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Combining Ability Analysis for Horticultural Traits in French Marigold

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Abstract

Background/Objectives: French marigold (*T. patula*) hardy annual, about 30 cm tall, forming a bushy plants are grown as a loose flower and a garden flower. Four male sterile lines and 18 diverse pollinators as tester were used to produce 72 F_1's. These crosses and parents were evaluated for different ornamental characteristics. **Methods/Statistical Analysis:** These F_1 hybrids along with 22 parental lines were evaluated during the summer (2009) and rainy season (2009) in Randomized Block Design. Highly significant variances for all the traits indicated the sufficient variability was observed in the parental material for all the characters under study. **Findings:** Among male sterile lines, ms_8 (summer season) and ms_9 (rainy season) proved good general combiners, while testers Spray Mix -1, Bonita Bolero and Safari Queen were the best general combiners for both the seasons. However, cross combinations viz. ms_8 x Hero, ms_{10} x Hero, ms_{10} x Cupidon Yellow, ms_8 x Double Dwarf Lemon was the best in terms of specific combining ability during the summer. Whereas, during winter the combinations viz. ms_9 x French Bonita-3, ms_{10} x French Bonita-3, ms_9 x Bonita Bolero, ms_8 x Sunkist and ms_9 x French Bonita-2 were best specific combiners. In both the seasons, the ration of σ^2 GCA/σ^2 SCA was less than unity for all the characters showing the preponderance of dominance variance. **Applications:** Marigold is especially used for festive occasions, marriages, religious ceremonies, social function and in landscape plans because its having a wide range of attractive colours, shape and size having good keeping quality. Now a days, marigold is used as a source of pigment for poultry feed. Caretonoids is used as poultry feed mix and food colourant. Lutin, is major component of Caretonoid is having therapeutic values. Marigold cultivation controls the nematode population in as well as mosquito repellant products are also being used. The mean sum of square for parentsvs crosses in this study for all the traits during summer and rainy season indicated the presence of heterosis. Thus it is obvious that heterotic effects represent an important resource in hybrid breeding of French marigold.

Keywords: Combinig Ability, Carotene Content, GCA, Inbred Lines, Male Sterile Lines, Marigold, SCA

1. Introduction

Marigold (*Tagetes* spp) is one of the major loose flower crops among ornamentals. It belongs to the family Asteraceae and native of Central and South America, especially Mexico. Out of 33 species of genus *Tagetes*; two species, namely *Tagetes erecta* (African marigold) and *T. patula* (French marigold) are popularly grown for loose flowers, bedding plants and pot plant production. Prospects of commercialization of marigold are increasing, because of ease grow, low nutrient requirement and easy availability of planting material. Marigold is especially used for festive occasions, marriages, religious ceremonies, social functions and in landscaping owing to its wide range of attractive colors, pigment for poultry feed. Carotenoids are used as poultry feed mix and food colorant[1]. In a recent study of *Tagetes patula* two male sterile lines and ten inbred lines were crossed to estimate heterosis, results showed that the hybrid combinations displayed higher ornamental values[2] and showed obvious heterosis over the male-parent for most of the ornamental traits evaluated. In marigold, with the availability of male

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sterile line hybridization becomes economically viable and commercially feasible. In another report[3] similar approach was used for improvement of carotenoid in *T. erecta*. Keeping in view the importance of marigold in our socioeconomic set up studies was conducted to evaluate heterosis for important floral characteristic during summer and rainy season. The objectives of this study were to evaluate combining ability of parents and hybrids and to estimate heterosis for selecting the superior hybrids which can be used in further breeding program of French marigold.

2. Materials and Methods

The field experiment was carried out at the experimental farm of the Department of Floriculture and Landscaping, University of Horticulture and Forestry, Nauni, Solan (H.P.) during summer and rainy season (2009). The seeds of these inbred lines were procured from the Department of Floriculture and Landscaping. The seeds were produced under the project" Promotion of F_1 hybrids in floriculture (Antirrhinum, Pansy, Petunia and Marigold)" during 2005-2008. The parental material used for the present studies consisted of four male sterile lines, namely; ms_7, ms_8, ms_9 and ms_{10}. A set of 18 diverse testers/ pollinators was used for crossing with each four male sterile lines.

Seeds of all the parental materials viz. male sterile lines and testers were sown during rainy season, i.e. July (2008) in the nursery to raise the seedlings. Transplanting of these seedlings was carried out after one month of sowing, of the seeds in the nursery. The experiment was laid in polyhouse. The seedlings were planted at a spacing of 30 x 30 cm and the standard cultural practices like hoeing, irrigation, weeding and staking were followed as per the requirement of the crop. Buds of male sterile lines were bagged before anthesis to avoid contamination from unwanted pollens. The testers were also bagged to avoid cross pollination and to ensure their progenies. For producing F_1 hybrids, 4 male sterile lines were crossed with 18 testers in line x tester fashion[4], resulting in 72 F_1 hybrid combinations at a stagewhen the flowers of male sterile lines were fully opened. The crossing was done from 9:30 AM to 1.30 PM and was repeated for three consecutive days to ensure good seed set. These crossed flowers were again bagged and labeled. The resulting seeds from all the 72 hybrid combinations were harvested and kept separately in plastic moisture proof seed jars.

The 72 cross combinations made during 2008 were raised during March-July (summer) and July-November (rainy) 2009, respectively, along with parents comprising lines and testers in-order to judge their performance for biochemical and commercial traits. The experiment was laid out in the Completely Randomized Block Design with three replications in both the seasons. The data recorded on 72 crosses along with 18 testers and 4 male sterile lines was used to estimate general combining ability of parents and specific combining ability of cross combinations using appropriate formulae and statistical package SPAR 2.0. The ANOVA for randomized block design in the present study was calculated[5] according to the suggested model.

2.1 Estimation of GCA Effects

The GCA effects of the parents were obtained by SPAR 2.0 software package and significance of the GCA of lines and testers were estimated using the following formulae:

2.1.1 Test of Significance for GCA Effect of Lines and Testers

GCA effect of the lines were significant for those lines in which we had $| gi-0 | \geq SE (g_i) \times t$.

Where,

g_i = GCA value of the i^{th} line

SE(gi) = Standard error for the GCA lines

t = Student 't' value at the error degree of freedom and 5% level of significance

GCA effect of the lines were significant for those lines in which we had $| gj-0 | \geq SE (g_j) \times t$.

Where;

g_j = GCA value of the j^{th} tester

SE (gj) = Standard error for the GCA testers

t = Student 't' value at the error degree of freedom and 5% level of significance

The GCA values which were found significant at 5% level of significance were marked with '*' sign.

