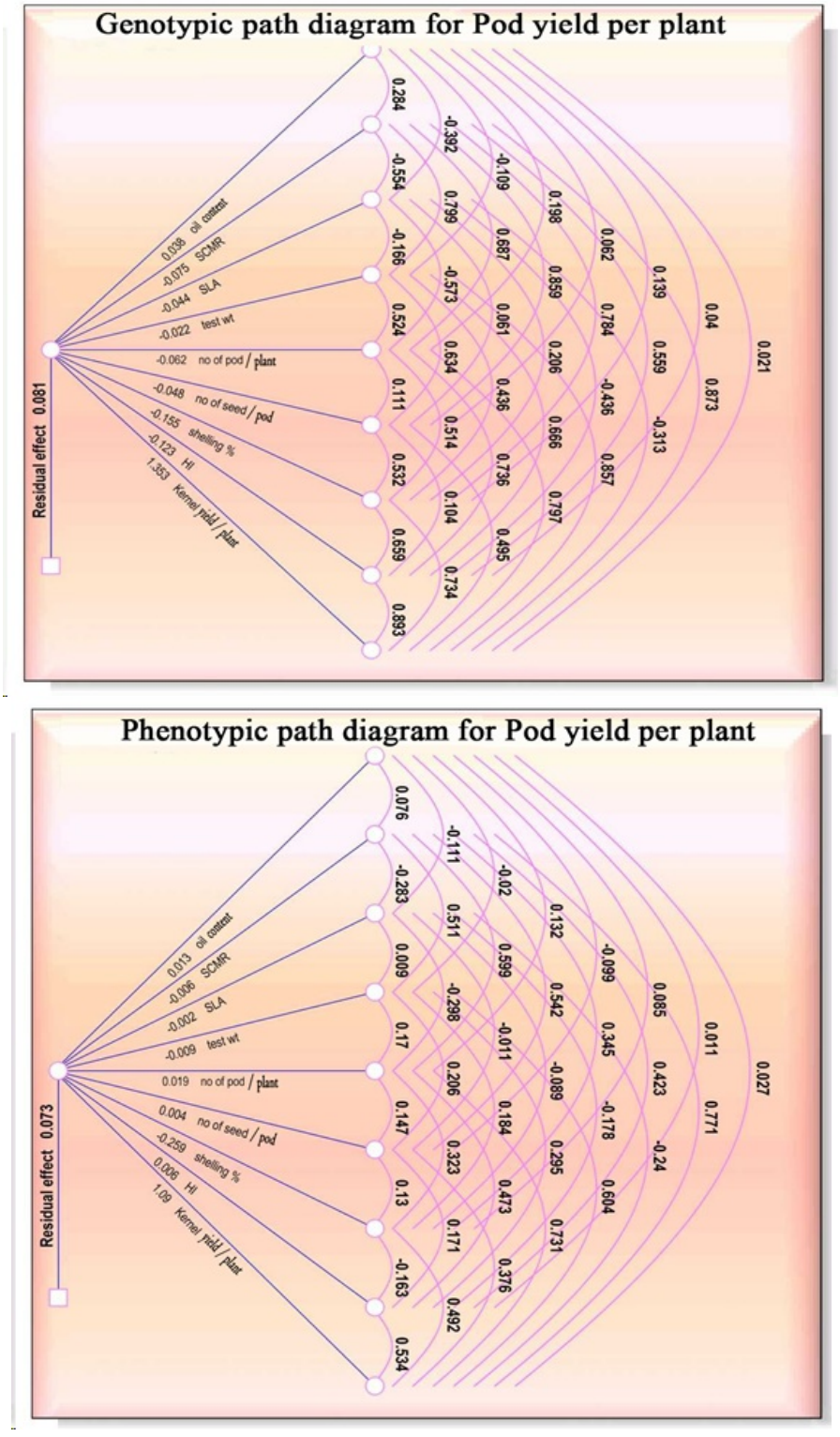

Fig. 2. Graphical representation of genotypic and phenotypic path diagram for pod yield per plant under stress condition

Table 4b Estimates of path coefficient analysis among yield, yield contributing and drought tolerance related characters in groundnut for stress condition

Characters		Oil content	SCMR	SLA	Test weight	No. of pods/ plant	No. of seeds/pod	Shelling per cent	Harvest index	Kernel yield/plant	Pod yield/ plant
Oil content	G	0.0383	0.0109	-0.0150	-0.0042	0.0076	0.0024	0.0053	0.0015	0.0008	0.0229
	P	0.0135	0.0010	-0.0015	-0.0003	0.0018	-0.0013	0.0011	0.0001	0.0004	0.0230
SCMR	G	-0.0212	-0.0746	0.0413	-0.0596	-0.0512	-0.0641	-0.0585	-0.0417	-0.0651	0.8512**
	P	-0.0005	-0.0065	0.0018	-0.0033	-0.0039	-0.0035	-0.0022	-0.0027	-0.0050	0.7576**
SLA	G	0.0171	0.0242	-0.0437	0.0073	0.0250	-0.0027	-0.0090	0.0190	0.0137	-0.3829**
	P	0.0002	0.0004	-0.0015	0.0000	0.0004	0.0000	0.0001	0.0003	0.0004	-0.2459
Test weight	G	0.0024	-0.0176	0.0037	-0.0220	-0.0115	-0.0139	-0.0096	-0.0147	-0.0189	0.8693**
	P	0.0002	-0.0044	-0.0001	-0.0085	-0.0014	-0.0018	-0.0016	-0.0025	-0.0051	0.6038**
No. of pods/plant	G	-0.0123	-0.0425	0.0354	-0.0324	-0.0618	-0.0068	-0.0318	-0.0455	-0.0493	0.8118**
	P	0.0025	0.0112	-0.0056	0.0032	0.0187	0.0028	0.0061	0.0089	0.0137	0.7314**
No. of seeds/pod	G	-0.0030	-0.0411	-0.0029	-0.0303	-0.0053	-0.0478	-0.0254	-0.0050	-0.0237	0.4422**
	P	-0.0004	0.0023	0.0000	0.0009	0.0006	0.0043	0.0006	0.0007	0.0016	0.3776**
Shelling per cent	G	-0.0214	-0.1213	-0.0318	-0.0675	-0.0794	-0.0823	-0.1546	-0.1019	-0.1135	0.6285**
	P	-0.0220	-0.0895	0.0232	-0.0478	-0.0839	-0.0337	-0.2594	0.0422	-0.1278	0.2803
Harvest index	G	-0.0049	-0.0685	0.0535	-0.0817	-0.0903	-0.0128	-0.0808	-0.1227	-0.1096	0.8982**
	P	0.0001	0.0025	-0.0010	0.0017	0.0028	0.0010	-0.0009	0.0058	0.0031	0.6349**
Kernel yield/plant	G	0.0278	1.1817	-0.4233	1.1597	1.0788	0.6703	0.9929	1.2090	1.3535	0.9879**
	P	0.0296	0.8405	-0.2611	0.6579	0.7962	0.4098	0.5365	0.5821	1.0895	0.9708**

Genotypic residual effect = 0.0812; Phenotypic residual effect = 0.0732; *5 per cent significance level; ** 1 per cent significance level

In the studied genotypes of groundnut, sufficient amount of variability was seen under both stress and non stress conditions. High GCV and PCV estimates, high heritability coupled with high genetic advance as per cent of mean was noticed for kernel yield and pod yield per plant under both conditions. Thus selection for improvement of those characters would be more effective. Moderate heritability coupled with moderate to low genetic advance as per cent of mean recorded for test weight, harvest index, oil content, number of seeds per pod, shelling per cent and SLA under stress condition indicated the presence of non additive gene action and influence of environment in the expression of these characters, and thus suggested that the selection for these traits would be less effective under both situations. Path coefficient among the characters showed highest positive direct effect of kernel yield per plant on pod yield per plant under both environments.

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Synthesis and evaluation of high oleic hybrids in relation to oil quality and seed yield in sunflower (*Helianthus annuus* L.)

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ABSTRACT

Sunflower (*Helianthus annuus* L.) is one of the most important oilseed crops of the world. Oils with high oleic content maintain oil oxidative stability and better dietary properties for customers. Such oils are known to help in reducing the cholesterol level and prevent heart diseases. In this study, 49 sunflower hybrids were synthesized using seven CMS and seven restorer lines and evaluated along with check hybrid RSFH-1, during 2015-16 at Main Agricultural Research Station, UAS, Raichur. Among parents, four CMS lines had 60-79 per cent oleic acid and four restorer parents had 66 to 85 per cent oleic acid. Out of the 49 hybrids evaluated, two hybrids, CMS-3109A x RHA-1390 (82.01%) and CMS-3114A x RHA-64NB (81.29%), exhibited higher oleic acid proportion., and these two hybrids also showed higher seed yield per plant, high oil content, high test weight and early maturity.

Keywords: Oil quality, Oleic acid, Seed yield, Sunflower

Sunflower (*Helianthus annuus* L.) an annual oilseed crop belonging to the family Asteraceae was basically developed as a premier oilseed crop in Russia and has found wide acceptance throughout Europe. Selection for high oil in Russia began in 1860 and was largely responsible for increasing oil content from 28 per cent to 50 per cent (Skoric *et al.,* 2008). In India sunflower is being grown in over an area of 0.55 million hectares with production of 0.41 million tonnes and productivity of 752 kg/ha. Presently Karnataka is the leading state in the country, contributing 63.76 per cent and 53.70 per cent of total area and production, respectively. However, productively (597 kg/ha) is relatively low compared to the national average of 752 kg/ha (Anonymous, 2016).

Sunflower oil is a premium oil because of its light colour, bland flavour, high smoke point and good nutritional quality. In Indian conditions the oil content varies from 30 to 42 per cent (Skoric *et al.,* 2008; Vairam and Gnanamalar, 2016; Reena Ravi *et al.,* 2016; Meena and Prabakaran, 2017; Neelima *et al.,* 2018). The fatty acid composition of sunflower oil is: palmitic acid (SFA): 5-8 per cent, stearic acid (SFA): 4-6 per cent, oleic acid (MUFA) omega-9 (18:1): 25-30 per cent, lenoleic acid (PUFA) omega-6 (18:2): 60-72 per cent. Thus, sunflower oil is nutritionally important owing to the proportion of oleic acid and linoleic acid content which determine the proportion of polyunsaturated fatty acid. Sunflower seeds also contain quality protein up to 14-19 per cent (Skoric *et al.,* 2008). It is grouped among prominent plant oils for human diet due to its nutritional values (Skoric *et al.,* 2008). There is genetic variation for the fatty acid composition in sunflower oil (Cumminis *et al.,* 1967; Simpson *et al.,* 1985).

High oleic acid (MUFA) sunflower is usually defined as the oil having more than 60 per cent of oleic acid (Lacombe and Bervillé, 2001; Pecureanu-Joita *et al.,* 2005). Such oil has a very neutral taste and provides very high oxidative stability without hydrogenation. High oleic sunflower oil offers oil with lower trans fatty acid. The oil has many uses including culinary purpose, bakery applications, spray coating for cereals, crackers, preparation of cosmetics, pharmaceuticals and other uses (Fick and Miller, 1989). An intake of omega 6, omega 3 and omega 9 (Oleic acid) in the ratio of 5 to 10 has been recommended by world health organization (WHO, 2003). They help in diminishing the cholesterol leading to reduction in heart diseases. Since there is a significant variability for oleic acid proportion in genotypes of sunflower, which varies from 30 to 90 per cent, it offers scope for selecting the lines with higher oleic acid content. Breeding efforts in sunflower have focused on modifying the proportions of fatty acids in the seed oil in order to increase its suitability for potential applications such as deep frying. The present investigation was carried out to evaluate parents and their derived crosses with a view to identify best parents and hybrids for high oleic acid content, higher seed yield and oil content.

MATERIALS AND METHODS

This research work was carried out during 2015-16 at Main Agricultural Research Station at University of Agricultural Science, Raichur, Karnataka to evaluate parents and crosses with a view to identify best parents and hybrids for higher seed yield, high oleic acid content and high oil content. The materials for the study comprised of 64

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genotypes, which included seven CMS lines, seven restorer lines, 49 F_1s and one check hybrid obtained from Head, AICRP on Sunflower, Main Agricultural Research Station, Raichur and Head, AICRP on Sunflower, UAS, GKVK, Bengaluru.

Seven CMS lines *viz.,* CMS-3109A, CMS-3114A, CMS-3137A, CMS-103A, CMS-400A, CMS-852A, CMS-1511A and seven restorer lines *viz.,* RHA-349, RHA-64NB, RHA-1072, RHA-1390, RHA-1393, RHA-3000 and RHA-3003, were crossed in all possible combinations to obtain 49 hybrids. Parents and hybrids were evaluated along with check (RSFH-1) in lattice design with two replications and a plot size of 3 m x 1.2 m (two rows of three meter length). Observations were recorded on 11 traits *viz.,* days to flowering, days to 50% flowering, days to maturity, number of leaves per plant, plant height, head diameter, test weight, stem girth, yield per plant, oil content and leaf size. The oleic acid estimation was carried out using gas chromatography (Lacombe and Bervillé, 2001; Pecureanu-Joita *et al.,* 2005). Statistical analysis was done to work out mean *per se* performance of all parental lines and hybrids.

RESULTS AND DISCUSSION

The analysis of variance revealed significant differences among genotypes for all the characters studied (Table 1). The results of mean per se performance of parents and crosses for 11 different characters studies are presented in Table 2. The mean *per se* performance of seven CMS lines revealed that four lines *viz.,* CMS-103A (79%), SMC-311A (74%), CMS-3109A (63%) and CMS-1511A (60%) showed higher oleic acid content. Among these lines, CMS-103A was found to be significantly superior for other morphological traits such as oil content (39%), yield per plant (31 g), test weight (5 g), head diameter (25 cm), leaf size (32 cm), stem girth (3 cm) and days to 50% flowering. Among seven restorer lines, four lines exhibited higher oleic acid proportion ranging from 66 to 85%. The highest oleic acid content was observed in RHA-1390 (85%) followed by RHA-3003 (78%) and it was also significantly superior for the traits *viz.,* oil content (40%), test weight (5 g), stem girth (3 cm) and number of leaves (33).

The mean per se performance of 49 hybrids revealed that, oleic acid content varied from 20 to 82%, oil content varied from 27 to 41%, seed yield per plant varied from 11 to 45 g, test weight ranged from 3 to 7 g, head diameter varied from 12 to 24 cm, stem girth (1 to 3 cm), plant height varied from 91 to 165 cm, number of leaves varied from 25 to 37, leaf size varied from 16 to 35 cm, days to 50% flowering varied from 53 to 69 days and days to maturity varied from 85 to 106 days.

Three hybrids *viz.,* CMS-3109A x RHA-1390, CMS-311A x RHA-64NB and CMS-103A x RHA-64NB exhibited higher oleic acid content of 82, 81 and 78 per cent, respectively. Influence of environment on fatty acid accumulation is well documented. During seed development, high temperature favoured accumulation of oleic acid (Kinman and Earie, 1964). In the present study few CMS lines and restorer lines and derived crosses recorded higher oleic acid (60-82%). Genetic control of oleic acid in sunflower has been reported earlier (Urie, 1985; Miller *et al.,* 1987; Fernandez Martunez *et al.,* 1989), and their results have indicated involvement of one or more major, dominant OL genes and also modifier genes in the inheritance of this trait.

Apart from high oleic acid proportion of 82.0 per cent, the hybrid CMS-3109 x RHA-1390 showed significant superiority for seed yield per plant (42 g), high oil content (39 %), high test weight (4.0 %), larger head size (16 cm) and medium duration (89 days) followed by the cross CMS-3114A x RHA-64NB with high oleic acid of 81%, significant seed yield per plant (45 g), thicker stem girth (3 cm) and medium maturity of 95 days compared to check hybrid RSFH-1.

In all the experimental hybrids tried, the late maturing ones exhibited more oil content of more than 37 per cent and these results are in agreement with pervious findings (Dubbelde, 1989; El Hinnaway *et al.,* 1981). Ahmad and Abdin (1999) also reported significant difference in oil content among hybrids. Ceccarini *et al.* (2004) recorded non significant differences in oil concentration of two hybrids which might be explained by environmental factors and or owing to genetic similarity of the hybrids in their studies. High oleic hybrids are reported to have positive association with seed yield, earliness and harvest index (Franandez-Hartineg *et al.,* 1993).

Table 1. Analysis of variance for different characters in sunflower

Source of variation	Df	Days to 50 % flowering	Days to maturity	No. of leaves	Plant height (cm)	Head diameter (cm)	Test weight (g)	Stem girth (cm)	Oil content (%)	Leaf size (cm)	Yield per plant (g)
Replications	1	53.82	105.12	99.75	835.19	40.61	1.64	0.98	24.68	48.56	143.10
Treatments	63	21.69**	57.19**	27.95**	13633.13**	13.55**	0.915**	0.42**	14.10**	38.33**	81.99**
Error	63	0.40	1.10	0.17	66.72	0.67	0.17	0.009	0.30	0.12	4.60

** Significance at P=0.01 level

Table 2 Mean *per se* performance of CMS, restores lines and crosses for different characters in sunflower

Parents/crosses	Days to 50% flowering	Days to maturity	No. of leaves per plant	Plant height (cm)	Head diameter (cm)	Test weight (g)	Stem girth (cm)	Oil content (%)	Oleic acid (%)	Leaf size (cm)	Seed yield per plant (g)
CMS lines											
CMS-3109A	57**	97	34**	160	17	3	2	33	63	25	30**
CMS-3114A	61	102	35**	147**	17	3	2	33	74	23	29*
CMS-3137A	57**	97	33**	136**	19**	4	1	40 **	35	26	32**
CMS-103A	59**	97	29	170	25**	4**	2**	37**	79	33**	31**
CMS-400A	61	99	27	128**	15	3	1	37	20	27*	24
CMS-852A	60*	102	33**	154**	15	4	1	34	25	23	21
CMS-1511A	66	102	23	142**	19	4	1	36	60	21	25
Range	57-66	97-102	23-35	128-170	15-25	3-4	1-2	33-40	20-79	21-33	21-32
Restorer lines											
RHA-349	55**	91**	35**	167	15	3	3**	34	47	19	15
RHA-64NB	66	100	23	140**	16	3	2*	35	26	27	22
RHA-1072	57**	95**	37**	128**	13	3	2	37	41	26	25
RHA-1390	60*	97	35**	160	16	3	2	36	85	27*	23
RHA-1393	65	102	27	125**	15	4	1	35	66	16	18
RHA-3000	57**	98	33**	150**	18	3	2**	35	68	30*	25
RHA-3003	63	99	33**	164	17	4**	2**	39**	77	23	25
Range	55-66	91-102	23-37	125-167	13-18	3-4	1-3	34-39	26-85	16-30	15-25
Crosses											
CMS-3109A x RHA-349	60*	90**	35**	137**	16	4	2	31	43	22.75	12.95
CMS-3109A x RHA-64NB	60*	85**	27	157	17	5**	3	30	39	34.75**	31.46**
CMS-3109A x RHA-1072	57**	86**	26	158	15	4	3**	36	51	30.00**	22.07
CMS-3109A x RHA-1390	61	89**	25	158	17	4	2	39**	82	17.35	42.05**
CMS-3109A x RHA-1393	59*	90**	25	160	19	4	2	35	67	17.15	31.50
CMS-3109A x RHA-3000	58**	91*	26	153**	15	5**	1	38**	32	15.75	27.36
CMS-3109A x RHA-3003	57**	87*	26	160	16	4	3**	37	32	26.75	23.97
CMS-3114A x RHA-349	59**	92**	37**	138**	13	4	2	36	31	27.35	18.72
CMS-3114A x RHA-64NB	60*	95**	29	156	18	4	3**	27	82	23.00	45.43**
CMS-3114A x RHA-1072	55**	88**	28	131**	17	5**	2	39*	29	31.55	13.20
CMS-3114A x RHA-1390	69	89*	35**	165	17	4	3**	30	65	23.00	33.60
CMS-3114A x RHA-1393	58**	97	28	145**	17	4	2	37	53	26.50	29.70*
CMS-3114A x RHA-3000	56**	89**	32**	108**	17	7**	2	39*	29	21.00	27.00
CMS-3114A x RHA-3003	60*	94**	32**	139**	14	4	2	37	61	24.05	39.05**
CMS-3137A x RHA-349	65	89**	31*	105**	15	5*	2	37	55	19.50	22.95
CMS-3137A x RHA-64NB	60*	92**	27	118**	12	4	2	39**	33	27.25*	33.65*
CMS-3137A x RHA-1072	61	92**	29	140**	13	4	2	40**	27	30.90**	18.70
CMS-3137A x RHA-1390	63	96**	27	110**	14	4	2	35	31	27.75*	26.37
CMS-3137A x RHA-1393	66	95**	27	98**	13	3	2	39**	30	23.00	16.00
CMS-3137A 3 x RHA-3000	62	92**	29	120**	15	4	2	36	51	27.25*	28.20
CMS-3137A RHA-3003	61	99	27	108*	15	3	2	38**	31	28.00**	40.97**
CMS-103A x RHA-349	55**	88**	32**	112**	20**	4	3	32	24	28.15**	37.56**
CMS-103A x RHA-64NB	57**	95**	35**	146**	24**	4	3 **	38**	77	24.00	35.65**
CMS-103A x RHA-1072	53**	85**	28	120**	23**	5**	3	35	32	32.50**	25.85
CMS-103A x RHA-1390	56**	88**	29	100**	14	4	1	33	39	22.25	37.65**
CMS-103A x RHA-1393	55**	90**	33**	133**	16	5**	3**	35	42	26.75	24.90
CMS-103A x RHA-3000	60*	92**	35**	125**	17	4**	2	34	61	24.75	22.85
CMS-103A x RHA-3003	58**	94**	29	121**	18	4	3**	37	36	23.25	17.13
CMS-400A x RHA-349	60*	92**	34**	117**	14	5**	2.	39**	30	22.25	13.47
CMS-400A x RHA-64NB	63	102	27	108**	20**	5**	4**	34	31	29.00**	17.15
CMS-400A 5 x RHA-1072	61	102	26	91**	16	3	2	37	28	22.50	14.67
CMS-400A x RHA-1390	60*	104	25	98**	15	4	2	37*	26	23.00	16.31
CMS-400A x RHA-1393	59**	106	29	113**	17	4	3*	38**	28	32.25**	29.01*
CMS-400A x RHA-3000	56**	86**	29	120**	17	3	3*	37	23	29.25**	27.90
CMS-400A x RHA-3003	58**	88**	33**	128**	19	4	2	33	32	28.75**	17.25
CMS-852A x RHA-349	63	88**	34**	125**	17	4	2	40**	20	22.25	32.55**
CMS-852A x RHA-64NB	58**	88**	31*	137**	19*	5**	3**	37*	23	17.25	24.36
CMS-852A x RHA-1072	59**	91**	32*	128	18	5**	2	35	32	24.25	12.15
CMS-852A x RHA-1390	55**	84**	29	124**	21**	4	3**	38*	26	19.25	19.06
CMS-852A 6 x RHA-1393	55**	89**	33**	122**	18	4	3*	34	37	25.75	15.76
CMS-852A x RHA-3000	56**	92**	35**	122**	18	4	2	36	40	28.25**	26.20
CMS-852A x RHA-3003	59**	96**	29	145**	17	5**	3*	37	41	27.75**	19.65
CMS-1511A x RHA-349	58**	92**	35**	158	22**	4	3**	39**	37	20.00	10.69
CMS-1511A x RHA-64NB	61	96**	33**	145**	19	5**	2*	35	47	25.25	25.02
CMS-1511A x RHA-1072	55**	90**	37**	128**	20	4	2	36	33	31.00**	22.77
CMS-1511A x RHA-1390	59**	93**	33**	109**	17	5**	1	35	41	17.25	16.05
CMS-1511A x RHA-1393	55**	92**	29	114**	18	6**	2	36	49	22.75	23.99
CMS-1511A x RHA-3000	55**	87**	35**	120**	19*	4	2	41**	44	24.50	22.97
CMS-1511A x RHA-3003	60*	99	35**	140**	15	4	3*	34	50	25.75	15.70
Range	53-69	85-106	25-37	91-165	12-24	3-7	1-4	27-41	20-82	15.75-34.75	10.69-45.43
Check RSFH-1	58**	101	28	170	20**	5**	3.3**	37.8**	78.6	25.50	39.55
General mean	60	94	31	133	17	4	2.3	36.0	44.2	25.02	24.39
CD@ 5%	1	2	0.8	16	2	0.3	0.2	1.1	------	2.11	4.31
CD@ 1%	2	3	1	22	2	0.3	0.3	1.5	------	2.81	5.75
CV(%)	1	1	1	6	5	3.1	4.2	1.5	------	4.23	8.80

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

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Identification of superior sunflower (*Helianthus annuus* L.) hybrids suitable for *rabi*-summer season in West Bengal

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ABSTRACT

An experiment was carried out during *rabi*-summer season of 2012-13 and 2013-14 to identify superior sunflower hybrids suitable for *rabi*-summer season in West Bengal. A total of 32 sunflower hybrids were evaluated in randomized complete block design with three replications at AICRP on Sunflower, Nimpith centre; Baruipur farm, Calcutta University and Radhakantapur (Nimpith Centre-adopted Village) as multilocation trial. In this study, highly significant genetic differences were observed among the sunflower hybrids in respect to the plant height at harvest, head diameter, seed weight per head, 100-seed weight, days to 50% flowering, days to maturity, husk content (%), volume weight (g/100cc), oil percentage and oil yield (kg/ha). The field observation reveals that, the hybrids developed from Nimpith Centre *viz.,* CMS-607 A x R 273, CMS-607A x RHA-95C-1, CMS-607 A x R-83 and 207 A x R-83 significantly out yielded the best check KBSH-44 (668 kg oil/ha) in respect to oil yield (kg/ha) by recording oil yield of 836 kg/ha, 817 kg/ha, 810 kg/ha and 794 kg/ha, respectively. The hybrids, RSFH-1887 (796 kg oil/ha) and SMLHT KH-12-04 (796 kg oil/ha), SMLHT KH-12-03 (784 kg oil/ha) and LSFH-171 (719 kg oil/ha) recorded significantly high oil yield (kg/ha) than check hybrids KBSH-44 (668 kg oil/ha) and DRSH-1 (696 kg oil/ha). Considering the other yield attributing parameters like plant height and days to maturity; the sunflower hybrids, CMS-207A x R-83, CMS-607 A x R 273, CMS-607A x R-83, SMLHT-KH-12-03, SMLHT-KH-12-04, were the superior sunflower hybrids developed or identified by the Nimpith centre on basis of their performance in multilocation trial (MLT) and Station Hybrid Trial. The seed yield of the above said sunflower hybrids were recorded at par with the KBSH-44 but significantly higher oil yield (kg/ha) coupled with 7-10 days earliness and 30-50 cm shorter plant height at harvest as compared to other sunflower hybrids.

Keywords: Multilocation Testing, Sunflower Hybrid, Seed yield, West Bengal

Edible oil is the basic requirement of the human body because it is very important for the escalation and improvement of body. There is need to focus on conventional as well as non-conventional oilseed crops to fill the gap between consumption and production. Sunflower is non-conventional crop introduced in our country (Reena Rai *et al.,* 2016). India is facing a shortage of edible oil in recent years. Sunflower has maximum potential for bridging the gap in the demand and production of edible oil in the country. Its seeds contain high oil content ranging from 35 to 40 per cent with some types yielding up to 50 per cent (Skoric and Marinkovic, 1986). Sunflower is the second important source of vegetable oil in the world. Due to its low to moderate production requirements, high oil quality, protein content, and utilization of all plant parts (Vanitha *et al.,* 2017; Meena *et al.,* 2017; Vairam and Gnanmalar, 2016). In India, sunflower is cultivated in an area of 0.7 million ha with a total productivity of 0.50 million tonnes (Padmaiah *et al.,* 2015) and with an average productivity of 713 kg/ha (Anonymous, 2016). In West Bengal, it is grown in an area of 12,500 ha during *rabi* season.

