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Estimation of heterobeltiosis in F_1 hybrids of China aster [*Callistephus chinensis* (L.) Nees]

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Abstract
Heterosis over better parents was estimated in thirty crosses of China aster involving six lines viz., Matsumoto Pink, Matsumoto Red, Matsumoto Rose, Matsumoto Yellow, Matsumoto Scarlet and Matsumoto White and five testers *viz.*, Phule Ganesh Violet, Phule Ganesh Purple, IIHRJ3-2, IIHRG13 and Local White during 2016-17 at ICAR-Indian Institute of Horticultural Research, Bengaluru during 2016-17. Results revealed that the cross L6 × T5 exhibited highest positive significant heterobeltiosis at 5% level of significance for plant height (33.85), flower stalk length (73.76), number of flowers per plant (101.18), weight of flowers per plant (47.90) and flower yield per hectare (47.91). The cross L1 x T3 exhibited maximum negative heterobeltiosis for days to first flowering (-47.41). L5 x T4 recorded the maximum positive heterobeltiosis (at 5%) for flower head diameter (26.44) and 100 flower weight (3.41).

Keywords: China aster, Heterobeltiosis, Line, Tester, Yield

INTRODUCTION

China aster belongs to the family Asteraceae and is native of Northern China (Navalinskien *et al.*, 2005). It is one of the most popular annual flower crops cultivated widely due to existing of various colours ranging from violet, purple, magenta, pink and white; forms, sizes and comparatively longer vase life (Dilta *et al.*, 2007). It is grown commercially as cut flower for flower arrangement, interior decoration and loose flower garland making, worshipping (Munikrishnappa, 2013). It can also be grown as bedding plant and potted plant in landscaping (Bhargav *et al*. 2016). China aster is commercially grown by marginal and small farmers in Karnataka, Tamil Nadu, Telangana, Andhra Pradesh, Maharashtra and West Bengal states of India (Kumari *et al.*, 2017). In Karnataka alone, it is grown in an area of 1693 ha with productivity of 9.39 t/ha (Anonymous, 2016).

However, information on heterosis is meager in China aster. Exploitation of heterosis proved to be most viable method of breeding in increasing productivity and the production. The hybrids have various advantages over open pollinated varieties such as earliness, profuse and uniform flowering, increased flower weight, large flower size, elongated flower stalk, longer flower duration etc. Hence, the present study was carried out to estimate het-erobeltiosis in 30 crosses for vegetative, flowering, yield and vase life traits in China aster.

MATERIALS AND METHODS

An experiment was carried out in the Floriculture and Medicinal Crops, ICAR-Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru, India during 2016-17. The experimental site was geographically located at 13^o 58' N Latitude, 78^{o}E Longitude and an elevation of 890 m above mean sea level. A total of 30 F_1 hybrids were developed through crossing in Line x Tester mating design (Table 1); six lines *viz*., Matsumoto Pink, Matsumoto Red, Matsumoto Rose, Matsumoto Yellow, Matsumoto Scarlet and Matsumoto White, and 5 testers *viz*., Phule Ganesh Violet, Phule Ganesh Purple, IIHRJ3-2, IIHRG13 and Local White were used for crossing. The experiment was laid out in randomized complete block design with two replications and 20 plants in each were planted at a spacing of 25 x 25 cm under open field conditions. Five random plants per replication were selected for recording various observations on plant height (cm), number of leaves per plant, plant spread (cm), number of branches per plant, days to first flowering, flower stalk length (cm), flower head diameter (cm), 100 flowers weight (g), number of flowers per plant, weight of flowers/plant (g), duration of flowering (days) and vase life (days). The recommended agronomical practices were adopted to raise the successful crop.

All statistical analysis were performed using WINDOSTAT version 8.6 (statistical software developed by Indostat Services, Hyderabad) licensed to LAN Indian Institute of Horticultural Research, Hessaraghatta, Bangalore. Data were uniformly recorded and subjected to analysis of variance (Singh and Chaudhary,1985). Heterobeltiosis was estimated using the following formula (Hallauer and Mir-inda, 1988):

$$\text{Heterobeltiosis (\%)} = \frac{F_1\text{-}BP}{BP} \times 100 \quad \text{............Eq.1}$$

where, F_1 = Mean of F_1 hybrid,
BP = Value of better parent

RESULTS AND DISCUSSION

Analysis of variance showed highly significant differences due to parents for all the traits indicating that experimental material had sufficient genetic variability for all the traits under study. The genotypic variance was further partitioned into variance due to parents, parents vs cross and crosses. The mean square due to parents and crosses were highly significant for all the traits indicating that the performance of crosses was different than that of parents for most of the traits. However, mean square due to parents vs. cross were also highly significant except for number of branches per plant and number of flowers per plant (Table 2).