2.1.2 Estimation of SCA Effects of Crosses

The SCA effects of the cross combinations were obtained by SPAR 2.0 software package and significance of the SCA of the cross combinations were estimated using the following formulae.

2.1.2.1 Test of Significance for SCA Effects of the Crosses

SCA effect of the crosses were significant for those crosses in which we had | sij-0 | ≥ SE (S_{ij}) x t.

Where,

S_{ij} = SCA value of the ijth cross

SE (S_{ij}) = Standard error for the SCA crosses

t = Student 't' value at the error degree of freedom and 5% level of significance

The SCA values which were found significant at 5% level of significance were marked with '*' sign.

The gene action was studied by the estimation of GCA and SCA variances and components of variances which are discussed as follows.

2.2 Estimation of GCA and SCA Variances

The variance components were estimated by the covariance of the full sib (denoted by Cov (FS)) and covariance half sib average (denoted by Cov [HS (average)]obtained by SPAR 2.0 and further calculated by the following formulae as suggested by[6,7].

σ^2_{GCA} = Cov HS (average)

σ^2_{SCA} = [Cov (FS) -2 COV (HS)]

3. Results and Discussion

Analysis of variance performed for the design of experiment revealed that treatments differences were highly significant for all the characters under study during both the crop seasons, thus meeting the prerequisite for line x tester analysis. During summer season crop, mean sum of squares for parents vs. crosses, parents and crosses were highly significant for all the characters suggesting sufficient variability among the various genotypes whereas during rainy season, mean sum of square for parents vs. crosses and crosses were found significant for all the characters whereas, mean sum of square for parents were highly significant except for flower yield and number of flowers.

Significance of mean sum of square for parents vs. crosses for all the trait during summer and rainy season indicated the presence of heterosis. GCA and SCA effects were found to be highly significant, indicating preponderance of both additive and non additive gene action in inheritance of most of the characters, These results are matching with Other group[8] also. Variance component of SCA ability was greater than the values of GCA for all characters, showing preponderance of non-additive gene action and similarly results were obtained by[9] in petunia. The tester Single Petal Red showed the highest GCA (Tables 1 & 2) for days taken to flowering during summer and rainy season, while in terms of per se performance, it exhibited low value. Thus, though the testers had good GCA but owing to its low per se performance it could not be used effectively in breeding programme. The hybrid ms_{10} x Single Petal Red showed the maximum positive SCA (Table 3) effect during summer. The parents involved in the cross showed the high x low GCA in desirable direction. Dominance variance was pronounced to additive variance suggesting that the hybrid breeding method is effective for the improvement of the characters. In similar findings[10,11] the role of non-additive gene action in controlling flowering days in marigold was observed. This hybrid is also exhibited highest heterosis for the given trait. During rainy season hybrid ms_9 x Hero B showed highest SCA effect (Table 4) and the parents involved in the cross showed low x high GCA effects. The dominance components of variance were higher in rainy season as compared to summer season suggesting better expression of dominance components during the rainy season. The ratio of σ^2 GCA/ σ^2 SCA was less than 1 indicating the importance of non-additive gene action in both seasons. Thus, selection may be deferred to later stages in both seasons.

In case of plant height, the tester Spray Boy and Nana Jambo Bicolour showed highest GCA effects during both the seasons, but their per se performance was low which suggested their limited potential in reducing the plants height of hybrids. The hybrid ms_{10} x Cupid on Yellow showed the maximum positive effect. The parents involved in the cross showed high x low GCA effects indicated the non-additive gene action during the summer. In rainy season, hybrid ms_7 x Spray Mix-1 exhibited high SCA effect and its parent showed high x high GCA effect indicated the additive gene action for these traits and selection could be done at early stages. Similar findings were observed by[12] in crop balsam. For this trait, negative heterosis was observed for both the seasons. As mentioned in the result from other two groups[13,14] which showed similar findings.

The tester Safari Queen exhibited highest GCA effect, but its average mean performance was low in trait plant spread indicating the non-additive gene action during summer. While tester Bonita Bolero showed highest GCA and its average mean performance was also high,

indicating the additive gene action during rainy season. Additive gene action was more important in addition to non-additive gene action in the production of marigold. In case of plant spread, hybrid ms_9 x Single Petal Red exhibited high SCA effects and the parents involved also showed high x high GCA inferred that there was additive gene action during summer season, while hybrid ms_7 x Hero B showed maximum SCA effect but their parents showed high x low GCA effect indicating the dominance effect of gene. The ratio of σ^2 GCA/σ^2 SCA was less than 1 indicating the importance of non-additive gene action in both seasons. For improving the plant spread in these potential crosses, it would be advisable to start the selection at later generation.

For duration of flowering, tester FM-786 showed highest GCA effect and in terms of per se performance, it ranked seventh among the testers which indicate that the additive gene action is operative during summer, while in rainy season, similar trend was seen in tester Harmony Boy. Hybrid ms_7 x French Bonita-4 showed maximum SCA effect in summer and its parents also exhibited high x high GCA effect which indicated the additive gene action. Identical trend was seen during rainy season in the hybrid ms_7 x Hero B. The selection for this trait at early stages might be useful.

For number of flowers per plant during summer season, tester French Bonita-6 exhibited high GCA effects and among average mean performance, it ranked fourth suggesting the line would be a potential line in a breeding programme to increase number of flowers per plant. However, in rainy season Spray Mix-1 showed the high GCA coupled with high average mean performance. In this case, Selection at early stages would be advisable. Hybrid ms_9 x Single Petal Red exhibited highest SCA effect for the trait. The parents involved in the cross showed low x high effects while in rainy season, ms_{10} x French Bonita-3 exhibited highest SCA effects and its parents had high x high GCA effects. For this trait, additive and non-additive gene actions appeared equally important as observed by[14]. For flower size, FM-786 exhibited maximum GCA effect for the trait, but its per se performance was low which suggests that in spite of high combining ability the line could not impart much to the trait owing to its less magnitude in terms of performance during summer season. Hybrid ms_8 x Hero B was the best combination in terms of SCA effects and the parents involved in the combination had low x high GCA effect during summer while in rainy season, ms_7 x Cupidon Orange exhibited high SCA effects and its parents also showed high x high GCA effect indicating the additive gene action coupled with non-additive gene action. This hybrid also exhibited a considerable degree of heterosis for the trait. The summer season showed high dominance component of variance in comparison to rainy season. However, SCA variance was higher than the GCA variance suggesting the preponderance of non-additive gene action for the control of the trait. It would be advisable to delay the selection to later stages to improve the flower size.

