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Analysis of variance of general and specific combining ability for 16 characters in ornamental safflower (*Carthamus tinctorius* L.)

MS Tagade, AB Bhosale, SK Marbhal, SG Bhalekar and AA Bhagat

Abstract
Twenty one hybrids were obtained by crossing 7 x 7 genotypes in half diallel fashion was evaluated in randomized block design with two replication during rabi 2021-22 at research farm of Horticulture, College of Agriculture, Pune-05, (M.S). The cross combination GMU-7942-1 x SSF-658, SSF-658 x Bhima, SSF-708 x CO-1, SSF-658 x GMU-7942-2, GMU-7942-1 x SSF-708, GMU-7942-1 x GMU-7943-1 were best on the basis of heterosis over mid and better parents. Among them GMU-7942-1 x SSF-658 was best cross combination. The mean sum of squares due to GCA was showed highly significant for all the characters except days required for bud initiation and mean sum of squares due to SCA was highly significant for all the character except days required for bud initiation and plant canopy. The germplasm line GMU-7942-1 (number of flower per plant, diameter of flower head, number of disc florets, fresh flower weight, shelf life of flower, plant canopy, seed yield per plant), SSF-658 (flower duration, length of disc florets, length of flower stalk) and Bhima (rosset stage, number of flower per plant).The cross combination which showed best specific combining ability are GMU-7942-1 x SSF-658 (number of flower per plant, diameter of flower head, fresh flower weight, shelf life of flower, seed yield per plant, plant canopy), SSF-658 x GMU-7942-2 (seed yield, number of disc florets, number of branches) and SSF-658 x Bhima (rosset stage, length of flower stalk). The crosses also recorded high heterotic effect, high per se performance. They also depicted high SCA effect and high heterosis for number of flowers per plant, seed yield, diameter of flower head, shelf life of flower flowering duration and plant height. The SCA effects were more than GCA effects showing greater role of non-additive effects for all the traits except which the plant canopy showed greater role of additive gene interaction. GCA: SCA ratio also indicated predominance of non-additive gene effect for these traits. Hence it is observed that the dominance as well as additive component of variation was important for expression of safflower yield and its components.

Keywords: Ornamental safflower, heterosis, half diallel, SCA, GCA, gene action

1. Introduction
Safflower (*Carthamus tinctorius* L..) is one of the most important oldest edible oilseed crop of India and other countries of recent introduction and is widely grown under the hot, dry climate of the Middle East, the centre of its origin and diversity (Knowles and Ashri, 1995) [7]. It is a multipurpose crop, has been grown from centuries in India for the orange-red dye (Carthamin) extracted from its brilliant coloured flowers and is cultivated mainly for its seed, which gives edible oil. Traditionally this crop was grown for its flowers, fabric dyes, food colouring and for medicinal purposes (Weiss, 2000) [11]. However it is currently grown as an oilseed crop worldwide. Safflower is basically self-pollinated crop but insects particularly bees are necessary for optimum pollination and maximization of yield. Safflower is a member of family-Compositae, sub family- Asteraceae, tribe -Tubiflorae, sub-division- Angiosperm of division - Phenerogams (Das, 1997) [2]. Cross pollination mainly through bees to the extent of 10-28% depending on genotype and insect activity has been reported in safflower (Weiss, 2000; Knowles, 1969) [11, 8]. Classen (1950) [1], however, reported cross pollination ranging from zero to 100 percent but the detectable crossing ranged from 5 to 40 percent. Shades of orange, yellow and red flowers are most common in early bloom, but post-bloom colours are darker. White flowers occur rarely. Pollination occurs as the style and stigma grow through the surrounding anther column at the base of the clasping corolla. An unpollinated, elongated stigma may remain receptive for several days.
In recent years, to improve the productivity of this crop using high yielding varieties and improved crop production technology efforts are implemented.

The half diallel analysis techniques provide systematic approach for identification of superior parents and crosses, which is the basic requirement on which the success of plant breeding programme rests. Hybridization has potential for breaking yield and quality barriers and developing hybrid varieties having built in high yield potential. For hybridization the parents should be selected on the basis of genetic potential. Hybrid vigour exploitation on commercial basis has lead to remarkable yield advance in several crops irrespective of their breeding system development of new hybrids and testing magnitude of heterosis is a continuous process of breeding program. In order to assess the extent of heterosis in F_1 hybrids and to know the possibility of exploiting heterosis at commercial scale, it is essential to evaluate newly developed crosses as well as parents in cross combinations for seed yield and its components (Shivani *et al*., 2011) [9].