Most of the sunflower seed is imported in the country that is actually not bred for our environment. That's why it gives low yield due to the adaptation problem (Kokhar *et al.,* 2006; Meena and Prabakaran, 2017). In West Bengal, sunflower is second important oilseed crop after rapeseed-mustard during *rabi*-summer season. Due to short winter spell and delayed and heavy rainfall during rainy season, the sowing of mustard was delayed which ultimate reduced the production of rapeseed-mustard. The delayed sowing also invites the insect pests in most of the years. Sunflower being a photoperiod natural crop has wide scope to replace the rapeseed-mustard cultivation with high yield potentiality. Present research programme was carried out during December 2012-13 to 2014-15 with a total of 32 sunflower hybrids including the two national check hybrids, KBSH-44 and DRSH-1. Though oil yield is influenced by many plant traits like days to 50% flowering, plant height, 100-seed weight, volume weight (seed weight in gram per 100 ml) and oil content(%), the present study was aimed to identify the superior sunflower hybrids suitable for *rabi*-summer season in West Bengal agro-climatic condition.

MATERIALS AND METHODS

The experiment was carried out during *rabi*-summer season, 2013-14 and 2014-15 at research farm under AICRP (Sunflower), Nimpith Centre to identify the suitable

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sunflower hybrids for cultivation in *rabi*-summer season for West Bengal. A total of 32 sunflower hybrids developed at AICRP (Sunflower), Nimpith centre and collected from AICRP (Sunflower), UAS, GKVK, Bangalore; AICRP-Sunflower, UAS Raichur and AICRP (Sunflower), Latur, Maharashtra were evaluated along with national check hybrids, KBSH-44 and DRSH-1 in randomized complete block design with three replications. The plot size was 4.5 m x 3.0 m. In the 1st year (2012-13), a total of 32 sunflower hybrids were tested in RAKVK-AICRP (Sunflower) research farm, Nimpith Centre, West Bengal. In the next year, 2013-14 the same hybrids were tested along with national checks, KBSH-44 and DRSH-1 in on-station trial at Nimpith centre and another three locations *viz*., at Research Farm, Institute of Agriculture Sciences, Calcutta University, Baruipur and Radhakantapur (AICRP-adopted Village) as multilocation trial. The soil texture was clay loam in on-station and MLT plots. Three irrigations were provided during the cropping period. One foliar spray was given with boron @ 2g/l of water in ray floret stage. The row per plot were five in number with a row spacing of 60 cm and plant to plant was 30 cm. Uniform dose of fertilizer @80 kg N,40 Kg P_2O_5 and 40 kg K_2O per ha was applied. The germinated seed of sunflower used as the planting materials and one per hill were maintained throughout the cropping period. The data was recorded in ten randomly selected plants from each plot of all replications on the following characters *viz.,* days to 50% flowering, days to maturity, plant height at harvest (cm), head diameter per plant (cm), seed weight per head (g), 100-seed weight (g), husk content (%) and volume weight (g/cc). The seed yield (kg/ha), oil percentage and oil yield (kg/ha) were estimated on plot basis. The mean values were subjected to statistical analysis.

RESULTS AND DISCUSSION

Yield and yield component: The data for seed yield and other yield attributing traits for the test hybrids along with the checks are presented in Table 2. Highly significant differences were observed for seed yield and other yield attributing traits among the test hybrids. Statistical analysis of the data on seed yield (kg/ha) in MLT and in on-station and station hybrid trial (average data from MLT & SHT over locations in Table 3) reveals that the highest seed yield of (2232 kg/ha) was recorded in the experimental sunflower hybrid CMS-607 A x RHA-95C-1 which was closely followed by sunflower hybrid CMS-607 A x R-273 and hybrid CMS-607 A x AK-345 with seed yield 2196 kg/ha and 2061 kg/ha respectively which was closely followed by other public (AICRP) sunflower hybrids LSFH-171 with seed yield 2158 kg/ha and RSFH-1887 and KBSH-53 with seed yield of 2114 kg/ha and 2127 kg/ha, respectively. The best national check hybrid, KBSH-44 was recorded at par seed yield (2221 kg/ha) and less yield was recorded 1758 kg/ha in DRSH-1. The other sunflower hybrids like SMLHT-KH-04 and SMLHT-KH-03 also recorded the higher seed yield in comparison to DRSH-1 (1758 kg/ha) with seed yield 2033 kg/ha and 2016 kg/ha, respectively. The best national check hybrid i.e. KBSH-44 was recorded at par seed yield (2221 kg/ha) and less yield was recorded 1758 kg/ha in DRSH-1. The other sunflower hybrids like SMLHT-KH-04 and SMLHT-KH-03 also recorded the higher seed yield in comparison to DRSH-1 (1758 kg seed yield/ha) with seed yield 2033 kg/ha and 2016 kg/ha respectively. The maximum oil (%) was recorded in the experimental hybrids like CMS-607 A x R-83 (40.1) and CMS-207 A x R-83 against the national check hybrid, DRSH-1 with 40 per cent oil. In both the hybrids were high volume weight recorded (39-40g/100cc). The findings were supported by Vidhyavathi *et al.* (2005) and Manivannan *et al*. (2005).

Multilocation trial: From the experiment and statistical analysis of the data on oil yield (kg/ha) in on-station trial and MLT (average data from MLT over locations in Table 2 and 3) reveals that highest oil yield of 836 kg/ha was recorded in the sunflower hybrid CMS-607 A x R- 273. From the experiment reveals that in response to oil yield (kg/ha), the newly developed sunflower hybrids were significantly high oil yielder over the national check hybrids, KBSH-44 and DRSH-1. The field observation reveals that, among the 32 sunflower hybrids under study, the sunflower hybrids developed by the AICRP (Sunflower), Nimpith Centre *viz.,* CMS-607 A x R 273, CMS-607A x RHA-95C-1,CMS-607 A x R-83 and 207 A x R-83 significantly out yielded the best national check sunflower hybrid, KBSH-44 (668 kg oil /ha) in respect to oil yield (kg/ha) by recording oil yield of 836 kg oil/ha, 817 kg oil/ha, 810 kg oil/ha and 794 kg oil/ha, respectively. From the study it was also observed that, the other sunflower hybrids like, RSFH-1887(796kg oil/ha) and SMLHT KH-12-04 (796 kg oil/ha), SMLHT KH-12-03 (784 kg oil/ha) and LSFH-171 (719 kg oil/ha) also recorded significantly high oil yield (kg/ha) than check hybrids, KBSH-44 (668 kg oil/ha) and DRSH-1 (696 kg oil /ha). The similar type findings was reported by Chandra *et al.* (2013).

The Nimpith centre developed sunflower hybrids CMS-207A x R-83, CMS-607A x R-83, CMS-607 A x R 273 as well as other AICRP centres sunflower hybrids like SMLHT-KH-12-03, SMLHT-KH-12-04, LSFH-171 and RSFH-1887 were the superior sunflower hybrids identified by the Nimpith centre on basis of their performances in multilocation trial and Station Hybrid Trial(SHT). From the study it was observed that the sunflower hybrids, CMS-207A x R-83, CMS-607A x R-83, CMS-607A x R 273, SMLHT-KH-12-03, SMLHT-KH-12-04 were at par with the best check hybrids (KBSH-44 and DRSH-1) in respect to seed yield (kg/ha) but significantly high oil yielder coupled with semi-tall in nature and matured 7-10 days earlier than

the best national check hybrids. The semi tallness and earliness (coupled with good seed yield and high oil percentage) were the main two reasons for their selection by local sunflower farmers surrounding the Nimpith region when the hybrids were evaluated in the farmer's plot.

Such type of good cross combinations for yield attributing traits in sunflower was reported by Gourishankar *et al.* (2007), Parmeshwarappa *et al.* (2008), Binodh *et al.* (2008), Mohanasundaram *et al.* (2010), Karasu *et al.* (2010), Chandra *et al.* (2013), Nandini (2013), Tyagi *et al.* (2013) and Supriya *et al.* (2016). The sunflower hybrids *viz.,* CMS-207A x R-83, CMS-607A x R 273, CMS-607A x R-83, SMLHT-KH-12-03 and SMLHT-KH-12-04 were the superior sunflower hybrids developed or identified by the Nimpith centre on basis of their performance in multilocation trial (MLT) and station hybrid trial. The seed yield of the above said sunflower hybrids were recorded at par with the KBSH-44 but significantly higher oil yield (kg/ha) coupled with 7-10 days earliness and 30-50 cm shorter plant height at harvest, therefore these sunflower hybrids are recommended to be promoted in state multilocaion trial to evaluate the performance and stability of seed yield, oil yield and other yield attributing traits.

Table 1 Performance of sunflower hybrids in station hybrid trial : AICRP (Sunflower), Nimpith (*rabi*-summer 2013-14)

Hybrid	Pl. Ht. (cm)	Head Dia.(cm)	Days to 50% Flowering	Days to Maturity	Seed yield/pl (g)	Vol. Wt. (g/100 cc)	Grain Filling %	Seed yield (kg/ha)	100 seed wt (g)	Hull cont. (%)	Oil %	Oil Yield (Kg/ha)
SMLHT –KH-12-01	103.5	13.0	57.0	87.0	29.2	45.5	91.0	1619	6.4	35.8	38.5	623
SMLHT –KH-12-02	136.8	12.1	60.5	90.5	25.4	43.1	96.5	1411	5.6	37.8	37.4	527
SMLHT –KH-12-03	102.0	13.9	64.5	94.5	38.6	42.1	94.5	2142	4.6	34.4	39.4	843
SMLHT –KH-12-04	95.6	14.6	63.0	93.0	37.8	41.0	96.5	2100	5.2	33.5	41.2	865
SMLHT –KH-12-05	135.0	12.0	66.0	96.0	19.3	38.9	91.0	1069	3.9	34.7	40.5	432
KBSH-1	134.4	13.9	67.0	97.0	31.7	45.0	95.0	1761	5.2	37.5	38.9	685
KBSH-41	141.5	14.3	67.5	97.5	37.1	44.9	92.0	2061	5.1	33.7	40.8	840
KBSH-42	123.7	12.6	68.5	97.5	32.4	42.7	92.5	1800	4.7	46.0	39.5	621
KBSH-44	166.0	15.2	69.5	100.5	40.9	37.8	91.0	2272	5.6	37.1	31.2	708
KBSH-55	156.7	13.8	70.0	100.5	38.3	43.9	90.0	2128	4.2	32.4	41.7	887
KBSH-53	135.5	11.9	62.5	92.5	27.2	42.2	86.5	1508	5.6	30.8	42.6	642
KBSH-58	91.4	9.4	59.5	90.0	21.1	38.1	93.0	1172	7.0	30.3	42.4	496
KBSH-65	113.8	11.4	68.0	97.0	32.1	43.6	93.5	1783	4.0	36.7	39.2	698
KBSH-68	109.3	14.6	66.0	96.0	40.6	43.8	92.0	2253	5.8	35.5	39.5	889
KBSH-69	88.9	13.5	63.5	93.5	31.6	48.0	87.0	1756	5.2	36.9	38.6	677
KBSH-70	79.9	10.1	57.5	87.5	26.1	40.5	94.5	1447	4.2	32.2	41.3	597
RSFH-1	132.9	12.1	68.0	98.0	30.6	47.9	90.5	1697	4.5	34.7	42.5	721
RSFH-130	125.8	12.7	65.0	94.5	34.0	43.1	92.5	1886	5.5	32.6	41.6	784
RSFH-10-600	154.6	14.1	69.5	99.5	40.1	45.7	96.5	2228	4.8	39.8	37.1	826
RSFH-1887	135.4	15.5	70.5	100.5	40.7	43.6	96.5	2261	5.6	34.5	40.5	915
LSFH-35	116.9	13.5	62.0	92.0	33.1	41.7	93.0	1836	5.6	33.3	41.5	761
CMS-207A X R-103	157.5	14.6	71.0	102.0	34.6	35.2	87.5	1922	4.8	38.8	39.8	765
CMS-207A X R-83	131.0	15.3	61.5	91.5	36.4	39.0	91.0	2022	4.5	35.0	39.1	790
CMS207A X R-106	154.4	15.4	71.0	102.0	33.3	31.5	93.5	1850	4.4	40.0	38.5	712
CMS-607 A X AK-345	154.2	16.5	72.5	103.0	36.2	36.4	85.5	2011	6.5	37.3	38.2	768
CMS-607A X R-83	123.0	15.7	63.5	93.5	38.1	39.5	90.0	2117	5.6	33.6	41.3	874
CMS207A XR-35	124.2	15.8	60.5	91.5	32.8	39.0	93.5	1822	1.6	38.2	39.6	721
CMS-607A XR273	138.0	14.9	63.0	94.0	36.9	39.8	95.5	2050	3.9	36.6	40.4	828
CMS-RR-1A X DOR-R-2	163.5	16.5	69.0	100.0	37.3	36.5	81.0	2072	6.4	40.1	37.5	777
CMS607A X RHA-95C-1	152.9	16.1	69.0	100.0	39.4	42.0	90.0	2189	4.5	36.7	38.6	844
DRSH-1	158.8	14.0	67.0	97.0	30.8	46.8	91.5	1708	5.5	34.1	40.8	696
LSFH-171	110.6	15.0	64.5	94.5	38.3	43.5	93.5	2128	6.4	36.1	38.2	812
KBSH-44	166.0	15.2	69.5	100.5	40.9	37.8	91.0	2272	5.6	37.1	31.2	708
SEm (±)	2.9	0.43	0.82	0.9	0.9	0.6	0.6	47	0.27	1.2	0.9	15.1
LSD (p=0.05)	8.6	1.29	2.5	2.9	2.8	1.8	1.7	142	0.82	3.8	2.7	46.2
CV (%)	10.7	9.6	7.8	9.4	10.3	8.3	8.1	10.35	11.4	10.5	9.4	11.5

Table 2 Performance of sunflower hybrids in multilocation trials (*rabi*-summer 2014-15)

Hybrid	Location 1 (Nimpith)										Location 2 (Average performance of the hybrids at CU Research Farm, Baruipur and Radhakantapur)									
	Pl. Ht. (cm)	Head Dia. (cm)	Days To Maturity	Seed yield/ pl(g)	Vol. Wt (g/ 100cc)	Grain Filling %	Seed Yield (kg/ha)	100 seed wt (g)	Hull cont.%	Oil %	Pl. Ht. (cm)	Head Dia. (cm)	Days To Maturity	Seed yield/pl(g)	Vol. Wt g/100cc	Grain Filling %	Seed Yield (kg/ha)	100 seed wt (g)	Hull cont.%	Oil%
SMLHT –KH-12-01	104.7	12.1	86	29.6	44.3	96	1644	6.27	36.7	39.6	102.3	13.8	88	28.7	46.7	86	1594	6.49	34.9	37.4
SMLHT –KH-12-02	128.5	12.2	90	24.6	42.5	98	1366	5.49	37.0	38.2	145.0	11.9	91	26.2	43.7	95	1455	5.61	38.6	36.6
SMLHT-KH-12-03	92.7	12.8	93	38.2	40.5	95	2122	4.50	33.2	39.1	97.3	12.2	92	38.9	43.6	94	1910	4.77	35.6	38.7
SMLHT-KH-12-04	92.7	11.4	94	37.9	41.1	98	2105	4.78	32.0	39.2	98.5	10.9	92	38.5	40.9	95	1960	4.95	34.9	39.2
SMLHT-12-05	132.6	11.7	95	17.9	38.4	91	994	3.80	33.6	38.2	137.4	12.3	97	20.6	39.3	91	1144	3.95	35.9	37.6
KBSH-1	130.6	11.7	98	35.9	43.7	91	1820	4.68	36.1	39.7	134.4	12.3	97	31.7	45.0	95	1761	5.19	38.5	38.1
KBSH-41	138.7	12.32	97	35.5	45.2	92	1732	4.88	32.8	38.2	144.3	14.6	98	36.7	44.5	92	1872	5.37	34.5	37.5
KBSH-42	125.6	13.3	97	26.0	42.2	92	1474	4.62	39.6	30.2	121.8	13.8	98	23.8	43.2	93	1417	4.83	37.5	38.7
KBSH-44	155.5	13.3	101	40.2	37.4	91	2230	5.46	30.2	30.2	150.4	14.6	100	41.6	38.2	91	2211	5.72	38.1	30.0
KBSH-53	132.4	12.6	100	37.7	43.5	90	2094	4.30	31.5	36.5	141.0	12.6	101	38.9	44.3	90	2160	4.16	33.4	36.9
KBSH-55	139.7	12.0	92	26.2	42.6	85	1455	5.48	29.6	34.6	131.3	11.8	93	28.1	41.8	88	1561	5.66	31.9	37.2
KBSH-58	89.7	9.2	90	21.5	37.8	93	1194	7.18	30.9	30.9	93.1	9.6	90	20.7	38.3	93	1149	6.89	29.7	37.5
KBSH-65	102.3	11.0	97	31.6	43.4	93	1755	4.09	35.6	35.6	125.3	11.8	97	32.6	43.8	94	1811	3.95	37.7	37.9
KBSH-68	115.3	13.5	95	41.0	44.3	92	1860	5.75	34.8	34.8	103.2	13.7	97	40.1	43.2	92	1920	5.88	36.1	37.3
KBSH-69	87.9	11.4	94	31.6	48.3	86	1755	5.15	36.9	37.5	89.8	11.6	93	31.6	47.6	88	1755	5.21	35.2	38.7
KBSH-70	80.8	9.8	88	25.8	39.7	94	1433	4.18	31.8	38.1	78.9	10.4	87	26.3	41.2	95	1461	4.31	32.5	38.0
RSFH-1	135.2	11.9	98	30.5	47.5	90	1694	4.51	33.5	38.6	130.6	12.3	98	30.6	48.2	91	1699	4.68	35.9	38.1
RSFH-130	119.1	12.8	93	33.6	42.7	92	1866	5.58	33.4	38.5	132.5	12.6	96	34.3	43.5	93	1905	5.36	31.8	38.5
RSFH-10-600	156.6	13.8	97	41.1	40.4	98	1980	4.78	38.1	37.5	152.6	14.4	98	39.1	40.9	95	1932	4.85	38.0	37.0
RSFH-1887	132.2	13.2	100	41.1	40.8	95	2020	5.72	33.0	38.6	138.6	13.8	101	40.3	40.4	98	2208	5.49	37.0	37.0
DRSH-1	156.6	13.8	96	30.1	40.3	91	1772	5.45	32.7	40.0	161.0	14.1	98	31.4	41.2	92	1744	5.52	35.6	39.6
LSFH-35	111.9	10.8	92	32.5	37.8	93	1980	5.75	31.8	37.5	121.8	12.2	92	33.6	37.9	93	1866	5.41	34.8	34.8
LSFH-171	113.3	12.5	94	37.3	36.2	93	2220	6.56	34.5	32.5	107.8	12.2	95	39.2	36.9	94	2180	6.29	37.7	32.7
CMS-207A X R-83	131.0	15.3	91	35.6	38.7	92	1977	4.72	36.5	40.0	136	15.3	92	37.2	39.2	90	2066	4.25	33.5	38.5
CMS-207A X R-103	155	14.8	102	35.7	34.6	87	1983	4.41	39.5	38.1	160	14.4	102	33.5	35.7	88	1861	5.22	38.1	38.1
CMS207A X R-106	158.6	15.6	102	32.8	31.7	91	1822	4.40	38.4	37.2	150.2	15.1	102	33.8	34.2	96	1877	4.41	41.6	37.6
CMS-607 A X AK-345	155.6	16.8	103	35.6	37.1	87	1977	6.58	39.1	36.8	152.7	16.2	103	36.8	35.6	84	2144	6.42	35.7	35.7
CMS-607A X R-83	141.0	15.5	93	40.3	39.2	92	2038	5.62	34.5	40.1	145.0	15.9	94	43.8	39.7	88	2080	5.51	37.7	38.7
CMS-RR-1A X DOR-R-2	161.2	16.9	100	38.9	36.2	82	1980	6.25	41.6	37.5	165.7	16.1	100	35.6	36.7	80	1977	6.57	38.7	36.1
CMS207A XR-35	125.6	15.8	92	33.6	39.1	93	1866	1.70	39.4	39.0	122.8	15.7	91	31.9	38.9	94	1772	1.58	37.0	37.4
CMS-607A XR273	131.2	16.4	94	40.2	39.4	96	2140	4.10	37.8	38.2	136.8	16.2	94	41.4	40.1	95	2160	3.78	35.4	38.0
CMS607A X RHA-95C-1	149.6	14.8	100	43.4	37.3	92	2232	3.95	38.2	36.1	156.2	14.4	100	45.2	41.7	88	2252	4.98	35.2	36.4
SEm (±)	2.7	0.44	0.91	1.03	0.63	0.57	51.3	0.28	1.2	1.1	3.1	0.41	1.0	1.1	0.56	0.51	44.2	0.26	1.1	0.8
LSD(P=0.05)	8.2	1.42	2.8	3.2	1.9	1.7	153	0.92	3.6	3.2	9.2	1.33	3.1	3.5	1.7	1.6	131	0.8	3.2	2.4
CV(%)	10.2	9.2	9.3	10.4	8.7	8.5	11.2	11.7	9.5	9.1	11.2	8.3	9.7	9.2	8.7	8.4	10.1	11.5	10.3	8.7

Table 3 Performance of sunflower hybrid entries in station hybrid trial and multilocation trials in West Bengal (2014-15)

Hybrid	Location 1 (Nimpith)			Location 2 (Average performance of the hybrids at CU Research Farm , Baruipur and Radhakantapur)				
	Seed yield (kg/ha)	Oil (%)	Oil yield (kg/ha)	Seed yield (kg/ha)	Oil (%)	Oil yield (kg/ha)	Avg. Seed yield (kg/ha)	Avg. Oil yield (kg/ha)
SMLHT –KH-12-01	1644	39.6	651.0	1594	37.4	596.2	1619	623.6
SMLHT-KH-12-03	2122	39.1	829.7	1910	38.7	739.2	2016	784.5
SMLHT-KH-12-04	2105	39.2	825.2	1960	39.2	768.3	2033	796.8
KBSH-41	1732	38.2	661.6	1872	37.5	702.0	1802	681.8
KBSH-44**(Ch-1)	2230	30.2	673.5	2211	30.0	663.3	2221	668.4
KBSH-53**	2094	36.5	753.6	2160	36.9	797.0	2127	728.3
KBSH-55	1455	34.6	430.7	1561	37.2	580.7	1508	505.7
KBSH-58	1194	30.9	368.9	1149	37.5	430.9	1172	399.9
KBSH-65	1755	35.6	624.8	1811	37.9	686.4	1783	655.6
KBSH-68	1860	34.8	647.3	1920	37.3	716.2	1890	681.8
RSFH-10-600	1980	37.5	742.5	1932	37.0	714.8	2056	728.4
RSFH-1887	2020	38.6	779.7	2208	37.0	817.0	2114	798.4
DRSH-1(Ch-2)	1772	40.0	708.8	1744	39.6	681.9	1758	695.6
LSFH-35	1980	37.5	742.5	1866	34.8	649.4	1923	696.0
LSFH-171**	2220	32.5	725.9	2180	32.7	712.8	2158	719.4
CMS-207A x R-83	1977	40.0	790.8	2066	38.5	795.1	2022	793.5
CMS-207A x R-103	1983	38.1	755.5	1861	38.1	709.0	1922	732.3
CMS207A x R-106	1822	37.2	677.8	1877	37.6	705.8	1850	692.8
CMS-607 A x AK-345	1977	36.8	727.5	2144	35.7	765.4	2061	746.5
CMS-607A x R-83	2038	40.1	815.4	2080	38.7	804.2	2059	810.5
CMS-RR-1A x DOR-R-2	1980	37.5	742.5	1977	36.1	713.7	1979	728.1
CMS207A x R-35	1866	39.0	727.7	1772	37.4	662.7	1819	695.2
CMS-607A x R-273	2140	38.2	818.0	2160	38.0	820.8	2196	836.7
CMS607A x RHA-95C-1	2232	36.1	814.8	2252	36.4	819.7	2232	817.3
LSD (P=0.05)	153	3.2	47.2	131	2.4	42.6		
CV (%)	11.2	9.1	9.4	10.1	8.7	9.8		

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ICH-66, a new high yielding and biotic stress-resistant castor hybrid suitable for rainfed conditions of Peninsular India

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ABSTRACT

ICH-66, a new castor hybrid has been developed at ICAR-Indian Institute of Oilseeds Research (ICAR-IIOR), Hyderabad, India and identified by Combined Varietal Identification Committee of Oilseed Crops during 2018 for release under rainfed areas of Peninsular India in *kharif* season. The hybrid was developed using the parents SKP-84 and ICS-164 and tested at station trials of ICAR-IIOR during 2013-14 and 2014-15. Considering its superiority over checks, it was evaluated in MLTs of AICRP (Castor) during 2015-16, 2016-17 and 2017-18 along with hybrid checks DCH-519 and DCH-177. ICH-66 recorded a mean seed yield of 1566 kg/ha which is 14.9 and 18.3 per cent higher than the checks DCH-519 (1324 kg/ha) and DCH-177 (1363 kg/ha) respectively. It also had a mean oil content of 48.6 per cent, which is 2.2 and 3.4 per cent higher than the check DCH-177 (47.0% oil content) and DCH-519 (47.6% oil content), respectively. The hybrid had a longer effective primary spike length (45 cm) and better 100-seed weight (29.0 g) under rainfed conditions compared with checks DCH-177 (39 cm and 27.3 g) and DCH-519 (44.8 cm and 26.4 g). The hybrid is medium in maturity duration (100-130 days for primary spike maturity), non-lodging and non-shattering type. The hybrid showed resistance against Fusarium wilt and Macrophomina root rot. It was also found resistant to leafhopper with hopper burn grade of 0 to 1 (on 0-4 scale) at multilocations in all the years of screening. Owing to its superiority for seed yield, oil content and biotic-stress resistance, it will be suitable for rainfed areas of Telangana, Andhra Pradesh, Karnataka, Tamil Nadu and Odisha states in India.

Keywords: Castor, Hybrid, ICH-66, Leafhopper, Peninsular India, Resistance, Root rot, Wilt

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop in India. Its seed oil has vast and varied industrial applications such as lubricants, cosmetics, surfactants, surface coatings, plasticizers, nylon, medicines etc. (Ogunniyi, 2006; Suresh, 2009). India ranks first in global castor area (8.07 lakh hectares), production (13.76 lakh tonnes) and productivity (1704 kg/ha) and holds a premier position with 80 per cent of worlds castor oil exports (DES, 2017). In India, castor is cultivated under two contrasting environments *viz.,* irrigated conditions with high productivity (1338 to 2072 kg/ha) in Gujarat and Rajasthan; and rainfed conditions under low input application with low productivity (312 to 631 kg/ha) in Andhra Pradesh, Telangana, Tamil Nadu, Karnataka and Odisha (DES, 2017). Among the 22 public sector bred hybrids, GCH-4 released in the year 1993 for all castor growing regions of the country was popular in rainfed areas of Southern India due to its wide adaptability and higher hundred seed weight. Among other hybrids, DCH-177 released in 2000 for rainfed regions of Southern states and parts of Maharashtra and Madhya Pradesh and DCH-519 released in 2006 for all castor growing regions of the country are popularly grown by the farmers in southern India (Lavanya and Solanki, 2010; Lavanya and Varaprasad, 2012; Sujatha *et al.,* 2017). However, GCH-4 is highly susceptible to Fusarium wilt and DCH-177 has low hundred seed weight (26 to 27 g) coupled with susceptibility to leafhopper due to its single bloom nature. Though, DCH-519 is high yielding and wilt resistant under both irrigated and rainfed conditions across India, its susceptibility to gray mold disease during cyclone weather condition has been a major constraint in peninsular India. There is always a need to develop improved varieties/hybrids with high yield and good quality characteristics (Naeem-ud-Din *et al.,* 2012). Success of heterosis breeding is dependent on identification of wilt resistant parental lines with good combining ability and evaluation of hybrids with good agronomic management. Thus, castor hybrid ICH-66 has been developed which exhibited desirable features *viz*., high yielding, high seed weight and oil content coupled with resistance to Fusarium wilt, Macrophomina root rot and leafhopper. The hybrid has been identified by Combined Varietal Identification Committee meeting of Oilseed Crops during 2018 for rainfed areas of Peninsular India. In this paper, the development of hybrid and its unique features are discussed.