For flower weight, the tester Cupid on Yellow showed high GCA effect in both the seasons coupled with high average mean performance. It enabled the tester to improve the flower weight owing to its intense capability to improve the trait by additive gene effect. Hybrid ms_7 x Hero B exhibited high SCA effect and their parents showed high x high GCA effects, respectively, suggesting the combined action of additive and non-additive gene action for the superiority of the hybrid.

In case of flower yield, the tester French Bonita-6 showed maximum GCA effect during summer, coupled with low per se performance indicating limited potential of line to exploit additive gene action, while in rainy season, tester French Bonita-1 showed high GCA effect and its per se performance was also high suggesting good potential of lines to exploit the additive gene action for the trait. However, in summer, hybrid ms_8 x Nana Jambo Bicolour exhibited highest SCA and their parents had low x low GCA effects, respectively. In rainy season, ms_{10} x French Bonita-1 showed maximum SCA effects and the parents involved had high x high GCA, respectively, suggesting the role of both additive and non additive gene action for the superiority of the hybrid.

In terms of carotene content, tester Single Petal Red showed maximum GCA, however, its average mean performance was low, suggesting the limited use of tester to exploit additive gene action for the character during summer. Where as in the rainy season, Spray Mix-1 showed the maximum GCA along with average mean good performance reflecting the superioty of the tester to exploit additive gene action in a better manner. Hybrid ms_7 x Single Petal Red showed maximum SCA effect and the parents involved showed low x high GCA effect, respectively. In rainy season, ms_{10} x French Bonita-1 showed maximum SCA effect with parents having high x high GCA effects, respectively, indicating the importance of additive and non-additive gene action for the given combinations. It defers the selection for later generation for this trait.

Table 1. Estimates of GCA Effects of Parents During Summer Season (2009)

Genotype / Testers	Days taken to flowering	Plant height (cm)	Plant spread (cm)	Duration of flowering	Number of flowers/ plant	Flower size (cm)	Flower weight (g)	Flower yield (g/plant)	Carotene content (µg/g)
Spraymix-1	-0.78	7.09*	1.37*	0.24	-6.08	0.06	-0.09	-11.51	59.08*
Hero B	0.31	-0.64	-0.76	2.29*	-18.60*	0.02	0.07	-22.55*	-66.45*
Cupidon Yellow	2.98*	0.89	-1.81*	-1.83*	-37.77*	0.19	0.24*	-49.20*	-186.05*
Cupidon Orange	0.79	1.30	-1.80*	1.78*	-35.60*	-0.11	0.16	-48.10*	-19.60
French Bonita-3	0.81*	-0.12	0.98	4.14*	11.86*	-0.22	0.09	25.25*	5.45
Bonita Bolero	-0.01	-1.00	1.57*	3.19*	1.99	0.14	0.02	5.70	5.09
French Bonita-4	-0.10	-1.05	0.57	-0.08	2.24	0.14	0.06	9.25	70.99*
FM-786	0.83*	0.79	0.96	4.73*	14.24*	0.30*	0.02	24.42*	7.09
Single Petal Red	-2.95*	-3.75*	0.67	-0.71	21.12*	0.22	-0.12	22.64*	138.06*
Double Dwarf Lemon	0.64	1.89*	0.23	-3.48*	-2.63	-0.39*	-0.09	-8.05	68.18*
Spray Boy	0.66	-6.65*	-3.97*	-1.61*	-8.35*	-0.38*	0.02	-7.46	-96.31*
French Bonita-1	0.06	-0.74	-2.10*	4.11*	3.99	-0.23	-0.03	6.10	75.39*
French Bonita-6	-1.08*	-3.29*	-0.46	0.54	25.71*	0.18	-0.16	24.72*	-101.28*
Harmony Boy	-0.93*	8.02*	1.56*	-4.65*	21.57*	0.25	-0.11	23.56*	-186.32*
Safari Queen	-0.66	6.90*	4.13*	1.69	13.52*	0.08	-0.01	20.04*	39.69*
Sunkist	-0.28	-2.40*	-0.12	-4.86*	1.41	-0.08	-0.10	-3.39	115.49*
Nana Jambo Bicolor	0.28	-2.32*	1.52*	-4.81*	-19.05*	0.25	0.15	-19.91*	29.59*
French Bonita-2	-0.55	-4.89*	-2.57*	-0.66	10.41*	-0.46*	-0.13	8.41	41.84*
CD (0.05) Testers	1.14	2.11	1.82	1.72	10.97	0.38	0.22	17.22	38.04
Lines									
ms_7	-0.33	0.36	-0.99*	-1.05*	2.86	-0.07	-0.05	1.83	24.73*
ms_8	-0.30	-0.09	0.54	0.15	0.67	-0.05	0.16*	9.00*	-19.9*
ms_9	0.45*	0.41	0.46	0.43	-2.66	0.20*	-0.06	-6.86*	-11.91
ms_{10}	0.18	-0.69	-0.02	0.46	-0.87	-0.07	-0.05	-3.97	7.13
CD (0.05) Lines	**0.54**	**0.99**	**0.86**	**0.81**	**5.17**	**0.18**	**0.10**	**8.12**	**17.93**

Significance at 5% of level of significance

Table 2. Estimates of GCA Effects of Parents During Rainy Season (2009)

