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Short Communication

Selection of elite parents and crosses for seed yield and its components using combining ability analysis over the three environments in safflower (*Carthamus tinctorious* L.)

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Abstract

Thirty crosses developed through line × tester mating design were evaluated along with parents in three environments to estimate gca and sca effects of parents and crosses, respectively for yield and its contributing traits. Based on consistent performance over three environments in safflower (*Carthamus tinctorious* L.) genotypes, BHIMA, GMU 3876, GMU 3863, GMU 7351, GMU 2757, AKS 08R and AKS CMS 2B were found to be good general combiners for yield and most of yield contributing characters. Hybrids, AKS CMS 2A x BHIMA, AKS CMS 2A x GMU 3876 and AKS CMS 2A x GMU 3863 having high sca effects were found promising for seed yield per plant and other traits over the three environments. The results indicated that these parents could be exploited in hybridization programmes for genetic improvement of individual traits. However, the promising hybrids having high sca effects may be used for heterosis breeding after multi-locations testing.

Key words : Safflower, combining ability, gca, sca, different environments

Safflower is one of the important *rabi* oilseed crops, which can be exploited in changing climatic conditions. It is an excellent crop with drought tolerance and good nutritional value. The seed contains 27.5% oil, 15% proteins, 41% crude fibers and 2.3% ash (Latha and Prakash 1984). Safflower oil cake is a valuable animal feed (Weiss 2000). More than 60 countries in the world grow safflower but over half is produced in India mainly for vegetables oil market. The average productivity of this crop is very low as compared to other countries where it is grown. Hence, the real breakthrough can be achieved by developing high yielding hybrids in safflower.

Combining ability analysis provides the information for selection of better parents and cross combinations for their exploitation (Sprague and Tatum 1942). In addition, this information will determine breeding method to be adopted for the further genetic improvement in specific trait, cytoplasmic male sterile lines were taken to generate crosses with teters. The present investigation was under taken to estimate combing ability of parents and crosses over three different environments as it is expected to give more relevant results as compared to testing in a single environment, to discriminate various parents and crosses appropriately for further utilization in breeding programme and for commercial cultivation after thorough testing.

The experimental material comprised of genetically diverse parents comprising of 15 males namely, AKS-322, AKS-325, GMU 5728, GMU 7351, GMU 2757, GMU 3876, GMU 3863, GMU 2453, GMU 3773, GMU 3313, GMU 6877, GMU 6881, AKS 08R and AKS 10R and two females *viz*., AKS CMS 2A and AKS CMS 3A. Thirty experimental hybrids along with their parents were raised in a randomized block design with three replications over three season, *rabi* 2017-2018 (E1), *rabi* 2018-2019 (E2) and late *rabi* 2018-

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19 (E3). This experiment was carried out at the experimental field of Oilseeds Research Unit, Department of Agril. Botany, Dr, PDKV, Akola. In each replication each hybrid and its parents were sown in a plot of 3×0.45 m^2 size accommodating one row of 3m length each and plant to plant distance within row maintained was 25cm. All the recommended agronomical package of practices and plant protection measures were followed timely to raise a healthy crop. The observations were recorded on plot basis for days to 50 % flowering, days to maturity and oil content [using Bench Top Pulse Nuclear Magnetic Resonance Spectrometer (model MQC OXPORD)]. However, the observations on other traits were recorded on five randomly selected plants. The data were subjected to analysis of variance for mean performance (Panse and Sukhatme 1985). Estimates of combining ability are known to be greatly influenced by environment. The results of combining ability analysis based on single environment might be highly biased and therefore, Elitriby et al. (1981) proposed model to understand the picture of the interaction of gene action with different environments was adopted. In this model, the data of line x tester analysis (Kempthorne 1957) over the environments were subjected to pooled analysis.