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MATERIALS AND METHODS

The new hybrid ICH-66 was developed at ICAR-Indian Institute of Oilseeds Research, Hyderabad, using the parents, SKP-84 and ICS-164 in *kharif*, 2012. SKP-84 (female), a pistillate line was developed through pedigree method of selection by hybridizing SKP-1 and VP-1 at SDAU. ICS-164, a monoecious inbred (male) was developed through pedigree method of selection from the cross 48-1 x RG-1582. This hybrid along with 135 new hybrids generated at ICAR-IIOR was evaluated at ICAR-IIOR, Hyderabad (under rainfed) and Anand, Gujarat (irrigated conditions) during *kharif* 2013. The genotypes were sown in two rows in an augmented design along with two checks *viz.,* DCH-177, DCH-519 at Hyderabad and DCH-519 and GCH-7 at Anand. Recommended agronomical practices were followed to raise a good crop. Observations were recorded on quantitative characters *viz.,* plant height upto primary spike (cm), days to 50% flowering, number of nodes to primary spike, total and effective spike length (cm), number of effective spikes per plant, pick wise seed yield (g/plant) and 100-seed weight (g). The data were analyzed for seed yield and yield components as per ARBD analysis of Federer (1961). Promising hybrids identified in the common hybrid trial were further re-evaluated in a replicated trial (RBD, 4 rows per entry) both under rainfed and irrigated conditions.

Based on its superiority over the best checks and wilt resistance, ICH-66 was included in the Initial Varietal and Hybrid Trial (IVHT) of All India Coordinated Research Project (AICRP) on Castor during 2015-16. Due to its good performance, it was further promoted to Advanced Varietal and Hybrid Trials (AVHT-I & II) during 2016-17 and 2017-18 at multi locations (Table 3) along with check hybrids. All the trials were conducted under rainfed conditions in Peninsular India. The recommended package of practices were followed while conducting the trials to raise a healthy crop. Yield potential and ancillary observations with respect to yield traits of ICH-66 and the checks were recorded as described by AICRP (Castor) guidelines. The oil content was estimated using a bench top pulsed low-resolution nuclear magnetic resonance analyser (Oxford-MQC-5, London, UK) according to the method of Yadav and Murthy (2016).

Reaction to biotic stresses (insect pests and diseases) were assessed during 2015-16 to 2017-18. Screening of the hybrid against major insect pests was carried using infester row technique (Anjani *et al.,* 2018) along with susceptible checks (DPC-9 and DCS-107) and existing hybrid checks (DCH-519, DCH-177, GCH-7) at three locations (Palem, Yethapur and S.K Nagar). Observations on incidence of sucking pests (leafhopper, thrips), defoliators (semilooper and spodoptera) and capsule borer were recorded from five randomly selected plants. The data on leafhopper were recorded on three leaves, representing top, middle and lower canopy of each entry and the respective hopper burn was recorded on 0-4 scale (Lakshminarayana, 2005). Population of thrips was observed on the top most tender but not fully opened leaf and also on immature spikes. Absolute larval population of defoliators from each plant was recorded. Number of capsules damaged by the capsule borer was recorded from five randomly selected plants and then per cent capsule damage was computed (Duraimurugan and Alivelu, 2017; Duraimurugan and Lakshminarayana, 2014).

Screening of the hybrid along with susceptible, resistant and hybrid checks for wilt resistance was carried out in permanent wilt sick plots maintained at ICAR-IIOR, Hyderabad, AICRP (Castor) centres at Palem, Telangana state and S.K. Nagar, Gujarat during 2015-16 to 2017-18. Reaction of experimental material against wilt was categorized as per the scale given by Lakshminarayana and Raoof (2006). Based on the wilt incidence, the genotypes which were found free from wilt disease (0% wilt disease) were scored as highly resistant. The cultivars with wilt incidence up to 20% were classified as resistant and those with more than 20% wilt incidence were considered as susceptible. The hybrid was screened against gray mold disease at ICAR-IIOR, Hyderabad under artificial, glass house and natural conditions as described by Prasad and Kumaraswamy (2017). Screening for root rot resistance was carried out in a permanent root rot sick plot maintained at AICRP (Castor) centre, Junagadh during 2015-16 to 2017-18 along with resistant and susceptible checks. The experimental materials were categorized as per Mayee and Datar (1986).

RESULTS AND DISCUSSION

Among the 136 hybrids evaluated in Preliminary Hybrid Trial (PHT), under rainfed conditions at IIOR, Hyderabad, seed yield of 17 hybrids was better than the best check, DCH-177 (409 g/plant). The same set of hybrids when evaluated under irrigated conditions at Anand, ICH-32 with 57% significant increase over the best check GCH-7 (4102 kg/ha), followed by ICH-382, ICH-66 (47%), ICH-65 (41%), ICH-605 and ICH-851 with 30% significant increase over the national check, DCH-519 (3796 kg/ha) were promising (Table 1). Six hybrids, which were promising either in rainfed or irrigated conditions alone or both the conditions, were further re-evaluated in a replicated trial both under rainfed and irrigated conditions during 2014-15. Among the six hybrids, ICH-66 (15%) and ICH-68 (35%) with significant increase over the best check, GCH-7 (3188 kg/ha) were nominated as potential hybrids for evaluation in coordinated trials (Table 2). The comparative performance of castor hybrid, ICH-66 during three consecutive years (2015-16 to 2017-18) for mean seed yield (kg/ha) is presented in Table 3. In *kharif* evaluation, for three years, under rainfed conditions, ICH-66 recorded a weighted mean

seed yield of 1566 kg/ha pooled over 20 trials, which is 18.3 and 14.9 per cent higher than the check hybrids, DCH-519 (1324 kg/ha) and DCH-177 (1363 kg/ha), respectively. The perusal of data obtained from 15 trials during *kharif* season under rainfed conditions revealed that the castor hybrid, ICH-66 had a mean oil content of 48.6 per cent which is 2.2 and 3.4 per cent higher than the checks, DCH-177 and DCH-519, respectively (Table 3). ICH-66 recorded a mean oil yield of 659 kg/ha over 15 rainfed locations which is 10 per cent higher than the check DCH-177 (599 kg/ha) and 19.3 per cent higher than the check DCH-519 (552 kg/ha) (Table 3).

The ancillary characters of ICH-66 along with check hybrids (DCH-519 and DCH-177) are presented in Table 4. The hybrid had medium crop duration (95 days for primary spike maturity), which was similar to DCH-519 (94.3 days) and DCH-177 (93.3 days). ICH-66 had longer effective primary spike length (45 cm) and better mean 100-seed weight (28.6 g) under rainfed conditions compared to checks DCH-177 (39.3 cm and 27.4 g) and DCH-519 (44.8 cm and 26.4g) respectively. Important agronomic and morphological characteristics of ICH-66 and its parents are presented in Table 5. Morphological features of ICH-66 include red stem colour, triple bloom, flat leaf, semi spiny capsules, long and loose spike, basal divergent branching, oval seed and chocolate seed coat colour. ICH-66 is similar to GCH-4 with red stem colour, triple bloom and semi spiny capsules (Fig. 1).

The major diseases limiting castor cultivation are gray mold, wilt and root rot. Wilt causes an yield loss of 20 to 50 per cent and gray mold disease causes an yield loss of 5 to 85 per cent in Andhra Pradesh, while wilt causes an yield loss of 20 to 60 per cent and root rot leads to an yield loss of 5 to 50 per cent in Gujarat. The extent of yield loss due to wilt depends on the stage at which plant wilts and ranged from 77 per cent at flowering to 39 per cent in later stages on secondary branches (Pushpawathi *et al.,* 1998). Lakshminarayana and Raoof (2006) reported reduction of 10 to 40 per cent in yield, 8 to14 per cent in seed weight and 1 to 2 per cent in seed oil content due to wilt infection. Host plant resistance is the cost effective approach to manage the wilt and root rot diseases. The screening techniques are well developed for wilt and root rot and resistant sources identified led to the development of resistant castor cultivars. Permanent wilt sick plots were developed at IIOR, Hyderabad; Palem, Telangana state and S.K. Nagar, Gujarat by growing and *in situ* incorporation of infected plant debris of highly susceptible variety. The inoculum was incorporated in wilt sick plots prior to sowing and inoculum load of at least 2×10^3 CFU/g of soil was maintained in wilt sick plots during the screening.

The parental line ICS-64 was screened under wilt sick plot conditions during 2014-15 and 2016-17 and the wilt incidence varied from 10 to 11.4 per cent with average of 10.7 per cent, which was on par with 48-1, the resistant check (10.2% wilt), while the JI-35, susceptible check (Table 8), showed 92.8 per cent wilt incidence. The new hybrid ICH-66 recorded wilt incidence ranging from 5.3 to 34.7 per cent with an average of 16.9 per cent under sick plot of IIOR, Hyderabad. This was on par with DCH-519 in which wilt ranged from 3 to 23.5 per cent with average of 15.2 per cent. Wilt incidence varied from 30.5 to 54.6 per cent with average of 40.2 per cent in DCH-177. At sick plot of S.K. Nagar, Gujarat, wilt incidence in ICH-66 varied from 1.9 to 27.3 per cent with an average of 15.7 per cent, while the disease incidence ranged from 5.5 to 15.6 per cent in DCH-519 with an average wilt of 9.4 per cent (Table 6). The wilt incidence ranged from 52.8 to 91.8 per cent in DCH-177. Wilt disease was not observed in 48-1 (resistant check), however 100 per cent wilt was recorded in JI-35 (susceptible check). The wilt incidence was moderate and varied from 30.3 to 33.9 per cent with average of 31.9 per cent in ICH-66 at sick plot of Palem, while average wilt incidence was 30.7 per cent in DCH-519. The disease ranged from 38.5 to 68.5 per cent with average of 52.1 per cent in DCH-177. The wilt incidence was 4.6 per cent and 95.8 per cent in 48-1 and JI-35, respectively (Table 6). The gray mold severity ranged from 35 to 70 per cent in ICH-66, while the severity was 55 to 81.3 per cent in DCH-519. The gray mold was 25 to 53.3 per cent in DCH-177 (Table 6).

The root rot incidence was lower (11.4 to 20% with average of 16.4%) in ICH-66 under sick plot conditions, compared to the checks, DCH-519 (0-34.6%; mean 17.9%) and DCH-177 (15-36.7%, mean 25%). In susceptible check GCH-4, the root rot incidence varied from 68.2 to 85.8 per cent with mean of 79 per cent while root rot was 7.4 to 24.5 per cent in JI-357, resistant check (Table 7).

The hybrid ICH-66 was screened against major insect pests of castor at three locations for three years along with susceptible checks (DPC-9 and DCS-107) and hybrid checks (DCH-519, DCH-177, GCH-7). ICH-66 showed resistant reaction to leafhopper with hopper burn grade of 0 to 1 on 0-4 scale across locations over years, while susceptible checks (DPC-9 and DCS-107) recorded hopper burn grade of 2 to 4. Hopper burn grade in hybrid checks *viz.*, DCH-519, DCH-177 and GCH-7 ranged from 0 to 2, 0 to 3 and 0 to 2, respectively (Table 8). During the three years of testing against thrips, ICH-66 recorded 3.7 to 32 thrips/spike and 0.6 to 2.4 thrips/tender most top leaf, while the population in susceptible check (DPC-9) and hybrid checks ranged from 3.6 to 32 thrips/spike and 0.7 to 2.4 thrips/tender most top leaf. The reaction of ICH-66 to defoliators *viz.,* semilooper and *spodoptera* (0.0 to 7.9 larvae/plant) was found similar to the checks (0.0 to 8.7 larvae/plant). Castor crop is attacked by a number of insect pests and the magnitude of insect pest problem is quite high in Southern India, where castor is

grown mainly as rainfed crop, resulting in lower seed yields. Host-plant resistance is the most reliable, economical and eco-friendly measure to minimize the pests incidence and severity. In low value crops, other methods are often too expensive, development of varieties or hybrids resistant to insect pests can be an acceptable recommendation for the farmers. Plant waxes have the primary function of maintaining the water balance but they also interfere with insect-plant relationship either positively or negatively. In castor, double and triple blooms reported to harbour low population of leafhopper and thrips (Lakshminarayan and Duraimurugan, 2014). ICH-66, a triple bloom is found resistant to leafhopper compared to existing hybrid, DCH-177, which is susceptible to leafhopper due to its single bloom nature.

Table 1 Promising hybrids in Preliminary Hybrid Trial (2013-14) at Anand

Hybrids	Days to 50 % flowering	Plant height (cm)	Effective spike length (cm)	Number of effective spikes per plant	Number of capsules per primary	Seed yield (kg/ha)			
						Primary	Secondary	Tertiary	Total
ICH-605	58	76	59	13	87	1918	1574	1431	4923
ICH-382	67	126	75	18	76	678	1191	4147	6017
ICH-851	57	71	73	12	121	1172	1679	2080	4931
ICH-23	56	87	52	11	72	791	775	3382	4948
ICH-32	59	90	84	14	135	1269	1460	3729	6458
ICH-65	66	93	75	14	88	1175	1461	3136	5772
ICH-66	66	84	84	18	128	1715	604	3728	6047
DCH-519 ©	59	80	70	12	94	646	943	2207	3796
GCH-7 ©	61	81	66	16	81	561	830	2711	4102
Mean	58	79	63	13	84	711	766	1723	3200
CV (%)	6	12	9	16	14	25	34	24	13
CD (Trts vs Checks)	4.4	26	15	5.4	31	477	324	1124	1136

Table 2 Promising hybrids identified in Preliminary Hybrid Trial-II at Anand (2014-15)

Hybrids	Number of nodes to primary raceme	Plant height up to primary spike (cm)	Days to 50% flowering of primary spike	Days to maturity of primary spike	Effective primary spike length (cm)	No. of effective spikes/ plant	100 seed weight (g)	Oil content (%)	Total seed yield (kg/ha)
ICH- 66	17	54	60	125	50	8	33	46.7	3665
ICH-68	16	63	60	125	51	7	30	45.5	4297
GCH- 7	18	69	60	136	62	8	29	43.9	3188
Mean	17	63	58	131	62	8	29	44.4	2748
C.D (p=0.05)	2	11	3	2	11	1	2	2.0	553
CV%	8	11	3	1	11	12	5	2.78	12

Table 3 Comparative performance of ICH-66 for seed yield, oil content and oil yield in coordinated trials under rainfed conditions (*kharif*, 2015-16 to 2017-18)

Parameters	Year of testing	No. of trials/locations	ICH-66	DCH-519	DCH-177
Mean seed yield (kg/ha)	1st year (2015-16)	10	1562	1275	1263
	2nd year (2016-17)	6	1451	1350	1468
	3rd year (2017-18)	4	1748	1406	1457
	Weighted mean	-	1566	1324	1363
Percentage increase or decrease of ICH-66 over checks	1st year (2015-16)	-	-	22.5	23.7
	2nd year (2016-17)	-	-	7.5	-1.2
	3rd year (2017-18)	-	-	24.3	20.0
	Weighted mean	-	-	18.3	14.9

Table 3 (contd...)

Parameters	Year of testing	No. of trials/locations	ICH-66	PCH-519	DCH-177
Mean oil content (%)	1st year (2015-16)	7	49.4	47.3	47.4
	2nd year (2016-17)	4	49.5	47.4	48.2
	3rd year (2017-18)	4	46.4	46.1	47.3
	Weighted mean	-	48.6	47.0	47.6
Percentage increase or decrease of ICH-66 over checks	1st year (2015-16)	-	-	4.4	4.2
	2nd year (2016-17)	-	-	4.4	2.7
	3rd year (2017-18)	-	-	0.7	-1.9
	Weighted mean	-	-	3.4	2.2
Mean oil yield (kg/ha)	1st year (2015-16)	7	621	534	550
	2nd year (2016-17)	4	686	562	663
	3rd year (2017-18)	4	698	574	619
	Weighted mean	-	659	552	599
Percentage increase or decrease of ICH-66 over checks	1st year (2015-16)	-	-	16.2	12.7
	2nd year (2016-17)	-	-	22.1	3.4
	3rd year (2017-18)	-	-	21.7	12.8
	Weighted mean	-	-	19.3	10.0

Table 4 Ancillary characters of the hybrid, ICH-66 under rainfed conditions (*kharif*, 2015-16 to 2017-18)

Character	Year of testing	ICH-66	DCH-519	DCH-177
Days to 50% flowering of primary spike	2015-16	51	52	51
	2016-17	51	54	48
	2017-18	50	51	46
	Mean	51	52	48
Days to maturity of primary spike	2015-16	97	98	94
	2016-17	94	93	96
	2017-18	94	92	90
	Mean	95	94	93
Number of nodes to primary spike	2015-16	15	15	13
	2016-17	19	15	14
	2017-18	16	16	13
	Mean	17	15	13
Plant height up to primary spike (cm)	2015-16	102	101	88
	2016-17	112	108	91
	2017-18	109	128	92
	Mean	108	112	90
Effective length of primary spike (cm)	2015-16	46	45	39
	2016-17	41	39	40
	2017-18	49	51	39
	Mean	45	50	39
Number of capsules per primary spike	2015-16	55	50	46
	2016-17	59	57	54
	2017-18	68	61	50
	Mean	61	60	50
Number of effective spikes per plant	2015-16	5	4	4
	2016-17	4	5	4
	2017-18	6	6	6
	Mean	5	5	5
100-seed weight (g)	2015-16	29.5	26.4	26.6
	2016-17	28.8	26.5	27.4
	2017-18	27.6	26.4	28.1
	Mean	28.6	26.4	27.4

Fig. 1. Representative picture of spike at maturity and seeds of ICH-66

Table 5 Morphological features of the hybrid, ICH-66 and its parents

Characters	ICH-66	SKP-84 (Female)	ICS-164 (Male)
Hypocotyl : Anthocyanin pigmentation	Present	Present	Present
Leaf : Anthocyanin pigmentation of young emerging leaves	Present	Present	Present
Leaf : Waxi bloom on upper side	Present	Present	Absent
Leaf : Waxi bloom on lower side	Present	Present	Present
Stem : Waxi bloom	Present	Present	Present
Stem : Colour (after removal of bloom)	Red	Red	Red
Stem : Type of internodes	Elongated	Condensed	Elongated
Leaf : Length of 4th leaf from top (cm)	Medium	Medium	Medium
Plant : Time of 50% flowering of primary spike (days)	Medium	Medium	Medium
Stem : Number of nodes on main stem upto primary spike	Medium	High	Medium
Leaf : Shape	Flat	Deep cup	Flat
Leaf: Number of lobes	Many	Few	Many
Leaf: Lascination	Shallow	Shallow	Shallow
Petiole : Length (cm)	Medium	Medium	Medium
Petiole : Surface	Smooth	Smooth	Smooth
Inflorescence: Type of flowers on primary spike	Monoecious	Pistillate	Monoecious
Inflorescence: Spike shape	Conical	Conical	Conical
Inflorescence: Spike compactness	Loose	Semi compact	Loose
Inflorescence : Length of primary spike (cm)	Long	Long	Long
Capsule : Spininess	Semi-spiny	Dense	Non-spiny
Capsule: Length (cm) (central part of the spike)	Medium	Medium	Medium
Plant: Location of branches	Basal	Basal	Basal
Plant : Branching pattern	Divergent	Convergent	Divergent
Plant : Height up to the base of primary spike (cm)	Medium	Medium	Medium
Seed : Weight of 100 seeds (g)	Medium	Medium	Medium
Seed : Shape	Oval	Oval	Oval
Seed : Coat colour	Chocolate	Chocolate	Chocolate
Seed : Mottling	High	High	High
Seed : Caruncle	Small	Small	Small
Seed: Oil content (%)	High	High	High

Table 6 Reaction of ICH-66 against Fusarium wilt and gray rot diseases (2015-16 to 2017-18)

Year of testing	Centre	ICH-66	DCH-177	DCH-519	GCH-7	Resistant check 48-1	Susceptible check JI-35
Fusarium wilt incidence							
1st year (2015-16)	IIOR, Hyderabad	5.3	30.5	3.0	23.9	9.4	100
2nd year (2016-17)		34.7	54.6	19.0	43.7	6.9	100
3rd year (2017-18)		10.7	35.6	23.5	19.0	2.5	92.7
	Mean	16.9	40.2	15.2	28.9	6.3	97.5
1st year (2015-16)	SK Nagar	1.9	52.8	5.5	5.4	0.0	100*
2nd year (2016-17)		27.3	91.8	15.6	0.0	0.0	100
3rd year (2017-18)		17.9	85.2	7.1	19.3	0.0	100
	Mean	15.7	76.6	9.4	8.2	0.0	100
1st year (2015-16)	Palem	30.3	38.5	16.9	31.1	6.0	87.5
2nd year (2016-17)		33.9	49.2	31.3	29.6	4.1	100
3rd year (2017-18)		31.4	68.5	44.1	40.0	3.7	100
	Mean	31.9	52.1	30.8	33.6	4.6	95.8
Gray rot disease severity (%)							
1st year (2015-16)	IIOR, Hyderabad					Susceptible check (DCH-519)	
2nd year (2016-17)	Natural	39.0	53.3	81.3	96.7	99	
3rd year (2017-18)	Artificial*	50.0	50.0	65.0	60.0	85	
	Natural	35.0	25.0	55.0	30.0	95	
	Glasshouse	70.0	30.0	80.0	40.0		

*Using artificial inoculation followed by field fogging technique

Table 7 Reaction of ICH-66 against root rot disease in sick plot at Junagadh (2015-16 to 2017-18)

Year of testing	Root rot incidence (%)				Resistant check	Susceptible check
	ICH-66	DCH-177	DCH-519	GCH-7	JI-357	GCH-4
1st year (2015-16)	17.9	15.0	34.6	15.7	24.5	83.1
2nd year (2016-17)	11.4	36.7	19.2	21.9	9.9	85.8
3rd year (2017-18)	20.0	23.3	0.0	0.0	7.4	68.2
Mean	16.4	25.0	17.9	12.5	13.9	79.0

Table 8 Reaction of ICH-66 against sucking pests (2015-16 to 2017-18)

Pest	Year of testing	Centre	ICH-66	Susceptible check	Susceptible check	Hybrids		
				DPC-9	DCS-107	DCH-519	DCH-177	GCH-7
Leafhopper*	2015-16	Palem	32.6 (1)	-	103.6 (2)	53.4 (0)	35.2 (2)	50.0 (2)
Hopper burn scale (0 to 4)		SK Nagar	2.8	-	3.8	3.3	4.1	4.4
	2016-17	Palem	44.0 (1)	55.8 (4)	-	46.0 (2)	45.2 (1)	44.8 (1)
		Yethapur	14.6 (1)	16.3 (2)	-	6.0 (0)	18.3 (2)	20.6 (1)
		SK Nagar	3.1	20.7	-	2.7	14.4	3.0
	2017-18	Yethapur	6.3 (0)	24.6 (3)	-	3.0 (0)	6.3 (0)	7.0 (0)
		SK Nagar	24.1 (1)	74.9 (4)	-	20.2 (1)	39.1 (3)	22.0 (1)
Thrips/spike	2015-16	Yethapur	3.7	15.2	3.5	9.7	8.0	7.7
	2016-17	Yethapur	32.0	32.0	-	-	-	-
		SK Nagar	12.0	12.1	-	-	-	-
	2017-18	Yethapur	7.3	4.0	-	13.6	9.3	3.6
		SK Nagar	21.9	21.8	-	24.4	19.3	23.0
Thrips/top leaf#	2015-16	SK Nagar	2.4	-	2.4	-	-	-
	2016-17	SK Nagar	1.5	1.3	-	-	-	-
	2017-18	Yethapur	0.6	0.8	-	0.7	0.7	0.8

*Figures in parenthesis indicate hopper burn scale [*Hopper burn grade: 0 - No injury (Highly resistant), 1- Hopper burn up to 10% (Resistant), 2 -11 to 25% (Moderately Resistant), 3-26 to 50% (Susceptible), 4 - above 50% (Highly Susceptible)]; # Figures in parenthesis indicate number of thrips/top leaf

In conclusion, ICH-66 is not only a high-yielding hybrid with better oil content but also possess resistance to wilt, root rot and leafhopper. Due to its better adaptability, it has the potential to replace GCH-4, DCH-177 and DCH-519 in rainfed castor growing regions of peninsular India in *kharif* season especially in states like Telangana, Andhra Pradesh, Karnataka, Tamil Nadu and Odisha.

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Inheritance study of some qualitative traits in safflower (*Carthamus tinctorious* L.)

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ABSTRACT

Safflower (*Carthamus tinctorius* L.) is a multipurpose crop giving quality oil, but poorly studied for genetics of traits. In the present investigation, 14 genotypes (germplasm lines and varieties) *viz.,* JSF-1, RSS-2011-2, PKV Pink, Aceitera, GMU-1303, PBNS-12, TGMS, RSS-2011-1-1, RVS-12-13, SAF-2036, GMU-1810, IIOR-SAF-39, NARI-6 and RSS-2016-7 were used as parents, which are diverse for many traits, to make 10 crosses. The observations of contrasting traits of parents, the trait appeared in F_1 and F_2 were recorded. The data recorded were analysed by χ^2- test for goodness of fit. Some of the traits such as capitulum shape, days to flowering, leaf margin and capitulum size appeared to be monogenic as the F_2 population segregated in 3:1 ratio. Inheritance pattern of leaf shape, petal colour, spines, bract shape and size and branching habit revealed complementary or inhibitory gene interactions, indicating involvement of two genes.

Keywords: Capitulum shape, Inheritance, Leaf shape, Petal colour, Safflower, Spininess

Safflower is humanity's oldest crop and has survived for over 4000 years producing quality oil rich in poly and monounsaturated fatty acids. The flowers have pharmaceutical properties which can cure many chronic diseases, and also a source of natural dye called carthamin. Safflower is a drought-resistant crop grown under rainfed conditions in many countries including India, Mexico, the United States, Australia, Kazakhstan, China, Ethopia, Uzbekistan, Iran, Turkey, Spain, the Russian Federation, Canada and Pakistan (Singh and Nimbkar, 2016; Kadirvel *et al.,* 2017; Patel and Shrivastava, 2016). The cultivation of safflower, since time immemorial under diverse climatic conditions in different countries, suggests that the sustainability of the crop is very high (Shweta Kumari *et al.,* 2017). Diversity in the crop for different traits play an important role in making the crop sustainable (Saisanthosh *et al.,* 2018). For any crop improvement program, knowledge of genetics of traits is desirable as helps in deciding breeding strategies and approaches. In safflower, only a little information is available about the inheritance of leaf shape, bract size and shape, capitulum shape, capitulum size, days to flowering and leaf margin. In view of the above facts, an attempt has been made in the present study to know the mode of inheritance and the number of genes that control above mentioned traits in safflower.

MATERIALS AND METHODS

Fourteen parents including safflower varieties and germplasm lines *viz.,* JSF-1, RSS-2011-2, PKV Pink, Aceitera, GMU-1303, PBNS-12, TGMS, RSS-2011-1-1, RVS-12-13, SAF-2036, GMU-1810, IIOR-SAF-39, NARI-6 and RSS-2016-7 were used in the study. These parents were diverse for many traits such as petal colour, branching pattern, leaf shape, spininess and capitulum size etc. (Table 1)

Crosses JSF-1 x RSS-2011-2, PKV Pink x Aceitera, JSF-1 x PBNS-12, TGMS x RSS-2011-1-1, RVS-12-13 x SAF-2036, TGMS x GMU-1810, TGMS x IIOR-SAF-39, TGMS x NARI-6, TGMS x GMU-1303 and RVS-12-13 x RSS-2016-7 were made for studying the genetics of different traits.

Parents and F_1 were grown together in *rabi* 2016-17. The observations of contrasting traits of parents and the trait that appeared in F_1 were critically recorded. The F_2 populations were grown during *rabi* 2017-18 in bulk and observations for clear-cut contrasting traits were recorded in each individual plant of the populations and they were counted for each trait separately. The data recorded for each trait were analysed by χ^2- test for goodness of fit of observed data with the expected segregating ratio (Panse and Sukhatme, 1967). The scoring of traits were done as per the DUS guidelines provided by ICAR-Indian Institute of Oilseeds Research (2010-11). The traits leaf serration, leaf shape, petal colour, capitulum shape, capitulum size, bract shape and size, leaf spininess, days to 50% flowering and branching habit are qualitative traits and therefore, the observations recorded for those traits were classified into two clear-cut classes and no intermediate class was observed.

RESULTS AND DISCUSSION

In cross JSF-1 x RSS-2011-2, the F_1 exhibited normal serrated long leaves, indicating dominant nature of normal

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serrated long leaves. The observations of individual plants in F_2 were classified into two distinct groups fitting 3 serrated long leaves: 1 lanceolate non-serrated leaf. This indicated that inheritance of leaf margin is monogenic. This result confirms the finding of Ramachandram and Goud (1982) and Ashri and Efron (1964).

