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Research Article

Selection of promising parents and crosses using combining ability analysis for development of high yielding varieties and hybrids in safflower (*Carthamus tinctorious L*)

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Abstract
The general and specific combining ability effects and variances for eight characters related to seed yield and its contributing traits in safflower were studied using Line x Tester mating design in forty CMS based hybrids, involving 20 lines (males) and two testers (females) along with three checks (PKV PINK, AKS 207 and PBNS 12). Combining Ability Analysis indicated the predominance of non-additive gene action for all the traits under study. Out of 20 males, GMU 3876, GMU 3924, GMU 3965 and AKS CMS 2B were identified as good general combiners for seed yield per plant, whereas, S-518, CCC-B2 and AKS 325 were identified as good general combiners for other yield contributing traits, and the parents GMU 3876, GILA and AKS CMS 2B for oil content. Hence, these parents may be exploited in further breeding programme to improve the concerned traits. Three crosses *viz.,* AKS CMS 2A X GMU 3876, AKS CMS 2A X GMU 3863 and AKS CMS 3A X AKS/NS1 were identified as promising crosses on the basis of SCA effects for seed yield per plant, with good GCA effect of one of the parents. Thus, these crosses may be used for further evaluation in preliminary or multi-location hybrid trials for the further exploitation at commercial level. The crosses *viz*., AKS CMS 2A X GMU 3965, AKS CMS 2A X GMU 3325 and AKS CMS 2A X AKS 325 performed well over the best check i.e. PKV PINK along with a positive and highly significant GCA effects of one of the parents involved in the cross and low SCA effects (non-significant), it is recommended to utilize these crosses further by generation advancement for the development of varieties after re-crossing with ‘B’ line of the respective CMS line.

Keywords
Safflower, line x tester, GCA, SCA, seed yield, oil content

INTODUCTION

Safflower is one of the most important oilseed crops. It has been gaining increasing popularity in the recent years in several parts of the county because of its adaptability under the drought conditions (Sarode *et al.,* 2008). Safflower is known for its cultivation since time immemorial, for orange red dye extracted from its florets and for its much valued oil. Safflower seeds contain 27.5 *per cent* oil, 15 *per cent* protein, 41 *per cent* crude fiber and 2.3 *per cent* ash. Safflower oil, which on average contains 75% linoleic acid, also contains tocopherols, known to have antioxidant effect and high vitamin E content (Latha and Prakash, 1984). For this reason, safflower oil is used in the diets of patients with cardiovascular disease, and bears great importance for its anti-cholesterol effect (Jhajharia *et al.*, 2013). Combining ability studies furnish useful information about the selection of suitable parents for an effective hybridization programme (Sprague and Tatum, 1942). It is a powerful tool to discriminate good as well as poor combiners and choose appropriate parental material in breeding programmes and it also gives the information about the nature of gene action involved in the inheritance of various characters. The biometrical technique Line x Tester analysis appeared to be the most useful tool for screening lines rapidly and with reasonable confidence. It also provides information about the General Combining Ability (GCA) and Specific Combining Ability (SCA) variances and effects. In addition, it also gives information about additive (D) and dominance (H) components of genetic variances

It is essential to evaluate newly developed parents in cross combinations to test its combining ability for seed yield and its components. Therefore, the present investigation was undertaken to study the combining ability for identification of good combiners and promising crosses for future improvement in yield and yield contributing traits in safflower.

MATERIAL AND METHODS

Plant Material :Genetically diverse parents were deliberately selected on the basis of their distinguishing characters i.e. two CMS lines viz., AKS CMS 2A and AKS CMS 3A (Cytoplasmic male sterile lines developed by Oilseed Research Unit, Dr. P.D.K.V., Akola) as females and 20 males viz., S-518, CW-99, CCC-B2, GILA, AKS/NS-1, AKS-322, AKS-325, AKS/S-33, GMU-3923, GMU-3965, GMU 3924, GMU 3876, GMU 3863, GMU 3963, GMU 3325, GMU 6877, GMU 6881, GMU 6835, AKS 08R and AKS 10R. The crosses were effected in line x tester (L x T) scheme for obtaining F_1 seeds of 40 crosses at the experimental field of Oilseeds Research Unit, Dr, P.D.K.V., Akola. Utilising CMS based system, only hand pollination using pollens from protected flowers from male parents was done with the protected flowers of CMS based females in the morning hours. The parental seeds were multiplied by selfing.

