

Heterobeltiosis in French Marigold (*Tagetes patula* L.)

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Abstract

The studies on heterosis were carried with four male sterile lines namely; ms₇, ms₈, ms₉, ms₁₀ and 18 diverse pollinators as tester by using line × tester crossing programme. The 72 F₁ hybrids were produced and evaluated along with 22 parental lines during summer 2009 and rainy season 2009 in Randomized Block Design. Observations were recorded on nine quantitative traits during both the seasons. Highly significant variances for all the traits indicated the sufficient variability in the parental material for all the characters under study. The performance of F₁ hybrids was much better than the mean performance of parents during both the crop seasons. Appreciable heterosis was observed in all the characters, except flower weight in summer and plant height in rainy season.

Keywords: marigold, male sterile lines, inbred lines, heterosis, carotene content

1. Introduction

Marigold (*Tagetes* spp.) is one of the major loose flower crop among ornamentals, and grown commercially in all states of India. It gained popularity among crops due to its easy culture and wider adaptability. It is commonly grown as loose flowers and highly suitable for cultivation under different agro-climatic conditions. Marigold is especially used for festive occasions, marriages, religious ceremonies, social function and in landscape plans due to its wide range of attractive colour, shape, size and having good keeping quality. Besides this, its leaves and flowers are equally important for medicinal value (Tripathy et al., 1991). Now a day, marigold is used as a source of pigment for poultry feed. Carotenoids are used as poultry feed mix and food colourant (Sreekala et al., 2002). In recent years, Exploitation of heterosis proved to be most viable and successful technology in increasing productivity and the production. The hybrids have various advantages over open pollinated varieties like; earliness, profuse and uniform flowering, increased flower weight, large flower size, elongated flower stalk, longer flower duration etc. Apetalous and double-flowered (Goldsmith, 1963) are two kinds of male sterility found in marigold and with the availability of male sterile line, hybridization becomes economically viable and commercially feasible.

2. Material and Methods

The field experiment were 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 parental material used for present studies consisted of four male sterile lines namely; ms₇, ms₈, ms₉ and ms₁₀. A set of 18 diverse testers/ pollinators were used for crossing with each four male sterile lines.

Seeds of all the parental materials viz male sterile lines and testers were sown during summer and rainy season 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 × 30 cm and the standard cultural practices 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 F₁ hybrids, 4 male sterile lines were crossed with 18 testers in line × tester fashion (Kempthorne, 1957), resulting into 72 F₁ hybrid combinations at a stage when the flowers of male sterile lines were fully opened. 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 Completely Randomized Block Design with three replications in both the seasons. The data recorded on 72 crosses along with 18 testers and 4 lines was used to estimate heterosis over better parent using appropriate formulae and statistical package SPAR 2.0. The ANOVA for randomized block design in the present study was calculated (Tables 5 and 6) according to the model suggested by Panse and Sukhatme (1967). Heterosis was calculated as deviation of the F_1 mean from the better parent (BP) (Hayes et al., 1955).

3. Results and Discussion

Exploitation of heterosis proved to be most viable and successful technology of increasing productivity and the production. Success achieved in production and cultivation of F_1 hybrids in maize, sorghum and pearl millet, encouraged the application of this technique even in self-pollinated crops like cotton (Basu et al., 1995) and rice (Paroda, 1995). In vegetables crops, production of F_1 hybrids are being increasingly adopted (Kalloo, 1996). However in ornamentals plants, this technique is to be fully exploited (Swarup, 1995). Line \times testers is very helpful in selecting the lines on the basis of their combining ability. The significant means sum of square due to parents vs. crosses in both the seasons for most of the traits suggested sufficient diversity among the parental material (lines and testers) and the crosses. Further, the significant sum of square for all the traits during both the seasons reflected a wide range of diverse hybrids generated as given in Tables 3 and 4. The 72 F_1 hybrids were produced and evaluated along with 22 parental lines during summer 2009 and rainy season 2009 in Randomized Block Design. Thus, these hybrids could be selected for some particular desirable traits based on their performance for these characters.

3.1 Early Flowering

During summer and rainy season, among male sterile line ms_9 (53.27 days) and ms_{10} (48.07 days) were found significantly early in flowering. However, tester Spray Boy (54.33 days) and French Bonita-6 (45.53 days) were earliest to flower. Among hybrids, $ms_{10} \times$ Single Petal Red (48.13) days was earliest in flowering during summer and $ms_7 \times$ Nana Jambo Bicolour (45.33 days) during rainy season. It revealed the non additive gene action. The selection at later stages might be useful.

3.2 Plant Height

Minimum height is consider in French marigold as it can be grown as potted plant and in turn increase the yield. Hybrid $ms_7 \times$ Single Petal Red showed minimum plant height (21.40 cm) while its parent $ms_7 \times$ Single Petal Red had higher plant heights in summer season while in rainy season $ms_7 \times$ Sunkist had minimum plant height (33.60 cm) while its parent ms_7 (99.37 cm) and Sunkist (32.53 cm) both were taller which clearly showed that genes controlling the plant height in parent were showing non additive gene action in hybrids. Thus, it would be advisable to delay the selection at later generation in order to improve the plant height

3.3 Plant Spread

In the summer, maximum plant spread was exhibited by ms_9 (34.87 cm) and ms_7 (39.10 cm) during rainy season. The testers, Spray Mix-1 showed maximum plant spread (32.70 cm) during both the seasons. In both season, male sterile line ms_7 flowered for longest duration. Within the set of hybrids, $ms_9 \times$ Single Petal Red (39.97 cm) revealed maximum plant spread during summer and $ms_{10} \times$ Spray Mix-1 (48.37cm) during rainy season. Plant spread and plant height is interrelated. It was found that for plant spread male sterile lines as well as testers had lower values for the traits during both the season in comparison to hybrids, thus suggesting the presence of divergent gene in the parents which helped in heterotic with more plant spread.

3.4 Flowering Duration

Among testers, Cupidon Orange (51.87 days) and French Bonita 6 remained in flowering for maximum duration (56.47 days) during summer and rainy season. The best hybrid $ms_{10} \times$ Safari Queen flowered for the longest duration (53.40 days) in summer season and $ms_{10} \times$ Spray mix-1 flowered for the maximum duration (74.47 days) in rainy season.

3.5 Number of Flowers per Plant

The most important characters which contributes towards the production, is the number of flowers per plant. Hybrid values were higher for number of flowers per plant than those of the parents during both the seasons

which indicated that, for this trait widely diversified genes were present in both the parents which lead to heterotic hybrids in both the seasons. Among hybrids, $ms_9 \times$ Single Petal Red produced maximum number of flowers per plant (104.33) during summer and in rainy season $ms_9 \times$ French Bonita-2 produced maximum number of flowers per plant (96.47).

3.6 Flower Size

Flower size is another desirable character as flowers of marigold are being used for making garland and other decorative and religious purposes. FM-786 produced maximum number of flowers per plant (56.60 flowers) during summer and Nana Jambo Bicolour (49.27) during rainy season. Among the 72 hybrids $ms_7 \times$ Cupidon Yellow produced largest flower in both seasons. The remarkable increase in flower size indicated the presence of non additive gene action for the traits and selection at later stages would be useful.

3.7 Flower Weight

ms_8 (1.90 g) and ms_{10} (2.00 g) among lines and Cupidon Yellow (3.06 g) and Cupidon Orange (1.47 g) among testers, were found maximum flower weight during respective season. Within different hybrid combinations, $ms_8 \times$ Hero B recorded highest flower weight (2.05 g) during summer and Cupidon Orange registered maximum flower weight (1.47 g) during rainy season as indicated in fig. Thus, it was clearly evident that the non additive gene action leads to the production of hybrid with very higher flower weight surpassing the range of both the parents. In this case, selection at later stages would be adopted.