In the cross PKV Pink x Aceitera, the F_1 exhibited narrow leaves suggesting the dominant nature of narrow leaves over broad leaves. The observed values in F_2 fitted well into ratio of 13 narrow: 3 broad leaves, indicating di-genic inheritance of leaf shape in safflower. This observation is in line with the findings of Richharia (1945), Joglekar and Deshmukh (1958) and Ramachandram and Goud (1982).

In cross JSF-1 x PBNS-12, the F_1 exhibited yellow petals indicating dominant nature of yellow petals over white. The segregation pattern of yellow and white petals fitted well in a ratio of 13 yellow: 3 white petals. Similarily, in cross RVS-12-13 x RSS-2016-7, the F_1 exhibited red petals, indicating dominant nature of red petal color over white. The segregation of observed values in F_2 fitted well in an expected ratio of 9 red petals: 7 white petals. These indicated that petal colour is governed by two genes. This confirms the findings of Main (1912) and Ashri and Efron (1964).

In the cross TGMS x RSS-2011-1-1, the F_1 exhibited late flowering, indicating dominant nature of late flowering over early flowering. The observed values in F_2 fitted well in the ratio 3 late: 1 early, with the delayed flowering recorded as dominant trait.

In the cross RVS-12-13 x SAF-2036, F_1 exhibited large capitulum indicating its dominant nature over normal size capitulum. The observed values of F_2 fitted well in ratio of 3 large: 1 normal capitulum. Similarly, in the cross TGMS x GMU-1810 all the F_1 plants were having flat shaped capitula, indicating the dominant nature of flat shaped capitula over beaked shaped capitula. In F_2, the observed values fitted well in the ratio 3 flat: 1 beak capitulum. This confirmed the findings of Dille and Knowles (1975).

Table 1 List of parents and their distinguishing traits

Parent	Distinguishing traits	No. of plants observed	Score of parents for traits under study
JSF-1	Normal serrated long leaves, spiny, white petals	20	All plants had serrated leaves
RSS 2011-2	Non-serrated lanceolate leaves	20	All plants were having non-serrated leaves
PKV Pink	Spiny, broad leaves	20	All plants were having Spiny broad leaves
Aceitera	Narrow leaves	20	All plants had narrow leaves
GMU-1303	Spineless	20	All plants were spineless
PBNS-12	Yellow petals	20	All plants had yellow petals
TGMS	Late flowering, beak shaped capitulum, narrow and long bracts, spiny	20	All plants had late flowering , beak shaped capitulum, narrow and long bracts with spiny leaves
RVS-12-13	Large capitulum, non-waxy succulent branches, dark red petals	20	All plants were having large capitula, non- waxy succulent branches and dark red petals
RSS 2011-1-1	Early flowering	20	All plants were having early flowering
SAF-2036	Normal capitulum	20	All plants were having normal shaped capitula
GMU-1810	Flat capitulum	20	All plants were having flat capitula
IIOR SAF-39	Short and broad bracts	20	All plants had short and broad bracts
NARI-6	Spineless leaves	20	All plants were spineless
RSS 2016-7	White petals, waxy hard branches	20	All plants had white petals with waxy hard branches.

In the cross TGMS x IIOR-SAF-39, F_1 were having short and broad bracts indicating the dominant nature of short and broad bracts over long and narrow bracts. In F_2, the observed values fitted well in 13 short and broad bracts: 3 long narrow bracts ratio. In the cross TGMS x NARI-6, F_1 exhibited spines in leaves as well as on bracts indicating the dominant nature of spininess over spinelessness. The observations of individual plants in F_2 of TGMS x NARI-6 were classified into two distinct groups that fitting into 13:3 ratio of spiny to non-spiny. This indicated the involvement of two genes in inheritance of spininess in safflower. This was in agreement with the findings of Pal (1939), Rao (1943), Joglekar and Deshmukh (1958) and Ashri and Efron (1964).

In the cross TGMS x GMU-1303, F_1 were having spiny leaves indicating the dominant nature of spiny leaves over non-spiny leaves. In F_2 the observed values fitted well in 3 spiny: 1 spineless leaves ratio. This indicated that spininess is controlled by one major gene. In the cross RVS-12-13 x RSS-2016-7, the F_1 exhibited hard waxy branches indicating the dominant nature of hard waxy branches over succulent non-waxy branches. The observations of individual plants in F_2 population fitted well in an expected ratio of 13 hard waxy branches: 3 succulent non-waxy branches. This indicated that inheritance of branching habit is digenic.

From this study inheritance pattern for leaf shape, petal colour, bract shape and size and branching habit was found to be di-genic with complementary and inhibitory gene action, whereas leaf margin, days to 50% flowering, capitulum size and capitulum shape was found to be controlled by single major gene. The trait spininess in one cross was di-genic, while in another cross it was found to be monogenic.

Table 2 Parents and their origin/source

Parents	Origin/Source	Parentage or EC No.
JSF-1	Indore	Selection from IC 11839
RSS 2011-2	Raipur	Selection from GMU 3099
PKV Pink	Akola	-
Aceitera	IIOR	EC-755675
GMU-1303	IIOR	EC-181579
PBNS-12	Parbhani	-
TGMS	NARI, Phaltan	-
RSS 2011-1-1	Raipur	Selection from GMU 3099
RVS 12-13	Indore	-
SAF-2036	Solapur	-
IIOR SAF-39	IIOR	NARI-57 x EC-736500
GMU-1810	IIOR	-
NARI-6	NARI, Phaltan	CO-1 x JL-8
RSS 2016-7	Raipur	-

Table 3 Inheritance of traits in different crosses in safflower

Crosses	Traits	F_1	No. of plants in F_2	F_2				Expected ratio	χ^2 value
				Observed value		Expected value			
JSF-1 x RSS 2011-2	Leaf margin	Serrated	301	222 (serrated)	79 (non- serrated)	262 (serrated)	75 (non- serrated)	3:1	0.24
PKV Pink x Aceitera	Leaf shape	Narrow	351	295 (narrow)	56 (broad)	285 (narrow)	66 (broad)	13:3	1.80
JSF-1 x PBNS-12	Petal colour	Yellow	346	295 (yellow)	51 (white)	281 (yellow)	65 (white)	13:3	3.65
TGMS x RSS 2011-1-1	Days to flowering	Late flowering	210	210 (late)	60 (early)	203 (late)	67 (early)	3:1	1.11
RVS-12-13 x SAF-2036	Capitulum size	Large capitulum	209	209 (large)	65 (normal)	206 (large)	68 (normal)	3:1	0.23
TGMS x GMU-1810	Capitulum shape	Flat capitulum	337	257 (flat)	80 (beak shaped)	253 (flat)	84 (beak shaped)	3:1	0.25
TGMS x IIOR SAF-39	Bract shape and size	Broad and short	260	209 (short and broad)	51 (long and narrow)	211 (short and broad)	49 (long and narrow)	13:3	0.12
TGMS x NARI-6	Spininess	Spiny	285	244 (spiny)	41 (non-spiny)	232 (spiny)	53 (non-spiny)	13:3	3.56
TGMS x GMU-1303	Spininess	Spiny	270	204 (spiny)	66 (non-spiny)	203 (spiny)	67 (non-spiny)	3:1	0.04
RVS-12-13 x RSS 2016-7	Branching habit	Hard waxy	275	234 (hard waxy)	41 (succulent non-waxy)	223 (hard waxy)	52 (succulent non-waxy)	13:3	2.86
	Petal colour	Red	236	128 (red)	108 (white)	132 (red)	103 (white)	9:7	0.43

Note: The tabulated value of Chi-square at 5% level of significance is 3.84.

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Genetic divergence study in linseed (*Linum usitatissimum* L.) through D^2 and principal component analysis

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ABSTRACT

Genetic diversity among thirty one linseed genotypes was studied using D^2 analysis and principal component analysis (PCA) to efficiently utilize the breeding potential of linseed genotype for improving the yield. On the basis of D^2 analysis, these genotypes were grouped into six divergent clusters in which cluster I was largest with 12 genotypes followed by cluster II and cluster V. The results showed the highest contribution of linolenic acid towards genetic diversity. However, inter cluster D^2 value was found to be highest between cluster II and VI followed by V and VI. On the basis of cluster mean, the genotypes of cluster IV were characterized by the highest cluster mean for seed yield per plant and cluster II for oil content and linolenic acid. Principal component analysis distributed all the variables into six principal components accounting for 88.17 per cent of the total variation suggesting the presence of considerable genetic diversity among the genotypes for different characters. Hence, the information obtained can be utilized in selecting diverse parents to get better segregants in linseed breeding programmes.

Keywords: D^2 analysis, Diversity, Linolenic acid, Linseed, PCA

Linseed (*Linum usitatissimum* L.), an important oilseed crop belonging to Linaceae family, with 14 genera and over 200 species is the only species in this family with economic and agronomic values (Tadesse *et al.,* 2009). It is a self pollinated crop but cross pollination occurs up to 2 per cent (Tadesse *et al.,* 2009). Every part of the linseed plant is utilized either directly or after processing. It is used as food (dietary fibres, micronutrients and omega -3 fatty acids), feed (oil cakes) and contains medicinal properties like antioxidant, phytoestrogen and anti-cancerous (Touré and Xueming, 2010; Chopra and Badiyala, 2016; Channabasavanagouda *et al.,* 2018). It also has a huge industrial demand for its fibre (flax and linen) and oil (paint, lubricant and varnish). It covers 2764 thousand hectare area with production of 2925 thousand tons having productivity of 1058 kg per hectare across the globe. In India its area is limited to 293 thousand hectares and production and productivity of 125 thousand tons and 427 kg per hectare, respectively (FAOSTAT, 2018).

However, in Bihar linseed is cultivated in an area of 16.7 thousand hectare having production of 14.3 thousand tonnes with productivity of 857 kg per hectare (DES, 2018). An insight into the magnitude of diversity and variability in a crop species is of prime importance as it forms the basis for any crop improvement programme. Genetic divergence and genetic variability have together played an important role in evolution of crop plants (Allard, 1961; Sharma *et al.,* 2017; Achila Singh *et al.,* 2017). Genetic diversity is one of the most important tools of plant breeding, which determine the potential of plants to produce improved and efficient one in diverse conditions.

Linseed being widely distributed in various geographical regions of the world has large spectrum of genetic diversity. A measure of genetic divergence must reflect the difference in gene frequencies. In the absence of experimental techniques to measure diversity with respect to genes affecting quantitative traits, phenotypic diversity is usually considered to be an indicator of underlying genetic differences. With the development of advanced biometrical techniques, several methods of divergence analysis based on quantitative traits have been proposed to suit various objectives. Some appropriate methods such as D^2 analysis, cluster analysis and principal component analysis (PCA) for genetic diversity identification, parental selection, tracing the pathway to evolution of crops and study interaction between the environments are currently available (Khodadadi *et al.,* 2011). Mahalanobis-D^2 statistic (Mahalanobis, 1936) occupies a unique place for discriminating the divergent populations (Mischner and Sokal, 1957; Morashima and Oka, 1960). Selection of parents in hybridization programme based on Mahalanobis D^2 statistic is more reliable as the required knowledge of parents in respect of many characters is available prior to crossing. Nair and Mukherjee (1960) were the pioneers to use D^2 statistics as a measure of genetic divergence in plant breeding studies for classification of teak. Past studies illustrated that parents with high yield potential and wide genetic diversity showed considerable amount of heterotic response in F_1 hybrids (Parhe *et al.,* 2014) and were likely to yield superior segregants within short span of time (Maurya and Singh, 1977). Therefore, measuring genetic divergence helps in proper selection of parents for crop

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improvement programme. D^2 is an important tool to quantify the degree of divergence between biological populations at genotypic level and also to assess the relative contribution of different components to the total divergence both at inter and intra cluster level. However, the clustering pattern helps in choosing parental combination for prospective breeding programme to generate the highest possible variability in the yield components, whereas, principal component analysis helps in identification of plant characters that categorize the distinctiveness among promising genotypes (Ojha *et al.,* 2017). Usually, the variables are standardized before calculation of the genetic distance to give similar importance of all the variables. Unfortunately, standardization decreases the differences among groups. This causes the relative differences in results of cluster analysis and PCA. The main advantage of using PCA over cluster analysis is that each genotype can be assigned to one group only (Mohammadi, 2002). So, there is a need to know about the genetic relationship between parents before initiating the crossing programme. Accordingly, thirty one linseed genotypes were selected and analyzed for their genetic diversity based on the studied trait using cluster analysis and PCA methods. The main objective of this study is to identify the diverse linseed genotypes for their utilization in future breeding programme.

MATERIALS AND METHODS

Field experiment and morphological studies: Field experiment was carried out at the agricultural farm of Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India (25º50' N latitude, 87º19' E longitude and at an altitude of 52.73 msl) during *rabi* season 2015-16. The climate of Sabour is sub-tropical in nature and characterized by hot summer, cold winter and moderate rainfall of about 1000 mm. The soil type in the experimental plot was heavy textured loam soil. Thirty one linseed genotypes were sown in RBD design with three replications. The row to row and plant to plant distance was maintained at 30 cm and 5 cm, respectively. All the recommended agronomical package and practices were followed throughout the experiment to raise a good crop.

Fourteen morpho-physiological data were collected including major pest i.e. bud fly infestation under environmental condition of Bihar. All the data were recorded on ten randomly selected plants per genotype in each replication except days to 50 % flowering and 50 % maturity, which were recorded on plot basis.

Oil composition and fatty acid profiling: Oil content was estimated using a bench top pulsed nuclear magnetic resonance (NMR)-Oxford-MQC-5 analyzer (London, UK). Fatty acid composition was determined using an Agilent 7860A gas chromatograph. All the biochemical data were measured at Biochemistry Unit, Indian Institute of Oilseeds Research, Rajendranagar, Hyderabad.

Statistical analysis: Genetic divergence study was carried out through D^2 statistics and PCA. The D^2 statistics for a measure of group distance based on multiple characters was worked out as per Mahalanobis (1936). Grouping of genotypes in different clusters was performed according to Tocher's method (Rao, 1952). All statistical analyses were performed at Khetan Studio, Rajendranagar Hyderabad, India, using INDOSTAT statistic software.

RESULTS AND DISCUSSION

D^2 value based Dispersion and Cluster analysis: Genetic diversity is the pre requisite for genetic improvement for yield and other related attributes. Before initiating the crossing programme, the selection of diverse parents must be given due weightage to generate better segregates. The analysis of dispersion in present study revealed that mean sum of squares - of genotypes (3.72**) was highly significant (Table 1). It indicated the presence of sufficient variability between mean values of characters studied. The V (stat) illustrated that differences between the means in respect to the pooled effect of twenty characters between different genotypes were significant. This is essential for estimation of further diversity pattern among the genotypes.

Based on the genetic diversity, estimated using D^2 values (Rao, 1952) as the square of the generalized distance, the thirty one genotypes under study were grouped into six clusters (Table 2). Cluster I had the highest number of genotypes i.e.12 followed by cluster II and cluster V with 7 genotypes each and cluster IV with three genotypes. The other two clusters *viz.,* Cluster III and cluster VI were solitary clusters. The averages D^2 values of intra and inter clusters have been illustrated in Table 3. Cluster V which comprises seven genotypes showed the highest genetic diversity among the genotypes within this cluster with 15126 D^2 value followed by cluster II with seven genotypes with 5567 D^2 value. The Cluster III and VI, represented by one genotype each, thus, making zero intra cluster distance.

With 336946 D^2 value, the highest inter cluster distance was estimated between Cluster II and VI, followed by that between cluster V and VI (with 216706 D^2 value) and the lowest was observed between cluster III and IV (with 3801 D^2 value). Cluster I was found nearest to III (D^2=8951) and most distant from Cluster VI (D^2=149290). Cluster II was most distant from Cluster VI (D^2=336946) and nearest to cluster V (D^2=26880). Cluster III was most distant from cluster VI (D^2=92335) and nearest to Cluster IV (D^2=3801). Cluster IV was most distant from cluster VI (D^2=103855) and nearest to cluster V (D^2=43167). Careful selection of parents out of these genotypes with optimum genetic divergence is necessary. Mian and Bhal (1989) reported that the parents separated by D^2 values generally show high heterosis. Similar attempts to get maximum diversity among different linseed genotypes have been reported previously by

other researchers (Fulkar *et al.,* 2007; Tadesse *et al.,* 2009; Pali and Mehta, 2015; Nizar and Mulani, 2015; Chandrawati *et al.,* 2017; Dhirhi *et al.,* 2017). In the present study, cluster II and cluster VI recorded the highest inter cluster distance, suggesting that crosses may be attempted using the genotypes of these two clusters to obtain better segregants.

Contribution of characters toward divergence and cluster mean analysis: Contribution of twenty agro-morphological and biochemical characters towards divergence was estimated from the number of times a character ranked first (Table 4). The relative ranking of different characters of D^2 showed that linolenic acid content had the highest contribution of 64.73 % followed by linoleic acid (15.27 %), oleic acid (9.68 %), oil content (5.38 %) and stearic acid (4.95 %). The rest fifteen agro-morphological characters showed less contribution (0.01 %) toward divergence. The relative ranking of oil contents in our study is simalar with the findings of Pali and Mehta (2015) and Nizar and Mulani (2015).

The mean values of the genotypes in each cluster are presented in Table 4. The result indicated that the Cluster VI consist of the genotypes having the earliest days to 50 % flowering, maturity and dwarfism (83 days, 105.67 days and 37.10 cm, respectively) in comparison to other clusters. Whereas, the genotypes of cluster IV were characterized by tall stature (79.53 cm), larger flower diameter (25.87 mm), capsule diameter (7.32 mm), larger seed size (4.93 mm), the highest number of capsule per plant (116.77) and the highest 1000-seed weight (7.40 g) with least infestation of bud fly (17.84 %). Number of primary branches per plant was found the highest in genotypes of cluster III (4.80). Whereas, number of seeds per plant was highest in genotypes of cluster I. Seed yield per plant was recorded highest in genotypes of cluster IV (1.91 g) with the mean of clusters for seed yield was 1.36 g per plant. The highest harvest index of 33.78 was reported in genotypes of cluster II.

In terms of oil content, the genotypes of cluster II had the highest oil content of 36.04 %. The cluster VI genotypes had the lowest saturated fatty acids content i.e. palmitic acid (5.87 %) and stearic acid (4.72 %). The highest unsaturated fatty acids namely, oleic acid and linoleic acid content in cluster VI genotypes was 55.57 and 18.09 %, respectively. However, the genotypes of cluster II had the highest linolenic acid content (46.14 %). Based on above results, it is concluded that genotypes of cluster II, IV and VI can be used in future breeding programe for improvement of seed yield, oil and fatty acid content in linseed.

Principal component analysis: Principal component analysis (PCA) reflects the importance of the largest contributor to the total variation at each axis of differentiation (Sharma, 1998). Previously, the PCA study have been performed in wheat by Khodadadi *et al.* (2011), rice by Ojha *et al.* (2017) and linseed by Paul *et al.* (2016) to study the genetic diversity. In the present study, the eigen roots value based percentage variations are presented in Table 5. The results showed that the six principal components extracted from the original data accounted for 88.17 % of the total variation and suggested the presence of considerable genetic diversity among the genotypes for different characters. Out of the total variations, the eigen root value of first principal component showed the variation of 33.53 % followed by second to sixth which accounted 22.71 %, 13.24 %, 8.92 %, 5.39 % and 4.38 % of total variation, present among the genotypes, respectively. The different traits loading in principal components and the score plot of thirty one linseed genotypes are represented in Table 5 and Fig. 1, respectively. The first principal component (PC1) had the highest positive loading for days to 50 % flowering (0.34), while the highest negative loading for oil content (-0.30). However, PC2 received highest positive loading for bud fly infestation (0.35) and highest negative value for seed length (-0.40). Third principal component (PC3) has highest positive loading for number of seeds per capsule (0.35) and highest negative for capsule diameter (-0.51). PC4 received highest positive loading for linolenic acid (0.61) and highest negative loading for oleic acid (-0.56). PC5 and PC6 have highest positive loading for biological yield (0.36) and linoleic acid content (0.37), respectively and highest negative loading for plant height (-0.46) and stearic acid content (-0.45), respectively.

It is suggested from the analysis that the traits having highest positive or negative loading on component showed larger contribution towards the diversity. Usually, only the best variable is selected from each group. Thus, days to 50% flowering is the best component for PC1which has the highest loading. Likewise, seed length, capsule diameter, linolenic acid, plant height and stearic acid were the best choice for PC2, PC3, PC4, PC5 and PC6, respectively.

Overall, it is clear from the observations of present study that the genotypes having the highest inter cluster distances and cluster means for different traits must be used in crop improvement programmes. The principal component analysis also revealed that the genotypes with highest variability for the various components must be considered for crossing in hybridization programmes.

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Table 1 Analysis of dispersion in linseed genotypes

Source of variation	d.f.	Sum of squares	Mean sum of squares	F-ratio
Genotypes	30	1.115	3.715	9.99*
Error	59	5.342	9.054	
Total	89	1.115	1.252	

Table 2 Composition of genotypes in different clusters in linseed

Clusters	Number of Genotypes	Genotypes
I	12	K.Selection, LBR-6, Polf- 23, EC-1529, Sharda, JRF-5, Meera, CI-1552, Ruchi, GS-440, CI-1559, SLS-72
II	7	Shekhar, BRLS-101, BRLS-102, BRLS-103, BRLS-104, NL 260, CI-1663
III	1	EC 537911
IV	3	Parvati, EC537911A, Neelum
V	7	BRLS-105, CI-2057, H-40, GS-202, T-397 , H-49, LCK-7035
VI	1	EC -1424

Table 3 Inter and intra cluster distances in linseed

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI
Cluster I	4810	43769	8951	11640	18999	149290
Cluster II		5567	80326	82428	26880	336946
Cluster III			0	3801	35946	92335
Cluster IV				2492	43167	103855
Cluster V					15126	216706
Cluster VI						0

Table 4 Mean performance of genotypes in clusters for twenty characters and their contribution towards divergence in linseed

Characters	I	II	III	IV	V	VI	Mean	Contribution towards divergence (%)
Days to 50% flowering	87.42	83.43	91.00	90.89	89.81	83.00	87.59	0.01
Days to 50% maturity	110.53	107.86	114.00	114.22	112.05	105.67	110.72	0.01
Plant height (cm)	66.48	56.37	69.60	79.53	64.98	37.10	62.34	0.01
Flower diameter (mm)	20.57	20.72	25.40	25.87	20.93	19.30	22.13	0.01
Number of primary branches per plant	2.7	1.87	4.80	3.37	3.28	3.00	3.17	0.01
Number of capsules per plant	80.57	70.20	93.80	116.77	74.83	51.40	81.26	0.01
Bud fly infestation (%)	21.5	26.20	18.49	17.84	29.78	37.12	25.15	0.01
Capsule diameter (mm)	6.75	6.80	6.63	7.32	6.28	6.12	6.65	0.01
Number of seeds per capsule	8.68	8.21	8.45	8.28	7.25	6.43	7.88	0.01
1000-seed weight (g)	5.64	6.18	5.68	7.40	4.79	4.70	5.73	0.01
Seed length (mm)	4.56	4.54	4.69	4.93	4.19	4.03	4.49	0.01
Biological yield per plant (g)	6.48	3.97	9.90	11.80	6.01	1.68	6.64	0.01
Seed yield per plant (g)	1.54	1.34	1.62	1.91	1.22	0.55	1.36	0.01
Harvest index	26.89	33.78	16.21	15.89	23.94	32.97	24.95	0.01
Oil content (%)	33.74	36.04	32.44	34.12	32.03	31.46	33.3	5.38
Palmitic acid (%)	6.33	6.46	6.62	6.80	6.30	5.87	6.4	0.01
Stearic acid (%)	6.88	6.22	6.68	8.93	5.98	4.72	6.57	4.95
Oleic acid (%)	38.02	28.62	41.83	41.46	32.05	55.57	39.59	9.68
Linoleic acid (%)	13.05	12.55	13.42	10.81	17.25	18.09	14.19	15.27
Linolenic acid (%)	35.73	46.14	31.44	32.00	38.41	15.74	33.24	64.73

Table 5 Principal component analysis of twenty traits showing traits loading in six principal components in linseed

Characters	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6
Days to 50% flowering	0.336	0.032	0.032	0.087	0.023	0.065
Days to 50% maturity	0.331	-0.101	-0.161	-0.041	0.127	0.198
Plant height	0.250	-0.183	-0.108	0.074	-0.456	0.273
Flower diameter	0.212	-0.303	-0.154	-0.062	0.237	0.133
Primary branches per plant	0.331	-0.142	0.038	0.005	0.009	0.225
Number of capsules per plant	-0.020	-0.358	0.203	0.172	0.149	-0.319
Bud fly infestation	-0.012	0.345	-0.290	-0.199	0.194	-0.210
Capsule diameter	0.095	0.054	-0.511	-0.250	-0.160	0.048
Number of seeds per capsule	-0.103	-0.255	0.354	0.142	-0.372	0.070
1000-seed weight	-0.215	-0.279	-0.240	-0.182	-0.091	-0.017
Seed length	-0.098	-0.393	-0.170	-0.191	0.168	0.175
Biological yield per plant	0.274	-0.186	0.064	-0.003	0.364	0.172
Seed yield per plant	-0.272	-0.258	0.120	0.020	0.216	0.116
Harvest index	-0.288	-0.241	-0.107	-0.073	0.258	-0.123
Oil content	-0.298	-0.105	-0.209	-0.087	-0.116	0.138
Palmitic acid	0.301	-0.010	0.015	0.124	0.262	-0.398
Stearic acid	0.211	-0.223	-0.163	0.072	-0.300	-0.447
Oleic acid	0.131	-0.087	0.260	-0.564	-0.093	-0.197
Linoleic acid	-0.019	0.256	0.303	-0.196	0.144	0.372
Linolenic acid	-0.106	0.063	-0.280	0.608	0.105	0.131
Eigene Value (Root)	6.706	4.542	2.648	1.784	1.077	0.876
% Var. Exp.	33.528	22.712	13.242	8.920	5.385	4.378
Cum. Var. Exp.	33.528	56.240	69.483	78.402	83.787	88.166

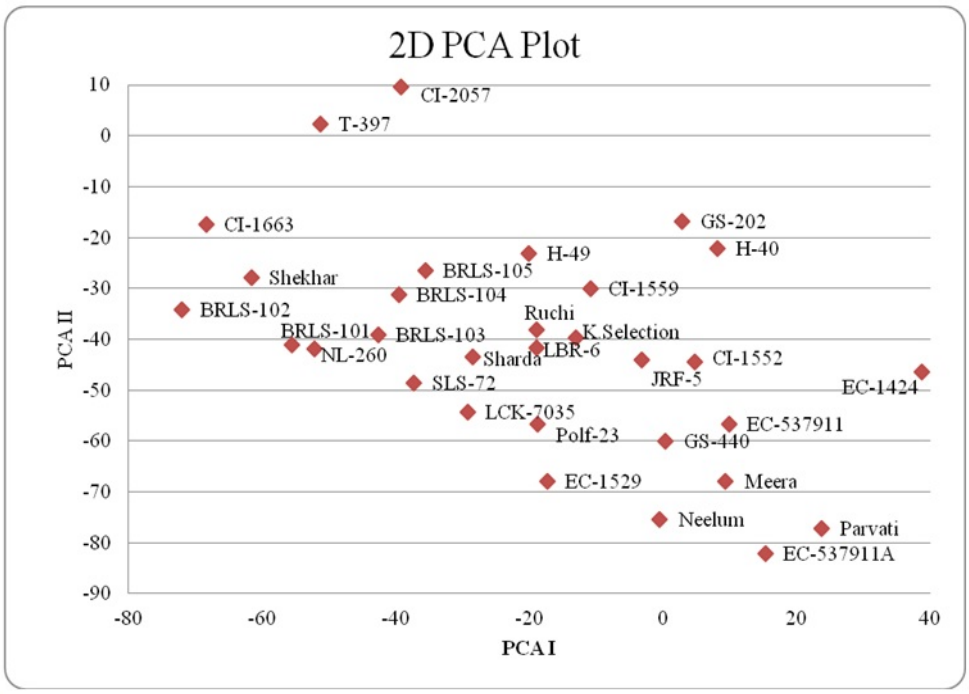

Fig. 1. Score plot of thirty one genotypes of linseed

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Efficacy of different chemical and non chemical approaches for management of Broomrape in Indian Mustard

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ABSTRACT

Indian mustard (*Brassica juncea*) is infested with a parasitic weed, Egyptian broomrape (*Phelipanche aegyptiaca*), threatening its production in south-western parts of Haryana. A field experiment was conducted to study the effect of broomrape control treatments on the growth rate, number of days to 50% flowering and siliqua initiation, primary branches, secondary branches and grain yield of Indian mustard. The crop growth rate, number of primary and secondary branches and the grain yield were higher when supplied with 125% of recommended fertilizer (N & P) + foliar spray of glyphosate at 25 and 50 g/ha + 1.0% solution of $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively. This was followed by foliar spray of glyphosate at 25 and 50 g/ha + 1.0% $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively. The broomrape control treatments had no significant effect the relative growth rate and number of days to 50% flowering.