Genotype / Testers	Days taken to flowering	Plant height (cm)	Plant spread (cm)	Duration of flowering	Number of flowers/ plant	Flower size (cm)	Flower weight (g)	Flower yield (g/plant)	Carotene content (µg/g)
Spraymix-1	0.21	21.64*	7.38*	9.05*	18.89*	0.04	-0.01	30.76*	465.03*
Hero B	1.10	-7.85*	2.40*	-4.51*	-16.10*	0.01	-0.0	-21.79*	-182.19*
Cupidon Yellow	6.31*	7.95*	-6.70*	-13.5*	-35.01*	0.22	0.84*	-28.11*	-295.80*
Cupidon Orange	5.41*	16.15*	-2.05*	-16.8*	-30.60*	-0.11	0.71*	-23.15*	-124.55*
French Bonita-3	-1.29*	-7.29*	0.68	-5.73*	7.71	-0.21	-0.04	10.97	-44.21
Bonita Bolero	-1.28*	-2.82	4.15*	2.20*	12.78*	0.13	-0.11	14.42*	176.78*
French Bonita-4	-0.96	0.09	-0.71	5.65*	5.56	0.14	-0.08	5.07	246.53*
FM-786	0.05	0.67	-0.07	-0.01	-4.45	0.30	-0.04	-5.04	-70.38
Single Petal Red	-1.06	-7.64*	-3.71*	1.36	-1.20	0.24	-0.20*	-11.10*	27.94
Double Dwarf Lemon	0.98	-1.27	2.78*	-0.98	16.43*	-0.40*	-0.13	15.34*	-119.22*
Spray Boy	-0.49	-9.94*	-3.05*	-0.06	-13.18*	-0.35	-0.006	-15.04*	-65.26
French Bonita-1	0.66	1.20	1.70	-0.28	15.69*	-0.23	0.05	31.51*	38.69
French Bonita-6	-1.74*	-7.44*	-5.36*	5.55*	3.54	0.17	-0.14	-0.78	-194.12*
Harmony Boy	-1.86*	14.07*	0.86	9.15*	10.03*	0.25	-0.15	8.96	44.81
Safari Queen	-1.08	9.22*	3.98*	8.61*	14.21*	0.09	-0.16	10.92	71.29
Sunkist	-0.59	-8.70*	-2.00*	2.35*	-2.20	-0.09	-0.26*	-13.17*	14.46
Nana Jambo Bicolor	-3.21*	-12.8*	1.84*	-2.38*	-15.06*	0.24	-0.08	-22.16*	-125.09*
French Bonita-2	-1.16	-5.15*	-2.14*	0.46	12.94*	-0.44*	-0.11	12.38*	135.28*
CD (0.05) Testers	1.72	6.80	2.52	2.32	11.33	0.56	0.18	15.60	162.02
Lines									
ms_7	-0.42	-4.48*	-0.20	-0.51	-0.25	-0.06	-0.1*	-8.03*	-14.48
ms_8	0.68*	2.94*	-0.48	-0.96*	-4.40*	-0.05	0.11*	-0.37	42.50
ms_9	-0.28	1.12	2.05*	1.28*	6.15*	0.20*	-0.19*	-2.45	-57.39*
ms_{10}	0.01	0.41	-1.37*	0.20	-1.49	-0.07	0.24*	10.86*	29.37
CD(0.05) Lines	**0.81**	**3.21**	**1.19**	**1.09**	**5.34**	**0.27**	**0.09**	**7.36**	**76.38**

Significance at 5% of level of significance

Table 3. Estimates of SCA Effects of Hybrids During Summer Season (2009)

Genotype	Days taken to flowering	Plant height (cm)	Plant spread (cm)	Duration of flowering	Number of flowers/ plant	Flower size (cm)	Flower weight (g)	Flower yield (g/plant)	Carotene content (µg/g)
ms_7 x Spraymix-1	0.03	-4.03	1.61	-3.74*	1.76	0.13	0.47*	3.99	-17.20
ms_8 x Spraymix-1	0.93	-4.84*	-5.22*	-3.42	-1.44	-0.86*	-2.72*	-14.64	23.88
ms_9 x Spraymix-1	-0.55	-1.81	0.25	0.03	3.56	0.39	1.56*	12.32	12.51
ms_{10} x Spraymix-1	-0.41	10.69*	3.34	7.13*	-3.88	0.32	0.67*	-1.67	-19.19
ms_7 x Hero B	-0.40	4.50*	-0.00	-5.99*	-2.98	-0.72	-1.54*	-8.98	-16.26
ms_8 x Hero B	-0.89	-6.57*	-2.34	4.39*	-0.85	1.07*	3.58*	8.88	12.42
ms_9 x Hero B	1.41	4.04	-2.36	1.91	-16.65	-0.61	-0.79*	-24.54*	4.71
ms_{10} x Hero B	-0.11	-1.97	4.72*	-0.31	20.49	0.26	-1.24*	24.65*	-0.86
ms_7 x Cupidon Yellow	-1.13	5.23*	-1.00	-4.12*	-6.48	1.02*	-0.99*	-9.46	-41.67
ms_8 x Cupidon Yellow	-1.09	1.22	-3.62	2.12	3.84	-1.31*	-0.17	-0.46	111.01*
ms_9 x Cupidon Yellow	5.08*	2.64	1.98	-4.28*	0.51	0.31	1.69*	5.28	-10.77
ms_{10} x Cupidon Yellow	-2.85*	-9.10*	2.64	6.28*	2.12	-0.02	-0.52*	4.64	-58.56
ms_7 x Cupidon Orange	2.98*	5.88*	-1.31	-0.74	-3.11	1.06*	-0.12	-1.72	116.89*
ms_8 x Cupidon Orange	1.15	-7.19*	-3.03	0.10	-6.25	-1.19*	2.61*	-11.25	-90.92*
ms_9 x Cupidon Orange	-1.26	-8.36*	1.44	-1.36	9.88	0.54	-2.65*	10.32	4.03
ms_{10} x Cupidon Orange	-2.86*	9.67*	2.90	2.04	-0.50	-0.41	0.16	2.65	-30.00
ms_7 x French Bonita-3	-1.63	0.05	-0.45	4.02*	8.88	0.06	0.98*	19.96	77.82*
ms_8 x French Bonita-3	-0.66	0.84	-1.82	-1.32	-12.19	-0.59	-1.06*	-23.24	0.21
ms_9 x French Bonita-3	-2.15	1.53	3.58	-0.46	5.94	0.08	0.41	10.34	17.47
ms_{10} x French Bonita-3	4.44*	-2.42	-1.29	-2.22	-2.63	0.44	-0.33	-7.06	-95.51*
ms_7 x Bonita Bolero	-1.13	3.06	3.52	4.10*	7.14	-0.01	0.18	11.28	58.68
ms_8 x Bonita Bolero	0.90	0.39	-0.91	1.35	-10.19	-0.11	-0.50*	-15.39	45.20
ms_9 x Bonita Bolero	1.88	-4.11	-3.96*	-1.11	3.68	0.27	0.75*	8.68	-165.67*
ms_{10} x Bonita Bolero	-1.65	0.65	1.35	-4.34*	-0.63	-0.14	-0.42	-4.58	61.78
ms_7 x French Bonita-4	-0.05	-1.94	0.98	8.52*	3.29	-0.38	0.03	4.87	13.28
ms_8 x French Bonita-4	0.32	0.04	-0.12	6.70*	-10.97	-0.20	0.33	-16.61	-13.19
ms_9 x French Bonita-4	0.29	3.46	-0.37	-8.16*	-10.23	0.52	-0.05	-11.06	10.42
ms_{10} x French Bonita-4	-0.56	-1.55	-0.48	-7.06*	17.91	0.05	-0.30	22.80	-10.51
ms_7 x FM-786	-1.31	-2.44	-1.03	2.97	8.23	0.00	-0.76*	3.88	-9.81
ms_8 x FM-786	-0.21	6.64*	4.22*	1.55	16.29	0.17	1.18*	36.29*	5.20
ms_9 x FM-786	1.96	-2.92	-1.59	-4.58*	-13.90	0.01	-0.40	-23.07	-103.17*
ms_{10} x FM-786	-0.43	-1.28	-1.60	0.05	-10.62	-0.18	-0.02	-17.10	107.78*
ms_7 x Single Petal Red	2.99*	-5.71*	-6.61*	-5.31*	-21.91	-0.12	-0.62*	-32.69*	202.21*
ms_8 x Single Petal Red	1.57	0.20	2.81	4.94*	4.20	0.37	-1.23*	2.34	-193.09*
ms_9 x Single Petal Red	0.21	6.69*	6.39*	-2.60	31.84*	0.18	-0.06	37.79*	-4.13