3.8 Flower Yield

The most important character which contributes towards the more number of flowers and more flower weight is the flower yield. The means of flower yield per plant of hybrids was higher than the mean flower yield per plant of parents during both crop seasons. In summer season, hybrid $ms_8 \times$ FM-786 gave highest flower yield of 145.91 g, while the flower yield of parents were 27.12 g and 92.67 g, respectively. In rainy season, hybrid $ms_{10} \times$ French Bonita-1 yielded 155.73 g flowers and its parents produced 73.67 g and 37.22 g flowers, respectively, proving that the highly divergent genes are present in these parents when brought together in hybrid combination and produced the F_1 hybrids with exceptionally high heterosis.

3.9 Carotene Content

Out of various hybrids combinations, $ms_7 \times$ Single Petal Red (771.00 μ g) and $ms_{10} \times$ French Bonita-4 recorded maximum carotenes content (1084.00 μ g) during respective seasons. The highest heterosis was obtained in carotene content which was 45.96%. during summer crop and 193.85%. during rainy crop.

Appreciable heterosis was observed in all the characters during summer and rainy season except flower weight and plant height, respectively. The highest heterosis was obtained in flower yield which was 148.28% during summer crop (Table 1) and 220.94% (Table 2) during rainy crop. During summer season, significantly positive heterobeltiosis was observed in 2 hybrids and 32 hybrids during rainy season out of 72 hybrids. During summer, hybrid $ms_7 \times$ French Bonita-2 (148.28%) and during rainy season $ms_8 \times$ French Bonita-6 (220.94%) recorded highest percentage of heterosis. During summer season, significantly positive heterobeltiosis was observed in 8 hybrids and 11 hybrids during rainy season out of 72 hybrids. During summer, hybrid $ms_9 \times$ Sunkist (45.96%) and during rainy season $ms_8 \times$ Safari Queen (193.85%) recorded highest percentage of heterosis. The highest heterosis observed in other traits was -13.33% days taken to flowering, -26.64% for plant height, 37.09% for plant spread, 23.60% for duration of flowering, 141.49% for number of flowers per plant, 48.68% for flower size during summer season. During rainy crop, the highest heterosis observed in other traits was -15.54% days taken to flowering, 36.42% for plant spread, 49.79% for duration of flowering, 205.92% for number of flowers per plant, 48.62% for flower size and flower weight 93.48%. in all the characters, the best performing F_1 was better than the better parent.

Table 1. Heterosis per cent of hybrids over better parent during summer season 2009

Genotype	Days taken to flowering (Days)	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 ($\mu\text{g/g}$)
ms ₇ x Spraymix-1	0.99	-14.31*	5.30	-21.80*	103.62*	33.11*	-14.14	88.18	7.90
ms ₈ x Spraymix-1	-1.65	-17.51*	-12.42*	-0.16	82.69	4.20	-34.71*	57.55	7.08
ms ₉ x Spraymix-1	2.88	-8.59	-0.96	-3.59	89.15*	48.68*	-0.45	87.19	6.32
ms ₁₀ x Spraymix-1	-3.19	20.20*	13.56*	10.10	67.18	38.57*	-10.37	57.51	0.00
ms ₇ x Hero B	2.22	121.70*	11.52	-22.19*	26.56	-18.17*	-33.67*	-15.90	0.35
ms ₈ x Hero B	-2.95	48.09*	-10.22	23.60*	26.32	22.96*	3.05	29.41	-4.27
ms ₉ x Hero B	8.64*	119.15*	-14.63*	-30.18*	-42.34	-9.57	-30.41*	-59.80	-4.17
ms ₁₀ x Hero B	-0.71	73.62*	23.98*	-1.26	97.37*	3.98	-32.42*	34.44	-23.66*
ms ₇ x Cupidon Yellow	5.80*	85.00*	4.06	-26.63*	-24.10	47.81*	-49.67*	-56.20	-35.76*
ms ₈ x Cupidon Yellow	1.42	62.67*	-17.23*	8.19	33.48	-14.26	-39.95*	-19.62	-10.32
ms ₉ x Cupidon Yellow	20.53*	72.33*	-5.16	-17.24*	-9.44	36.04*	-41.25*	-42.53	-37.58*
ms ₁₀ x Cupidon Yellow	-0.83	8.00	13.30*	3.93	-25.99	19.55	-48.33*	-37.45	-62.80*
ms ₇ x Cupidon Orange	9.37*	17.01*	2.97	-14.27*	-18.32	26.30*	-38.41*	-50.25	17.33*
ms ₈ x Cupidon Orange	3.49	-24.59*	-15.43*	-10.28	-42.34	-27.48*	-18.90*	-54.42	-38.78*
ms ₉ x Cupidon Orange	4.51*	-26.64*	-6.69	-12.6*	15.32	20.30*	-48.95*	-44.34	-15.89
ms ₁₀ x Cupidon Orange	-2.89	25.41*	14.20*	-6.04	-27.97	-9.22	-37.48*	-52.78	-19.76*
ms ₇ x French Bonita-3	0.86	43.03*	16.24*	1.04	141.49*	8.10	-0.96	135.48*	3.94
ms ₈ x French Bonita-3	-1.54	44.58*	-3.40	14.29*	69.09*	-8.67	-16.02	66.62*	-20.79*
ms ₉ x French Bonita-3	2.88	50.15*	7.46	3.66	115.15*	15.54	-5.16	100.49*	-15.67*
ms ₁₀ x French Bonita-3	8.39*	26.63*	9.43	-1.40	93.98*	17.67	-9.51	72.73*	-34.67*
ms ₇ x Bonita Bolero	0.25	41.14*	32.85*	-0.65	39.44	22.3*	-8.54	62.64*	33.65*
ms ₈ x Bonita Bolero	0.60	27.71*	1.10	18.46*	-1.83	19.86	-16.91	29.27	17.93
ms ₉ x Bonita Bolero	8.89*	10.57	-12.52*	0.25	20.42	37.71*	4.18	43.31	-36.89*
ms ₁₀ x Bonita Bolero	-3.10	26.29*	20.45*	-7.85	15.07	18.51	-9.95	25.55	5.96
ms ₇ x French Bonita-4	2.10	40.74*	20.00*	1.57	90.53*	6.95	-17.94	63.01*	17.18
ms ₈ x French Bonita-4	-1.53	48.48*	0.50	23.43*	40.25	12.14	-10.10	37.67	0.99
ms ₉ x French Bonita-4	5.76*	68.35*	-5.07	-21.79*	32.32	37.80*	-19.07	19.43	8.19
ms ₁₀ x French Bonita-4	-2.24	37.37*	10.8	-20.48*	123.72*	18.29	-20.24	84.43*	4.55
ms ₇ x FM-786	1.48	19.48*	14.06*	0.13	40.16*	29.13*	-18.28	14.75	22.29*
ms ₈ x FM-786	0.00	54.77*	14.73*	22.63*	50.53*	34.49*	-7.81	57.46*	13.81
ms ₉ x FM-786	10.64*	17.71*	-7.46	-3.87	-8.72	36.96*	-16.72	-23.74	-14.86
ms ₁₀ x FM-786	0.48	19.89*	8.30	4.63	0.24	23.67*	-14.10	-14.19	16.56
ms ₇ x Single Petal Red	2.47	-3.60	-7.27	-27.33*	8.38	7.08	-22.92	9.87	7.68
ms ₈ x Single Petal Red	-2.76	21.02*	9.62	-5.05	54.64*	19.68*	-28.32*	78.18*	-53.77*
ms ₉ x Single Petal Red	0.25	52.55*	14.63*	-19.17*	101.68*	21.39*	-11.73	109.74*	-26.26*
ms ₁₀ x Single Petal Red	-13.33*	12.01	3.98	-8.29	16.11	-0.31	-3.97	41.27	-23.72*
ms ₇ x Double Dwarf Lemon	1.48	26.11*	4.48	-20.89*	114.84*	17.06	-20.54	75.31	17.97
ms ₈ x Double Dwarf Lemon	-4.84*	26.63*	14.53*	0.96	79.43	39.52*	-18.16	77.36	31.00*
ms ₉ x Double Dwarf Lemon	4.63*	37.34*	0.19	-8.99	105.21*	6.20	-21.15	57.47	15.13
ms ₁₀ x Double Dwarf Lemon	8.03*	17.49*	-1.48	-17.95*	102.86*	30.24*	-8.00	86.22	2.10
ms ₇ x Spray Boy	3.08	18.82	-6.67	-7.96	-5.94	10.14	9.43	8.11	-48.33*
ms ₈ x Spray Boy	-0.96	29.75*	-6.91	-22.16*	-4.06	18.18	-22.42	-16.03	-13.44
ms ₉ x Spray Boy	2.38	19.71	-17.59*	-8.05	29.86	19.9	-17.21	8.16	-23.91*
ms ₁₀ x Spray Boy	9.04*	44.62*	-3.07	-23.48*	-23.04	32.62*	-33.26*	-48.73*	-39.46*
ms ₇ x French Bonita-1	3.08	54.24*	17.45*	0.39	63.37*	9.38	-13.91	66.25	-41.98*
ms ₈ x French Bonita-1	-1.53	58.31*	-7.92	5.14	96.89*	34.05*	-14.35	140.69*	-65.82*
ms ₉ x French Bonita-1	5.38*	35.93*	-21.51*	4.23	12.45	13.97	-7.11	12.65	-45.05*
ms ₁₀ x French Bonita-1	-1.65	56.95*	5.68	6.45	64.47*	27.16*	-12.73	63.31	-35.55*
ms ₇ x French Bonita-6	-1.85	49.65*	19.65*	-16.19*	75.94*	10.86	-24.51	96.03*	-36.11*