Keywords: Broomrape, Glyphosate, Indian mustard, Parasitic weed, Yield attributes

Rapeseed mustard crops (*Brassica* spp.) are commercially cultivated in more than 60 countries and major producers are China, Canada, India, Australia, France, Germany, United Kingdom, Poland, Ukraine, Russia, USA and Czech Republic with India ranking third in area and production in the world (DRMR, 2015). Over the past couple of decades, these crops have become one of the most important sources of vegetable oil in the world. India accounts for 16.22% and 9.55% of the total acreage and production of rapeseed- mustard in the world (Ministry of Agriculture and Farmers Welfare, 2017). Productivity of rapeseed- mustard in India (1188 kg/ha) is very less as compared to world's productivity of 1856 kg/ha (Pirri and Sharma, 2013; Prajapati *et al.,* 2017). Rapeseed-mustard crops are cultivated over an area of about 6.07 m ha with production of 7.92 m t in India (Ministry of Agriculture and Farmers Welfare, 2019). These groups of crops are grown in different agro climatic conditions varying from north eastern/north western hills to south under irrigated/rainfed conditions, timely sown/late sown, saline soils and mixed cropping (Singh *et al.,* 2016; Kumar *et al*., 2017). Although it is being cultivated across the country, 7 states (Rajasthan, MP, UP, Haryana, WB, Assam and Gujarat) contribute significantly to its production (>90%) and acreage (>80%). Rajasthan alone contributes almost 50% to acreage in the country. *Brassica juncea* is the most predominant crop out of Rapeseed-mustard crops in India and accounts for more than 90% of the area.

Haryana state ranks 1st with a productivity of 1853 kg/ha of rapeseed-mustard and ranks 2nd and 4th contributing 11.94% (0.945 m t) and 8.40% (0.51 m. ha) in production and total area in India, respectively. It is grown across Bhiwani, Hisar, Jhajjar, Mahendergarh, Rewari, Sirsa, Fatehabad, Gurgaon and Mewat districts of Haryana. The soils of these districts are light textured loamy to sandy loam soils characterized by poor fertility and low moisture holding capacity. Losses in mustard seed yield due to weed infestation depends on weed population, their composition, growth habit etc. Egyptian broomrape (*Phelipanche aegyptiaca*), a holoparasitic weed, has emerged as a major threat to rapeseed mustard production, especially in South-western Haryana and the adjoining areas of Rajasthan. Many farmers in these areas have discarded the cultivation of mustard under the threat of this parasitic weed. Broomrape infestation is mostly confined to major mustard growing states of northern Rajasthan, Haryana, Punjab, Western UP and North East Madhya Pradesh. Yield losses due to its infestation have also been reported in mustard by Khattri (1997) and Punia (2015).

Plant-hole application of neem cake at 200 kg/ha at 30 days after transplanting (DAT) or imazethapyr applied at 30 g/ha at 55 DAT as post emergence herbicide is suggested for controlling broomrape in tobacco (AICRP on weed control, 2013). Cochavi *et al.* (2015) found that glyphosate was the safest herbicide for controlling broomrape in carrot as it didn't cause any significant reduction in taproot biomass of carrot up to 149 g/ha. Three sequential foliar applications of glyphosate at 108 g/ha provided complete control of Egyptian broomrape. Moreover, Turner and Loader (1980) studied the effect of ammonium sulphate on phyto-toxicity of glyphosate to Agropyron repens. It was observed that addition of 1-10% w/v ammonium sulphate in glyphosate

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increased the phyto-toxicity as well as control. Irrespective of continuous and extensive research, no single method is able in effective and economic management of broomrape. Integration of preventive, cultural and chemical methods may be adopted in spite of the costly inputs. As infestation of this weed starts after 7-10 days of sowing, the control measures should also be applied in early stages of the crop growth. Application of any control measure after panicle initiation of broomrape is of no use as damage starts from 30 days after sowing while growing underneath for its initial growth stage (Punia *et al.,* 2010). As reported by Sheoran *et al.* (2014) and Punia (2015), glyphosate is used to control Indian mustard from *P. aegyptiaca.* Keeping this in view, a field experiment was conducted to study the effect of broomrape control treatments on growth rate, number of days to 50% flowering and siliqua initiation, primary branches, secondary branches and seed yield of Indian mustard.

MATERIALS AND METHODS

The field experiment was conducted at CCS Haryana Agricultural University (RRS, Bawal, Rewari) in *rabi* 2014-15 located at 28.1º N, 76.5º E and at an altitude of 266 m. The experiment was laid out in Randomized Block Design with eleven treatments and three replications. The details of treatments are shown in Table 1. The soil of the experimental field was sandy in texture, low in organic carbon and nitrogen, medium in available phosphorus and potassium and neutral in reaction. Crop growth rate (CGR) at 40, 65, 95, and 135 days after sowing (DAS) and at harvest and relative growth rate (RGR) at 65, 95, and 135 DAS and at harvest was measured by using the formula described by Reddy and Reddy (2009). Days to 50 % flowering were recorded in a plot when at least one flower on main raceme of 50% plants was opened. Days to siliqua initiation was recorded with the beginning of formation of siliqua on plants by regularly visiting the field. The number of primary and secondary branches produced per plant and seed yield was counted at harvest. Data were analysed statistically using ANOVA and means were compared at 5% level of significance.

RESULTS AND DISCUSSION

Different treatments resulted in significant difference in crop growth rate (g/m^2/day) of Indian mustard from sowing upto 130 DAS and thereafter it remained non significant (Table 1). The data showed an increase in crop growth rate (CGR) with the advancement of crop age and reached maximum between 65-95 DAS and declined afterwards. Among different treatments, the plants provided with 125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50 g/ha + 1.0% $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively (T_9) resulted in higher crop growth rate which might be due to better control of *Phelipanche aegyptiaca* coupled with beneficial effects of higher dose of N and P on mustard at active vegetative stages as a result of enhancement in cell multiplication, cell elongation and cell expression in the plant body which ultimately increased the CGR. Also, reduction in weed population because of the early application of herbicides is responsible for the observed increase in rapeseed yield (Ibrahim *et al.*, 1987). Between sowing to 40 DAS, CGR was higher (2.57) with the treatment T_9 which was significantly superior over all the other treatments. Between 40-65 and 65-95 DAS, higher CGR was recorded in T_9 (7.83 and 32.36) which was followed by T_7 (6.78 and 28.32) and T_8 (6.69 and 27.28). Similarly the CGR between 95-130 DAS was recorded highest in T_9 (13.67) that was statistically at par with T_7 (13.51), T_8 (13.25), T_3 (13.10) and T_2 (12.70). The lowest crop growth rate was recorded in unweeded control (1.96) followed by treatments T_{10}, T_1, T_4, T_5 and T_6 at all the intervals.

The data pertaining to relative growth rate presented in Figure 1 were found to be non-significant in relation to different treatments. However, the relative growth rate showed an increase with the advancement of crop age that reached maximum at 65-95 DAS and declined afterwards. A perusal of data given in Table 2 indicated that differences in days taken to 50% flowering and siliqua initiation were non-significant in relation to different treatments. Significant difference was observed on number of primary and secondary branches/plant and seed yield of crop at harvest. Among the different treatments, number of primary branches at harvest stage were higher (7.1) with 125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50 g/ha + 1.0% $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively which was at par with treatment T_7 (foliar spray of glyphosate at 25 and 50 g/ha + 1.0% $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively) but significantly higher over rest of the treatments. Similarly, highest number of secondary branches at harvest stage (14.3) was found in treatment T_9 (125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50 g/ha + 1.0% $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively) which was at par with treatments T_2 (neem cake at 400 kg/ha at sowing followed by foliar spray of glyphosate at 20 and 40 g/ha + 1.0% $(NH_4)_2SO_4$ at 25 and 45 DAS, respectively), T_3 (neem cake at 400 kg/ha at sowing followed by foliar spray of glyphosate at 25 and 50 g/ha + 1.0% $(NH_4)_2SO_4$ at 25 and 45 DAS, respectively), T_7 (foliar spray of glyphosate at 25 and 50 g/ha + 1.0% $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively) and T_8 (recommended practice i.e. foliar spray of glyphosate at 25 and 50 g/ha at 25 DAS and 55 DAS, respectively) but significantly higher than rest of the treatments. Increase in number of primary and secondary branches at harvest in T_9 might be due to increased availability of nutrients because of least crop weed competition and adequate amounts of N and P which led to increased vigour of the plant during the

vegetative phase, thus contributing towards the higher growth and vigour of the plants and production of more branches/plant or due to role of N in cell multiplication, cell elongation and tissue differentiation and sprouting lateral buds with adequate supply of nitrogen resulting in more branches plant/plant. Primary and secondary branches were minimum (5.7 and 11.1) in weedy check (T_{11}) which was followed by treatments T_{10} (6.0 and 11.7), T_1 (6.0 and 11.8) and T_4 (6.0 and 12.0).

Table 1 Crop growth rate of Indian mustard at different growth intervals as influenced by different broomrape control treatments

Treatments	Detail	Crop growth rate ($g/m^2/day$)				
		0-40 DAS	40-65 DAS	65-95 DAS	95-130 DAS	130 DAS-Harvest
T_1	Neem cake 400 kg/ha at sowing	2.04	5.16	20.49	9.20	1.74
T_2	Neem cake 400 kg/ha at sowing followed by foliar spray of glyphosate at 20 and 40 g/ha + 1.0 % $(NH_4)_2SO_4$ at 25 & 45 DAS, respectively	2.17	5.97	24.65	12.70	2.01
T_3	Neem cake 400 kg/ha at sowing followed by foliar spray of glyphosate at 25 and 50 g/ha + 1.0 % $(NH_4)_2SO_4$ at 25 and 45 DAS, respectively	2.22	6.19	25.40	13.10	2.17
T_4	Neem cake 400 kg/ha followed by soil application of metalaxyl 0.2 % at 25 DAS	2.06	5.28	21.13	9.97	1.82
T_5	Neem cake 400 kg/ha followed by pendimethalin (PPI) at 0.75 kg/ha followed by soil application of metalaxyl 0.2 % at 25 DAS	2.09	5.47	21.90	10.18	1.86
T_6	Neem cake 400 kg/ha at sowing followed by soil application of metalaxyl 0.2 % at 25 DAS followed by foliar spray of glyphosate at 40 g/ha at 45 DAS	2.13	5.74	22.22	11.10	1.90
T_7	Foliar spray of glyphosate at 25 and 50 g/ha + 1.0 % $(NH_4)_2SO_4$ at 25-30 DAS and 55 DAS, respectively	2.33	6.78	28.32	13.51	2.28
T_8	Foliar spray of glyphosate at 25 and 50 g/ha at 25-30 DAS and 55 DAS, respectively	2.30	6.69	27.28	13.25	2.44
T_9	125 % of recommended fertilizer (N & P) + foliar spray of glyphosate at 25 and 50 g/ha + 1.0 % $(NH_4)_2SO_4$ at 25 DAS & 55 DAS, respectively	2.57	7.83	32.36	13.67	2.67
T_{10}	Hand pulling of Phelipanche shoots at 45, 65 & 85 DAS, respectively	2.03	5.13	20.18	8.95	1.68
T_{11}	Weedy check	1.96	4.87	19.03	7.37	1.53
	SE(m) ±	0.07	0.39	2.21	0.66	0.40
	CD (P = 0.05)	0.20	1.16	6.55	1.96	NS

Table 2 Number of days to 50 % flowering, days to siliqua initiation, primary branches, secondary branches and seed yield of Indian mustard as influenced by different broomrape control treatments

Treatments	Detail	Days to 50 % flowering	Days to siliqua initiation	Primary branches	Secondary branches	Seed yield (kg/ha)
T_1	Neem cake 400 kg/ha at sowing	59.7	74.7	6.0	11.8	1537
T_2	Neem cake 400 kg/ha at sowing followed by foliar spray of glyphosate at 20 and 40 g/ha + 1.0 % $(NH_4)_2SO_4$ at 25 and 45 DAS, respectively	58.3	73.3	6.6	13.5	2147
T_3	Neem cake 400 kg/ha at sowing followed by foliar spray of glyphosate at 25 and 50 g/ha + 1.0 % $(NH_4)_2SO_4$ at 25 and 45 DAS, respectively	58.3	73.3	6.7	13.7	2238
T_4	Neem cake 400 kg/ha followed by soil application of metalaxyl 0.2 % at 25 DAS	59.7	74.3	6.0	12.0	1567
T_5	Neem cake 400 kg/ha followed by pendimethalin (PPI) at 0.75 kg/ha followed by soil application of metalaxyl 0.2 % at 25 DAS	59.0	74.3	6.2	12.5	1694
T_6	Neem cake 400 kg/ha at sowing followed by soil application of metalaxyl 0.2 % at 25 DAS followed by foliar spray of glyphosate at 40 g/ha at 45 DAS	59.0	74.3	6.2	12.7	1782
T_7	Foliar spray of glyphosate at 25 and 50 g/ha + 1.0 % $(NH_4)_2SO_4$ at 25-30 DAS and 55 DAS, respectively	58.3	72.7	6.9	14.0	2426
T_8	Foliar spray of glyphosate at 25 and 50 g/ha at 25-30 DAS & 55 DAS, respectively	58.3	72.7	6.7	13.9	2308
T_9	125 % of recommended fertilizer (N & P) + foliar spray of glyphosate at 25 and 50 g/ha + 1.0 % $(NH_4)_2SO_4$ at 25 DAS and 55 DAS, respectively	57.3	72.3	7.1	14.3	2648
T_{10}	Hand pulling of Phelipanche shoots at 45, 65 and 85 DAS, respectively	59.7	74.7	6.0	11.7	1519
T_{11}	Weedy check	60.3	74.7	5.7	11.1	1403
	SE(m) ±	1.0	0.8	0.1	0.3	76
	CD (P = 0.05)	NS	NS	0.3	1.0	225

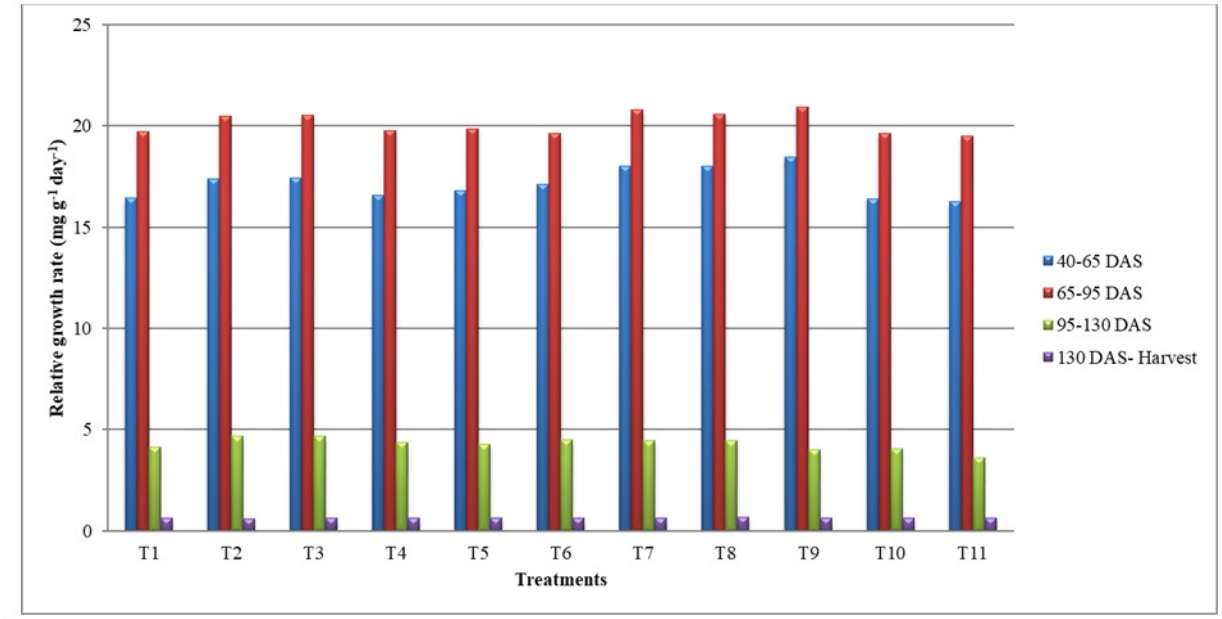

Fig. 1. Relative growth rate of Indian mustard at different growth intervals as influenced by treatments (T_{11} is the weed control)

Significantly highest seed yield (2648 kg/ha) was recorded with 125% of recommended fertilizer (N and P) + foliar spray of glyphosate at 25 and 50 g/ha + 1.0 % $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively (T_9) which was closely followed by T_7 (2426 kg/ha) i.e., foliar spray of glyphosate at 25 and 50 g/ha + 1.0% $(NH_4)_2SO_4$ at 25-30 and 55 DAS, respectively and significantly superior over other treatments. Better weed control and adequate nutrients (extra 25% nutrients) might have contributed to higher seed yield of mustard. Mousavi and Shimi (2008) showed the direct influence of nitrogen on seed germination of broomrape without any effect on the host ultimately creating conducive conditions for crop growth. The increase in seed yield with weed control methods is believed to be an indirect expression of reduction in weed-crop competition, which helped in increasing yield component and seed yield of the crop (Bazzaz *et al.,* 2003). Seed yield of mustard was observed to be lowest in treatment T_{11} i.e. weedy check (1403 kg/ha) which was statistically at par with T_{10} (1519 kg/ha), T_1 (1537 kg/ha) and T_4 (1567 kg/ha). The reduction in yield in previously mentioned treatments might be attributed to poor weed control.

Based on the present investigation, it could be concluded that foliar spray of glyphosate @ 25 and 50 g/ha + 1.0% $(NH_4)_2SO_4$ at 25 and 55 DAS, respectively either with 100 or 125 % recommended dose of fertilizer successfully eliminate broomrape and was found adequate for realizing higher yields in Indian mustard fields infested with Egyptian broomrape.

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Effect of establishment methods and varieties on yield and economics of linseed in vertisols

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ABSTRACT

The field experiment on the effect of establishment methods and varieties on yield components, yield and economics of linseed was undertaken in Vertisols during *rabi* season of 2013-14 and 2014-15. The experiment was laid out in split plot design with allocation of methods of establishment in main plot and varieties in sub plot. The treatments were replicated four times. The treatments comprised of three methods of establishment i.e. M_1: Dry seeding with planking followed by irrigation, M_2: Dry seeding without planking followed by irrigation and M_3: Seeding after pre-sowing irrigation and four varieties i.e. V_1: T 397 (National check), V_2: RLC 92, V_3: Indira Alsi 32 and V_4: Shekhar. Linseed sowing by dry seeding with planking followed by irrigation (M_1) gave higher plant population, enhanced the growth and yield attributes which in turn resulted in significantly higher seed yield (1298 kg/ha) as well as net income (₹37938/ha) amongst methods of establishment. With respect to varieties, RLC-92 (V_2) showed good crop stand establishment, highest oil content (41.4%) and produced vigorous growth and superior yield attributes and highest seed yield (1293 kg/ha) of linseed as well as accrued handsome net profits (₹37872/ha) and B:C ratio (1.91). The interaction effect among the methods of establishment and varieties was found non-significant in terms of yield and important yield attributing characters.

Keywords: Establishment method, Linseed, Oil content, Varieties, Yield

Linseed [*Linum usitatissimum* (L.)] is highly nutritious, unique and emerging among oilseeds for its technical grade vegetable oil and good quality fibre producing ability. Linseed oil is an excellent dyeing oil used in manufacturing paints, varnishes, soaps, printing inks, oil, cloth and linoleum tiles (Rowland *et al.,* 1995; Sarkar and Sarkar, 2017; Biradar *et al.,* 2016). Oilseeds are the second largest agricultural commodity after cereals sharing 14% of gross cropped area, 6% of gross national product and 10% of the agriculture product value in the country. The demand, supply and gap of edible oil in India are 18.94, 10.08 and 8.86 (47%) m.t., respectively (Anonymous, 2015a).

Chhattisgarh having third highest yield gap between improved technology and farmer's practice in irrigated condition (Singh *et al.,* 2015). Chhattisgarh is one of the important linseed growing state of India and have 0.026 m.ha, 0.011 mt and 423 kg/ha area, production productivity, respectively. Its productivity is low in Chhattisgarh (423 kg/ha) as compared to national (498 kg/ha) and global (877 kg/ha) (Anonymous, 2015b). The major reasons for low productivity of linseed could be the adoption of primitive sowing method i.e. relay cropping locally known as *Utera* and perpetual scarcity of basic agro-inputs like improved varieties, irrigation, fertilizers etc. Linseed is being produced under rainfed, low input and poor management. Concerning fertilizer utilization for linseed production, 89% of the farmers applied neither organic nor inorganic fertilizer (Abebe *et al.,* 2011).

Early and uniform establishment is paramount to the success of linseed crop for a number of reasons. Delay in emergence can result in highly non-uniform stands as plants emerged late are shorter and at a competitive disadvantage. Stand uniformity is influenced by seed placement and seed bed preparation. Lafond *et al.* (1996) and Robert (1998) suggested that seeding depth and seedbed preparation may be two important factors influencing fibre flax (Linseed) production. Seed placement plays a major role in the time to emergence of linseed seed and may also impact seedling vigour (Coulture *et al.,* 2004). In order to maximize the use of natural resources, the appropriate establishment method is very important since it ensures good seed germination as well as timely emergence of seedlings and the optimum development of the root system. Seed-to-soil contact is essential in agricultural production systems where typically high levels of germination and emergence of crops is desirable (Lafond *et al.,* 1996; Channabasavanagouda *et al.,* 2018). In the recent years, many efforts have been devoted to increase the productivity of linseed through improving the best cultural practices such as establishment methods and varieties for improving the productivity and quality of linseed (Sharma *et al.,* 2017). In India, many attempts have made to maximize total production of oil crops to bridge the gap between local production and consumption from edible vegetable oils by improving cultivation of linseed. The present level of seed replacement of old traditional varieties

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is only 6-8% which should at least 15-20% (Chauhan *et al.,* 2008). Due to gap between production and consumption, it is necessary to increase linseed productivity per unit area which could be achieved by using cultivars with high yield potential and the improved agricultural practices (Hussein, 2007; Ibrahim, 2009). Proper agronomic management is very important for maximization of linseed yield. Among the management practices, establishment methods and varieties are the most important and powerful factors that influence the yield. The present study was therefore carried out, to determine appropriate method of establishment and variety of linseed.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* seasons of 2013-14 and 2014-15 at the Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (21°4 N latitude, 81°35 E longitude and 290.20 meter above mean sea level) under Chhattisgarh plains. The experiment was laid out in split plot design with four replications and twelve treatments. Methods (M_1, M_2, M_3) of establishment was taken as main plot treatments and varieties (V_1 to V_4) as sub-plot treatments. The treatments consisted of three method of establishments M_1: Dry seeding with planking followed by irrigation, M_2: Dry seeding without planking followed by irrigation and M_3: Seeding after pre-sowing irrigation and four varieties i.e. V_1: T 397 (National check), V_2: RLC 92, V_3: Indira Alsi 32 and V_4: Shekhar. Linseed was planted on 18th November, 2013; 15th November, 2014 and harvested on 10th March, 2014; 7th March, 2015, respectively. All the recommended agronomic management practices were followed except the treatments. The experimental soil was clayey in texture, neutral in pH (6.68), normal in EC (0.18) and had low in available N (226 kg/ha), medium in available P (12.64 kg/ha), high in available K (367 kg/ha) and medium organic carbon (0.50%). Disease or insect control chemicals were not applied during the growth of linseed. Seed samples were collected from each plot for oil analysis with the adoption of standard procedures. Standard procedures were adopted for recording the data on various growth and yield parameters. Data collected were statistically analyzed by using the procedure suggested by the Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth and yield attributes: As the data from two years did not differ significantly, pooled analysis of the data (2013-14 and 2014-15) was carried out and the same is presented in Table 1. This analysis showed significant effects of establishment methods and varieties on growth and yield attributes of linseed. Among the establishment methods, dry seeding with planking followed by irrigation (M_1) exhibited the maximum and significantly higher plant population (initial and harvest) plant height (at harvest), primary branches/plant (at harvest) and capsule/plant and this was on par with M_2 (dry seeding without planking followed by irrigation). The dry matter accumulation (at harvest) was found significantly higher with dry M_1. The lowest value of above parameters was observed with the treatment of seeding after pre-sowing irrigation (M_3). Number of seeds/capsule and test weight did not differ statistically among methods of establishment. The significant results with M_1 treatment may be due to fine seedbed which provides proper seed-to-soil contact and availability of soil moisture as well as nutrients during initial stage in the root zone. Significant differences were detected among crop establishment practices by Robert (1998) and Abd El-Mohsen *et al.* (2013). With respect to varieties, RLC-92 (V_2) exhibited significantly higher plant population (initial and harvest), plant height (at harvest), dry matter accumulation (at harvest), primary branches/plant (at harvest) and test weight. Variety Shekhar (V_4) was found at par with RLC-92 with respect to plant population, dry matter accumulation and test weight. The number of seeds/capsule was significantly higher with variety RLC-92 (V_2) which was found at par with the variety T 397 (V_1) and Shekhar (V_4). Variety Shekhar (V_4) was found significantly superior with respect to capsules/plant. Among the varieties, Indira Alsi 32 (V_3) showed lowest values for all characters. Chauhan *et al.* (2008), Mirshekari *et al.* (2012) and Abd El-Mohsen *et al.* (2013) also reported significant differences among linseed genotypes. However, there was no significant interaction effects found between plating methods and genotypes for the growth and yield attributes.

Yield, oil content and economics: Crop yield is a function of environmental, genetic, morphological and physiological characters and their interactions. In the present study, pooled analysis of results over two years, with respect to methods of establishment and varieties showed significant differences (P=0.05). Among the method of establishment, although dry seeding with planking followed by irrigation (M_1) produced the maximum and significantly higher seed and stover yield, it was found comparable with dry seeding without planking followed by irrigation (M_2) and they proved significantly superior to seeding after pre-sowing irrigation (M_3) (Table 2). Significant differences of crop establishment practices were also detected by Robert (1998) and Abd El-Mohsen *et al.* (2013). Among the varieties, RLC-92 (V_2) showed significantly higher seed and stover yield and it was on par with Shekhar (V_4) but differed from T 367 and Indra Alsi. In case of oil content, variety RLC-92 (V_2) exhibited highest content and it proved significantly superior over rest of the varieties. Variety Shekhar (V_4) produced lowest oil content. Chauhan *et al.* (2008), Mirshekari *et al.* (2012) and Abd El-Mohsen *et al.* (2013) opined that different varieties have different yield and oil content potentials. Methods of

establishment did not exert any significant impact on oil content. Among the methods of establishment, dry seeding without planking followed by irrigation (M_2) gave the highest benefit: cost ratio and it was followed by dry seeding with planking followed by irrigation (M_1) and seeding after pre-sowing irrigation (M_3) in descending order. Among varieties, RLC-92 (V_2) gave the highest gross returns, net returns, and B:C ratio, while these computations were the minimum in Indira Alsi 32 (V_3) except for gross returns. The results are corroborated with the findings of Mirshekari *et al.* (2012). No significant interaction effects were observed between planting methods and the yield and oil content.