Field Trial :A field trial of 65 genotypes, including 22 parents, 40 F1s and three checks *viz.,* PKV PINK, AKS 207 and PBNS 12 were raised in Randomized block Design with three replications during *Rabi* 2017-18. Each genotype was planted in a single row of 3m length with 45cm spacing between rows and 20cm within rows. All the cultivation practices were followed as per recommendations for safflower cultivation to raise healthy crop.

Observations :The observations were recorded on randomly selected five competitive plants per plot per replication in parents, F_1s and checks for plant height at harvest, the number of primary branches per plant, the number of capsules per plant, the number of seeds per capsule, 100 seed weight (g) and seed yield per plant (g). Whereas, the observations were recorded on plot basis for days to 50 *per cent* flowering, days to maturity and oil content (%). The oil content (%) was determined by following technique on instrument (Bench top Pulse Nuclear Magnetic Resonance (NMR) Spectrometer-Model MQC OXFORD). The samples of 5-10 grams were taken for determination of oil content, before it, calibration had been done in the NMR. The samples were enclosed in a moisture-proof (*i.e.* Ziplock) bag for determination of oil content using NMR.

Statistical Analysis **:**The analysis of variance was performed as per the procedure given by Panse and Sukthame (1967) from the data obtained in the field trials. Further, the line x tester analysis was performed as per the standard procedure given by Kempthorne (1957).

Table 1. Analysis of variance for combining ability for seed yield and its components in safflower

Sources of Variation	Mean sum of squares								
	d.f.	Days to 50 % Flowering	Days to Maturity	Plant Height at Harvest	Number of Primary Branches per Plant	Number of Capsules per Plant	100 Seed Weight	Seed Yield per Plant	Oil Content
Replications	2	5.700	3.733	72.456	25.132	37.872	0.785	18.943	38.470
Crosses	39	16.259**	16.632**	61.337**	15.953**	67.216**	42.133**	26.287**	4.286**
Line effects	1	100.833**	52.008**	101.733**	161.402**	92.734**	4.033**	50.077**	16.361**
Tester effects	19	18.831**	16.078**	73.382**	15.099**	62.130**	16.05**	24.457**	4.592**
Line x Tester effects	19	9.236**	15.324**	47.166**	7.098**	70.959**	22.05**	26.864**	3.345**
Error	78	8.477	6.125	13.929	3.972	13.067	52.87	7.790	1.298
GCA variance		0.840	0.433	0.848	1.345	0.773	0.034	0.417	0.136
SCA variance		29.25**	48.52**	149.361**	22.48**	224.706**	3.675**	85.072**	10.594**

(*, ** Significant at 0.05 and 0.01 probability levels, respectively).

RESULTS AND DISCUSSION

It has been revealed from the analysis of variance for combining (**Table 1**) that estimates of mean squares due to the crosses were highly significant for seed yield and its contributing traits indicating the presence of substantial genetic variability among the crosses for all the traits studied. Further, the mean squares due to parents i.e. males and females and male v/s female naked shown the significant differences amongst themselves for all the characters. The mean squares for crosses were significant for all the characters indicating the presence of substantial genetic variability for all the traits. Further, there was presence of substantial genetic variability in females and males for the traits under study. The mean squares for males x females were significant for all the traits. Similar results were also reported by Wandhare *et al.* (2003), Sarode *et al.* (2008) and Nai *et al.* (2014) in safflower. The SCA variances were found highly significant for all the traits under study, therefore it indicates that the role of non-additive gene action was predominant for controlling all the traits under study. Hence, there is a good scope for the development of hybrids for the commercial cultivation in safflower from the parental materials studied. Predominance of SCA variances were also reported by Makne and Chaudhary, (1980) for days to 50 % flowering, days to maturity, plant height at harvest, primary branches, the number of capitula, oil content and seed yield per plant under study except 100 seed weight and Shivani *et al.* (2011) for all the traits i.e. days to 50 % flowering, days to maturity, plant height at harvest, primary branches, the number of capitula, oil content and seed yield per plant.