ms ₈ x French Bonita-6	-3.80	50.35*	-4.81	7.54	72.19*	18.79*	-27.97*	119.9*	18.61
ms ₉ x French Bonita-6	2.50	49.65*	-16.06*	-9.70	27.30	5.27	-11.23	48.63	-33.33*
ms ₁₀ x French Bonita-6	1.07	21.33	12.61*	5.89	43.21*	0.95	-15.46	72.05*	-20.31*
ms ₇ x Harmony Boy	0.99	20.67*	37.09*	-24.02*	42.89*	15.72	-19.17	50.39	-53.75*
ms ₈ x Harmony Boy	-3.90	30.56*	-8.38	-15.58*	23.22	38.68*	-23.89*	50.09	-54.89*
ms ₉ x Harmony Boy	5.63*	40.22*	-0.96	-18.50*	26.02	31.34*	-5.02	40.03	-52.03*
ms ₁₀ x Harmony Boy	-4.60*	28.09*	13.41*	-14.46*	83.25*	28.32*	-17.76	89.51*	-51.18*
ms ₇ x Safari Queen	7.15*	34.37*	35.52*	-29.11*	11.82	16.76	-9.80	25.94	-5.64
ms ₈ x Safari Queen	-3.42	42.48*	19.64*	2.89	20.13	33.62*	-20.97	48.69	-35.56*
ms ₉ x Safari Queen	1.38	28.64*	-1.05	11.77	25.97	38.58*	1.62	45.56	7.88
ms ₁₀ x Safari Queen	-5.08*	30.31*	18.30*	12.34*	68.18*	29.13*	-10.18	85.06*	-5.44
ms ₇ x Sunkist	0.49	36.00*	15.76*	-26.24*	52.65	21.59	-15.46	64.67	7.73
ms ₈ x Sunkist	0.71	38.15*	-6.31	-8.03	-6.13	34.5*	-20.35	22.71	15.96
ms ₉ x Sunkist	1.25	21.85*	-8.60	-5.15	97.358	34.81*	-18.98	87.18*	45.96*
ms ₁₀ x Sunkist	1.43	22.77*	17.05*	-19.78*	6.46	8.48	-9.51	21.27	6.73
ms ₇ x Nana Jambo Bicolor	0.49	53.15*	8.48	-24.54*	105.25*	33.96*	-21.9	57.25	40.83*
ms ₈ x Nana Jambo Bicolor	2.19	34.27*	8.62	-10.11	107.64*	19.83	0.80	106.62*	28.99*
ms ₉ x Nana Jambo Bicolor	5.38*	66.78*	2.96	-4.44	-47.26	24.06*	-21.82	-59.21	38.50*
ms ₁₀ x Nana Jambo Bicolor	4.74*	37.06*	15.8*	-20.06*	-65.39	9.28	-12.60	-70.11*	0.88
ms ₇ x French Bonita-2	2.47	10.48	2.55	-12.40*	48.37	14.23	-22.43	148.28*	-4.00
ms ₈ x French Bonita-2	-2.36	31.14*	8.62	4.17	94.11*	26.26*	-27.62*	275.4*	-6.21
ms ₉ x French Bonita-2	3.50	13.77	-8.70	6.93	16.12	29.36*	-5.23	112.62*	-9.17
ms ₁₀ x French Bonita-2	-2.83	4.79	-20.68*	-21.88*	40.47	22.89	-15.69	120.55*	-10.00
CD (0.05)	2.30	4.24	3.66	5.81	22.08	0.77	0.45	34.67	76.59

Note. *: Significance at 5% of level of significance.

Table 2. Heterosis percentage of hybrid over better parent during rainy season 2009

Genotype	Days taken to flowering (days)	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	-6.29	-5.15	6.14	10.37*	31.39	31.19	-16.09	52.27	55.49*
ms ₈ x Spraymix-1	-7.98*	20.49	11.40	37.91*	60.62*	4.12	7.85	108.19*	51.88*
ms ₉ x Spraymix-1	-8.71*	33.05*	12.46	49.72*	74.83*	48.3*	-17.86	93.61*	66.14*
ms ₁₀ x Spraymix-1	3.05	45.17*	28.18*	20.24*	59.81*	38.34*	-19.61*	72.76*	69.75*
ms ₇ x Hero B	11.05*	70.97*	9.21	10.37*	43.02	-18.63	-23.10	7.96	16.69
ms ₈ x Hero B	8.76*	116.40*	36.42*	-2.29	66.24	21.69	7.70	96.30	-1.98
ms ₉ x Hero B	-3.37	126.61*	12.37	22.44*	71.72	-9.81	-26.21*	25.93	7.71
ms ₁₀ x Hero B	2.50	46.77	-22.93*	-11.63*	-0.36	3.86	-9.42	-9.41	-0.93
ms ₇ x Cupidon Yellow	0.00	129.98*	-24.21*	-23.49*	-32.82	48.62*	14.87	-23.59	-14.93
ms ₈ x Cupidon Yellow	0.12	144.84*	-14.84	8.14	-8.12	-14.9	93.48*	100.21*	40.22
ms ₉ x Cupidon Yellow	-6.46*	132.13*	-16.03*	4.20	6.57	37.84*	15.14	22.61	-16.46
ms ₁₀ x Cupidon Yellow	21.78*	99.28*	-11.91	-28.2*	-44.12	21.28	40.40*	-22.71	-62.33
ms ₇ x Cupidon Orange	0.24	64.94*	-1.02	-25.5*	12.64	26.43	9.50	21.39	49.14
ms ₈ x Cupidon Orange	-2.52	101.34*	12.84	-9.16*	-13.96	-27.87*	67.33*	71.05	7.90
ms ₉ x Cupidon Orange	-10.38*	71.45*	5.92	1.74	24.49	19.83	12.70	40.58	36.71
ms ₁₀ x Cupidon Orange	23.02*	75.29*	-34.45*	-30.79*	-41.95	-9.45	34.05*	-22.81	-18.33
ms ₇ x French Bonita-3	-9.30*	17.96	-9.55	-27.62*	63.45*	8.06	-22.33	66.43*	35.11
ms ₈ x French Bonita-3	-1.10	22.54	21.37*	-2.42	25.69	-8.06	17.83	84.42*	47.91
ms ₉ x French Bonita-3	-15.54*	33.45	1.83	43.98*	74.66*	15.4	-15.71	106.728	8.24
ms ₁₀ x French Bonita-3	-2.36	30.28	4.33	5.06	118.97*	17.83	-29.78*	58.91*	16.33
ms ₇ x Bonita Bolero	-14.50*	29.82	14.49*	-18.1*	32.55	23.11	-30.90*	29.11	12.60
ms ₈ x Bonita Bolero	-5.08	36.49*	16.11*	20.48*	69.95*	18.3	2.04	126.71*	12.68