Dry seeding of linseed with planking followed by irrigation (M_1) produced higher values of growth, yield attributes and seed yield (1298 kg/ha) accompanied by highest net profits (₹37,938/ha). Whereas, highest B:C ratio was obtained with dry seeding without planking followed by irrigation (M_2), which was due to omission of leveling cost. Among different varieties, RLC-92 (V_2) showed good stand establishment, highest oil content (41.4%) and produced vigorous growth and superior yield attributes which in turn resulted in highest seed yield (1293 kg/ha) as well as accrued handsome net profits (₹37,872/ha) and B:C ratio (1.91).

Table 1 Effect of linseed establishment methods and varietal performance on plant population, plant height, dry matter accumulation, primary branches, no. of seeds/capsule, capsules/plant and test weight (Pooled mean)

Treatment	Plant Population/m^2		Plant height at harvest (cm)	Dry matter accumulation at harvest (g)	Primary branches/ plant at harvest	No. of seeds/ capsule	Capsules/ plant	Test wt (g)
	Initial	at harvest						
Method of Establishment								
M_1	139.7	119.5	60.5	9.4	5.2	7.4	47.4	7.73
M_2	136.0	118.3	58.0	8.2	4.9	7.3	45.6	7.58
M_3	109.1	89.6	54.4	7.2	4.7	7.2	44.0	7.28
SEm±	3.05	2.94	0.91	0.20	0.12	0.16	0.64	0.12
CD (0.05)	10.92	10.59	3.28	0.73	0.43	NS	2.4	NS
Varieties								
V_1	126.8	107.4	56.2	7.8	4.8	7.3	44.7	7.32
V_2	135.7	116.6	61.8	9.3	5.5	7.7	48.9	7.98
V_3	120.0	99.9	54.7	7.4	4.5	6.8	42.0	7.09
V_4	130.5	112.7	57.8	8.5	4.9	7.4	66.6	7.73
SEm±	2.85	3.09	1.00	0.34	0.14	0.26	1.68	0.16
CD (0.05)	8.19	8.89	2.88	0.99	0.38	0.73	4.82	0.45

M_1: Dry seeding with planking followed by come up irrigation, M_2: Dry seeding without planking followed by come up irrigation and M_3: Seeding after pre-sowing irrigation; V_1: T 397 (National check), V_2: RLC 92, V_3: Indira Alsi 32 and V_4: Shekhar. Interaction effects were non-significant and therefore not mentioned.

Table 2 Effect of linseed establishment methods and varietal performance on test weight, seed yield, stover yield, oil content, gross returns, net returns and B:C ratio (Pooled mean)

Treatment	Seed yield (kg/ha)	Stover yield (kg/ha)	Oil content (%)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
Method of Establishment						
M_1	1298	3494	38.8	58002	37938	1.88
M_2	1261	3340	38.9	56283	36969	1.99
M_3	1069	2758	38.6	47663	27599	1.37
SEm±	18.43	66.84	0.16	-	-	-
CD (0.05)	68.89	251.59	NS	-	-	-
Varieties						
V_1	1188	3168	37.9	53065	33251	1.68
V_2	1293	3372	41.4	57686	37872	1.91
V_3	1127	3011	39.1	54321	30507	1.54
V_4	1229	3239	36.9	54858	35044	1.77
SEm±	26.58	66.44	0.14	-	-	-
CD (0.05)	76.33	190.97	0.41	-	-	-

M_1: Dry seeding with planking followed by come up irrigation, M_2: Dry seeding without planking followed by come up irrigation and M_3: Seeding after pre-sowing irrigation; V_1: T 397 (National check), V_2: RLC 92, V_3: Indira Alsi 32 and V_4: Shekhar. Interaction effects were non-significant and therefore not mentioned.

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Evaluation of biocontrol potential of thermotolerant *Trichoderma* and Pseudomonas against seed and soil borne diseases of safflower

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ABSTRACT

A field experiment was conducted for two consecutive *rabi* seasons from 2012-13 to 2013-14 to evaluate the biocontrol potential of a thermotolerant *Trichoderma* strain (Th4d) and a *Pseudomonas* strain (P1) as seed dressers for management of seed and soil borne diseases of safflower. Among different seed treatments, carbendazim 50% WP @ 2g/kg seed recorded the least incidence of Macrophomina root rot (7.71%), Fusarium wilt (9.50%) and Phytophthora seedling blight (12.05%) followed by *Trichoderma harzianum* Th4d SC @ 2ml/kg seed (8.84%, 11.09% and 14.95%), *Trichoderma harzianum* Th4d WP @ 10g/kg seed (10.11%, 12.03% and 15.93%) and *Pseudomonas* sp. P1 WP @ 5g/kg seed (10.59%, 12.32% and 17.07%) . Moreover, seed treatment with carbendazim 50% WP @ 2g/kg seed recorded highest seed yield (806 kg/ha) and Benefit: Cost ratio of 1.84 followed by *T. harzianum* Th4d SC @ 2 ml/kg seed (770 kg/ha, 1.76), *T. harzianum* Th4d WP @ 10g/kg seed (743 kg/ha, 1.70) and bacteria P1 WP @ 5g/kg seed (691 kg/ha, 1.58) which were statistically at par with each other. The overall results indicated that for effective and economical management of the seed/soil borne diseases of safflower and getting higher seed yield, it is recommended to treat the safflower seed before sowing with carbendazim 50% WP @ 2 g/kg or *Trichoderma harzianum* Th4d SC @ 2ml/kg or *Trichoderma harzianum* Th4d WP @ 10g/kg or *Pseudomonas* sp. P1 WP @ 5g/kg seed.

Keywords: Bioagents, Fungicide, Fusarium, Macrophomina, Phytophthora, Safflower

Safflower (*Carthamus tinctorius* L.) is an important oilseed crop grown in *rabi* season on residual soil moisture. The wilt of safflower caused by *Fusarium oxysporum* f.sp. *carthami* is an important disease of safflower leading to yield losses as high as 80% (Kalpana Sastry *et al.,* 1993; Suresh *et al.,* 2016). The disease is reported to be seed transmitted to a tune of 10-40 per cent and the fungus perpetuates as mycelium and spores on the seed and seed coat or as chlamydospores in plant debris in soil (Chakrabarti, 1980). The fungus is specific in its pathogenicity on safflower and six other species of *Carthamus* (Klisiewicz and Houston, 1963). The soil borne, *Macrophomina* sp., cause root rot in safflower leading to considerable yield losses (Kore and Deshmukh, 1981; Gholve *et al.,* 2017). Damping off and seedling blight of safflower is caused by Phytophthora in the event of continuous rains during seed germination and seedling stage. The most common mode of infection was observed in the terminal bud or in young leaves of 12 to 15 days old seedlings starting as a small brown water-soaked lesion which spreads rapidly to the entire seedlings manifesting as blighting symptoms characterized by the water-soaked and shrunken appearance of the affected portion. The disease has been reported to cause seed yield losses to the tune of 25 to 93 per cent (Anonymous, 2015). Incidence of the disease is known to be high during cloudy days when the temperature falls below 25°C. High level of humidity is known to favour rapid spread of the disease and losses amounting to over 75 per cent, sometimes up to as high as 90 to 95 per cent. With this view, the present investigation was undertaken to evaluate the biocontrol potential of a few *Trichoderma* and a *Pseudomonas* strains as seed dressers for management of seed and soil borne diseases of safflower.

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MATERIALS AND METHODS

A field experiment was conducted in randomized block design with three replications during two consecutive *rabi* seasons from 2012-13 to 2013-14 to evaluate the biocontrol potential of two high temperature tolerant Trichoderma isolates *viz., Trichoderma asperellum* TaDOR 7316 and *Trichoderma longibrachiatum* TaDOR 673 (Sowmya *et al.,* 2014 and Sowmya *et al.,* 2016), a *Trichoderma harzianum* Th4d isolate having known biocontrol potential and commercialized by ICAR-Indian Institute of Oilseeds Research, two unidentified thermotolerant bacteria (*Pseudomonas* sp. P1 and P8) strains and *Pseudomonas fluorescens* Pf2 for management of seed and soil borne diseases of safflower like Macrophomina root rot, Fusarium wilt and Phytophthora seedling blight. The safflower variety, SSF-708 was sown during 2nd fortnight of September at 45 x 20 cm spacing with the gross plot size of 2.25 x 4.0 m and net plot size of 1.35 x 3.60 m and 50:25 kg N and P_2O_5 were applied at the time of sowing as basal dose. There were ten seed treatments (ST) as indicated below:

T_1: ST with *Trichoderma harzianum* Th 4d SC @ 2 ml/kg seed
T_2: ST with *Trichoderma harzianum* Th 4d WP @ 10 g/kg seed
T_3: ST with *Trichoderma asperellum* TaDOR 7316 WP @ 10 g/kg seed
T_4: ST with *Trichoderma longibrachiatum* TaDOR 673 WP @ 10 g/kg seed
T_5: ST with *P. fluorescens* Pf2 WP @ 5g/kg seed
T_6: ST with *Pseudomonas* sp. P8 WP @ 5 g/kg seed
T_7: ST with *Pseudomonas* sp. P1 WP @ 5 g/kg seed
T_8: ST with carbendazim 50% WP @ 2 g/kg seed
T_9: ST with captan 50% WP @ 3 g/kg seed
T_{10}: Untreated check

Overnight soaking of safflower seeds in the spore suspension of *Trichoderma harzianum* Th4d SC and solution of *T. harzianum* Th4d WP, *T. asperellum* TaDOR 7316, *T. longibrachiatum* TaDOR 673 WP, *P. fluorescens* Pf2 WP and *Pseudomonas* sp. P8/P1 WP was done before sowing and after drying in shade, the treated seeds were sown in the field. The fungicidal seed treatment was given at the time of sowing as per the standard procedures

The incidence of Macrophomina root rot, Fusarium wilt and Phytophthora seedling blight was recorded using 1-9 scale (Anonymous, 2012). The seed yield was recorded at harvest. The data on the incidence of Macrophomina root rot, Fusarium wilt and Phytophthora seedling blight and the seed yield was subjected to statistical analysis by employing standard methods of analysis of variance (Panse and Sukhatme, 1985).

RESULTS AND DISCUSSION

The pooled data on the incidence of Macrophomina root rot, Fusarium wilt and Phytophthora seedling blight of safflower as influenced by seed treatment with either chemical or biological agents are presented in Table 1. Among different seed treatments, carbendazim 50% WP @ 2g/kg seed recorded the least incidence of Macrophomina root rot (7.7%), Fusarium wilt (9.5%) and Phytophthora seedling blight (12.0%) followed by *Trichoderma harzianum* Th4d SC @ 2 ml/kg seed (8.8%, 11.0% and 14.9%), *Trichoderma harzianum* Th4d WP @ 10g/kg seed (10.1%, 12.0% and 15.9%) and *Pseudomonas* P1 WP @ 5g/kg seed (10.5%, 12.3% and 17.0%) which were statistically indistinguishable.

Amongst thermotolerant *Trichoderma* isolates, *Trichoderma longibrachiatum* TaDOR 673 WP @ 10g/kg seed recorded the least incidence of Macrophomina root rot (11.06%), Fusarium wilt (13.97%) and Phytophthora seedling blight (27.21%) followed by *Trichoderma asperellum* TaDOR 7316 WP @ 10g/kg seed (11.95%, 14.20% and 27.54% respectively), which were statistically at par with each other. Moreover, among thermotolerant bacterial isolates, bacteria P1 WP @ 5g/kg seed recorded the least incidence of Macrophomina root rot (10.5%), Fusarium wilt (12.3%) and Phytophthora seedling blight (17.0%) followed by *Pseudomonas* P8 WP @ 5g/kg seed (11.55%, 13.13% and 28.86% respectively), which were statistically insignificant.

The pooled results on seed yield of safflower (Table 2) indicated that seed treatment with carbendazim 50% WP @ 2g/kg seed recorded highest seed yield (806 kg/ha) followed by *T. harzianum* Th4d SC @ 2 ml/kg seed (770 kg/ha), *T. harzianum* Th4d WP @ 10 g/kg seed (743 kg/ha) and bacteria P1 WP @ 5g/kg seed (691 kg/ha) which were statistically at par with each other. The untreated check, on the other hand, recorded the lowest seed yield (487 kg/ha). Moreover, among different thermotolerant Trichoderma and bacterial isolates, *Pseudomonas* P1 WP @ 5g/kg seed recorded highest seed yield (691 kg/ha) followed by *Trichoderma longibrachiatum* TaDOR 673 WP @ 10g/kg seed (608 kg/ha) which were statistically indistinguishable. The cost-benefit analysis of different seed treatments (Table 2) showed that seed treatment with carbendazim 50% WP @ 2g/kg seed recorded the highest net monetary returns of ₹ 11,037/- and B:C ratio of 1.84 followed by *T. harzianum* Th4d SC @ 2 ml/kg seed (₹ 9,968/-, 1.76), *T. harzianum* Th4d WP @ 10 g/kg seed (₹ 9,143/-, 1.70) and Pseudomonas P1 WP @ 5g/kg seed (₹ 7,588/-, 1.58).

Results of the present investigation revealed that the most effective and economical management of the seed/soil borne diseases of safflower like Macrophomina root rot, Fusarium wilt and Phytophthora seedling blight and higher seed yield was by treating the safflower seed before sowing with carbendazim 50% WP@ 2 g/kg or *Trichoderma harzianum* Th4d SC @ 2ml/kg or *Trichoderma harzianum* Th4d WP @ 10g/kg or thermotolerant bacteria P1 WP @ 5g/kg seed. Prasad and Anjani (2008) reported that seed treatment with *Trichoderma harzianum* and *T. viride* @ 10g/kg seed was found very effective in reducing wilt incidence and increasing seed yield under field conditions. Moreover, Prasad and Suresh (2012) reported that seed treatment with carbendaim @ 1g/kg seed or *Trichoderma viride* @ 10g/kg seed or thiram @ 3g /kg + *T. harzianum* + *T. viride* (1:1) @ 4g/kg seed have been found effective against seed/soil borne pathogens of safflower. Furthermore, Sowmya *et al.* (2014) reported the antagonistic activity of highly efficient thermotolerant strains of Trichoderma against *Sclerotium rolfsii. Trichoderma viride* has been reported to be potent in managing Rhizoctonia root rot of safflower (Prashanti *et al.,* 2000). Howell (2003) reported that the antagonism of *Trichiderma* spp. against many fungi is mainly due to production of trichodermin, a major volatile antibiotic which suppress several plant pathogens. Pawar *et al.* (2013) reported that *Trichoderma harzianum* Th4d WP @ 10g/kg seed was found to be effective for the management of seed/soil borne diseases of safflower. Also, Indi *et al.* (2016) reported that carbendazim 12% + mancozeb 63% @ 2 g/kg or *Trichoderma harzianum* Th4d SC @ 2 ml/kg seed was found to be effective for the management of seed/soil borne diseases of safflower. Furthermore, Murumkar *et al.* (2016) reported that cymoxanil 8% + mancozeb 64% @ 2 g/kg or *Trichoderma harzianum* Th4d SC @ 1 ml/kg seed was found

to be effective for the management of Phytophthora seedling blight of safflower. The results of the present investigation are also in agreement with these findings.

From the above study, it could be concluded that for effective and economical management of the seed/soil borne diseases of safflower like Macrophomina root rot, Fusarium wilt and Phytophthora seedling blight and getting higher seed yield, seed treatment with carbendazim 50% WP @ 2 g/kg or *Trichoderma harzianum* Th4d SC @ 2ml/kg or *Trichoderma harzianum* Th4d WP @ 10g/kg or Pseudomonas P1 WP @ 5g/kg seed could be followed.

Table 1 Evaluation of biocontrol potential of thermotolerant *Trichoderma* and bacteria against seed and soil borne diseases of safflower (Pooled data: 2012-13 and 2013-14)

Treatment	Macrophomina root rot incidence (%)			Fusarium wilt incidence (%)			Phytophthora seedling blight incidence (%)		
	2012-13	2013-14	Mean	2012-13	2013-14	Mean	2012-13	2013-14	Mean
ST with *Trichoderma harzianum* Th 4d SC @ 2 ml/kg seed	7.22 (15.44)	10.46 (18.84)	8.84 (17.14)	10.77 (18.90)	11.41 (19.70)	11.09 (19.30)	12.75 (20.87)	17.15 (24.18)	14.95 (22.53)
ST with *Trichoderma harzianum* Th 4d WP @ 10 g/kg seed	8.80 (17.10)	11.41 (19.73)	10.11 (18.42)	12.36 (20.43)	11.69 (19.97)	12.03 (20.20)	13.96 (21.94)	17.89 (24.95)	15.93 (23.45)
ST with *Trichoderma asperellum* TaDOR7316 WP @ 10 g/kg seed	10.62 (18.81)	13.27 (21.34)	11.95 (20.08)	11.41 (19.70)	16.98 (24.26)	14.20 (21.98)	27.51 (31.62)	27.56 (31.64)	27.54 (31.63)
ST with *T. longibrachiatum* TaDOR 673 WP @ 10 g/kg seed	10.84 (19.20)	11.27 (19.59)	11.06 (19.40)	12.48 (20.67)	15.45 (23.03)	13.97 (21.85)	27.67 (31.66)	26.75 (31.09)	27.21 (31.38)
ST with *P. fluorescens* Pf2 WP @ 5g/kg seed	9.85 (18.28)	12.12 (20.36)	10.99 (19.32)	12.89 (21.00)	18.68 (25.59)	15.79 (23.30)	22.65 (28.32)	27.56 (31.64)	25.11 (29.98)
ST with *Pseudomonas* sp. P8 WP @ 5 g/kg seed	10.94 (18.99)	12.15 (20.35)	11.55 (19.67)	13.22 (21.31)	15.48 (23.11)	13.13 (21.01)	29.41 (32.77)	28.30 (32.11)	28.86 (32.44)
ST with *Pseudomonas* sp. P1 WP @ 5 g/kg seed	9.26 (17.70)	11.91 (20.15)	10.59 (18.93)	11.41 (19.70)	13.22 (21.31)	12.32 (20.51)	16.98 (24.26)	17.15 (24.18)	17.07 (24.22)
ST with carbendazim 50% WP @ 2 g/kg seed	7.94 (16.23)	7.48 (15.84)	7.71 (16.04)	7.31 (15.64)	11.69 (19.97)	9.50 (17.81)	10.13 (18.54)	13.96 (21.94)	12.05 (20.24)
ST with captan 50% WP @ 3 g/kg seed	9.75 (18.18)	12.02 (20.26)	10.89 (19.22)	11.41 (19.70)	16.98 (24.26)	14.20 (21.98)	22.65 (28.32)	25.72 (30.44)	24.19 (29.38)
Untreated check	14.22 (22.13)	17.47 (24.67)	15.85 (23.4)	15.16 (22.90)	24.91 (29.91)	20.10 (26.41)	39.07 (38.66)	37.73 (37.87)	38.40 (38.27)
S.Em.±	1.53	0.39	0.96	1.25	0.79	1.02	1.66	1.18	1.42
C.D. (p=0.05)	4.6	1.17	2.89	3.73	2.37	3.05	4.99	3.53	4.26
C.V. (%)	14.58	3.36	8.97	10.80	5.74	8.27	10.24	6.84	8.54

Table 2 Seed yield and benefit cost ratio in safflower as influenced by seed treatment of thermotolerant *Trichoderma* and bacteria (Pooled data: 2012-13 and 2013-14)

Treatment	Seed yield (kg/ha)			Benefit : Cost analysis			
	2012-13	2013-14	Mean	Gross returns (₹/ha)	Cost of cultivation (₹ ha)	Net returns (₹/ha)	B:C ratio
ST with *Trichoderma harzianum* Th4d SC @ 2 ml/kg seed	725	815	770	23100	13132	9968	1.76
ST with *Trichoderma harzianum* Th4d WP @ 10 g/kg seed	695	790	743	22275	13132	9143	1.70
ST with *Trichoderma asperellum* TaDOR7316 WP @ 10 g/kg seed	540	630	585	17550	13132	4418	1.34
ST with *T. longibrachiatum* TaDOR 673 WP @ 10 g/kg seed	580	635	608	18225	13132	5093	1.39
ST with *P. fluorescens* Pf2 WP @ 5g/kg seed	530	610	570	17100	13144	3956	1.30
ST with *Pseudomonas* sp. P8 WP @ 5 g/kg seed	525	572	549	16455	13144	3311	1.25
ST with *Pseudomonas* sp. P1 WP @ 5 g/kg seed	638	744	691	20732	13144	7588	1.58
ST with carbendazim 50% WP @ 2 g/kg seed	785	826	806	24165	13128	11037	1.84
ST with captan 50% WP @ 3 g/kg seed	594	695	645	19335	13128	6207	1.47
Untreated check	384	590	487	14609	13114	1495	1.11
S.E.±	49	53	51				
C.D. at 5 %	146	158	152				
C.V. (%)	14.3	12.0	13.1				

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Evaluation of botanicals against mustard aphid, *Lipaphis erysimi* (Kaltenbach) in Mid Hills of Meghalaya

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ABSTRACT

A field experiment was carried out at ICAR Research Complex for NEH Region, Umiam to evaluate some botanicals against mustard aphid *Lipaphis erysimi.* The experiment was laid out in randomized block design with eight treatments and three replications. The mustard seeds (cv. Varuna) was sown during third week of October. The treatments *viz.,* Bakain (*Melia azedarach*) leaf extract (5% aqueous solution), Lantana (*Lantana camara*) leaf extract (5% aqueous solution), Turmeric (*Curcuma longa*) rhizome powder (5% aqueous solution), Marigold (*Tagetes erecta*) leaf extract (5% aqueous solution), Vasaka (*Adhatoda vasica*) leaf extract (5% aqueous solution), chloropyrifos 20% EC (200 g a.i./ha) and imidacloprid 17.8% SL (25 g a.i./ha) along with control were applied at fifteen days interval. Results revealed that *Melia azedarach* was best among all botanicals with 50.5-61.9 per cent and 50.7-57.5 per cent reduction of aphid population during first and second spray, respectively. Next best treatment was *Adhatoda vasica* followed by *Curcuma longa, Lantana camara* and *Tagetes erecta.* Among all the treatments, chloropyrifos and imidacloprid recorded maximum reduction of aphid population after both the spray. Although all botanicals showed less toxicity towards non-target organisms whereas chlorpyriphos and imidacloprid were highly toxic to honey bees and coccinellid beetles.

Keywords: Aphid, Botanicals, Efficacy, Insecticides, *Lipaphis erysimi*, Mustard

Oilseed crops are the second most important determinant of agricultural economy, next to cereals. Among all of the oilseed crops, Indian mustard (*Brassica juncea: Brassicaceae*) occupied a great importance in agriculture. Rapeseed-mustard ranks second in area and production among all the oilseed crops after groundnut (Singh, 2013; Mukherjee, 2016). In India, the share of oilseeds is 14.1% out of the total cropped area and rapeseed-mustard occupies 3% of it (Shekhawat *et al.,* 2012) with a production of 1262 kg/ha in an area of 6.4 m.ha in 2013-14 (Anonymous, 2014). Indian mustard is used as a spice in all over the country apart from the oil production. In north-eastern India, it covers an area of 0.46 lakh ha and an average yield is 888 kg/ha (Munda *et al.,* 2006). In India, mustard production is lower compared to other crops due to many constraints, which effect the oil production of the country (Ganesh *et al.,* 2017). Among them, the major factor which attributed the lower yield is the damage caused by insect pests. Mustard aphid (*Lipaphis erysimi*) is one of the most serious, cosmopolitan pest which alone is responsible for severe reduction in yield varying from 35-73% and 5-6% reduction in oil content (Shylesha *et al.,* 2012). Aphids multiply very rapidly under favourable conditions on leaves, stems and inflorescence from where these pests suck the sap (Farooq and Tasawar, 2007). Due to the attack of aphids on *Brassica,* affected pods and seeds remain stunted (Devi *et al.,* 2002). Depending upon the season and localities the yield reduction of mustard due to mustard aphid varies from 30 to 40 per cent (Sultana *et al.,* 2009). The infestation of aphid on *B. juncea* continues till the harvesting starting from December (Bilashini *et al.,* 2007). For the management of this pest, growers generally rely upon the use of insecticides which create undesirable problems such as residues, development of resistance in the pest to insecticides, resurgence, environmental pollution, toxic effects on natural enemies etc. Moreover, the mustard crop harbours many natural enemies and pollinators in their ecosystem (Pande *et al.,* 2015). Continuous use of insecticides may be detrimental to these non-target organisms. Therefore, use of botanicals as well as plant extracts instead of chemical insecticides for the control of insect pests may be considered as a top most priority. The botanicals are more compatible with integrated pest management system as well as non-hazardous to human beings. Considering all these facts, the present experiment was conducted to evaluate some botanicals extracts against mustard aphid and natural enemies in mustard ecosystem.

MATERIALS AND METHODS

The field experiment was carried out at ICAR Research Complex for NEH Region, Umiam during *rabi* season of 2015-16 to evaluate some botanicals against mustard aphid. The experiment was laid out in randomized block design

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with eight treatments and three replications. The mustard seeds (variety: Varuna) was sown during third week of October. All the recommended agronomic management practices except plant protection were followed for raising the crop. The treatments *viz.,* Bakain (*Melia azedarach*) leaf extract (5% aqueous solution), Lantana (*Lantana camara*) leaf extract (5% aqueous solution),Turmeric (*Curcuma longa*) rhizome powder (5% aqueous solution), Marigold (*Tagetes erecta*) leaf extract (5% aqueous solution), Vasaka (*Adhatoda vasica*) leaf extract (5% aqueous solution), chloropyrifos 20% EC (200 g a.i./ha) and imidacloprid 17.8% SL (25 g a.i./ha) along with control were applied when infestation reached ETL level (30-35 aphid/twig) (Sahoo, 2012). Observation was taken from 10 cm apical shoot of inflorescence from ten randomly selected tagged plants /plot before spraying and 1, 3, 5, 7 and 15 days after spraying. Beneficial organisms like honey bee were counted at different time intervals of the day per minute per square metre in different plots (pre-and post-application of insecticides and botanicals). Number of the predators like ladybird beetles was counted from 5 randomly selected plants from each plot (pre-and post-application of insecticides). The data pertaining to various aspects were statistically analysed by using Fisher's method of ANOVA in randomized block design to work out the critical difference (CD) at 5% level of significance (Snedecor and Cochran, 1968).

RESULTS AND DISCUSSION

Effect of different treatments against mustard aphid: During first spray, there were significant differences among the treatments in reducing the aphid population. Among the botanicals *Melia azedarach* showed maximum reduction (50.54%) of aphid population followed by *Adhatoda vasica* (44.98%) after 1 day of spraying. The next best treatments were *Curcuma longa* (37.31%), *Lantana camara* (34.30%) and *Tagetes erecta* (30.33%). All the botanicals showed a gradual decrease in their efficacy against mustard aphid. Similar trends of bio-efficacy of these botanicals were observed against this pest even after 15 days of treatment (Table 1). Among all the treatments, imidacloprid 17.8 SL (25 g a.i./ha) gave the best result with 78.40% reduction of aphid population after 1 day of spraying followed by chloropyrifos 20 EC (200 g a.i./ha) treated plots (55.75%). Both the chemical insecticides maintained their superiority over other treatments up to 15 days of spraying. During second spray (Table 2), there were variances in the reduction of population among the treatments and retained the similar trend of efficacy as found during first spray. In the present experiment, *Melia azedarach* was found to be effective treatment among the botanicals. The toxic odour of the leaf extract may enter into the spiracle and block the oxygen supply or it may be the insects avoid the treated leaf foliage for longer time and without food after starvation the insects die. Results of *Melia azedarach* against mustard aphid are in agreement with Mekuaninte *et al.* (2011) who reported the deterrent properties of *Melia azedarach* leaf extract against cabbage aphid, *Bravicornye brassicae.* Debnath *et al.* (2015) reported that higher concentration of *M. azedarach* leaf extract caused a larval mortality of 53.17% in *Spodoptera litura. Adhatoda vasica* was also effective treatment against mustard aphid in the present experiment. Gyawali *et al.* (2015) reported that the effect of *Adhatoda vasica* was found gradually increased by increasing the strength of plant extract. Results of *Lantana camara* are in concurrence with the findings of Sable and Kushwaha (2014) who reported the effectiveness of lantana leaf extract against mustard aphid. Singh and Lal (2012) reported high mortality of mustard aphid with lantana leaf extracts treatment. Insecticidal activity of turmeric was found by Bushra *et al.* (2014) who reported that 3% turmeric powder extracts on *Sitobion avaenae* was effective. Efficacies of marigold against mustard aphid are in conformity with Ali *et al.* (2010). Chlorpyriphos was the very effective treatment after imidacloprid in the present experiment. Mandal *et al.* (2012) reported that chlorpyriphos and imidacloprid were effective treatments in reducing aphid population. Ahmed *et al.* (2007) reported that chlropyriphos was the best treatment against *L. erysimi* while Sharma and Kumar (2013) reported that imidacloprid very effective treatment against mustard aphid.