Combining ability described by Sprague and Tatum (1942) [10] elucidates the nature and magnitude of gene action involved in the inheritance of various characters. For estimation of combining ability of parents, several biometrical tools have been developed for identifying desirable parents. Among these, half diallel analysis (Griffings, 1956) [4] has been extensively used to assess the combining ability of parents and crosses for different quantitative characters as well as to study the extent of heterosis for yield and components in safflower. The knowledge of nature and magnitude of gene action involved in expressions of contributing characters are very useful for development of the breeding procedures to be followed for safflower improvement. There is a shortage of information and hybridization work for ornamental safflower. The primary goal of the breeding programme to evaluate the crosses for flower / ornamental characteristics, taking into account safflower's ornamental values.

2. Materials and Methods

The present investigation entitled "Analysis of variance of general and specific combining ability for 16 characters in ornamental safflower (*Carthamus tinctorius* L.)" was conducted during year 2022-2023 at Modibaug Garden, College of Horticulture, Pune. Seven diverse seeds of safflower were received from AICRP on Safflower Solapur and crossed using half diallel mating design with griffing method-II during *rabi* 2021-22. The resulted 21 crosses along with seven parents planted with randomized block design with two replication. Plot size is 35m x 27m (8 guntha). Each plot consisted of 3 rows and each row accommodates 11 plants with paired planting, each of 4 meter length spaced at 45 cm apart. Plant to plant distance was 20 cm. One guard row was planted on both the sides of the experiments. The recommended dose of fertilizer was applied 60 kg N + 30 kg P2O5 + 30 kg K2O/ha. All recommended agronomical practices and plant protection measures were followed as and when required to raise a good crop of safflower. The observations on 18 characters were recorded by selecting randomly three competitive plants from each replication *viz.* plant height (75 DAS), number of branches per plant, seed yield per plant, stem thickness, plant canopy (75 DAS), days required for rosette stage, number of branches, days required for bud initiation, node number at which first flower appeared, flowering duration (from blooming 1st flower to senescence of last), number of flowers per plant, length of flowers stalk, diameter of flowers head, number of disc florets per flower, fresh flowers weight, seed yield per plant, length of disc florets, shelf life of flowers, spininess, petal colour.

3. Results and Discussion

The analysis of variance for experimental design revealed significance differences among the parents, hybrids and parents *vs* hybrids for all the characters indicated the presence of genetic variability among the experimental material. Significant mid parent and heterobeltosis for ornamental safflower yield, majority for identification of good combiners and promising crosses for future better accomplishment in safflower for ornamental purpose. It has ample scope for exploiting heterosis commercially and possibilities of isolating desirable segregants.

The analysis of variance for combining ability is significant for all the characters except days required for bud initiation. A persual of the table revealed that mean sum of square of GCA and SCA variance was significant for all the characters except days required for bud initiation. This indicate the GCA of parents and SCA of crosses and significant combination of additive and non-additive gene effect in the expression of characters.

Significant heterotic crosses over mid parent and better parent, in favourable direction, were observed for almost all the characters except plant canopy.

The g.c.a effects of the parents for the rosset stage were significant. The highest negatively significant g.c.a for this character were revealed by the parent Bhima (-0.409) followed by GMU-7943-1 (-0.326). The highest positively significant g.c.a effect for this character was revealed by the SSF-658 (0.429).The specific combining ability effects (sij) in favourable negative direction were significant in 8 hybrids. The highest significant negative s.c.a. effect were exhibited by the hybrid SSF-658 x Bhima (-1.38) followed by SSF-708 x CO-1(-1.28), GMU-7942-1 x Bhima (-0.83) and GMU-7943-1 x CO-1 (-0.68).

The g.c.a effects of the parents for the plant height were significant. The highest negatively significant g.c.a for this character were revealed by the parent GMU-7942-2 (-7.68) followed by GMU-7943-1 (-2.37) and SSF-708 (-4.25). The highest positively significant g.c.a effect for this character were revealed by the GMU-7942-1 (9.42).

The specific combining ability effects (sij) in favourable negative direction were significant in 6 hybrids. The highest significant negative s.c.a effect were exhibited by the hybrid GMU-7942-1 x SSF-708 (-16.64) followed GMU-7943-1 x CO-1(-10.54).

For days required for bud initiation, the highest negatively significant g.c.a for this character were revealed by the parent CO-1 (-0.51). The highest positively significant g.c.a.effect for this character was revealed by the Bhima (0.47). The specific combining ability effects (sij) in favourable negative direction were non-significant. But the highest value in favourable direction was in hybrid GMU-79-42-2 x GMU-7943-1 (-0.81) which is non-significant. For node at which 1st flower appeared, the highest negatively significant g.c.a. for this character was revealed by the parent SSF-708 (-0.482). For plant height, highest negatively significant g.c.a for this character were revealed by the parent GMU-7942-2 (-7.68) followed by GMU-7943-1 (-2.37) and SSF-708 (-4.25).The highest significant negative s.c.a effect were exhibited by the hybrid GMU-7942-1 x SSF-708 (-16.64) followed GMU-7943-1 x CO-1 (-10.54).