ms ₉ x Bonita Bolero	-7.43*	38.25*	21.43*	49.79*	112.21*	37.37*	-19.33	147.44*	-13.51
ms ₁₀ x Bonita Bolero	2.77	44.91*	0.39	18.84*	52.58	18.5	-23.24*	35.66	66.67*
ms ₇ x French Bonita-4	-13.22*	5.40	-10.66	18.10*	42.84	7.30	-15.37	57.33*	83.85*
ms ₈ x French Bonita-4	-12.83*	14.44	3.67	29.52*	38.89	13.05	-9.33	30.55	117.53*
ms ₉ x French Bonita-4	-13.89*	21.19	-6.88	44.14*	43.57	38.26*	-23.12	41.51	20.50
ms ₁₀ x French Bonita-4	6.80	5.26	-0.56	6.03	34.8	18.44	-18.61	37.29	140.89*
ms ₇ x FM-786	-2.50	30.36	-5.63	4.55	17.41	28.05	-23.16*	24.43	-1.58
ms ₈ x FM-786	-4.08	50.49*	10.32	22.9*	20.25	34.74*	10.78	60.50	35.06
ms ₉ x FM-786	5.26	31.17	-3.22	18.54*	15.19	37.1*	-20.68	26.72	-10.16
ms ₁₀ x FM-786	4.58	30.52	6.89	-0.32	58.23*	23.5	-19.89*	43.53*	17.78
ms ₇ x Single Petal Red	-5.21	91.18*	-18.16*	-2.22	68.70	8.80	-33.01*	22.48	20.50
ms ₈ x Single Petal Red	-3.18	82.89*	7.89	20.61*	83.74*	19.24	-11.45	109.73*	1.08
ms ₉ x Single Petal Red	-8.01*	105.08*	-10.19	37.67*	91.06*	20.93	-30.94*	62.99	23.89
ms ₁₀ x Single Petal Red	0.55	81.02*	-11.52	4.41	35.80	-0.35	-20.57*	5.97	3.24
ms ₇ x Double Dwarf Lemon	-11.97*	30.69	-6.14	3.60	164.52*	14.95	-19.99	111.16*	-4.57
ms ₈ x Double Dwarf Lemon	-3.30	101.93*	20.74*	18.32*	118.27*	37.59*	2.27	149.69*	62.54
ms ₉ x Double Dwarf Lemon	-3.54	72.96*	5.75	33.14*	262.88*	4.88	-32.25*	144.11*	-23.84
ms ₁₀ x Double Dwarf Lemon	7.77*	86.48*	21.46*	-4.41	79.57*	27.96	-24.53*	33.67	16.44
ms ₇ x Spray Boy	1.48	32.95	-19.35*	3.28	41.48	10.27	-15.66	31.40	93.07
ms ₈ x Spray Boy	3.63	43.62	14.55	12.72*	30.06	20.05	11.87	88.28*	16.35
ms ₉ x Spray Boy	1.48	47.56	-14.11*	27.41*	27.86	19.79	-20.80	28.51	36.15
ms ₁₀ x Spray Boy	-1.53	103.48*	-4.13	6.03	28.93	33.04	-18.39	5.07	14.22
ms ₇ x French Bonita-1	-4.12	43.28*	-5.97	-5.82	126.54*	9.25	-13.63	102.80*	-52.88*
ms ₈ x French Bonita-1	1.93	66.79*	16.21*	14.25*	101.06*	33.26*	14.35	170.30*	-22.94
ms ₉ x French Bonita-1	-2.57	55.78*	3.83	37.26*	139.28*	13.62	-21.42	124.85*	-5.60
ms ₁₀ x French Bonita-1	6.38	63.62*	14.86	3.12	134.72*	26.05	-9.87	111.40*	50.22*
ms ₇ x French Bonita-6	4.83	35.80	-17.48*	4.34	87.36*	11.84	-28.50*	31.14	-1.85
ms ₈ x French Bonita-6	5.56	40.47*	-2.63	16.53*	163.03*	20.25	6.05	220.94*	19.05
ms ₉ x French Bonita-6	8.49*	51.75*	-18.82*	25.03*	168.73*	7.01	-30.44*	91.59*	-8.12
ms ₁₀ x French Bonita-6	8.05*	27.43	-12.20	15.93*	30.56	2.61	-24.97*	-2.71	-19.11
ms ₇ x Harmony Boy	-9.29*	24.13	-13.04*	11.53*	55.25*	15.34	-34.18*	54.50	16.98
ms ₈ x Harmony Boy	-7.25*	19.88	2.95	35.24*	39.07	38.18*	-5.57	79.35*	0.90
ms ₉ x Harmony Boy	-8.52*	40.00*	-4.36	46.38*	53.21*	31.37*	-29.80*	65.31	16.98
ms ₁₀ x Harmony Boy	3.74	34.25*	34.74*	18.08*	50.00*	27.63	-13.11	64.34*	0.96
ms ₇ x Safari Queen	-8.07*	33.62*	11.59	15.03*	156.03*	15.77	-24.73*	128.45*	71.04
ms ₈ x Safari Queen	-9.44*	64.19*	15.68	37.15*	52.50	32.27*	6.89	123.71*	193.85*
ms ₉ x Safari Queen	-9.57*	24.45	6.79	46.89*	107.05*	37.46*	-26.55*	102.89*	121.51*
ms ₁₀ x Safari Queen	5.27	38.86*	18.70*	12.06*	86.62*	27.54	-34.77*	21.45	-17.87
ms ₇ x Sunkist	-9.25*	3.28	-25.75*	10.37*	22.35	14.53	-37.3*	-13.73	-66.05*
ms ₈ x Sunkist	-8.39*	73.16*	21.79*	30.41*	60.78	27.1	1.80	115.21*	-45.22*
ms ₉ x Sunkist	-11.68*	35.25	-3.14	35.89*	96.08*	27.29	-31.64*	73.16	-62.94*
ms ₁₀ x Sunkist	0.55	57.79*	-3.44	-2.05	66.55*	2.63	-36.59*	5.79	-65.67*
ms ₇ x Nana Jambo Bicolor	-12.71*	37.53	1.79	-5.29	94.24*	-21.54*	-19.61	55.44	40.38
ms ₈ x Nana Jambo Bicolor	-8.22*	76.57*	5.37	14.63*	52.28	-29.3*	-4.86	50.74	66.55
ms ₉ x Nana Jambo Bicolor	-6.80*	73.05*	5.92	19.84*	49.75	-26.86*	-27.31*	9.18	4.33
ms ₁₀ x Nana Jambo Bicolor	-1.94	49.87	15.33*	-1.72	-5.24	-35.49*	-15.46	-20.09	-3.87
ms ₇ x French Bonita-2	-9.21*	66.02*	-22.51*	-0.32	141.23*	18.62	-29.48*	76.50*	18.71
ms ₈ x French Bonita-2	-8.00*	45.95*	5.05	14.50*	82.66*	26.95	5.45	142.47*	-34.29
ms ₉ x French Bonita-2	-13.09*	32.24	6.79	40.85*	205.92*	30.23	-24.78*	174.84*	-20.97
ms ₁₀ x French Bonita-2	0.69	33.40	-4.43	4.31	48.64	23.49	-20.73*	18.46*	-25.05
CD (0.05)	3.47	13.70	5.07	4.68	22.81	1.14	0.37	31.41	326.15