Table Cont.----------

ms_{10} x Single Petal Red	-4.78*	-1.19	-2.58	2.97	-14.17	-0.43	1.92*	-7.44	-4.98
ms_{7} x Double Dwarf Lemon	-1.13	-0.56	-2.93	0.45	0.78	-0.12	-0.56*	-1.35	-34.23
ms_{8} x Double Dwarf Lemon	-2.29*	0.02	4.88*	0.77	-6.09	0.58	0.38	-7.72	61.78
ms_{9} x Double Dwarf Lemon	-1.05	2.24	1.73	1.23	3.84	-0.75	-0.88*	0.36	-8.75
ms_{10} x Double Dwarf Lemon	4.48*	-1.70	-3.74*	-2.46	1.46	0.30	1.06*	8.72	-18.79
ms_{7} x Spray Boy	-0.28	-2.11	-1.78	5.18*	-5.23	-0.26	4.39*	13.98	-101.90*
ms_{8} x Spray Boy	-1.24	0.37	1.96	-3.69*	-2.17	-0.01	-1.57*	-12.05	99.78*
ms_{9} x Spray Boy	-2.26	-2.00	-0.18	3.16	16.76	-0.21	-0.02	22.72	44.64
ms_{10} x Spray Boy	3.79*	3.74	0.00	-4.66*	-9.35	0.48	-2.79*	-24.64*	-42.53
ms_{7} x French Bonita-1	0.31	0.20	2.96	3.72*	-1.38	-0.33	-0.06	-3.99	21.89
ms_{8} x French Bonita-1	0.15	1.45	-0.23	-5.09*	13.00	0.49	0.57*	24.71*	-150.42*
ms_{9} x French Bonita-1	-0.06	-3.45	-3.42	-0.16	-14.38	-0.44	-0.25	-21.12	30.53
ms_{10} x French Bonita-1	-0.40	1.79	0.69	1.53	2.76	0.28	-0.25	0.40	97.99*
ms_{7} x French Bonita-6	-1.20	0.95	2.92	-1.17	8.09	0.15	-0.41	4.67	-110.94*
ms_{8} x French Bonita-6	-0.29	1.54	-0.84	-0.52	8.35	0.46	-0.70*	10.58	126.57*
ms_{9} x French Bonita-6	-0.45	0.89	-3.16	-3.13	-11.43	-0.35	0.47*	-12.60	-64.79
ms_{10} x French Bonita-6	1.94	-3.39	1.08	4.83*	-5.02	-0.26	0.64*	-2.65	49.16
ms_{7} x Harmony Boy	0.18	-3.09	4.69*	0.02	-3.36	-0.39	-0.11	-6.34	-28.40
ms_{8} x Harmony Boy	-0.17	0.29	-4.06*	0.47	-11.50	0.42	-0.46*	-13.70	10.95
ms_{9} x Harmony Boy	1.06	2.64	0.07	-1.20	-6.70	-0.09	0.81*	-4.20	16.24
ms_{10} x Harmony Boy	-1.06	0.15	-0.70	0.70	21.57	0.06	-0.24	24.25	1.20
ms_{7} x Safari Queen	3.24*	-0.24	1.69	-8.92*	-12.98	-0.36	0.32	-17.97	-4.75
ms_{8} x Safari Queen	-0.17	2.47	2.68	-3.60*	-6.52	0.19	-0.93*	-10.67	-107.72*
ms_{9} x Safari Queen	-1.46	-1.90	-2.53	5.78*	-0.18	0.11	0.72*	3.20	98.62*
ms_{10} x Safari Queen	-1.60	-0.32	-1.84	6.75*	19.69	0.06	-0.12	25.44*	13.85
ms_{7} x Sunkist	-0.7	1.00	0.52	-0.89	3.19	-0.04	0.33	5.83	-79.21*
ms_{8} x Sunkist	1.37	1.92	-1.68	-1.57	-18.27	0.38	0.07	-21.83	1.14
ms_{9} x Sunkist	-1.91	-2.11	-0.90	4.41*	26.73*	0.14	-1.29*	25.54*	123.18*
ms_{10} x Sunkist	1.28	-0.80	2.05	-1.94	-11.65	-0.48	0.87*	-9.54	-45.11
ms_{7} x Nana Jambo Bicolor	-1.30	0.65	-3.13	-0.07	19.53	0.53	-1.14*	23.34	-37.81
ms_{8} x Nana Jambo Bicolor	0.33	-2.49	1.62	-2.49	22.39*	-0.02	1.54*	41.75*	31.70
ms_{9} x Nana Jambo Bicolor	-0.28	3.19	1.47	4.62*	-17.53	-0.11	-1.02*	-28.28*	-8.17
ms_{10} x Nana Jambo Bicolor	1.24	-1.35	0.02	-2.12	-24.38*	-0.40	0.61*	-36.81*	14.28
ms_{7} x French Bonita-2	0.59	-1.38	-0.66	1.97	-3.46	-0.21	-0.38	-9.30	-8.56
ms_{8} x French Bonita-2	0.30	3.67	5.72*	-0.70	18.39	0.15	-0.93*	23.02	25.45
ms_{9} x French Bonita-2	-0.45	-0.70	1.50	5.88*	-11.80	-0.003	1.02*	-11.68	3.07
ms_{10} x French Bonita-2	-0.45	-1.59	-6.57*	-7.14	-3.12	0.06	0.30	-2.03	-19.96
CD (0.05)	**2.29**	**4.21**	**3.64**	**3.45**	**21.94**	**0.78**	**0.44**	**34.44**	**76.08**