None of the parents recorded the significant GCA effects in desirable direction simultaneously for all the characters studied (Table 2). However, GMU 3924, GMU 3876 and GMU 3965 among the males and AKS CMS 2B among the females were found to be the good general combiners for seed yield per plant and other yield contributing characters. Hence, these genotypes were recognized as the good parental materials among the available genotypes for further genetic improvement programme. For days to 50 % flowering S 518, CCC B2 and GMU 6835 and for days to maturity GMU 3924 revealed highly significant and negative GCA effects, whereas, among the females, AKS CMS 2B showed significant GCA effects in desirable direction, hence, these genotypes could be used for the improvement of earliness in safflower. The good GCA was also been recorded by Pahlavani *et al.* (2007) and Sarode *et al.* (2008) for earliness in safflower.

Table 2. Estimates of general combining ability effects of parents for seed yield and its components

S.N.	Genotypes	Days to 50 % Flowering	Days to Maturity	Plant Height at Harvest	Number of Primary Branches per Plant	Number of Capsules per Plant	100 Seed Weight (g)	Seed Yield per Plant	Oil Content
	Lines (Males)								
1	S-518	-1.267*	-0.008	6.302**	3.137**	2.203	0.100	-1.509	0.641
2	CW-99	-1.933	0.992	5.915**	1.504	1.768	-0.067	-1.096	1.094
3	CCC-B2	-3.267**	0.158	4.757*	-0.646	1.615	0.433	-0.226	0.824
4	GILA	0.400	0.825	1.500	1.107	-0.638	-0.150	-0.449	1.124*
5	AKS/NS-1	1.067	1.492	-0.265	0.841	-4.908**	0.267	0.543	-0.876
6	AKS-322	2.067	-0.342	-0.843	2.104**	0.253	0.433	0.311	-0.679
7	AKS-325	4.400**	2.325*	5.128*	2.036*	-4.670*	-0.067	0.546	-0.587
8	AKS/S-33	1.900	-1.008	0.430	0.424	4.245*	-0.400	2.076	-1.357*
9	GMU-3923	0.233	0.992	-1.467	-1.248	0.850	-0.150	-2.582*	0.151
10	GMU-3965	0.400	0.658	-1.855	1.479	0.583	-0.483	2.735*	-0.177
11	GMU-3924	-0.267	-3.008**	5.807**	-0.438	0.783	0.267	3.938**	1.019
12	GMU-3876	-2.267	5.008**	-4.440*	1.637*	5.893**	0.433	3.096**	2.041**
13	GMU-3863	0.900	-1.008	-0.643	-0.693	1.430	-0.067	1.076	-0.147
14	GMU-3963	-1.933	-1.008	-1.103	1.037	1.658	0.100	-0.506	-0.606
15	GMU-3325	-0.600	0.325	1.400	-2.113**	-5.978**	0.183	0.846	-0.204
16	GMU-6877	0.900	0.658	2.262	-0.179	-1.487	-0.900*	-0.612	-0.976
17	GMU-6881	-0.767	0.658	-4.550*	-0.696	0.672	0.600	-0.239	-0.481
18	GMU-6835	-1.433*	0.825	-1.192	-2.763**	0.598	-0.317	-0.897	-0.661
19	AKS-08R	0.400	0.992	-3.210	-1.863*	-6.305**	0.183	-2.737*	0.288
20	AKS-10R	1.067	0.492	-2.320	-0.596	1.432	-0.400	-4.31**	-0.431
	SE(gi)	0.389	0.327	0.662	.0248	0.582	0.112	0.331	0.173
	CD (0.05)	0.774	0.651	1.318	0.495	1.158	0.223	0.659	0.346
	CD (0.01)	1.027	0.863	1.748	0.656	1.536	0.296	0.875	0.459
	Testers (Females)								
1	AKS CMS 2B	-0.917*	-0.658*	0.921*	1.160**	0.879**	0.183**	0.646**	0.369**
2	AKS CMS 3B	0.917*	0.658*	-0.921*	-1.160**	-0.879**	-0.183**	-0.646**	-0.369**
	SE(gi)	1.230	1.034	2.093	0.786	1.840	0.355	1.048	0.549
	CD (0.05)	2.450	2.059	4.168	1.566	3.664	0.707	2.086	1.094
	CD (0.01)	3.249	2.732	5.528	2.077	4.859	0.938	2.764	1.451

(*, ** Significant at 0.05 and 0.01 probability levels, respectively)