Note. *: Significance at 5% of level of significance.

Table 3. Mean performance of parents and 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 ($\mu\text{g/g}$)
ms ₇ x Spraymix-1	54.60	33.93	34.43	39.93	52.53	4.52	1.35	70.50	472.60
ms ₈ x Spraymix-1	55.53	32.67	29.13	41.47	47.13	3.54	1.24	59.03	469.00
ms ₉ x Spraymix-1	54.80	36.20	34.53	45.20	48.80	5.05	1.44	70.13	465.67
ms ₁₀ x Spraymix-1	54.67	47.60	37.13	52.33	43.13	4.71	1.36	59.01	453.00
ms ₇ x Hero B	55.27	34.73	30.67	39.73	35.27	3.62	1.32	46.48	348.00
ms ₈ x Hero B	54.80	23.20	29.87	51.33	35.20	5.44	2.05	71.52	332.00
ms ₉ x Hero B	57.87	34.33	29.77	32.73	16.07	4.00	1.38	22.22	332.33
ms ₁₀ x Hero B	56.07	27.20	36.37	46.93	55.00	4.60	1.34	74.30	345.80
ms ₇ x Cupidon Yellow	57.20	37.00	28.62	37.47	12.60	5.53	1.54	19.36	203.00
ms ₈ x Cupidon Yellow	57.27	32.53	27.53	44.93	20.73	3.21	1.84	35.53	311.00
ms ₉ x Cupidon Yellow	64.20	34.47	33.07	38.80	14.07	5.09	1.80	25.40	197.25
ms ₁₀ x Cupidon Yellow	56.00	21.60	33.23	49.40	17.47	4.48	1.58	27.65	168.50
ms ₇ x Cupidon Orange	59.13	38.07	28.32	44.47	18.13	5.27	1.55	28.19	528.00
ms ₈ x Cupidon Orange	57.33	24.53	28.13	46.53	12.80	3.02	2.03	25.83	275.50
ms ₉ x Cupidon Orange	55.67	23.87	32.53	45.33	25.60	5.02	1.28	31.54	378.50
ms ₁₀ x Cupidon Orange	53.80	40.80	33.50	48.73	17.00	3.79	1.57	26.76	363.50
ms ₇ x French Bonita-3	54.53	30.80	31.97	51.60	77.60	4.16	1.59	123.24	514.00
ms ₈ x French Bonita-3	55.53	31.13	32.14	47.47	54.33	3.52	1.60	87.20	391.70
ms ₉ x French Bonita-3	54.80	32.33	37.47	48.60	69.13	4.45	1.52	104.92	417.00
ms ₁₀ x French Bonita-3	61.13	27.27	32.10	46.87	62.33	4.53	1.45	90.39	323.05
ms ₇ x Bonita Bolero	54.20	32.93	36.53	50.73	66.00	4.45	1.43	95.09	494.50
ms ₈ x Bonita Bolero	56.27	29.80	33.63	49.20	46.47	4.37	1.58	75.58	436.33
ms ₉ x Bonita Bolero	58.00	25.80	30.50	47.00	57.00	5.02	1.48	83.79	233.50
ms ₁₀ x Bonita Bolero	54.20	29.47	35.33	43.80	54.47	4.32	1.37	73.41	480.00
ms ₇ x French Bonita-4	55.20	27.87	33.00	51.87	62.40	4.08	1.46	92.16	515.00
ms ₈ x French Bonita-4	55.60	29.40	33.43	51.27	45.93	4.28	1.71	77.83	443.83
ms ₉ x French Bonita-4	56.33	33.33	33.10	36.67	43.33	5.26	1.44	67.52	475.50
ms ₁₀ x French Bonita-4	55.20	27.20	32.50	37.80	73.27	4.51	1.42	104.27	473.60
ms ₇ x FM-786	54.87	29.23	31.37	51.13	79.33	4.63	1.34	106.33	428.00
ms ₈ x FM-786	56.00	37.87	38.17	50.93	85.20	4.82	1.75	145.91	398.33
ms ₉ x FM-786	58.93	28.80	32.27	45.07	51.67	4.91	1.37	70.67	298.00
ms ₁₀ x FM-786	56.27	29.33	31.77	49.73	56.73	4.43	1.41	79.52	528.00
ms ₇ x Single Petal Red	55.40	21.40	25.50	37.40	56.07	4.42	1.21	67.98	771.00
ms ₈ x Single Petal Red	54.00	26.87	36.47	48.87	80.00	4.93	1.36	110.18	331.00
ms ₉ x Single Petal Red	53.40	33.87	39.97	41.60	104.33	5.01	1.25	129.76	528.00
ms ₁₀ x Single Petal Red	48.13	24.87	30.50	47.20	60.07	4.11	1.46	87.40	546.20
ms ₇ x Double Dwarf Lemon	54.87	32.20	28.73	40.40	55.00	3.79	1.25	68.61	464.67
ms ₈ x Double Dwarf Lemon	53.73	32.33	38.10	41.93	45.93	4.52	1.56	69.41	516.00
ms ₉ x Double Dwarf Lemon	55.73	35.07	34.93	42.67	52.53	3.44	1.20	61.62	453.50
ms ₁₀ x Double Dwarf Lemon	61.00	30.00	28.90	39.00	51.93	4.22	1.40	72.87	462.50
ms ₇ x Spray Boy	55.73	22.10	25.67	47.00	43.27	3.67	1.86	84.54	232.50
ms ₈ x Spray Boy	54.80	24.13	30.97	39.33	44.13	3.94	1.48	65.67	389.50
ms ₉ x Spray Boy	54.53	22.27	28.73	46.47	59.73	4.00	1.40	84.58	342.40
ms ₁₀ x Spray Boy	60.33	26.90	28.43	38.67	35.40	4.42	1.13	40.10	274.27
ms ₇ x French Bonita-1	55.73	30.33	32.30	51.27	59.47	3.75	1.35	80.13	528.00
ms ₈ x French Bonita-1	55.60	31.13	30.63	43.67	71.67	4.60	1.63	116.01	311.00
ms ₉ x French Bonita-1	56.13	26.73	27.37	48.87	40.93	3.91	1.32	54.30	500.00
ms ₁₀ x French Bonita-1	55.53	30.87	31.00	50.60	59.87	4.36	1.32	78.72	586.50
ms ₇ x French Bonita-6	53.07	28.53	33.90	42.80	90.67	4.65	1.18	107.42	218.50