Significance at 5% of level of significance

Table 4. Estimates of SCA Effects of Hybrids During Rainy Season (2009)

Genotype	Days taken to flowering	Plant height (cm)	Plant spread (cm)	Duration of flowering	Number of flowers/ plant	Flower size (cm)	Flower weight (g)	Flower yield (g/plant)	Carotene content (µg/g)
ms_7 x Spraymix-1	1.52	-13.24*	-2.03	-1.93	-12.19	0.09	0.08	-15.88	-19.51
ms_8 x Spraymix-1	-0.52	-4.74	-1.21	1.25	6.35	-0.84	-0.06	8.60	-99.50
ms_9 x Spraymix-1	0.04	4.87	-2.75	-1.59	2.79	0.40	0.05	2.30	91.39
ms_{10} x Spraymix-1	-1.04	13.11*	6.01*	2.27	3.04	0.34	-0.08	4.96	27.62
ms_7 x Hero B	3.90*	-0.27	4.15*	11.63*	1.07	-0.73	-0.02	1.67	17.03
ms_8 x Hero B	1.66	3.55	4.93*	-6.24*	5.88	1.06	-0.05	5.23	-85.28
ms_9 x Hero B	-3.36*	7.90	2.19	-1.49	-3.00	-0.60	-0.06	-3.90	30.60
ms_{10} x Hero B	-2.19	-11.18*	-11.27*	-3.88*	-3.95	0.28	0.13	-3.00	37.64
ms_7 x Cupidon Yellow	-0.7	5.43	0.19	-0.61	-2.81	1.02	-0.28	-7.35	-42.68
ms_8 x Cupidon Yellow	-1.68	2.13	-2.19	8.30*	5.27	-1.37	0.31	12.81	172.99
ms_9 x Cupidon Yellow	0.61	0.42	0.43	-2.61	-1.28	0.34	-0.28	1.02	-5.27
ms_{10} x Cupidon Yellow	1.85	-7.99	1.56	-5.07*	-1.17	0.00	0.25	-6.48	-125.03
ms_7 x Cupidon Orange	0.25	-0.82	4.61*	1.38	6.43	1.08	-0.24	9.56	100.06
ms_8 x Cupidon Orange	-2.25	6.26	1.92	2.50	-0.67	-1.21*	0.17	-1.60	-101.25
ms_9 x Cupidon Orange	-1.35	-3.84	4.18*	-0.48	-0.96	0.53	-0.18	3.55	99.47
ms_{10} x Cupidon Orange	3.35*	-1.59	-10.71*	-3.40*	-4.79	-0.41	0.25	-11.51	-98.28
ms_7 x French Bonita-3	0.77	1.42	-1.45	-11.08*	-2.54	0.05	0.01	-2.65	30.73
ms_8 x French Bonita-3	4.12*	-4.28	1.88	-5.09*	-12.99	-0.57	0.11	-11.79	24.24
ms_9 x French Bonita-3	-2.76*	1.67	-0.11	8.51*	-4.61	0.07	0.12	-0.10	-32.35
ms_{10} x French Bonita-3	-2.13	1.18	-0.31	7.66*	20.15*	0.44	-0.25	14.56	-22.62
ms_7 x Bonita Bolero	-2.64*	1.62	4.46*	-13.01*	-14.34	0.02	-0.05	-24.26*	-28.76
ms_8 x Bonita Bolero	1.31	-3.28	-3.25	-1.03	5.73	-0.16	-0.03	9.34	-85.25
ms_9 x Bonita Bolero	1.01	-0.79	3.90*	5.78*	13.18	0.27	0.14	20.94	-146.85
ms_{10} x Bonita Bolero	0.31	2.45	-5.12*	8.26*	-4.57	-0.13	-0.05	-6.02	260.87*
ms_7 x French Bonita-4	-0.82	1.43	-0.49	6.33*	1.53	-0.39	0.16	10.90	-37.014
ms_8 x French Bonita-4	-1.60	-1.53	1.58	0.25	3.88	-0.17	-0.22	-11.83	44.49
ms_9 x French Bonita-4	0.49	3.62	-2.05	-3.46*	-4.53	0.52	0.04	-3.58	-254.60*
ms_{10} x French Bonita-4	1.93	-3.53	0.97	-3.12	-0.89	0.04	0.01	4.52	247.12*
ms_7 x FM-786	-0.57	2.32	0.83	3.46*	-4.11	-0.03	-0.001	-7.06	-40.09
ms_8 x FM-786	-2.48*	3.15	-0.85	2.45	1.23	0.19	0.01	0.88	65.24
ms_9 x FM-786	3.21*	-2.95	-1.29	-4.53*	-11.45	0.02	0.04	-13.06	-35.19
ms_{10} x FM-786	-0.14	-2.51	1.30	-1.38	14.32	-0.18	-0.05	19.24	10.04
ms_7 x Single Petal Red	0.87	4.77	-0.42	-2.18	-1.49	-0.07	0.0008	-1.96	58.16
ms_8 x Single Petal Red	0.82	-4.73	2.02	-0.13	7.58	0.35	-0.13	3.47	-100.75
ms_9 x Single Petal Red	-0.73	2.62	-0.31	2.15	-0.56	0.16	0.04	0.85	118.87