The line GMU 3876 exhibited the highest, significant and positive good GCA effects for the number of primary branches per plant, the number of capsules per plant, oil content and seed yield per plant. Whereas, the tester AKS CMS 2B exhibited the highest, significant and positive GCA effects for seed yield per plant and also recorded highly significant GCA effects in desirable direction for plant height at harvest, the number of seeds per capsule, 100 seed weight, and oil content. Hence, the genotypes *viz.,* GMU 3876 and AKS CMS 2B could be used for further genetic improvement of above traits in safflower. Similar results were also reported by Patil *et al.* (1992) and Prakash and Prakash (1993). For oil content, GILA and GMU 3876 among lines and AKS CMS 2B among testers were found to be the good general combiners. Therefore, these parents could be used for genetic improvement of oil content in safflower. Parents with good GCA effects for above trait were also identified and reported earlier by Prakash and Prakash (1993) and Nai *et al.* (2014).

In case of the specific combining ability, none of the crosses exhibited the significant SCA effects in desirable direction for all the characters studied (**Table 3**). The cross, AKS CMS 3A x GMU 6877 showed high significant SCA effect for days to 50 % flowering. Whereas, the crosses, AKS CMS 2A X GMU 3924 and AKS CMS 2A X GMU 3876 showed significant good SCA effect for days to maturity, the cross AKS CMS 2A X AKS 10R was good specific combination for plant height at harvest. For the number of primary branches per plant, the cross, AKS CMS 3A x GMU 6881 showed significant SCA effects in desirable direction. Whereas, the crosses AKS CMS 3A x CW-99 and AKS CMS 2A x GMU 6877 showed a good SCA effect for the number of capsules per plant.

Table 3. Estimates of specific combining ability effects of crosses for seed yield and its components