The analysis of variance for combining ability showed that the variances due to crosses were highly

Table 1. General combining ability effects of the parents for different characters over three environments (E1, E2 and E3)

	Genotypes	Days to 50% flowering	Days to maturity	Plant height at harvest	No. of branches at harvest	No. of capitula per plant	Seed yield per plant	100 Seed weight	Oil content
	Male								
1	GMU 7351	-0.380	-2.863 **	3.517 **	-0.681	1.114 *	-1.164 **	-0.379 **	0.011
2	GMU 3863	3.335**	0.592	-1.082	1.627 **	2.626 **	-1.286**	-0.241 *	0.843 *
3	GMU 5728	0.284	3.423 **	-2.040 **	-0.885 *	-2.979 **	-1.408 **	0.081	0.414
4	GMU 2757	3.680 **	-3.563 **	1.179	-1.172 **	-1.918 **	-1.853 **	-0.158	-1.753 **
5	GMU 3876	-1.876 *	-2.147 **	-3.839 **	1.379 **	4.238 **	2.442 **	0.373 **	2.096 **
6	GMU 3313	0.913	0.332	3.415 **	-1.812 **	-1.362 **	-1.519 **	0.287 *	0.274
7	GMU 2453	-1.670	-3.859 **	-0.414	-0.605	-0.601	1.860 **	0.390 **	-1.537 **
8	GMU 3773	-0.718	2.688 **	-0.468	-0.536	-0.068	-1.032	0.020	-0.464
9	GMU 6881	-1.829 *	1.060	1.114	-0.901 *	-1.946 **	0.481 *	-0.189	1.498 **
10	GMU 6877	0.239	1.473	0.048	0.188	-0.457	-1.019 **	-0.241 *	-0.768 *
11	BHIMA	-5.905 **	1.973 *	-0.740	0.947 *	2.571 **	-0.408	0.110	1.143 **
12	AKS 10R	1.900 *	1.086	2.439 **	-1.153 **	-2.687 **	0.114	0.063	-0.674
13	AKS 8R	1.356	-1.873 *	-3.785 **	1.878 **	1.502 **	1.475 **	-0.035	-0.783 *
14	AKS 322	-1.064	0.706	-1.266	1.716 **	1.071 *	1.103 **	0.070	-0.427
15	AKS 325	1.734	0.972	1.922 *	0.009	-1.101 *	1.214 **	-0.152	0.127
	SE(gi)	0.89	0.814	0.751	0.420	0.439	0.2204	0.119	0.349
	CD (0.05)	1.764	1.608	1.482	0.830	0.867	0.435	0.235	0.691
	CD (0.01)	2.322	2.122	1.956	1.0955	1.144	0.574	0.309	0.912
	Female								
1	AKS CMS 2B	-0.520 **	-1.324 **	1.045 **	0.327*	1.325**	0.602**	0.019	-0.132
2	AKS CMS 3B	0.520 **	1.324 **	-1.045 **	-0.327*	-1.325**	-0.602**	-0.019	0.132
	SE(gi)	0.326	0.297	0.244	0.1536	0.1605	0.0805	0.044	0.127
	CD (0.05)	0.644	0.587	0.541	0.303	0.317	0.159	0.086	0.252
	CD (0.01)	0.85	0.774	0.714	0.4	0.418	0.209	0.113	0.332

*,** significant at 5 and 1 per cent level of significance

significant for all the characters in all three environments. The variation between crosses was partitioned into different components representing the mean sum of square due to males, females and male x female interaction. Pooled combining ability analysis revealed that mean squares for environment was significant for the characters, nam ely, days to maturity, plant height at harvest and number of primary branches

Table 2. Specific combining ability effects of the crosses for different characters over three environments (E1, E2 and E3)