Table Cont.----------

ms_{10} x Single Petal Red	-0.96	-2.66	-1.28	0.16	-5.52	-0.44	0.09	-2.36	-76.28
ms_{7} x Double Dwarf Lemon	-2.84*	-8.66	-2.23	3.83*	5.07	-0.14	0.13	14.73	-72.26
ms_{8} x Double Dwarf Lemon	0.77	6.03	-0.41	1.01	-12.97	0.59	-0.02	-14.56	120.41
ms_{9} x Double Dwarf Lemon	1.61	-1.14	-0.72	-1.89	14.93	-0.74	-0.05	8.24	-101.02
ms_{10} x Double Dwarf Lemon	0.45	3.76	3.37	-2.95	-7.02	0.29	-0.06	-8.40	52.87
ms_{7} x Spray Boy	0.90	-2.39	-1.54	2.71	2.22	-0.28	0.07	6.31	146.25
ms_{8} x Spray Boy	0.86	-6.76	3.46	-2.83	2.57	0.03	-0.01	2.35	-139.37
ms_{9} x Spray Boy	0.76	-3.80	-2.47	-2.48	-8.71	-0.23	0.003	-9.57	4.19
ms_{10} x Spray Boy	-2.53*	12.96*	0.55	2.59	3.92	0.48	-0.06	0.90	-11.07
ms_{7} x French Bonita-1	-0.92	-0.54	-1.08	-2.79	-2.59	-0.32	0.05	-5.50	-278.68*
ms_{8} x French Bonita-1	1.09	0.41	-0.76	-1.81	-6.44	0.50	-0.03	-11.21	-141.00
ms_{9} x French Bonita-1	-0.26	-1.69	-0.37	3.60*	-5.00	-0.44	-0.06	-15.96	71.72
ms_{10} x French Bonita-1	0.10	1.81	2.22	1.01	14.04	0.26	0.04	32.68*	347.96*
ms_{7} x French Bonita-6	-0.44	3.43	1.49	-2.23	-5.24	0.12	0.01	-8.06	-1.96
ms_{8} x French Bonita-6	-1.22	-2.39	0.33	-1.71	13.23	0.46	0.04	24.68*	15.64
ms_{9} x French Bonita-6	1.08	3.29	-1.96	0.83	4.21	-0.34	-0.006	2.46	18.54
ms_{10} x French Bonita-6	0.58	-4.33	0.13	3.11	-12.20	-0.24	-0.05	-19.08	-32.22
ms_{7} x Harmony Boy	-0.52	1.58	-3.00	-1.29	2.93	-0.39	-0.07	-6.45	59.10
ms_{8} x Harmony Boy	-0.57	-8.11	-4.12*	-0.24	-0.31	0.42	-0.11	-4.79	-87.28
ms_{9} x Harmony Boy	-0.26	4.44	-2.66	0.70	-4.40	-0.08	0.004	-9.32	102.00
ms_{10} x Harmony Boy	1.36	2.08	9.80*	0.84	1.77	0.05	0.18	20.56	-73.82
ms_{7} x Safari Queen	0.49	1.43	3.50	1.43	19.75*	-0.37	0.09	27.55*	-115.78
ms_{8} x Safari Queen	-1.35	8.00	-3.21	1.28	-13.29	0.19	0.07	-10.02	332.56*
ms_{9} x Safari Queen	-0.45	-8.37	-1.52	-0.36	-4.25	0.12	0.07	-4.53	75.25
ms_{10} x Safari Queen	1.31	-1.06	1.24	-2.35	-2.20	0.05	-0.23	-12.99	-292.03*
ms_{7} x Sunkist	1.00	-8.22	-5.10*	4.76*	-14.22	-0.05	-0.01	-17.49	-72.94
ms_{8} x Sunkist	0.49	7.06	4.70*	4.01*	2.98	0.39	0.10	10.75	169.53
ms_{9} x Sunkist	-0.06	-3.44	0.66	-3.96*	4.43	0.14	0.08	7.17	14.71
ms_{10} x Sunkist	-1.43	4.60	-0.26	-4.82*	6.80	-0.48	-0.17	-0.42	-111.30
ms_{7} x Nana Jambo Bicolor	-1.35	-1.26	1.81	-0.36	15.43	0.50	0.09	25.14*	3.10
ms_{8} x Nana Jambo Bicolor	-0.15	1.63	-4.34*	0.48	1.18	-0.00	-0.13	-4.12	92.54
ms_{9} x Nana Jambo Bicolor	1.54	2.52	0.28	-0.23	-9.83	-0.10	-0.02	-10.51	-62.99
ms_{10} x Nana Jambo Bicolor	-0.01	-2.89	2.24	0.11	-6.79	-0.39	0.06	-10.49	-32.65
ms_{7} x French Bonita-2	1.17	11.95*	-3.69*	-0.08	5.08	-0.12	-0.03	0.83	295.23*
ms_{8} x French Bonita-2	0.72	-2.41	-0.45	-2.43	-9.22	0.12	0.001	-8.20	-197.95
ms_{9} x French Bonita-2	-1.10	-5.32	4.60*	1.51	19.08*	-0.03	0.04	24.02*	11.54
ms_{10} x French Bonita-2	-0.79	-4.21	-0.45	0.99	-14.94	0.03	-0.99	-16.64	-108.82
CD(0.05)	3.45	13.60	5.03	4.65	22.67	1.13	0.37	31.20	324.03

Significance at 5% of level of significance

Table 5. Three best general combiners and specific combiners for different traits in French marigold *(Tagetes patula L.)* during summer season

Characters	Parents	GCA	Crosses	SCA
Days to taken flowering	Single Petal Red	-2.95	ms_{10} x Single Petal Red	-4.78
	French Bonita-6	-1.08	ms_{10} x Cupidon Orange	-2.86
	Harmony Boy	-0.93	ms_{10} x Cupidon Yellow	-2.85
Plant height (cm)	Spray Boy French	-6.65	ms_{10} x Cupidon Yellow	-9.10
	Bonita-2	-4.89	ms_{9}x Cupidon Orange	-8.36
	Single Petal Red	-3.75	ms_{8} x Cupidon Orange	-7.19
Plant spread (cm)	Safari Queen	4.13	ms_{9} x Single Petal Red	6.39
	Bonita Bolero	1.57	ms_{8} x French Bonita-2	5.72
	Harmony Boy	1.56	ms10 x Hero B	4.72
Duration of flowering	FM-786	4.73	ms_{7} x French Bonita-4	8.52
	French Bonita-3	4.14	ms_{10} x Spray Mix-1	7.13
	French Bonita-1	4.11	ms_{10} x Safari Queen	6.75
Number of flowers/plant	French Bonita-6	25.71	ms_{9} x Single Petal Red	31.88
	Harmony Boy	21.57	ms_{9} x Sunkist	26.73
	Single Petal Red	21.12	ms_{8} x Nana Jambo Bicolor	22.39
Flower size (cm)	FM-786	0.30	ms_{8} x Hero B	1.07
	Harmony Boy	0.25	ms_{7} x Cupidon Orange	1.06
	Nana Jambo Bicolor	0.25	ms_{7} x Cupidon Yellow	1.02
Flower weight (g)	Cupidon Yellow	0.24	ms_{7} x Spray Boy	4.39
	Nana Jambo Bicolor	0.15	ms_{8} x Hero B	3.58
	French Bonita-3	0.09	ms_{8} x Cupidon Orange	2.61
Flower yield (g/plant)	French Bonita-6	24.72	ms_{8}xNana Jambo Bicolour	41.75
	FM-786	24.42	ms_{9} x Single Petal Red	37.79
	Harmony Boy	23.56	ms_{8} x FM-786	36.29
Carotene content (µg/g)	Single Petal	138.06	ms_{10} x Single Petal Red	202.21
	Red Sunkist	115.49	ms_{8} x French Bonita-6	126.57
	French Bonita-1	75.39	ms_{9} x Sunkist	123.18