Genotypes	Days to 50% Flowering	Days to Maturity	Plant Height at Harvest	Number of Primary Branches per Plant	Number of Capsules per Plant	100 Seed Weight	Seed Yield per Plant	Oil Content
AKS CMS 2A X S-518	-1.750	-0.175	0.311	-0.556	-4.977	-0.933	-1.259	1.606*
AKS CMS 2A X CW-99	0.583	1.158	-2.509	-0.876	-5.412*	-0.767	-0.869	0.569
AKS CMS 2A X CCC-B2	-0.083	0.325	-2.671	0.474	-1.459	-0.100	-2.439	0.899
AKS CMS 2A X GILA	-1.083	0.992	-2.471	0.454	0.988	-0.350	-1.913	0.769
AKS CMS 2A X AKS/NS1	1.250	1.325	-2.419	-0.080	-0.669	-0.100	-2.968*	-1.231
AKS CMS 2A XAKS-322	-0.417	-0.508	-1.127	0.157	-1.197	-0.267	-1.189	-0.114
AKS CMS 2A X AKS-325	0.250	-1.175	2.304	-0.860	-0.311	-0.100	-0.684	0.531
AKS CMS 2A XAKS/NS-33	0.417	0.158	-0.447	1.170	2.638	0.067	-2.014	0.004
AKS CMS 2A XGMU-3923	-0.917	-0.175	-3.317	-0.071	3.529	0.317	2.324	0.236
AKS CMS 2A XGMU-3965	1.250	1.158	-0.022	1.365	0.383	0.483	1.921	-0.439
AKS CMS 2A XGMU-3924	-1.083	-3.175*	1.106	-1.618	2.533	0.400	0.017	0.927
AKS CMS 2A XGMU-3876	-2.083	-4.508**	2.413	0.624	1.529	0.067	3.842*	0.366
AKS CMS 2A XGMU-3863	1.750	-0.842	-1.601	-1.613	-4.147	0.733	3.969**	-0.709
AKS CMS 2A XGMU-3963	0.583	0.158	1.186	-1.076	-2.876	0.067	1.431	-0.628
AKS CMS 2A XGMU-3325	-0.750	2.492	-3.937	-1.493	-4.786	-0.517	1.646	-0.919
AKS CMS 2A XGMU-6877	2.750*	1.825	-1.422	-0.626	6.303*	0.400	0.837	-0.241
AKS CMS 2A XGMU-6881	-0.917	-0.175	4.499	2.390*	4.098	0.233	-1.973	0.104
AKS CMS 2A XGMU-6835	-0.917	0.658	2.381	0.390	-2.942	0.650	-1.514	-0.463
AKS CMS 2A X AKS-08R	-0.083	0.158	0.583	0.957	2.788	-0.183	2.259	-1.088
AKS CMS 2A XAKS-10R	1.250	0.325	7.163*	0.890	3.991	-0.100	-1.423	-0.179
AKS CMS 3A X S-518	1.750	0.175	-0.311	0.556	4.977	0.933*	1.259	-1.606*
AKS CMS 3A X CW-99	-0.583	-1.158	2.509	0.876	5.412*	0.767*	0.869	-0.569
AKS CMS 3A X CCC-B2	0.083	-0.325	2.671	-0.474	1.459	0.100	2.439	-0.899
AKS CMS 3A X GILA	1.083	-0.992	2.471	-0.454	-0.988	0.350	1.913	-0.769
AKS CMS 3A X AKS/NS1	-1.250	-1.325	2.419	0.080	0.669	0.100	2.968*	1.231
AKS CMS 3A X AKS-322	0.417	0.508	1.127	-0.157	1.197	0.267	1.189	0.114
AKS CMS 3A X AKS-325	-0.250	1.175	-2.304	0.860	0.311	0.100	0.684	-0.531
AKS CMS 3A XAKS/S33	-0.417	-0.158	0.447	-1.170	-2.638	-0.067	2.014	-0.004
AKS CMS 3A XGMU-3923	0.917	0.175	3.317	0.071	-3.529	-0.317	-2.324	-0.236
AKS CMS 3A XGMU-3965	-1.250	-1.158	0.022	-1.365	-0.383	-0.483	-1.921	0.439
AKS CMS 3A XGMU-3924	1.083	3.175*	-1.106	1.618	-2.533	-0.400	-0.017	-0.927
AKS CMS 3A XGMU-3876	2.083	4.508**	-2.413	-0.624	-1.529	-0.067	-3.842*	-0.366
AKS CMS 3A XGMU-3863	-1.750	0.842	1.601	1.613	4.147	-0.733	-3.969**	0.709
AKS CMS 3A XGMU-3963	-0.583	-0.158	-1.186	1.076	2.876	-0.067	-1.431	0.628
AKS CMS 3A XGMU-3325	0.750	-2.492	3.937	1.493	4.786	0.517	-1.646	0.919
AKS CMS 3A XGMU-6877	-2.750*	-1.825	1.422	0.626	-6.303*	-0.400	-0.837	0.241
AKS CMS 3A XGMU-6881	0.917	0.175	-4.499	-2.390*	-4.098	-0.233	1.973	-0.104
AKS CMS 3A XGMU-6835	0.917	-0.658	-2.381	-0.390	2.942	-0.650	1.514	0.463
AKS CMS 3A X AKS-8R	0.083	-0.158	-0.583	-0.957	-2.788	0.183	-2.259	1.088
AKS CMS 3A XAKS-10R	-1.250	-0.325	-7.163*	-0.890	-3.991	0.100	1.423	0.179
SE (Sij) ±	1.740	1.463	2.960	1.112	2.602	0.502	1.482	0.777
CD (0.05)	3.464	2.913	5.894	2.215	5.182	1.000	2.951	1.547
CD (0.01)	4.595	3.863	7.817	2.937	6.872	1.327	3.913	2.052

(*, ** Significant at 0.05 and 0.01 probability levels, respectively)

The crosses AKS CMS 3A x S-518 and AKS CMS 2A x CW-99 were found to be the best combinations for 100 seed weight. For seed yield per plant, AKS CMS 2A X GMU 3924, AKS CMS 2A X GMU 3876 and AKS CMS 3A X AKS/ NS -1 exhibited good SCA effects in desirable direction. The cross AKS CMS 2A X S-518 showed a good SCA effect for oil content. Earlier workers have also noticed good SCA effects for above traits in safflower (Narkhede *et al*., 1984; Patil *et al.,* 1992 and Wandhare *et al.,* 2003).

For seed yield and major yield contributing traits *viz.,* the number of primary branches per plant, the number of capsules per plant, 100 seed weight and seed yield per plant, the high *per se* performance of crosses, AKS CMS 2A X GMU 3876, AKS CMS 2A X S-518, AKS CMS 2A X CW-99 and AKS CMS 2A X GMU 3924 were observed either due to good GCA effects of their parents or high SCA effects of the respective crosses. Similar observations also have been reported earlier by Pahlavani *et al.* (2007), Parde *et al.* (2010) and Jhajharia *et al.* (2013) in safflower. It is therefore indicated that, selection of parents should be done on the basis of high mean performance and significant GCA effects of one of the parents in cross combination might be effective for seed yield improvement.