ms ₈ x French Bonita-6	54.00	28.67	31.67	44.67	88.73	4.99	1.37	120.50	411.33
ms ₉ x French Bonita-6	54.60	28.53	29.27	42.33	65.60	4.42	1.26	81.45	228.00
ms ₁₀ x French Bonita-6	56.73	23.13	33.03	50.33	73.80	4.24	1.28	94.28	361.00
ms ₇ x Harmony Boy	54.60	35.80	37.70	38.80	75.07	4.18	1.27	95.25	216.00
ms ₈ x Harmony Boy	54.27	38.73	30.48	40.47	64.73	5.01	1.45	95.05	210.67
ms ₉ x Harmony Boy	56.27	41.60	34.53	39.07	66.20	4.75	1.35	88.68	224.00
ms ₁₀ x Harmony Boy	53.87	38.00	33.27	41.00	96.27	4.64	1.25	120.02	228.00
ms ₇ x Safari Queen	57.93	37.53	37.27	36.20	57.40	4.04	1.41	80.10	465.67
ms ₈ x Safari Queen	54.53	39.80	39.80	42.73	61.67	4.62	1.50	94.57	318.00
ms ₉ x Safari Queen	54.00	35.93	34.50	52.40	64.67	4.79	1.44	92.58	532.40
ms ₁₀ x Safari Queen	53.60	36.40	34.70	53.40	86.33	4.46	1.36	117.70	466.67
ms ₇ x Sunkist	54.33	29.47	31.83	37.67	61.47	4.19	1.33	80.47	467.00
ms ₈ x Sunkist	56.47	29.93	31.17	38.20	37.80	4.63	1.52	59.96	502.67
ms ₉ x Sunkist	53.93	26.40	31.87	44.47	79.47	4.64	1.15	91.47	632.75
ms ₁₀ x Sunkist	56.87	26.60	34.33	38.13	42.87	3.74	1.37	59.26	483.50
ms ₇ x Nana Jambo Bicolor	54.33	29.20	29.83	38.53	57.33	5.11	1.43	81.45	422.50
ms ₈ x Nana Jambo Bicolor	56.00	25.60	36.13	37.33	58.00	4.57	1.92	107.03	447.33
ms ₉ x Nana Jambo Bicolor	56.13	31.80	35.90	44.80	14.73	4.73	1.43	21.13	415.50
ms ₁₀ x Nana Jambo Bicolor	57.40	26.13	33.97	38.00	9.67	4.17	1.60	15.48	457.00
ms ₇ x French Bonita-2	55.40	24.60	28.20	44.73	63.80	3.63	1.22	77.13	464.00
ms ₈ x French Bonita-2	55.13	29.20	36.13	43.27	83.47	4.02	1.38	116.62	453.33
ms ₉ x French Bonita-2	55.13	25.33	31.83	50.13	49.93	4.11	1.35	66.05	439.00
ms ₁₀ x French Bonita-2	54.87	23.33	23.27	37.13	60.40	3.91	1.28	78.58	435.00
<i>Testers</i>									
Spraymix-1	57.53	39.60	32.70	34.47	25.80	3.40	1.45	37.47	438.00
Hero B	56.93	15.67	20.70	38.07	27.87	4.42	1.99	55.27	346.80
Cupidon Yellow	58.87	20.00	18.40	33.47	15.53	3.74	3.06	44.20	316.00
Cupidon Orange	55.40	32.53	23.57	51.87	22.2	4.17	2.51	56.67	450.00
French Bonita-3	56.40	21.53	22.97	35.13	32.13	3.85	1.60	52.33	494.50
Bonita Bolero	55.93	23.33	23.00	36.07	47.33	3.64	1.25	58.47	370.00
French Bonita-4	56.87	19.80	24.90	36.13	32.75	3.82	1.78	56.53	439.50
FM-786	56.00	24.47	25.50	38.00	56.60	3.58	1.64	92.67	350.00
Single Petal Red	55.53	22.20	27.50	51.47	51.73	4.12	1.19	61.87	716.00
Double Dwarf Lemon	59.80	25.53	26.17	32.20	25.60	3.24	1.53	39.13	393.90
Spray Boy	55.33	18.60	25.37	50.53	46.00	3.33	1.70	78.20	450.00
French Bonita-1	57.73	19.67	25.43	34.27	36.40	3.43	1.32	48.20	910.00
French Bonita-6	56.13	19.07	28.33	38.47	51.53	4.20	1.06	54.80	342.00
Harmony Boy	59.07	29.67	26.97	47.93	52.53	3.61	1.20	63.33	467.00
Safari Queen	58.80	27.93	21.80	32.20	51.33	3.46	1.24	63.60	493.50
Sunkist	56.07	21.67	27.30	35.73	40.27	3.45	1.24	48.87	433.50
Nana Jambo Bicolor	54.80	19.07	26.33	37.20	27.93	3.81	1.83	51.80	300.00
French Bonita-2	56.80	22.27	24.37	35.20	43.00	3.18	0.8	31.07	483.33
<i>Lines</i>									
ms ₇	54.07	47.00	27.50	51.07	16.60	2.49	1.57	25.87	216.75
ms ₈	56.47	47.07	33.27	41.53	14.33	2.37	1.90	27.12	346.80
ms ₉	53.27	47.53	34.87	46.88	14.40	2.31	1.42	20.46	233.50
ms ₁₀	56.47	44.87	29.33	47.53	23.60	2.69	1.52	35.63	453.00
CD (0.05)	2.30	4.24	3.66	5.81	22.08	0.77	0.45	34.67	76.59