S.No.	Genotypes	Days to 50% flowering	Days to maturity	Plant ht. at harvest	No. of branches at harvest	No. of capitula per plant	Seed yield per plant	100 Seed weight	Oil content
1	AKS CMS 2A x GMU 7351	1.095	4.064 **	-3.093 **	-0.902	2.255 **	1.298 **	0.542 **	1.347 **
2	AKS CMS 2A x GMU 3863	-1.698	-4.236 **	0.215	0.174	0.842	2.876 **	0.343 *	-0.078
3	AKS CMS 2A x GMU 5728	1.535	1.941	1.802	-0.224	-1.119	0.465	-0.292	0.099
4	AKS CMS 2A x GMU 2757	-0.268	-0.160	1.159	-1.504 *	0.653	-2.747 **	-0.380 *	-2.145 **
5	AKS CMS 2A x GMU 3876	-0.460	-4.790 **	1.198	0.111	2.164 **	3.680**	0.019	0.484
6	AKS CMS 2A x GMU 3313	1.301	0.597	-2.985 **	0.910	-0.630	1.476 **	-0.401 *	-0.205
7	AKS CMS 2A x GMU 2453	-1.855	-0.571	3.087 **	-0.264	1.003	0.908 **	0.285	0.084
8	AKS CMS 2A x GMU 3773	1.949	-2.217	-4.848 *	-1.323 *	-1.953 **	-3.004 *	-0.575**	1.030 *
9	AKS CMS 2A x GMU 6881	-2.268	-0.901	-1.207	1.286 *	-0.586	-0.458	-0.050	-0.441
10	AKS CMS 2A x GMU 6877	3.044 *	3.752 **	-0.443	1.117	1.380 *	1.765 **	0.413 *	-0.987 *
11	AKS CMS 2A x BHIMA	-2.083	-0.106	0.407	2.467 **	2.797 **	2.887 **	0.761**	1.113 *
12	AKS CMS 2A x AKS10R	-0.940	0.852	0.510	0.016	-0.744	0.748**	-0.775**	1.507 **
13	AKS CMS 2A x AKS 8R	-1.820	-0.657	3.212 **	-0.380	0.573	3.241**	0.284	-0.600
14	AKS CMS 2A x AKS 322	1.261	2.483 *	-0.876	-0.676	4.069 **	-1.013 **	-0.035	0.023
15	AKS CMS 2A x AKS 325	1.208	-0.051	1.860	-0.808	2.564 **	-1.380 *	-0.139	-1.232 *
16	AKS CMS 3A x GMU 7351	-1.095	-4.064 **	3.093 **	0.902	-2.255 **	-1.298 *	-0.542 **	-1.347 **
17	AKS CMS 3A x GMU 3863	1.698	4.236 **	-0.215	-0.174	-0.842	-2.876 **	-0.343 *	0.078
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21	AKS CMS 3A x GMU 3313	-1.301	-0.597	2.985 **	-0.910	0.630	-1.476 *	0.401 *	0.205
22	AKS CMS 3A x GMU 2453	1.855	0.571	-3.087 **	0.264	-1.003	-0.908 **	-0.285	-0.084
23	AKS CMS 3A x GMU3773	-1.949	2.217	4.848 **	1.323 *	1.953 **	3.004 **	0.575 **	-1.030 *
24	AKS CMS 3A x GMU 6881	2.268	0.901	1.207	-1.286 *	0.586	0.458	0.050	0.441
25	AKS CMS 3A x GMU 6877	-3.044 *	-3.752 **	0.443	-1.117	-1.380 *	-1.765 *	-0.413 *	0.987 *
26	AKS CMS 3A x BHIMA	2.083	0.106	-0.407	-2.467 **	-2.797 **	-2.887 **	-0.761 **	-1.113 *
27	AKS CMS 3A x AKS10R	0.940	-0.852	-0.510	-0.016	0.744	0.00	0.775 **	-1.507 **
28	AKS CMS 3A x AKS 8R	1.820	0.657	-3.212 **	0.380	-0.573	3.241**	-0.284	0.600
29	AKS CMS 3A x AKS 322	-1.261	-2.483 *	0.876	0.676	- 4.069 **	1.013 **	0.035	-0.023
30	AKS CMS 3A x AKS 325	-1.208	0.051	-1.860	0.808	-2.564 **	1.380 **	0.139	1.232 *
	SE(gi)	1.264	1.152	1.064	0.594	0.621	0.3118	0.168	0.494
	CD(0.05)	2.495	2.274	2.096	1.174	1.227	0.615	0.332	0.977
	CD (0.01)	3.292	3.001	2.766	1.5493	1.6189	0.8119	0.4382	1.288

*,** significant at 5 and 1 per cent level of significant.

per plant, number of capitula per plant, oil content, seed yield per plant indicating that the environment had positive impact for combining ability for the trait. Mean squares for males were non-significant for all characters indicated negligible variability among the males. Further, female parents were also found non-significant for most of the traits. However, the mean squares for crosses were significant indicating the presence of substantial genetic variability for all the traits. The mean squares for lines x testers were significant for all the traits. The result obtsained in the present study were in agreement with the earlier findings (Sarode et al. 2008; Nai et al. 2014) in safflower.