Three crosses *viz*., AKS CMS 2A X GMU 3876, AKS CMS 2A X GMU 3963 and AKS CMS 3A X AKS/NS1 were identified as promising crosses for seed yield per plant on the basis of good GCA effects of parents and SCA effects of crosses. Thus, these crosses might be further evaluated in the preliminary or multi-location hybrids trials for further exploitation at commercial level. The crosses *viz*., AKS CMS 2A X GMU 3965, AKS CMS 2A X GMU 3325 and AKS CMS 2A X AKS 325 were highly significant GCA effects of one of the parents involved in the cross and low SCA effects (non-significant) for almost all the traits, it is therefore recommended to utilize these crosses further by generation advancement by crossing again using 'B' lines of CMS line with same male parents and advancing the generations from F_2 to F_7 generations to select transgressive segregants in later generations for the development of varieties.

REFERENCES

Jhajharia, S., Chaudhary, P. Jhajharia, A., Meena, L. K and Singh, D. 2013. Heterosis and combining ability in safflower (*Carthamus tinctorius* L.) germplasm lines. *The Bioscan*, **8**(4):1453-1460.

Kempthorne, O. 1957. An introduction to genetical statistics. John Wiley and Sons, Inc., New York.

Latha, T. S. and Prakash, V. 1984. Studies on the proteins from safflower seed (*Carthamus tinctorius* L). *J. Agric. Food Chem.,* **32** (6):1412-1416. [Cross Ref]

Makne, V. G. and Chaudhary, V. P. 1980. Combining ability in safflower. J. Maharashtra Agric. Univ., **5** (2):128-130.

Nai, G., Singh, J. Sharma, S. P. and Lal. C. 2014. Combining ability analysis in Safflower (*Carthamus tinctorious* L.). *Electronic Journal of Plant Breeding*, **5** (2):208-212.

Narkhede, B. N., Deokar, A. B. and Patil, J. V. 1984. Line x Tester analysis in safflower. *J. Maharashtra Agric. Univ*., **9** (3):334-336.

Pahlavani, M. H., Saeidi, G. and Mirlohi, A. F. 2007. Genetic analysis of seed yield and oil content in safflower using F_1 and F_2 progenies of diallel crosses. *Int. J. Plant Prod.,* **2**:129-140.

Panse, V. G. and Sukhatme, P. V. 1967. Statistical method for agricultural workers, New Delhi, ICAR Publication.

Parde N. S., Lande, S. S. Wakode, M. M. and Deshmukh, S. N. 2010. Heterosis and combining ability in safflower. *PKV Res. J.,* **34**:35-38.

Patil, P. S., Patil, A. M. and Deokar, A. B. 1992. Line x Tester analysis for combining ability in safflower. *J. Maharashtra Agric. Univ.,* **17** (1):64-66.

Prakash, K. S. and Prakash, B. G. 1993. Yield structure analysis of oil yield in safflower (*Carthamus tinctorius* L.). *Oleagineux,* **48**:83–89.

Sarode, S. B., Ghorpade, P. B. Wayazade, P. M. Deshmukh, S. B. and Gomashe, S. S. 2008. Heterosis and combining analysis in safflower (*Carthamus tinctorius* L.). *Asian J. Bio Sci.,* **3** (1):(56-60).

Shivani, D., Sreelakshmi, C. and Sameer Kumar, C. V. 2011. Combining ability studies and heterosis for yield and its component traits in safflower [Carthamus tinctorius L.]. *Electronic Journal of Plant Breeding*, **2** (3):377- 383.

Sprague, G. F. and Tatum, L. A. 1942. General v/s specific combining ability in single cross of corn. *J. Am. Soc. Agron*., **34:**923-932. [Cross Ref]

Wandhare, M. R., Ghorpade, P. B. Patil, B. R. Satange, I. V. and Sakhare, B. A. 2003. Combining ability analysis in safflower (*Carthamus tinctorius* L.). *J. Soils and Crops,* **13** (1):108-111.