Table 4. Mean performance of parents and hybrids during rainy season 2009

Gnotype	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 ($\mu\text{g/g}$)
ms ₇ x Spraymix-1	51.67	58.93	41.50	69.53	64.73	4.50	1.35	87.52	992.00
ms ₈ x Spraymix-1	50.73	74.87	42.03	72.27	79.13	3.57	1.49	119.67	969.00
ms ₉ x Spraymix-1	50.33	82.67	43.03	71.67	86.13	5.08	1.30	111.28	1060.00
ms ₁₀ x Spraymix-1	49.53	90.20	48.37	74.47	78.73	4.74	1.61	127.27	1083.00
ms ₇ x Hero B	54.93	42.40	42.70	69.53	43.00	3.64	1.24	52.52	381.33
ms ₈ x Hero B	53.80	53.67	43.20	51.20	43.67	5.44	1.49	63.73	336.00
ms ₉ x Hero B	47.80	56.20	43.00	58.20	45.33	4.03	1.17	52.52	352.00
ms ₁₀ x Hero B	49.27	36.40	26.10	54.73	36.73	4.64	1.81	66.73	445.80
ms ₇ x Cupidon Yellow	55.47	63.93	29.63	48.20	20.20	5.61	1.85	37.17	208.00
ms ₈ x Cupidon Yellow	55.67	68.07	26.97	56.67	24.13	3.21	2.73	65.00	480.67
ms ₉ x Cupidon Yellow	57.00	64.53	32.13	48.00	28.13	5.20	1.82	51.13	202.50
ms ₁₀ x Cupidon Yellow	58.53	55.40	29.83	44.47	20.60	4.57	2.80	56.93	169.50
ms ₇ x Cupidon Orange	55.60	65.87	38.70	46.93	33.87	5.33	1.76	59.05	522.00
ms ₈ x Cupidon Orange	54.20	80.40	35.73	47.60	22.60	3.04	2.46	55.53	377.67
ms ₉ x Cupidon Orange	54.13	68.47	40.53	46.87	32.87	5.05	1.78	58.62	478.50
ms ₁₀ x Cupidon Orange	59.13	70.00	22.20	42.87	21.40	3.82	2.68	56.87	367.50
ms ₇ x French Bonita-3	49.40	44.67	35.37	45.60	63.20	4.20	1.25	80.96	533.00
ms ₈ x French Bonita-3	53.87	46.40	38.43	51.13	48.60	3.57	1.63	79.47	583.50
ms ₉ x French Bonita-3	46.00	50.53	38.97	67.00	67.53	4.49	1.34	89.08	427.00
ms ₁₀ x French Bonita-3	46.93	49.33	35.33	65.07	84.67	4.58	1.40	117.07	523.50
ms ₇ x Bonita Bolero	46.00	49.33	44.77	51.60	56.47	4.52	1.11	62.80	694.50
ms ₈ x Bonita Bolero	51.07	51.87	36.77	63.13	72.40	4.34	1.41	104.07	695.00
ms ₉ x Bonita Bolero	49.80	52.53	46.47	72.20	90.40	5.04	1.28	113.58	533.50
ms ₁₀ x Bonita Bolero	49.40	55.07	34.00	73.60	65.00	4.35	1.53	99.93	1028.00
ms ₇ x French Bonita-4	48.13	52.07	34.93	74.40	65.13	4.12	1.36	88.62	756.00
ms ₈ x French Bonita-4	48.47	56.53	36.73	67.87	63.33	4.34	1.26	73.53	894.50
ms ₉ x French Bonita-4	49.60	59.87	35.63	66.40	65.47	5.30	1.22	79.71	495.50
ms ₁₀ x French Bonita-4	51.33	52.00	35.23	65.67	61.47	4.54	1.63	101.13	1084.00
ms ₇ x FM-786	49.40	53.53	36.90	65.87	49.47	4.63	1.24	60.53	436.00
ms ₈ x FM-786	48.60	61.80	34.93	64.40	50.67	4.87	1.54	76.13	598.33
ms ₉ x FM-786	53.33	53.87	37.03	59.67	48.53	4.96	1.26	60.11	398.00
ms ₁₀ x FM-786	50.27	53.60	36.20	61.73	66.67	4.47	1.60	105.73	530.00
ms ₇ x Single Petal Red	49.73	47.67	32.00	61.60	55.33	4.53	1.08	59.58	632.60
ms ₈ x Single Petal Red	50.80	45.60	34.17	63.20	60.27	4.97	1.23	72.67	530.67
ms ₉ x Single Petal Red	48.27	51.13	34.37	67.73	62.67	5.04	1.09	67.97	650.40
ms ₁₀ x Single Petal Red	48.30	45.13	29.97	64.67	50.07	4.15	1.59	78.07	542.00
ms ₇ x Double Dwarf Lemon	48.07	40.60	36.70	65.27	79.53	3.81	1.29	102.72	355.00
ms ₈ x Double Dwarf Lemon	52.80	62.73	38.23	62.00	57.33	4.57	1.42	81.07	604.67
ms ₉ x Double Dwarf Lemon	52.67	53.73	40.47	61.33	95.80	3.48	1.07	101.80	283.33
ms ₁₀ x Double Dwarf Lemon	51.80	57.93	41.13	59.20	66.20	4.25	1.51	98.47	524.00
ms ₇ x Spray Boy	50.33	38.20	31.53	65.07	47.07	3.71	1.36	63.92	627.47
ms ₈ x Spray Boy	51.40	41.27	36.27	59.07	43.27	4.04	1.55	67.60	398.83
ms ₉ x Spray Boy	50.33	42.40	32.87	61.67	42.53	4.03	1.25	53.59	442.50
ms ₁₀ x Spray Boy	47.33	58.47	32.47	65.67	47.53	4.48	1.63	77.40	514.00
ms ₇ x French Bonita-1	49.67	51.20	36.77	59.33	71.13	3.80	1.39	98.65	306.50
ms ₈ x French Bonita-1	52.80	59.60	36.80	59.87	63.13	4.63	1.58	100.60	501.17
ms ₉ x French Bonita-1	50.47	55.67	39.73	67.53	75.13	3.95	1.24	93.77	614.00
ms ₁₀ x French Bonita-1	51.13	58.47	38.90	63.87	86.53	4.38	1.80	155.73	977.00
ms ₇ x French Bonita-6	47.73	46.53	32.27	65.73	56.33	4.66	1.15	63.79	350.40

ms ₈ x French Bonita-6	48.07	48.13	30.83	65.80	70.67	5.01	1.47	104.20	425.00
ms ₉ x French Bonita-6	49.40	52.00	31.07	70.60	72.20	4.46	1.10	79.90	328.00
ms ₁₀ x French Bonita-6	49.20	43.67	29.73	71.80	48.13	4.28	1.50	71.67	364.00
ms ₇ x Harmony Boy	47.53	66.20	34.00	70.27	71.00	4.21	1.06	75.15	650.00
ms ₈ x Harmony Boy	48.60	63.93	32.60	70.87	63.60	5.04	1.31	84.47	561.00
ms ₉ x Harmony Boy	47.93	74.67	36.60	74.07	70.07	4.80	1.11	77.85	650.40
ms ₁₀ x Harmony Boy	49.87	71.6	45.63	73.13	68.60	4.66	1.74	121.07	561.33
ms ₇ x Safari Queen	49.33	61.20	43.63	72.47	92.00	4.08	1.21	111.12	502.00
ms ₈ x Safari Queen	48.60	75.20	36.63	71.87	54.80	4.66	1.48	81.20	1007.33
ms ₉ x Safari Queen	48.53	57.00	40.87	72.47	74.40	4.84	1.16	84.61	650.13
ms ₁₀ x Safari Queen	50.60	63.60	40.20	69.40	68.80	4.49	1.30	89.47	369.60
ms ₇ x Sunkist	50.33	33.60	29.03	69.53	41.60	4.21	1.01	41.96	488.00
ms ₈ x Sunkist	50.93	56.33	38.57	68.33	54.67	4.67	1.41	77.87	787.47
ms ₉ x Sunkist	49.40	44.00	37.07	62.60	66.67	4.68	1.08	72.21	532.75
ms ₁₀ x Sunkist	48.33	51.33	32.70	60.67	61.40	3.77	1.27	77.93	493.50
ms ₇ x Nana Jambo Bicolor	45.33	36.40	39.80	59.67	58.40	5.11	1.29	75.61	424.50
ms ₈ x Nana Jambo Bicolor	47.67	46.73	33.37	60.07	40.00	4.60	1.35	54.00	570.93
ms ₉ x Nana Jambo Bicolor	48.40	45.80	40.53	61.60	39.53	4.76	1.15	45.53	315.50
ms ₁₀ x Nana Jambo Bicolor	47.13	39.67	39.06	60.87	34.93	4.20	1.69	58.87	432.60
ms ₇ x French Bonita-2	49.93	57.33	30.30	62.80	76.07	3.79	1.13	85.85	977.00
ms ₈ x French Bonita-2	50.60	50.40	33.27	60.00	57.60	4.05	1.46	84.47	540.80
ms ₉ x French Bonita-2	47.80	45.67	40.87	66.20	96.47	4.16	1.19	114.62	650.40
ms ₁₀ x French Bonita-2	48.40	46.07	32.37	64.60	54.80	3.94	1.58	87.27	616.28
<i>Testers</i>									
Spraymix-1	55.13	62.13	37.73	47.87	49.27	3.43	1.15	57.48	638.00
Hero B	49.47	24.80	19.30	47.53	21.33	4.47	1.26	27.24	326.80
Cupidon Yellow	61.20	27.80	16.30	37.80	15.93	3.77	1.41	22.51	216.00
Cupidon Orange	60.40	39.93	20.43	39.60	12.00	4.22	1.47	17.36	350.00
French Bonita-3	54.47	37.87	26.47	46.53	38.67	3.89	1.11	43.09	394.50
Bonita Bolero	53.80	38.00	29.87	48.20	42.60	3.67	1.10	45.90	616.80
French Bonita-4	57.60	49.40	35.43	42.40	45.60	3.84	1.24	56.33	411.20
FM-786	50.67	41.07	27.53	50.33	42.13	3.62	1.13	47.44	443.00
Single Petal Red	52.47	24.93	22.43	49.20	32.80	4.17	1.05	34.65	525.00
Double Dwarf Lemon	54.60	31.07	25.10	44.40	25.40	3.32	1.04	26.22	372.00
Spray Boy	49.60	28.73	23.73	48.40	33.27	3.37	1.09	35.90	325.00
French Bonita-1	51.80	35.73	29.80	49.20	31.40	3.48	1.18	37.22	650.40
French Bonita-6	45.53	34.27	25.50	56.47	26.87	4.17	1.09	28.68	357.00
Harmony Boy	52.40	53.33	28.40	50.60	45.73	3.65	1.03	47.10	556.00
Safari Queen	53.67	45.80	28.07	49.33	35.93	3.52	1.02	36.30	293.50
Sunkist	55.93	32.53	25.70	44.07	34.00	3.67	1.06	36.18	1437.50
Nana Jambo Bicolor	51.93	26.47	23.60	51.40	25.07	6.51	1.42	35.82	302.40
French Bonita-2	55.00	34.53	27.50	47.00	31.53	3.19	1.10	34.84	823.00
<i>Lines</i>									
ms ₇	55.47	99.37	39.10	63.00	30.07	2.53	1.61	48.64	244.50
ms ₈	55.60	87.73	31.67	52.40	26.27	2.42	1.39	32.47	342.80
ms ₉	60.93	98.93	38.27	46.07	26.40	2.42	1.58	41.70	242.40
ms ₁₀	48.07	84.53	33.87	61.93	36.87	2.74	2.00	73.67	450.00
CD (0.05)	3.47	13.70	5.07	4.68	22.81	1.14	0.37	31.41	326.15