Effect of different treatments on honey bees: Effect of botanicals and chemical insecticides on honey bees are presented in Table 3 and 4 for first and second spray, respectively. There were no significant variances in honey bee count among the botanicals up to 15 days of spraying. During first spray, *Melia azedarach* treated plots, the honey bee count varied 2.37 to 2.49 honey bee/m^2/min from 1 to 15 days of spraying against pre-count of 2.40 honey bee/m^2/min. Post treatment counts of honey bees in case of *Lantana camara* (2.57 to 2.62 honey bee/m^2/min), *Curcuma longa* (2.15 to 2.20 honey bee/m^2/min), *Tagetes erecta* (1.92 to 1.96 honey bee/m^2/min) and *Adhatoda vasica* (2.43 to 2.52 honey bee/m^2/min) were at par with pre-treatment counts of 2.59, 2.16, 1.94 and 2.47 honey bee/m^2/min, respectively. On the other hand, post treatment counts of honey bees were very less in imidacloprid and chlorpyriphos treated plots. Imidacloprid treated plots recorded 0.18 to 0.43 honey bee/m^2/min against the pre-treatment count of 2.46 honey bee/m^2/min whereas chlorpyriphos recorded 0.43 to 0.62 honey bee/m^2/min against pre-treatment of 2.38 honey bee/m^2/min. Similar pattern were observed during second spray (Table 4), on number honey bees. In the present experiment, chlorpyriphos and imidacloprid recorded less number of honey bees after spraying. It may be due to repellent effect on honeybees after application of chlorpyriphos. Organophosphates and carbamates were

known to be highly toxic to honeybee workers when sprayed in cotton fields (Brar *et al.,* 1992). Carbaryl, oxydemeton methyl and imidacloprid were highly toxic and therefore, applied in the late evening with minimum hazard (Sihag, 1991). Scott-Dupree *et al.* (2009) reported that foliar applications of neonicotinoid insecticides, deltamethrin or spinosad affected bee foraging. Similarly, Atkins and Anderson (1967), who found that most organophosphates were highly toxic to bees, but some (profenophos) declined rapidly and almost, disappeared 5 days after application. The findings were in agreement with Sharma and Abrol (2014) who reported that imidacloprid treated plots showed a significant reduction of honey bee visit. For botanicals pesticides, there was no visible or significant reduction from pre-count to 15 days after treatment during both the sprays. There was no effect found of marigold on bees (Dodia *et al.,* 2007) while Singh *et al.* (2011) reported that Neem products, Achook was found least toxic to honey bees.

Table 1 Effect of different treatments against mustard aphid, *Lipaphis erysimi* in mustard (first application)

Treatments	Pre-treatment count	Per cent (%) reduction of aphid population at different days interval of spraying				
		1 DAT	3 DAT	5 DAT	7 DAT	15 DAT
Melia azedarach @5%	49.23 (44.56)	50.54 (45.31)	57.85 (49.52)	61.92 (51.90)	57.82 (49.50)	52.41 (46.38)
Lantana camara @5%	48.83 (44.33)	34.30 (35.82)	37.74 (37.89)	40.48 (39.49)	36.38 (37.07)	30.92 (33.72)
Curcuma longa @5%	50.43 (45.25)	37.31 (37.60)	41.33 (39.98)	43.80 (41.40)	38.40 (38.20)	35.01 (36.12)
Tegetus erecta @5%	49.80 (44.89)	30.33 (33.41)	34.35 (35.87)	36.36 (37.07)	30.32 (33.40)	28.97 (32.56)
Adhatoda vasica @5%	52.53 (46.45)	44.98 (42.12)	52.03 (46.16)	55.22 (48.00)	50.12 (45.07)	47.56 (43.60)
Chloropyrifos 20 EC @ 200 g a.i./ha	53.67 (47.10)	55.75 (48.31)	61.98 (51.93)	71.28 (57.64)	66.31 (54.56)	61.95 (51.95)
Imidacloprid 17.8 SL @ 25 g a.i./ha	53.67 (47.10)	78.40 (62.31)	80.52 (63.82)	83.62 (66.16)	76.79 (61.21)	70.56 (57.18)
Control (water spray)	49.53 (44.73)	0.00	0.00	0.00	0.00	0.00
SEm±	1.66	1.27	0.92	1.28	1.48	1.83
CD (p=0.05)	NS	3.84	2.79	3.88	4.49	5.54

Figures in the parenthesis are square root transformed values; DAT - Days after treatment

Table 2 Effect of different treatments against mustard aphid, *Lipaphis erysimi* in mustard (second application)

Treatments	Pre-treatment count	Per cent (%) reduction of aphid population at different days interval of spraying				
		1 DAT	3 DAT	5 DAT	7 DAT	15 DAT
Melia azedarach @5%	44.90 (42.07)	51.48 (45.86)	56.74 (48.33)	57.53 (49.34)	54.51 (47.60)	50.71 (45.41)
Lantana camara @5%	44.89 (42.07)	31.34 (33.93)	36.74 (37.21)	34.50 (35.85)	30.04 (33.05)	28.53 (32.05)
Curcuma longa @5%	46.23 (43.83)	34.59 (35.97)	39.71 (39.01)	41.75 (40.19)	38.22 (38.10)	36.86 (37.30)
Tegetus erecta @5%	44.97 (42.11)	31.72 (34.25)	35.37 (36.45)	37.60 (37.78)	33.81 (35.53)	30.58 (33.55)
Adhatoda vasica @5%	49.44 (44.68)	46.35 (42.90)	54.47 (47.57)	56.51 (48.76)	52.44 (46.40)	49.73 (44.84)
Chloropyrifos 20 EC @ 200 g a.i/ha	50.13 (45.08)	61.97 (51.93)	66.62 (54.72)	70.61 (57.18)	67.95 (55.53)	63.30 (52.71)
Imidacloprid 17.8 SL @ 25 g a.i./ha	51.19 (45.08)	81.94 (64.86)	83.17 (65.78)	85.79 (67.86)	81.21 (64.32)	74.68 (59.80)
Control (water spray)	46.37 (42.91)	0.00	0.00	0.00	0.00	0.00
SEm±	1.88	1.62	1.67	1.89	1.87	1.94
CD (p=0.05)	NS	4.93	5.06	5.73	5.66	5.88

Figures in the parenthesis are square root transformed values; DAT - Days after treatment

Table 3 Effect of different treatments on honey bees in mustard (first application)

Treatments	Pre-treatment count	Number of honey bee/m^2/min at different days interval of spraying				
		1 DAT	3 DAT	5DAT	10DAT	15DAT
Melia azedarach @5%	2.40 (1.69)	2.37 (1.68)	2.39 (1.69)	2.42 (1.70)	2.49 (1.72)	2.46 (1.71)
Lantana camara @5%	2.59 (1.76)	2.57 (1.75)	2.58 (1.75)	2.61 (1.76)	2.60 (1.76)	2.62 (1.76)
Curcuma longa @5%	2.16 (1.63)	2.15 (1.63)	2.19 (1.64)	2.20 (1.64)	2.18 (1.64)	2.19 (1.64)
Tegetus erecta @5%	1.94 (1.56)	1.93 (1.56)	1.96 (1.57)	1.94 (1.56)	1.92 (1.55)	1.93 (1.56)
Adhatoda vasica @5%	2.47 (1.72)	2.43 (1.71)	2.48 (1.73)	2.50 (1.73)	2.52 (1.74)	2.49 (1.73)
Chloropyrifos 20 EC @200 g a.i./ha	2.38 (1.70)	0.62 (1.06)	0.48 (0.99)	0.43 (0.97)	0.47 (0.98)	0.50 (1.00)
Imidacloprid 17.8 SL @ 25 g a.i/ha	2.46 (1.72)	0.43 (0.96)	0.18 (0.82)	0.20 (0.83)	0.22 (0.85)	0.25 (0.86)
Control (water spray)	2.66 (1.78)	2.66 (1.78)	2.69 (1.79)	2.68 (1.78)	2.71 (1.79)	2.70 (1.79)
SEm (±)	0.21	0.20	0.19	0.18	0.17	0.15
CD (p=0.05)	NS	0.62	0.58	0.55	0.50	0.47

Figures in the parenthesis are square root transformed values; DAT - Days after treatment

Table 4 Effect of different treatments on honey bees in mustard (second application)

Treatments	Pre-treatment count	Number of honey bee/m^2/min at different days interval of spraying				
		1 DAT	3 DAT	5 DAT	7 DAT	15 DAT
Melia azedarach @5%	1.94 (1.55)	1.92 (1.54)	1.90 (1.54)	1.88 (1.53)	1.79 (1.50)	1.81 (1.51)
Lantana camara @5%	1.59 (1.44)	1.58 (1.44)	1.59 (1.44)	1.56 (1.43)	1.50 (1.41)	1.46 (1.40)
Curcuma longa @5%	1.41 (1.38)	1.42 (1.38)	1.40 (1.37)	1.41 (1.38)	1.39 (1.37)	1.33 (1.35)
Tegetus erecta @5%	1.46 (1.40)	1.44 (1.39)	1.47 (1.40)	1.49 (1.41)	1.45 (1.40)	1.39 (1.37)
Adhatoda vasica @5%	1.61 (1.45)	1.60 (1.45)	1.58 (1.44)	1.58 (1.44)	1.56 (1.43)	1.52 (1.42)
Chloropyrifos 20 EC @200 g a.i./ha	1.39 (1.37)	0.52 (1.01)	0.41 (0.95)	0.28 (0.88)	0.30 (0.89)	0.36 (0.93)
Imidacloprid 17.8 SL @ 25 g a.i/ha	1.66 (1.46)	0.38 (0.94)	0.24 (0.86)	0.19 (0.83)	0.20 (0.83)	0.28 (0.88)
Control (water spray)	1.58 (1.44)	1.57 (1.43)	1.55 (1.43)	1.49 (1.41)	1.50 (1.41)	1.48 (1.40)
SEm (±)	0.26	0.22	0.22	0.21	0.18	0.17
CD (p=0.05)	NS	0.66	0.66	0.63	0.54	0.52

Figures in the parenthesis are square root transformed values; DAT - Days after treatment

Table 5 Effect of different treatments on *Coccinella* spp. in mustard (first application)

Treatments	Pre-treatment count	Number of coccinelids/plant at different days interval of spraying				
		1 DAT	3 DAT	5 DAT	7 DAT	15 DAT
Melia azedarach @5%	0.90 (1.18)	0.90 (1.18)	0.89 (1.17)	0.90 (1.18)	0.88 (1.17)	0.90 (1.18)
Lantana camara @5%	0.93 (1.19)	0.92 (1.19)	0.92 (1.19)	0.90 (1.18)	0.90 (1.18)	0.91 (1.18)
Curcuma longa @5%	0.83 (1.15)	0.81 (1.14)	0.82 (1.15)	0.81 (1.14)	0.80 (1.14)	0.82 (1.15)
Tegetus erecta @5%	0.87 (1.16)	0.87 (1.16)	0.85 (1.16)	0.86 (1.16)	0.87 (1.17)	0.86 (1.16)
Adhatoda vasica @5%	0.83 (1.15)	0.83 (1.15)	0.82 (1.14)	0.84 (1.15)	0.83 (1.15)	0.85 (1.16)
Chloropyrifos 20 EC @ 200 g a.i./ha	0.77 (1.13)	0.47 (0.98)	0.25 (0.87)	0.18 (0.83)	0.16 (0.81)	0.17 (0.82)
Imidacloprid 17.8 SL @ 25 g a.i./ha	0.79 (1.14)	0.42 (0.96)	0.22 (0.85)	0.13 (0.80)	0.10 (0.78)	0.13 (0.80)
Control (water spray)	0.80 (1.14)	0.80 (1.14)	0.79 (1.13)	0.80 (1.14)	0.81 (1.15)	0.82 (1.15)
SEm (±)	0.14	0.14	0.13	0.12	0.12	0.12
CD (p=0.05)	NS	0.43	0.39	0.38	0.36	0.36

Figures in the parenthesis are square root transformed values; DAT - Days after treatment

Table 6 Effect of different treatments on *Coccinella* spp. in mustard (second application)

Treatments	Pre-treatment count	Number of coccinelids/plant at different days interval of spraying				
		1 DAT	3 DAT	5 DAT	7 DAT	15 DAT
Melia azedarach @ 5%	0.87 (1.16)	0.87 (1.16)	0.89 (1.18)	0.91 (1.19)	0.91 (1.19)	0.88 (1.17)
Lantana camara @ 5%	0.83 (1.15)	0.84 (1.16)	0.87 (1.17)	0.88 (1.18)	0.89 (1.18)	0.85 (1.16)
Curcuma longa @ 5%	0.70 (1.09)	0.70 (1.09)	0.71 (1.10)	0.72 (1.10)	0.72 (1.10)	0.68 (1.09)
Tegetus erecta @ 5%	0.67 (1.07)	0.69 (1.09)	0.69 (1.09)	0.70 (1.09)	0.71 (1.10)	0.69 (1.09)
Adhatoda vasica @ 5%	0.77 (1.13)	0.77 (1.13)	0.78 (1.13)	0.78 (1.13)	0.77 (1.13)	0.74 (1.11)
Chloropyrifos 20 EC @ 200 g a.i./ha	0.69 (1.09)	0.46 (0.98)	0.37 (0.93)	0.30 (0.89)	0.28 (0.88)	0.21 (0.84)
Imidacloprid 17.8 SL @ 25 g a.i./ha	0.63 (1.06)	0.39 (0.94)	0.28 (0.88)	0.25 (0.87)	0.20 (0.84)	0.17 (0.82)
Control (water spray)	0.73 (1.11)	0.73 (1.11)	0.75 (1.12)	0.76 (1.12)	0.76 (1.12)	0.71 (1.10)
SEm (±)	0.09	0.08	0.07	0.07	0.07	0.05
CD (p=0.05)	NS	0.23	0.22	0.20	0.20	0.15

Figures in the parenthesis are square root transformed values; DAT - Days after treatment

Effect of different treatments on *Coccinella* spp. : Effect of different treatments on *Coccinella* spp. is presented in Table 5 and 6 for first and second spray, respectively. Number of *Coccinella* spp. varied significantly among the treatments during consecutive observation for the both the sprayings. Among botanicals, there were no significant differences between pre-treatments (0.83 to 0.93 and 0.67 to 0.87 coccinellids/plant) and post-treatment counts (0.81 to 0.92 and 0.69 to 0.87 coccinellids/plant) of *Coccinella* spp. during first and second spraying, respectively. It was cleared from the Table 5 and 6 that there was no adverse effect of botanicals on *Coccinella* spp. in mustard ecosystem. However, there was a drastic change in coccinellids population in chlorpyriphos and imidacloprid treated plots.

The corresponding values for chlorpyriphos were 0.16 to 0.47 and 0.21 to 0.46 coccinellids/plant against pre-treatments values of 0.77 and 0.69 coccinellids/plant, respectively. In imidacloprid treated plots, coccinellids population varied from 0.10 to 0.42 and 0.17 to 0.39 coccinellids/plant against pre-treatment counts of 0.79 and 0.63 coccinellids/plant during first and second spray, respectively. The present findings are in conformity with Maula *et al.* (2010) who reported that chlorpyriphos treated plots exhibited higher reduction of coccinellids whereas Aziz *et al.* (2014) reported that coccinellids count was reduced after application of imidacloprid. Bharpoda *et al.* (2012) reported that vasaka and neem leaf extract recorded the highest population and proved to be safer botanical against coccinellids. Patel *et al.* (2003) also revealed that the population of aphidophagous insects in various plots treated with Lantana extracts showed non-significant difference and the number of the predator was as good as that found in control, which suggested its safety to natural enemies.

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Studies on genetic variability in linseed (*Linum usitatissimum* L.)

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ABSTRACT

The field experiment was conducted during winter season of 2012-13 at C.S. Azad University of Agriculture and Technology, Kanpur with 73 genotypes including checks Shekhar and T-397 to study the genetic variability in linseed. A wide range of variability was observed for all the traits under study. The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) estimates were high for seed yield per plant and number of secondary branches per plant. High heritability was observed for all the traits except oil content and 1000-seed weight. High heritability coupled with high genetic advance as per cent of mean was recorded for seed yield per plant, number of secondary branches per plant, number of primary branches per plant and number of capsules per plant.

Keywords: Genetic advance, Heritability, Linseed, Variability

Linseed (*Linum usitatissimum* L.) is one of the most important non-edible oilseed crop grown in *rabi* season. It is a major source of omega-3 fatty acid, which is essential for human beings. India's total production of linseed is around 1.41 lakh tonnes from an area of 2.84 lakh hectare with a productivity of 502 kg/ha (Anonymous, 2017). The progress of any breeding programme depends upon the extent of genetic variability present in the genepool. Genetic variability along with heritability gives a reliable picture of the genetic advance to be expected for selection while the heritability coupled with genetic advance aids in predicting the valuable conclusion for effective selection based on phenotypic performance (Singh and Tewari, 2016). Keeping this in view, 73 genotypes of linseed were investigated to explore the genetic variability by determining the magnitude of genetic coefficient of variation, heritability estimates and expected genetic advance of different biometric traits in linseed.

The experimental material for the present study comprised of seventy three genotypes of linseed including checks Shekhar and T-397 collected from different places of the country. These genotypes were grown at Oilseed Research Farm, C.S. Azad University of Agriculture and Technology, Kanpur under rainfed condition in Randomized Block Design with three replications. In each replication genotypes were sown in a plot of 5.0 x 2.0 m^2 size accommodating one row of 5m length with eight rows. Observations were recorded on five randomly selected plants in each genotype replication wise for ten traits *viz.,* days to 50% flowering, plant height (cm), days to maturity, number of primary branches per plant, number of secondary branches per plant, number of capsules per plant, number of seeds per capsule, 1000-seed weight (g), oil content (%) and seed yield per plant (g). The data were statistically analysed using the mean values. The phenotypic and genotypic coefficient of variations was calculated as per Burton and Devane (1953). Heritability and genetic advance were estimated according to Johnson *et al.* (1955) and Allard (1960).

Our study indicated (Table 1) sufficient variability among the genotypes for all the traits implying ample scope for improving the traits. The estimates of phenotypic coefficient of variation (PCV) were little higher than genotypic coefficient of variation (GCV), which is an indicator of additive effect of environment on the expression of these traits (Table 2). Similar results were observed by Ram *et al.* (2010). Seed yield per plant exhibited maximum GCV and PCV followed by the traits, number of secondary branches per plant and number of primary branches per plant. Similar findings were also observed by Tewari and Singh (2014) and Kanwar *et al.* (2014). High phenotypic variations with high genetic variability for these traits showed less influence of environment. It suggested that phenotype alone may be effective for the improvement of these traits. On contrary, moderate GCV and PCV were recorded for number of capsules per plant, 1000-seed weight, plant height and days to 50% flowering. This indicated that little improvement could be expected for these traits. However, low estimates of variability were recorded for days to maturity and oil content. These results are in accordance with the findings of Reddy *et al.* (2013). The estimates of heritability act as predictive instrument in expressing the reliability of phenotypic value. Heritability is a good index of transmission of characters from parents to its progeny. The estimates of heritability help the plant breeder in selection of elite genotypes from diverse genetic populations. High heritability was observed for all the traits except oil content and number of seeds per capsule. High heritability of the above characters indicated that the influence of environment on these characters is low or negligible. Similar results have been reported by Reddy et al. (2013). The estimates of heritability alone, is not very much useful on predicting the resultant effect for selecting the best genotypes because it includes the effect of both additive as

well as non-additive gene interactions. High genetic advance only occurs due to additive gene action. So, heritability coupled with genetic advance would be more useful than heritability alone. On examining the estimate of genetic advance for different traits, it was observed that seed yield per plant had high genetic advance as percentage of mean and was followed by number of secondary branches per plant, number of capsules per plant, number of primary branches per plant and 1000-seed weight. High heritability coupled with high genetic advance as per cent of mean was recorded for seed yield per plant, number of secondary branches per plant, number of capsules per plant, number of primary branches per plant and 1000-seed weight. Similar results were also reported by Kanwar *et al.* (2014). These characters representing high values of heritability and genetic advance are the ideal traits for improvement through selection. Since the additive gene action is involved in inheritance of these traits, hence, it is suggested that linseed breeder should give more emphasis on the selection process for these traits to accumulate favourable genes to realize high yielding genotypes in linseed.

Table 1 Analysis of variance (ANOVA) for different characters in linseed

Character	MS (Rep)	MS (Treat)	MS (Error)
Days to 50% flowering	2.458**	2.290**	1.413
Plant height (cm)	1.792**	2.391**	1.138
Days to maturity	1.547**	2.150**	1.144
No. of primary branches/plant	1.721**	1.761**	1.774
No. of secondary branches/plant	1.711**	2.708**	1.739
No. of capsules/plant	1.740*	2.180**	1.669
No. of seeds/capsule	1.354**	1.246**	1.649
1000-seed weight (g)	1.170**	2.824**	1.369
Oil content (%)	1.625*	1.112**	1.246
Seed yield/plant (g)	1.111*	2.250**	1.348

Table 2 Estimates of variability, heritability and genetic advance for ten characters in linseed

Character	Mean	Range	PCV (%)	GCV (%)	Heritability	GA	GA as% of mean
Days to 50%flowering	70.09	45.0-85.0	14.23	13.93	95.8	19.69	28.02
Plant height (cm)	63.29	41.67-90.0	18.67	17.72	90.1	21.94	34.67
Days to maturity	137.0	123.0-151.0	5.65	4.92	76.0	12.11	8.84
No. of primary branches/plant	6.61	4.0-12.0	26.45	22.85	74.6	2.69	40.70
No. of secondary branches/plant	25.74	13.0-46.0	30.55	28.67	88.1	14.27	55.44
No. of capsules/plant	114.68	64.6-186.3	22.17	20.99	89.6	46.93	40.92
No. of seeds/capsule	8.07	6.33-9.33	13.88	9.63	48.2	1.11	13.75
1000-seed weight (g)	7.75	4.00-11.90	22.34	20.91	87.7	3.13	40.39
Oil content (%)	40.52	36.40-44.60	5.73	4.22	54.4	2.60	6.42
Seed yield/plant (g)	6.35	3.10-16.80	46.83	45.90	96.1	5.88	93.60

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Biology, seasonal activity and natural enemies of Tussock caterpillar, *Dasychira mendosa* Hubner infesting on oil palm nursery

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ABSTRACT

Tussock caterpillar, *Dasychira mendosa* Hubner (Lepidoptera: Lymantriidae), a polyphagous pest was observed to cause severe defoliation to oil palm leaves in the nursery. Biology, seasonal activity and natural enemies of this pest were studied at oil palm nursery, ICAR-Indian Institute of Oil Palm Research, Pedavegi, Andhra Pradesh, India. The incubation period, larval period and pupal period lasted for about 5.5±0.2, 43.1 ±2.8 and 6.2±0.2 days, respectively. The larvae developed through seven to ten instars. The pest completed its life cycle in about 65.1±3.6 days (egg to adult). The longevity of the male and female was 8.4 ± 0.7 and 9.6 ± 0.2 days respectively. Each female laid an average of 302.9 ±39.9 eggs, mostly on the under surface of the leaves. The larvae of *D. mendosa* were found parasitized by a unidentified tachinid fly to the tune of 10.2 per cent and pupae were parasitized by *Brachymeria albotibialis* to the extent of 40.0 per cent under field conditions. The pest activity was active during July to first fortnight of November in oil palm nursery.

Keywords: Biology, *Dasychira mendosa,* Natural enemies, Oil palm nursery, Tussock caterpillar

Tussock caterpillar, *Dasychira mendosa* Hubner (Lepidoptera: Lymantriidae) is a polyphagous pest widely distributed in India and reported to feed on wild and cultivated plants. It is found in India, Bangladesh, Sri Lanka, Indonesia, Taiwan, Thailand and Australia. Many workers have reported that caterpillars of *D. mendosa* defoliated on tea, mango (Mukerji, 1929), castor (Koshiya *et al.,* 1976), cotton (Mathew, 1978), pigeon pea (Verma and Saini, 1977; Nair *et al.,* 2017), citrus (Nagalingam and Savithri, 1980), sorghum, sun hemp, maize, ber, sapota, brinjal, coffee, sunflower (Bilapate and Jadhav, 1995), *Acacia nilotica* (Sasidhran *et al.,* 1995), *Cedrus deodara* (Kalia *et al.,* 2002), cinnamon (Rajapakse and Wasantha Kumara, 2007), cauliflower, potato (Chandel *et al.,* 2011), *Flemingia semialata* (Meena *et al.,* 2014), teak, arecanut, cocoa and many other plant species. Dileepan (1992) reported *D. mendosa* defoliating oil palm nursery leaves to the tune of 20.0 per cent. However, the detailed information on bio ecology, seasonal incidence, nature of damage, association of bio agents etc are not available to this pest on oil palm. Therefore, the present study was aimed to obtain the above information for formulating pest management strategies against this pest infesting on oil palm nursery.

The cultures of the test insect was established in the laboratory from egg batches collected in the oil palm nursery, Indian Institute of Oil Palm Research, Pedavegi, Andhra Pradesh, India (located in 16.81'N, 81.10'E). The freshly hatched larvae were reared on oil palm secondary nursery leaves. Fresh leaves were provided to the larvae regularly till pupation. For mating and subsequent egg laying 10 pairs of newly emerged male and female adults were transferred into transparent plastic jars individually (10x10 cm) provided with 10 per cent honey solution fortified with multivitamin. Piece of blotting paper was kept as substrate for laying eggs. The mouth of the plastic jar was covered with a piece of cotton cloth. Oviposition and adult survival were recorded daily. Newly hatched larvae from the insect stock culture were released individually on the fresh oil palm leaves kept in transparent specimen tubes (37 x 15 mm). Fresh foliage was provided regularly until pupation. Each developmental stage was observed daily. Instars of larvae were confirmed by examining for released exuviae and head capsule. Insect culture and experimental units were maintained in BOD incubator at 28±1°C with 70±5% RH and 14:10 (L:D) photoperiod. To know the natural enemies association and their activity, the egg masses, larvae and pupae of hairy caterpillar were collected regularly from the oil palm nursery. The larvae were provided with fresh oil palm nursery leaves and kept individually in specimen tubes until pupation. The life stages *viz.,* egg, larvae and pupae were observed daily for the emergence of parasitoids. Fifty oil palm nursery plants were observed at fortnight interval in order to record the activity of the pest.