For number of flower per plant, the highest positively significant g.c.a. for this character were revealed by the parent

GMU-7942-1 (5.235) followed by Bhima (4.832). The highly positively significant s.c.a. effect were exhibited by hybrid GMU-7942-1 x SSF-658 (22.53) followed by GMU-7942-2 x CO-1 (23.11), GMU-7942-1 x GMU-7943-1 (20.35), Bhima x CO-1 (13.45).For length of flower stalk, the highest positively significant g.c.a. for this character were revealed by the parent SSF-658 (0.909) followed by GMU-7942-1 (0.678). The highly positively significant s.c.a. effect were exhibited by hybrid SSF-658 x Bhima (2.84). For diameter of flower head, the highest positively significant g.c.a. for this character were revealed by the parent GMU-7942-1 (0.498) followed by SSF-708 (0.261) and SSF-658 (0.227). The highly positively significant s.c.a. effect were exhibited by hybrid GMU-7942-1 x SSF-658 (1.04). For stem thickness, the highest positively significant g.c.a for this character was revealed by the parent GMU-7942-1 (0.349) followed by Bhima (0.222) and CO-1(0.109). The highly positively significant s.c.a effect were exhibited by hybrid GMU-7942-1 x Bhima (0.56) followed by GMU-7943-1 x CO-1(0.51).

For seed yield per plant, the highest positively significant g.c.a for this character were revealed by the parent GMU-7942-1 (8.29) followed by SSF-658 (2.83). The positively significant s.c.a effect were exhibited by hybrid GMU-7942-1 x SSF-658 (15.41) followed by SSF-658 x GMU-7942-2(14.01) and GMU-7942-1 x CO-1(8.97). The findings reported by Fokmare (2001) [5].

The SCA effects were more than GCA effects showing greater role of non-additive effects for all the traits except which the plant canopy showed greater role of additive gene interaction. GCA: SCA ratio also indicated predominance of non-additive gene effect for these traits. Hence it is observed that the dominance as well as additive component of variation was important for expression of safflower yield. The findings reported by Jan *et al.* (2006b) [6], Devi *et al.* (2005) [3].

GMU-7942-1 x SSF-658

SSF-658 x GMU-7942-2

GMU-7942-1 x SSF-708

SSF-658 x Bhima

Table 1: Analysis of variance of general and specific combining ability for 16 characters in ornamental safflower

Sr. No	Mean sum of squares						
	Source of variation	GCA	SCA	Error	σ^2 gca	σ^2 sca	σ^2gca/sca
	D.F	6	21	27	-	-	-
1	Rosset stage	0.749**	0.340*	0.1656	0.0648	0.1748	0.3706
2	Days req. for bud initiation	0.2264	0.5481	0.3139	-0.0096	0.2351	-0.0409
3	Node at 1st flower appeared	1.5403**	0.9505*	0.4225	0.1242	0.5280	0.2352
4	No of flowers/ plant	433.92**	273.57**	13.9350	46.665	259.63	0.1797
5	Length of flowers stalk (cm)	3.5536**	2.4876**	0.2745	0.3643	2.2131	0.1646
6	Diameter of flowers head (cm)	0.7189**	0.1822**	0.0225	0.0773	0.1597	0.4844
7	No. of disc florets	941.84**	196.14**	7.8436	103.78	188.30	0.5511
8	Length of disc florets (cm)	0.0412**	0.1154**	0.0099	0.0034	0.1056	0.0329
9	Stem thickness (cm)	0.7050**	0.1290**	0.0125	0.0769	0.1165	0.6601
10	No of branches	18.152**	9.1630**	0.7561	1.9328	84.068	0.2299
11	Flowering duration	49.758**	11.117**	4.2548	5.0560	6.8619	0.7368
12	Plant height	301.07**	64.138**	5.0368	32.893	59.100	0.5565
13	Fresh flowers weight (g)	2.7691**	1.2587**	0.0945	0.2971	1.1642	0.2552
14	Shelf life of flowers	0.9480**	0.4490**	0.0614	0.0985	0.3876	0.2541
15	Plant canopy (cm)	109.339*	36.8027	36.6013	8.0819	0.2009	40.2245
16	Seed yield /plant (g)	170.27**	24.040**	2.7853	18.651	21.265	0.8771

Conclusion

Thus, in general, it can be concluded that the heterosis can be successfully exploited for yield and its component characters by utilizing the material included in the studies and also by selecting additional material which shows better performance for these characters. The promising crosses GMU-7942-1 x SSF-658, SSF-658 x GMU-7942-2, GMU-7942-2 x SSF-708, GMU-7942-1 x SSF-708, SSF-658 x Bhima utilized for future breeding programme for exploitation of hybrid vigour. The parents GMU-7942-1, SSF-658 and Bhima also utilized in various breeding programme.

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