Table 6. Three best general combiners and specific combiners for different traits in French marigold *(Tagetes patula L.)* during rainy season

Characters	Parents	GCA	Crosses	SCA
Days to taken flowering	Nana Jambo Bicolor	-3.21	ms_9 x Hero B	-3.36
	Harmony Boy	-1.86	ms_7 x Double Dwarf Lemon	-2.84
	French Bonita-6	-1.74	ms_9 x French Bonita-3	-2.76
Plant height (cm)	Nana JamboBicolor	-12.8	ms_7 x Spray Mix-1	-13.24
	Spray Boy	-9.94	ms_{10} x Spray Mix-1	-13.11
	Sunkist	-8.70		
Plant spread (cm)	Bonita Bolero	7.38	ms_{10} x Harmony Boy	9.80
	Spray Mix-1	4.15	ms_{10} x Spray Mix-1	6.01
	Safari Queen	3.98	ms_8 x Hero B	4.93
Duration of flowering	Harmony Boy	9.15	ms_7 x Hero B	11.63
	Spraymix-1	9.05	ms_9 x French Bonita-3	8.51
	Safari Queen	8.61	ms_8 x Cupidon Yellow	8.30
Number of flowers /plant	Spraymix-1	18.89	ms_{10} x French Bonita-3	20.15
	Double Dwarf Lemon	16.43	ms_7 x Safari Queen	19.15
	French Bonita-1	15.69	ms_9 x French Bonita-2	19.08
Flower size (cm)	Harmony Boy	0.25	ms_7 x Cupidon Orange	1.08
	Nana Jambo Bicolor	0.24	ms_8 x Hero B	1.06
	Cupidon Yellow	0.22	ms_7 x Cupidon Yellow	1.02
Flower weight (g)	Cupidon Yellow	0.84	ms_8 x Cupidon Yellow	0.31
	Cupidon Orange	0.71	ms_{10} x Cupidon Yellow	0.25
	French Bonita-1	0.05	ms_{10} x Cupidon Yellow	0.25
Flower yield (g/plant)	French Bonita-1	31.51	ms_{10} x French Bonita-1	32.68
	Spray Mix-1	30.76	ms_7 x Nana Jambo Bicolour	25.14
	Double Dwarf Lemon	15.34	ms_9 x French Bonita-2	24.02
Carotene content (µg/g)	Spray Mix-1	465.03	ms_{10} x French Bonita-1	347.96
	French Bonita-4	246.53	ms_7 x French Bonita-2	295.23
	Bonita Bolero	176.78	ms_{10} x Bonita Bolero	260.87

4. Conclusion

A summarized picture indicated that out of 72 crosses evaluated, ms_8 x FM-786, ms_7 x French Bonita-3, ms_8x French Bonita-6, ms_8 x French Bonita-1, ms_9 x Single Petal Red, ms_{10} x Harmony Boy, ms_{10} x Safari Queen and ms_8 x French Bonita-2 during summer. Hybrids ms_{10} x French Bonita-1, ms_{10} x Spraymix-1, ms_{10} x Harmony Boy, ms_8 x Spraymix-1, ms_{10} x French Bonita-3, ms_9 x French Bonita-2, ms_9 x Bonita Bolero, ms_9 x Spraymix-1 and ms_9 x Safari Queen during rainy season were found good for most of the desirable characters. Similarly, looking into high GCA performance of ms_8 (summer) and ms_9 (rainy) breeder will be tempted to use these male sterile lines extensively for F_1 hybrid production.

Among pollinators, high GCA performance was recorded in testers namely; Spraymix-1, Bonita Bolero and Safari Queen. Further, it is suggested that the large number of testers should be evaluated in selecting the considerably good number of pollinators with high GCA status for the production of commercially important hybrids in marigold. based on these studies three best general combiners for rainy and summer season were suggested in Tables 5 & 6.

5. References

1. Sreekala C, Raghava SPS, Misra RL and Maini SB. Path analysis for total carotenoid yield in African marigold. Journal of Ornamental Horticulture. 2002; **5**(2):8–10.
2. Ai Y, Zhang Q, Pan C, Zhang H, Ma S, He Y, Bao M. A study of heterosis, combining ability and heritability between two male sterile lines and ten inbred lines of *Tagetespatula*. Euphytica. 2015 May; 203(2):349–66.
3. Raghava SPS, Sreekala C. Exploitation of heterosis for carotenoid content in African marigold (*Tageteserecta L.*) and its correlation with esterase polymorphism. Theoratical and Applied Genetics. 2003 Feb; 106(4): 771–6.

4. Kempthorne O. An introduction to genetic studies. New York: John Wiley and Sons; 1957. p. 458–71.
5. Panse VG, Sukhtame PV. Statistical method for agricultural workers. 2nd ed. New Delhi: ICAR; 1967; p. 381.
6. Singh RK,Chaudhary BD. Biometrical methods in Quantitative genetic analysis. New Delhi: Kalyani Publishers; 1985; p. 318.
7. Dhabolkar AR. Elements of biometrical genetics. New Delhi: Concept Publishing Company; 1999; p. 193.
8. Mohanty A, Mohanty CR,Mohapatra KC. Heterosis studies in African marigold. Journal of Ornamental Horticulture. 2003; 6(1): 55–7.
9. Song CY, Bang CS. Correlation and combining ability of plant height and characters related to flowering of F_1 hybrids by diallel cross in Petunia hybrida. J Korean Soc Hort Sci. 2001; 42(5): 601–5.
10. Singh B. Morphological and genetical studies in marigolds (*Tageteserecta*, *T. patula* and *T. tenuifolia*). [PhD Thesis]. Agra University, Agra; 1970.
11. Swarup V, Raghava SPS, Balakrishnan KA. Genetical studies in hollyhock. Indian Journal of Genetics**.** 1973; 33(3): 446–51.
12. Swarup V, Raghava SPS, Balakrishnan KA. Heterosis in balsam. Indian Journal of Genetics. 1975; 35(1): 69–75.
13. Kumar S, Shanmugavelu KG,Irulappan I. Hybrid vigour in marigolds for economic characters. South Indian Horticulture. 1990; 38(3): 173–4.
14. Reddy NT, Muthuswamy S, Irulappan I, Abdul Khader M. Heterosis and combining ability for yield and yield components in African marigold (*Tageteserecta L.*). South Indian Horticulture. 1989.