The details of findings on the biology of *D. mendosa* is presented in Table 1. The adult is smoky brown with hind wings that are pale gray in colour. Fore wings are uniformly brown, with black specks and a pale patch outside the sub basal line. Females are bigger in size with filiform antennae, while males are smaller with pectinate type of antennae (Fig 1 D). Gravid female laid eggs in masses mostly on the under surface of the nursery leaves of oil palm. On an average, each female laid 302.9±39.9 eggs under confinement on blotting paper (as substrate for egg laying). The freshly laid eggs were more or less spherical in shape, creamy white in colour (Fig. 1A). They later changed to brown and blackish in

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colour just before hatching. The eggs hatched in 5.5±0.2 days. Soon after hatching, the neonate larvae damage the leaves by scrapping the lower surface of the leaves in groups, leaving epidermis intact. Older larvae (4th instar onwards) defoliate the leaves vigourously and irregularly leaving with main veins intact (Fig.2 A and B). A group of tussock moth caterpillars could defoliate a whole plant overnight. Surface of the leaves grazed by young larvae is littered with black small frass. Frass is present on soil under defoliated plants. The fully grown caterpillar is yellowish to grayish with red stripes on the prothorax and paired lateral tufts of grayish white hair on each segment of the body. A pair of brownish hairy long tufts project anteriorly over the head. On the last abdominal segment, on tail like brownish hairy tuft is present (Fig.1B). This description is in accordance with the observation of Sandhu *et al.* (1979). The larvae passed through 7 to 10 instars in about 43.1± 2.8 days (ranging from 39.0 to 50.0 days) and reached pupal stage. It was observed that 10.0 per cent of the larvae passed through 7 instars, 40.0 per cent passed through 8 instars, 30.0 per cent passed through 9 instars and 20.0 per cent larvae passed through 10 instars before reaching pupal stage. Similar findings were reported by Junko (1956) in tea tussock moth, *Euproctis pseudoconspersa* Strand. He reported that the number of the larval instars was usually 6-7, often 8, 9, or 10. The length of the larval period as well as the number of the ecdysis seemed to be evidently increased by the decrease of the number of the caterpillers fed together. Moreover, the size of the final instar larvae, as measured by the cranium, did not differ regardless the number of the ecdysis. The last instar larvae attached itself to the leaves or come down to the bottom of the plant, stopped feeding and start spinning, entered in a quiescent stage to convert itself into pre-pupal stage which lasted for 1-2 days. The size of the caterpillars got reduced in size and transformed into pupa leaving the exuviae. The pupation took place in loose dirty brown silken cocoons interwoven with larval body hairs (Fig. 1C). The pupae were obtect and brown in colour. Adults emerged out of pupae in about 6.2±0.2 days. The longevity of male and female were about 8.4±0.7 and 9.6±0.2 days respectively. An average total life cycle was (from egg to adult) 65.1±3.6 days. Nagalingam and Savithri (1980) reported that *D. mendosa* completed its life cycle in about 25 days on citrus. Sasidharan *et al.* (1995) reported that *D. mendosa* on *Acacia nilotica* subsp. *indica* took 57.80 ± 2.94 days to complete its life cycle. The female moth laid 211.43 ± 41.70 eggs. The incubation period was about 8 days and the larval period was about 41.80 ± 3.19 days, with 6-8 instar stages and the pupation period was about 7.82±0.27 days. The adult longevity was about 7.63 ± 0.60 days and the difference between the male and female longevity was not significant. Farooqui and Siddiqua (2018) studied the biology of this pest on *Mangifera indica* Linn. and found that incubation period was about 10.0 days, larval period was about 50.4±6.02 days, pupal period was about 10.5± 1.68 days and total life lasted for about 60.87±5.03 days. The above discussion clearly indicates that there is difference in developmental period in each life stage. This might be attributed to nutritional status, other chemical composition and physical properties of different hosts, as they play a significant role in insect development and study conditions.

Table 1 Duration of different life stages and fecundity of *D. mendosa* on oil palm nursery leaves

Stages	Duration (in days)	
	Range	Mean ± Standard Error
Egg	5-6	5.5 ± 0.2
Larva		
1st instar	5-6	5-7 ± 0.1
2nd instar	3-4	3.0 ± 0.1
3rd instar	3-4	3.2 ± 0.1
4th instar	2-4	3.1 ± 0.3
5th instar	3-4	3.8 ± 0.2
6th instar	4-5	4.0 ± 0.3
7th instar	4-5	4.2 ± 0.3
8th instar	4-5	4.6 ± 0.2
9th instar	5-6	5.5 ± 0.6
10th instar	6-7	6.0 ± 0.6
Total larval period	39-50	43.1 ± 2.8
Pre pupa	1-2	1.2 ± 0.1
Pupa	6-7	6.2 ± 0.2
Adult	8-10	9.1 ± 0.3
Male		8.4± 0.7
Female		9.6± 0.2
Life period (egg to adult)	59-75	65.1 ± 3.6
Fecundity	25-670	302.9± 39.9

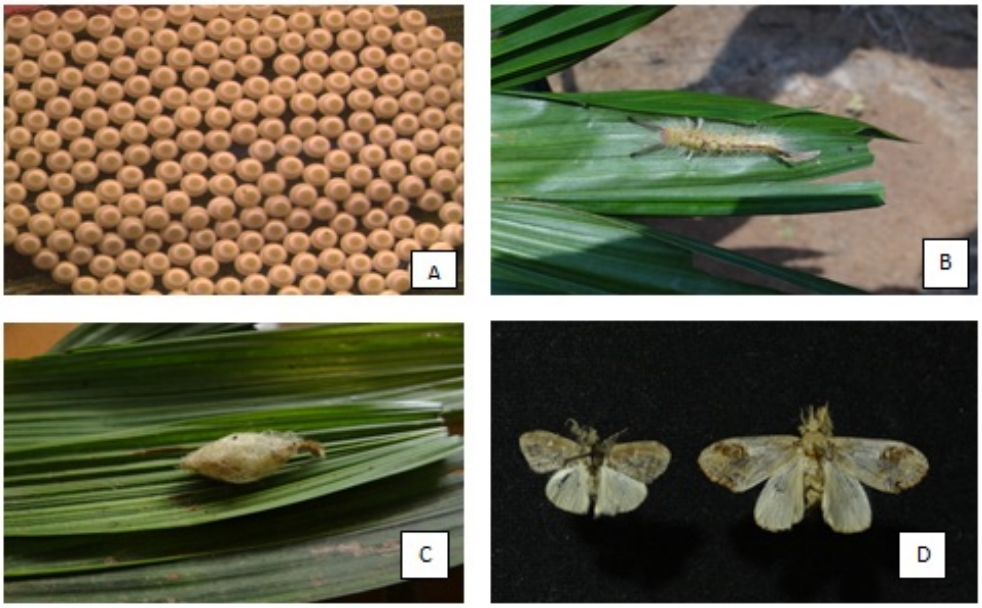

Fig. 1 (A-D). Different life stages of *D. mendosa*. A: Eggs; B: Larva; C: Silken cocoon having pupa; D: Adults-Male (left), Female (right)

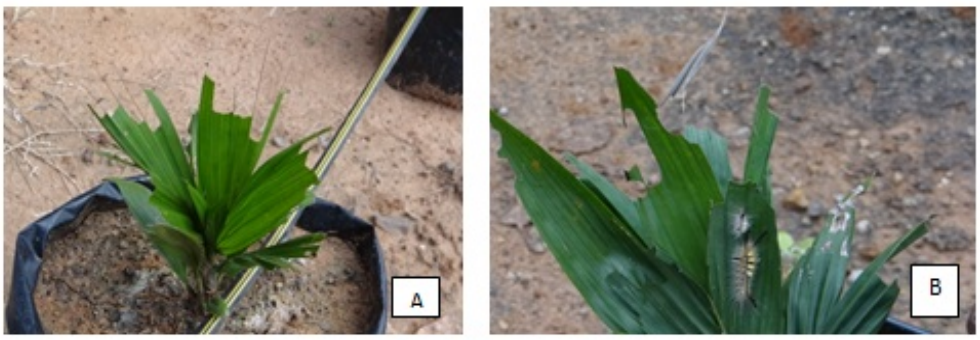

Fig. 2. A and B. Damaged oil palm nursery plants

Fig. 3. Tachnid parasitoid with its case

F ig. 4. *Brachymeria albotibialis* with dead pupa

The pest appeared in the oil palm nursery at the onset of South west monsoon i.e. June-July and remained active up to first fortnight of November. It was not observed in other months in Andhra Pradesh. Dhileepan (1992) reported that though the pest incidence was noticed throughout the year in oil palm nursery in Kerala conditions, the highest incidence was recorded during the months of June-July, coinciding with onset of rains.

An unidentified tachinid fly (Diptera: Tachinidae) was recorded to parasitize the larvae of *D. mendosa* (Fig.3). The fly injects egg into the caterpillar. Upon hatching the fly maggots burrowed inside the host and fed from inside. The affected caterpillar become sluggish reduced in size and failed to pupate and eventually died. The mean parasitism was about 10.2 per cent during pest activity period. In addition, the pupae of *D. mendosa* was parasitized by *Brachymeria albotibialis* (Ashmead) (Hymenoptera: Chalcididae) (Fig.4). The parasitized pupa turned to dark brown or black in colour. Only one parasitoid individual emerged out per host pupa. Once the parasitoid emerged out, the empty pupal case was remained with circular hole at the head region. The level of parasitism at field conditions was recorded as 40.0 per cent. These two parasitoids are reported for the first time on *D. mendosa* infesting oil palm nursery in Andhra Pradesh, India. No egg parasitoid was reported during this study. The information obtained in this study on biology, nature of damage, seasonal activity and natural enemies of *D. mendosa* could be used for developing effective pest management strategies in oil palm nursery

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Popularization of improved sunflower (*Helianthus annuus* L.) production technology through frontline demonstrations in non-traditional belts of West Bengal

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ABSTRACT

The Front Line Demonstrations (FLDs) on modern approaches of sunflower cultivation was attempted during *rabi* season 2011-12 to 2013-14 on farmers' field in the non-traditional belts of West Bengal (Bankura and Purulia districts) under Tribal Sub-Plan Programme. The average seed yield of sunflower under demonstration plot was recorded 1875-2250 kg/ha compared to conventional rapeseed mustard cultivation where production was recorded 1000-1200 kg/ha. In West Bengal, the yield gaps between improved technology (full package of sunflower demonstration with best management practices) and farmers practice (rapeseed mustard cultivation through conventional approaches) was recorded 875-1050 kg/ha. The study recommends that the gross return and net return can be improved by adopting technologies *viz.,* use of sunflower hybrids (DRSH-1, KBSH-44, KBSH-41, KBSH-53), adopting proper spacing and thinning, spraying of boron at ray floret stage and use of bio-inoculants for management of diseases.

Keywords: FLD, Non-traditional area, Sunflower, Yield improvement, West Bengal

Sunflower (*Helianthus annuus* L.) is one of the most important edible oilseed crops. The crop is well-known for its broad range of adoptability (Anonymous, 2014) and high oil content (40-43%) (Nasim *et al.,* 2011; Meena *et al.,* 2017). In West Bengal, sunflower is an important emerging oilseed crop after rapeseed-mustard during *rabi*-summer season. In West Bengal, south 24 parganas district is most of the prominent sunflower growing areas, but there is a huge scope of growing sunflower in non-traditional districts like Bankura and Purulia where the crop is largely cultivated under irrigated conditions during *rabi* seasons. It was observed that productivity level of sunflower in farmer's fields was low due to several biotic and abiotic factors besides unavailability of quality seeds of improved sunflower hybrids in time and non adoption of recommended production technologies. Selection of the right sunflower hybrid is very crucial as the final income is dependent on both seed yield and oil yields. Further, maintaining optimum plant population and plant density plays a greater role in increasing the sunflower productivity, Also, sunflower, is one of the most sensitive crops to boron (B), and its deficiency at flowering stage affects pollen viability and abortion of stamens and pistils resulting in poor seed yield (Cakmak and Romheld, 1997). The poor seed yield in farmer's fields a wide gap between the available improved techniques and its actual application by the farmers (Lokesh and Dandoti, 2017). Hence, there is a tremendous opportunity for increasing the production and productivity of sunflower grown in the area by adopting the improved technologies which in turn helps in improving the economic and social status the farmers.

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The role of Front Line Demonstration (FLD) in Extension activities to improve farmer's knowledge as well as agriculture scenario was critically pointed out by Ingle and Lalit Arun (1997) and Sharma and Sharma (1999). In the FLDs, awareness of new varieties of oilseed crops under specific agro-climatic situation and better crop management practices can be achieved by the farmers which not only will increase the productivity of oilseed in a sustainable manner but also give a good economic return. Through FLD prgramme, the AICRP centre started disseminating the technology of sunflower cultivation through modern scientific approaches in Bankura and Purulia district by adopting best management practices for sunflower cultivation. The AICRP (Sunflower), Nimpith centre recommended full package of practices for the hybrid DRSH-1, KBSH-44, KBSH-53 or KBSH-41 to State Agriculture Department, GOWB for up-scaling the technology. There is huge demand for good quality hybrid sunflower seed from the farmers in this year indicating the popularity of sunflower cultivation in a backward as well as nontraditional districts like Bankura and Purulia.

FLD on sunflower were conducted at farmer's fields in different villages of Bankura and Purulia districts of West Bengal to assess its performance during rabi-summer season of 2011-12, 2012-13 and 2013-14 under irrigated condition. The soils of the districts where FLDs were taken up is are sandy loam in texture, low in nitrogen, low to medium in phosphorus and medium to high in potash. For conducting FLD on sunflower two village meetings were conducted through Farm Science Club. In this meeting a vigorous discussion was held with the farmers to assess their needs for increasing the productivity of oilseed and pulses during the

rabi-summer season. After that, farmers were interviewed in this regard and ultimately the technological gaps were identified which were responsible for low productivity of oilseed in this region. The farmers who expressed keen interest in adopting new technology were selected for this purpose. The training and group meeting on oilseed crops were conducted with the selected farmers and critical inputs were supplied. Time to time visit and supervision of the FLD plots were conducted from sowing to harvest and the suggestions were given accordingly. Moreover, farmers and extension workers were trained up through on-campus and off-campus training programmes.

The sunflower varieties selected for FLD programme were DRSH-1 for 2011-12, KBSH-44 for 2012-13, KBSH-53, DRSH-1 and KBSH-41 for 2013-14. The seed and other need based inputs were distributed to 100 farmers during 2011-12 and 2012-13 and among 200 farmers during 2013-14. The seeds of sunflower were sown in the last week of November to 1st week of December, with the seed rate of 7.5 kg/ha (2.0 kg/acre) and recommended spacing (60 cm x 30 cm). Vermicompost was applied @ 5 q/acre at the time of land preparation for enhancement of soil fertility and increased the seed yield of sunflower. The seed treatment was done with bio-inoculants (*T. viride* + *P. fluorescens* and *Azatobactor* and PSB each @ 10g/kg of seed). Chemical fertilizers for phosphate and sulphur based fertilizers like single super phosphate (SSP) or 20:20:0:13 was applied. Proper thinning was completed (single plant/hill) before 1st irrigation (21-25 DAS). Half of the nitrogen (40 kg N/ha), full dose of phosphorus (40 kg P_20_5/ha) and potash (40 K_20/ha) were applied as basal and remaining 1/4th (25%) of nitrogen (20 kg/ha) was given as top dressing in the form of urea before first irrigation (25-30 DAS) at the time of earthing up and rest 25% (20kg/ha) was given as top dressing in the form of urea before second irrigation at the time of second earthing up (45-50 DAS). The sunflower was sown in residual moisture and one irrigation was provided at star-bud stage (21-25DAS), the 2nd irrigation was provided at the preflowering stage (40-45 DAS) and 3rd (if needed) in post flowering stage (60-65 DAS). The satisfactory yield of sunflower was recorded by utilizing the residual moisture for germination with three life saving irrigation. Boron spray @ 0.2% at the ray floret opening stage, use of bio-inoculants *viz., Trichoderma viride* and *Pseudomonas flurescens* (10g + 10g/l of water) for spraying at crown region before 1st and 2nd irrigation for the management of sunflower wilt and need based pesticides like Spinosad or Koragen 3.0 ml/10 l of water (2 sprays at 21 days interval after appearance of *Spodoptera litura*). Farmer's practices included broadcast sowing of mustard and growing the crop without thinning, weeding, earthing up and under unprotected conditions. Finally, data on seed yield, cost of cultivation and returns were collected after harvesting of the crop. Different parameters as suggested by Yadav *et al.* (2004) were used for calculating the gap analysis, cost and returns.

Yield Gap = Demonstration Yield -Farmer's Practice Yield
Additional return = Demonstration Return-Farmer's Practice Return.

Table 1 Details of farming situation in non-traditional belts of West Bengal (Sunflower)

Season	Farming situation (RF/ Irrigation)	Soil type	Status of soil			Previous crop	Sowing date	Harvest date	Seasonal rainfall (mm)	No. of rainy days
			N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)					
Rabi-Summer, 2011-12	Irrigated	Sandy-loam	182.3 to 242.7	22.9 to 45.2	387.5 to 779.6	Paddy	3rd week of November to 1st week of December	1st –last Week of March	Nil	-
Rabi-Summer, 2012-13	Irrigated	Sandy-loam	195.7 to 252.1	24.2 to 46.1	395.8 to 788.1	Paddy	3rd week of November to 1st week of December	1st –last Week of March	11mm	2
Rabi-Summer, 2013-14	Irrigated	Sandy-loam	167.5 to 261.2	26.1 to 46.1	372.5 to 817.2	Paddy	3rd week of November to 1st week of December	1st –last Week of March	14	3

From the above table it is observed that the soil type of FLD plots under different villages is sandy-loam in texture. The available phosphorus and nitrogen are low to medium but the available potassium is high ranging from 355.8 to 779.6 kg/ha. The germination of the seed was recorded over 90% in every year (Table 1).

The study suggested that the production level of oilseed crop can be improved by cultivation of suitable oilseed crop like sunflower by adopting suitable cultivars/ hybrids like DRSH-1, KBSH-41 and KBSH-53. In demonstration plots the mean seed yield was recorded 1875 kg/ha (2013-14) to 2100 kg/ha (2011-12) and it was produced 100-110% more seed yield over the traditional oilseed cultivation (Mustard through conventional approaches) (Table 2).

From the demonstration field data it was recorded that gross return of the farmers was ₹ 58,800/ha (2011-12) to ₹65,625/ha (2013-14) compared to conventional practices where the farmers earned ₹ 36750/ ha to ₹ 40,000/ha and

thereby the additional net return under sunflower cultivation following the best management practices ₹ 14540/ha (2011-12), ₹ 23768(2012-13) and ₹ 21875(2013-14) (Table 3). Besides suitable hybrids judicious application of NPK fertilizers played a key role on growth, yield and economics of sunflower. The results from the demonstration plots indicated that, judicious application of NPK fertilizers in proper stage could markedly increased the seed yield. Under irrigated condition, the yield advantage may be associated with influence of NPK fertilizer and NPK fertilization on growth, yield and economics of sunflower was critically analyzed by Kumar *et al.* (2013).

Besides suitable hybrids, seed setting is also one of the major constraints in maximizing the sunflower productivity. Unavailability of optimum "Boron" in soil leads to boron deficiency in crop plants that effects flowering, pollen germination, pollen tube growth and seed development (Dell and Longbin 1997). However, in this study it was observed that, generally farmers do not apply the B fertilizers to oilseed crops like rapeseed mustard, sesame and sunflower in this region. The results from the demonstration plots indicated that, foliar application of boron in the ray floret stage (2 g/l of water) opening stage could markedly increased the seed yield and hence, foliar application of boron was advised in the ray floret stage to improve the seed yield in sunflower. This findings is highly supported by the findings of Cakmak and Romheld (1997). Under irrigated condition, the yield advantage may be associated with boron, supplemental irrigation and judicial application of chemical fertilizers at proper stage of the crop. The yield advantage also associated with the seed treatments with bio-inoculants as well as application of the bio fungicides before 1st and 2nd irrigation for effectively management of the sunflower wilt which is main disease of that region.

Table 2 Performance of sunflower FLDs in non-traditional belts of West Bengal

Crop	Technology Demonstrated	Hybrid	No. of Farmers/ demon-strations	Area (ha)	Demo. Yield (qt/ha)	Yield of local Check (qt/ha)	Variety used in local check	Increase in yield (%)	Yield (q/ha)	
									Potential (q/ha)	District average (q/ha)
Sunflower	Hybrid with Full package of practice	DRSH-1	100	40ha	21.00	10.50	Varuana/ Aghrani	100%	25.0	12.28
Sunflower	Hybrid with Full package of practice	KBSH-44	100	40ha	22.50	11.25	Varuana/ Aghrani	100%	27.0	12.85
Sunflower	Hybrid with Full package of practice.	DRSH-1 DRSH-1 KBSH-53	200	80ha	18.75	9.75	Varuana/ Aghrani	110%	25.0	12.67 & 11.92

Table 3 Yield and economics of sunflower FLDs in non-traditional belts of West Bengal

Year	Mean seed yield (kg/ha)		Yield gap (kg/ha)	Cost of cultivation (₹/ha)		Gross return (₹/ha)		Net return (₹/ha)		Additional net return (₹/ha)	B:C ratio	
	IP	FP		IP	FP	IP	FP	IP	FP		IP	FP
2011-12	2100	1050	1050	38010	30500	58800	36750	20790	6250	14,540	1.55	1.20
2012-13	2250	1125	1125	38675	31818	72000	39375	31325	7558	23,768	1.81	1.24
2013-14	1875	900	975	39375	32125	65625	40000	30000	8125	21,875	1.67	1.25
Avg.	2075	1025	1050	38687	31481	65475	38708	27372	7311	20,061	1.68	1.23

Maintaining optimum plant population is essential for higher seed yield of sunflower in farmer's field. Through regular field level training and monitoring before sowing and during crop growth stage, the awareness was developed among the farmers regarding the proper spacing, thinning and weeding and earthing up at proper crop growth stage. The yield advantage in demonstration plot also associated with the adoption of these agronomical practices in farmer's level. The data across of the years of demonstration indicated that the economic advantage in terms of the B:C ratio of the farmers under improved method of sunflower cultivation was recorded 1.55 (2011-12), 1.81 (2012-13), 1.67 (2013-14) which was much higher compared to traditional cultivation systems /farmer's practice, 1.20 (2011-12) to 1.25 (2013-14). Sharma and Sharma (1999), Satyanarayanan and Kurumvasi (1999), Nagaraj and Katteppa (2002) have pointed out that changing of income status of the farmers by adopting the new technologies was significantly associated with the adoption and dissemination of improved cultivation technologies/practices. The findings of our study have close proximity with the findings of Meti and Hanchinal (1994) and Yadav *et al.* (2004).

The study depicted that there is sufficient yield gap between improved technologies and farmer's practices and

the yield gap can be achieved by adoption of appropriate selection of oilseed crop for particular season, adoption of appropriate hybrid, boron spray and maintaining the optimum plant population though proper row spacing and thinning. Meanwhile, it is expected that the combination of all these technologies would have interactive impact on sunflower productivity in farmer's field. Therefore sunflower cultivation following the best management practices proven to be an potential alternative source of oilseed cultivation in *rabi*-summer season in irrigated condition in "Red Lateritic" belts of West Bengal with an additional income of ₹ 14,475 - ₹ 21,875.00/ha per year.

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The data in tables should be corrected to minimum place of decimal so as to make it more meaningful. Do not use full stop with CD, SEm $\pm$, NS (not C.D., S.E.m $\pm$, N.S.). Do not put cross-rules inside the table. Tables should be numbered consecutively and their approximate positions indicated in the margin of the manuscript. Tables should not be inserted in the body of the text. Type each table on a separate sheet. Do not use capital letters for the tabular headings, do not underline the words and do not use a full-stop at the end of the heading. All the tables should be tagged with the main body of the text i.e. after references.

Figures

Figures include diagrams and photographs. Laser print outs of line diagrams are acceptable while dot-matrix print outs will be rejected. Alternatively, each illustration can be drawn on white art card or tracing cloth/ paper, using proper stencil. The lines should be bold and of uniform thickness. The numbers and letterings must be stenciled; free-hand drawing will not be accepted. Size of the illustrations as well as numbers, and letterings should be sufficiently large to stand suitable reduction in size. Overall size of the illustrations should be such that on reduction, the size will be the width of single or double column of the printed page of the Journal. Legends, if any, should be included within the illustration. Each illustration should have a number followed by a caption typed/ typeset well below the illustration.

Title of the article and name(s) of the author(s) should be written sufficiently below the caption. The photographs (black and white) should have a glossy finish with sharp contrast between the light and the dark areas. Colour photographs/ figures are not normally accepted. One set of the original figures must be submitted along with the manuscript, while the second set can be photocopy. The illustrations should be numbered consecutively in the order in which they are mentioned in the text. The position of each figure should be indicated in the margin of the text. The photographs should be securely enclosed with the manuscript after placing them in hard board pouches so that there may not be any crack or fold. Photographs should preferably be 8.5 cm or 17 cm wide or double the size. The captions for all the illustrations (including photographs) should be typed on a separate sheet of paper and placed after the tables.

Expression of Plant Nutrients on Elemental Basis

The amounts and proportions of nutrient elements must be expressed in elemental forms e.g. for ion uptake or in other ways as needed for theoretical purposes. In expressing doses of nitrogen, phosphatic, and potassic fertilizers also these should be in the form of N, P and K, respectively. While these should be expressed in terms of kg/ha for field experiments, for pot culture studies the unit should be in mg/kg soil.

SI Units and Symbols

SI Units (System International d 'Unities or International System of Units) should be used. The SI contains three classes of units: (i) base units, (ii) derived units, and (iii) supplementary units. To denote multiples and sub-multiples of units, standard abbreviations are to be used. Clark's Tables: Science Data Book by Orient Longman, New Delhi (1982) may be consulted.

Some of these units along with the corresponding symbols are reproduced for the sake of convenience.

Names and Symbols of SI Units

Physical Symbol for SI Unit Symbol Remarks quantity physical quantity for SI Unit

Primary Units

length	l	time	t
metre	m	second	s
mass	m	electric current	I
kilogram	kg	ampere	A

Secondary Units

plane angle	radian	rad	Solid angle	steradian	sr

Unit Symbols

centimetre	cm	microgram	µg
cubic centimetre	cm^3	micron	µm
cubic metre	m^3	micronmol	µmol
day	d	milligram	mg
decisiemens	dS	millilitre	mL
degree-Celsium	°C [=(F-32)x0.556]	minute	min

gram	g	nanometre	nm
hectare	ha	newton	N
hour	h	pascal	Pa
joule J	(= 10^7 erg or 4.19 cal.)	second	s
kelvin	K (= °C + 273)	square centimetre	cm^2
kilogram	kg	square kilometre	km^2
kilometre	km	tonne	t
litre	L	watt	W
megagram	Mg		

Some applications along with symbols

adsorption energy	J/mol (=cal/molx4.19)	leaf area	m^2/kg
cation exchange capacity	cmol (p+)/kg (=m.e./100 g)	nutrient content in plants (drymatter basis)	µg/g, mg/g or g/kg
Electrolytic conductivity	dS/m (=mmhos/cm)	root density or root length density	m/m^3
evapotranspiration rate	$m^3/m^2/s$ or m/s	soil bulk density	Mg/m^3 (=g/cm^3)
heat flux	W/m^2	specific heat	J/kg/K
gas diffusion	$g/m^2/s$ or $m^3/m^2/s$ or m/s	specific surface area of soil	m^2/kg
water flow	$kg/m^2/s$ (or) m^3m^2s (or) m/s	thermal conductivity	W/m/K
gas diffusivity	m^2/s	transpiration rate	$mg/m^2/s$
hydraulic conductivity ion uptake	m/s	water content of soil	kg/kg or m^3/m^3
(Per kg of dry plant material)	mol/kg	water tension	kPa (or) MPa

While giving the SI units the first letter should not be in capital i.e cm, not Cm; kg not Kg. There should not be a full stop at the end of the abbreviation: cm, not cm. kg, not kg.; ha, not ha.

In reporting the data, dimensional units, viz., M (mass), L (length), and T (time) should be used as shown under some applications above. Some examples are: 120 kg N/ha; 5 t/ha; 4 dS/m etc.

Special Instructions

I. In a series or range of measurements, mention the unit only at the end, e.g. 2 to 6 cm2, 3, 6, and 9 cm, etc. Similarly use cm2, cm3 instead of sq cm and cu m.

II. Any unfamiliar abbreviation must be identified fully (in parenthesis).

III. A sentence should not begin with an abbreviation.

IV. Numeral should be used whenever it is followed by a unit measure or its abbreviations, e.g., 1 g, 3 m, 5 h, 6 months, etc. Otherwise, words should be used for numbers one to nine and numerals for larger ones except in a series of numbers when numerals should be used for all in the series.

V. Do not abbreviate litre to` l' or tonne to `t'. Instead, spell out.

VI. Before the paper is sent, check carefully all data and text for factual, grammatical and typographical errors.

VII. Do not forget to attach the original signed copy of `Article Certificate' (without any alteration, overwriting or pasting) signed by all authors.

VIII. On revision, please answer all the referees' comments point-wise, indicating the modifications made by you on a separate sheet in duplicate.

IX. If you do not agree with some comments of the referee, modify the article to the extent possible. Give reasons (2 copies on a separate sheet) for your disagreement, with full justification (the article would be examined again).

X. Rupees should be given as per the new symbol approved by Govt. of India.

Important Instructions

- Data on field experiments have to be at least for a period of 2-3 years
- Papers on pot experiments will be considered for publication only as short communications
- Giving coefficient of variation in the case of field experiments Standard error in the case of laboratory determination is mandatory. For rigorous statistical treatment, journals like Journal of Agricultural Science Cambridge, Experimental Agriculture and Soil Use and Management should serve as eye openers.

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