None of the parents recorded significant gca effects in desirable direction simultaneously for all the studied characters (Table 1). However, GMU 3876, GMU 7351, BHIMA, AKS 8R and GMU 2757 among the males and AKS CMS 2B among the females were found to possess good gca for most of the yield contributing characters. Hence, these genotypes were recognized as the good parental material for further genetic improvement programme. For days to 50 % flowering and days to maturity, the line GMU 3863 and GMU 5728 showed highly significant and negative gca effects, respectively whereas, among the testers, AKS CMS 2B showed significant gca effects in desirable direction hence, these parents may be used for improvement of earliness in safflower. The good gca was also recorded by Pahlavani et al*.* (2007) and Sarode et al*.* (2008) for earliness in safflower. Among the testers, AKS CMS 2B and lines GMU 3876, BHIMA exhibited highest, significant and positive gca effects for number of capitula per plant, oil content, 100 seed weight and seed yield per plant. Another line GMU 7351 and AKS 8R showed significant and positive gca for seed yield along with oil content. Hence, these parents can be used for further genetic improvement of above traits. Similar results with good gca effects for oil contents were also reported by Prakash and Prakash (1993) and Nai et al. (2014) in safflower with a different set of material.

The specific combining ability has positive association with heterosis and helps in the identification of superior cross combinations for commercial exploitation of heterosis. In case of specific combining ability, none of the hybrids exhibited the significant sca effects in desirable direction for all the characters studied (Table 2). The crosses, AKS CMS 2A X GMU 3876 and AKS CMS 2A X GMU 3863 showed significant good sca effects for days to maturity, the cross AKS CMS 2A X GMU 3773 was good specific combination for plant height at harvest. For number of primary branches per plant, the cross, AKS CMS 2A x BHIMA showed significant sca effects in desirable direction. Whereas, the hybrids AKS CMS 2A x BHIMA, AKS CMS 2A X AKS 8R and AKS CMS 2A x GMU 3876 showed good sca effects for number of capsules per plant. The hybrids AKS CMS 2A x BHIMA and AKS CMS 2A x GMU 7351 were found to be best combinations for 100 seed weight. For seed yield per plant, AKS CMS 2A x BHIMA, AKS CMS 2A X GMU 3876 and AKS CMS 2A X GMU 3863 exhibited good sca effects in desirable direction. Further, the hybrid AKS CMS 2A X GMU 2757 showed good sca effects for oil content. Similar results in respect of good sca effects for above traits in safflower have also been reported previously.

The hybrids, AKS CMS 2A X GMU 3876, AKS CMS 2A X BHIMA, AKS CMS 2A X GMU 3863, AKS CMS 2A X AKS 8R and AKS CMS 2A X GMU 7351 were noticed as promising hybrids for seed yield and major yield contributing traits either due to good gca effects of their parents and or high sca effects of the respective hybrids. Significant increase in SCA effects was reported by Sumalini et al. (2020) in all the environments Significant G $\times$ E interaction was also observed for yield suggesting the environment effect on it. They also reported significant gca effects on parents yielding superior hybrids in certain combinations. Earlier, Pahlavani et al*.* (2007) and Jhajharia et al*.* (2013) also reported some promising hybrids in safflower. These promising hybrids may be exploited for generation advancement and development of varieties having desired traits. However, fresh crosses need to be effected involving “b” line.

Authors’ contribution

Conceptualization of research (VLG); Designing of experiments (VLG); Contribution of experimental material (VLG, IHT); Execution of field/lab experiments and data collection (IHT); Analysis of data and interpretation (IHT,VLG); Preparation of manuscript (IHT, VLG).

Declaration

The authors declare no conflict of interest.

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