Table 5. Analysis of variance for Line × Tester including parents during summer season 2009

Source of variation	d.f.	Mean sum of squares								
		Days to taken 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)
Replications	2	9.00*	47.36*	5.74	16.85*	176.93	0.04	0.24*	787.95	93.281
Treatments	93	12.72*	146.20*	58.73*	100.31*	1421.89*	1.32*	0.25*	2540.70*	46600.34*
Parents	21	7.85*	333.69*	47.40*	144.99*	585.89*	1.04*	0.72*	884.76*	67565.92*
P. vs. C.	1	38.39*	403.15*	1965.26*	908.78*	19515.38*	42.70*	0.98*	34238.86*	27427.12*
Crosses	71	13.80*	87.12*	35.23*	75.71*	1414.31*	0.83*	0.11*	2584.03*	40669.30*
Testers	17	17.05	195.31*	44.68	117.26	4060.68*	0.74	0.16*	6669.10	105343.63*
Lines	3	7.91	14.30	27.20	27.81	297.97	0.97	0.66*	2653.48*	21649.06
Line x Testers	51	13.56*	55.34*	32.56*	64.67*	597.86*	0.86*	0.06	1218.25*	20230.02*
Error	186	2.05	6.92	5.16	4.64	187.97	0.23	0.07	463.21	2260.58

Note. *: Significance at 5% of level of significance.

Table 6. Analysis of variance for Line × Tester including parents during rainy season 2009

Source of variation	d.f.	Mean sum of squares								
		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)
Replication	2	4.82	15.07	5.78	6.26	460.20	0.31	0.06	884.29	13090.02
Treatment	93	36.34*	718.39*	121.42*	282.20*	1205.18*	1.47*	0.37*	2221.03*	163530.47*
Parents	21	48.14*	1720.49*	113.50*	109.43*	276.26	2.21*	0.18*	486.65	212080.43*
P. vs. C.	1	637.01*	3075.79*	3526.64*	10085.43*	34310.39*	31.4*	2.07*	86115.88*	427680.42*
Crosses	71	24.34*	388.79*	75.80*	195.23*	1013.67*	0.84*	0.40*	1552.40*	145450.20*
Testers	17	68.72*	1188.19*	154.70*	596.11*	3147.82*	0.72	1.04*	4040.80*	388996.52*
Lines	3	13.26	545.07*	115.20	51.99	1071.55*	0.99	2.57*	3396.06*	111111.50
Line x Testers	51	10.20*	113.13*	47.20*	70.03*	298.88*	0.87*	0.06	614.49*	66288.02*
Error	186	4.64	72.29	9.89	8.43	200.59	0.50	0.05	380.20	40997.26

4. Conclusions

In general, the mean value of number of flowers per plant for hybrids (58.29) was more during rainy season in comparison to summer crops which was 53.99 due to the abundant moisture during rainy season. Similar trend was also seen in traits like flower yield and flower weight. A critical analysis of data indicated that rainy season can profitably utilized for commercial cultivation of the marigold crop to increase the flower production. In case of male sterile lines and testers, mean values for all the characters were higher during rainy season as compared to summer season, this would again be attributed to conducive climatic conditions French Bonita-6 flowered for 56.47 days during rainy season while 38.47 days in summer season. Such differences could be attributed to photoperiod and temperature. Similar results were obtained by Tsukamoto et al. (1971).

References

- Basu, A. K., Narayanan, S. S., & Bhatt, M. G. (1995). Hybrid cottons: Historical development, present status and future perspective in Indian context. *Hybrid Research and Development*. Proceeding of the Seminar held on Dec. 6-8, 1993 at IARI, New Delhi.
- Goldsmith, G. A. (1963). Currents developments in the breeding of F₁ hybrids in annuals. *Hort. Sci.*, 3(4), 269-271.
- Hayes, B. K., Immer, I. R., & Smith. (1955). *Methods of Plant Breeding*. McGraw Hill Company, New York.
- Kaloo, G. (1996). Vegetable production with special emphasis on hybrid technology for enhancing productivity in Asia and Pacific regional scenario. *Vegetable Research in Asia Pacific*.
- Kempthorne, O. (1957). *An introduction to genetic studies* (pp. 458-471). John Wiley and Sons, New York.

- Panse, V. G., & Sukhtame, P. V. (1967). *Statistical method for agricultural workers* (p. 381, 2nd ed.). ICAR, New Delhi.
- Paroda, R. S. (1995). Hybrid technology for improving productivity of cereals in Asia: Issues and strategies. *Hybrid Research and Development*. Proceeding of the Seminar held on Dec. 6-8, 1993 at IARI, New Delhi.
- Sreekala, C., Raghava, S. P. S., Misra, R. L., & Maini, S. B. (2002). Path analysis for total carotenoid yield in African marigold. *Journal of Ornamental Horticulture*, 5(2), 8-10.
- Tripathy, A. K., & Gupta, K. K. (1991). Plant phenolics of *Tagetes erecta*. *Fetoterapea*, 62(1), 91-92.
- Tsukamoto, Y., Imanshi, Y., & Yahara, H. (1971). Studies on the flowering of marigold II. Interaction among day length, temperature, light intensity and plant regulators. *Journal of Japan Society for Horticultural Sciences*, 40, 65-70.

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