Heterobeltiosis estimates in 30 crosses for vegetative traits are presented in Table 3. Plant height is an important character which determines the

Table 1. Cross combinations of lines (L) x testers (T) evaluated for heterobeltiosis.

Sl. No.	Cross	Cross combinations
1.	L1 × T1	Matsumoto Pink x Phule Ganesh Violet
2.	L1 × T2	Matsumoto Pink x Phule Ganesh Purple
3.	L1 × T3	Matsumoto Pink x IIHRJ3-2
4.	L1 × T4	Matsumoto Pink x IIHRG13
5.	L1 × T5	Matsumoto Pink x Local White
6.	L2 × T1	Matsumoto Red x Phule Ganesh Violet
7.	L2 × T2	Matsumoto Red x Phule Ganesh Purple
8.	L2 × T3	Matsumoto Red x IIHRJ3-2
9.	L2 × T4	Matsumoto Red x IIHRG13
10.	L2 × T5	Matsumoto Red x Local White
11.	L3 × T1	Matsumoto Rose x Phule Ganesh Violet
12.	L3 × T2	Matsumoto Rose x Phule Ganesh Purple
13.	L3 × T3	Matsumoto Rose x IIHRJ3-2
14.	L3 × T4	Matsumoto Rose x IIHRG13
15.	L3 × T5	Matsumoto Rose x Local White
16.	L4 × T1	Matsumoto Yellow x Phule Ganesh Violet
17.	L4 × T2	Matsumoto Yellow x Phule Ganesh Purple
18.	L4 × T3	Matsumoto Yellow x IIHRJ3-2
19.	L4 × T4	Matsumoto Yellow x IIHRG13
20.	L4 × T5	Matsumoto Yellow x Local White
21.	L5 × T1	Matsumoto Scarlet x Phule Ganesh Violet
22.	L5 × T2	Matsumoto Scarlet x Phule Ganesh Purple
23.	L5 × T3	Matsumoto Scarlet x IIHRJ3-2
24.	L5 × T4	Matsumoto Scarlet x IIHRG13
25.	L5 × T5	Matsumoto Scarlet x Local White
26.	L6 × T1	Matsumoto White x Phule Ganesh Violet
27.	L6 × T2	Matsumoto White x Phule Ganesh Purple
28.	L6 × T3	Matsumoto White x IIHRJ3-2
29.	L6 × T4	Matsumoto White x IIHRG13
30.	L6 × T5	Matsumoto White x Local White

Table 2. Analysis of variance for thirteen traits in Line x Tester mating.

Source of variation	DF	Plant height (cm)	Number of leaves/ plant	Plant spread (cm)	Number of branch-es/plant	Days to first flow-er open-ing	Flower stalk length (cm)	Flower head diameter (cm)	100 flow-ers weight (g)	Number of flow-ers per plant	Weight of flowers per plant (g)	Duration of flow-ering (days)	Flower yield per hectare (q)	Vase life (days)
Replication	1	4.64	6.78	1.24	5.02	68.89**	1.30	0.01	19.95**	1.02	0.50	0.29	0.35	2.09**
Parents	10	242.12**	40.59**	169.09**	8.90**	467.45**	188.23**	2.64**	10114.52**	157.90**	2730.33**	29.03**	1926.36**	1.71**
Parents vs cross	1	855.31**	123.59**	341.33**	0.41	1329.00**	399.36**	17.86**	16003.55**	0.82	2063.55**	152.03**	1455.91**	5.75**
Crosses	29	105.65**	18.68**	76.46**	10.51**	177.59**	48.96**	0.28**	749.03**	103.26**	374.23**	53.87**	264.07**	2.92**
Line	5	175.96	10.79	16.30	9.54	549.99**	65.88	0.63*	1417.47	208.42	704.49	85.09	497.03	4.44
Tester	4	116.71	34.20	360.52**	21.63	324.18**	90.18	0.18	306.636	46.80	216.85	44.46	153.04	4.00
Line x Tester	20	85.87**	17.55**	34.69**	8.53**	55.17**	36.48**	0.21**	670.40**	88.27**	323.34**	47.95**	228.04**	2.32**
Error	29	2.89	2.32	1.82	1.48	0.71	3.48	0.03	4.91	2.76	9.43	2.94	6.66	0.04

Note: * and ** indicates significance of value at p< 0.05 and p< 0.01, respectively

utility of the hybrid. Taller plants with longer stalks are preferred for cut flowers, whereas shorter ones are selected for landscaping and pot culture. The heterobeltiosis for plant height ranged from -41.96 (L4 x T4) to 33.85 (L6 x T5). Among 30 crosses, four crosses showed significant positive heterobeltiosis and 16 crosses showed significant negative heterobeltiosis. The cross L6 x T5 (33.85) showed significantly highest positive heterobeltiosis at 5% level of significance followed by L5 x T1 (31.64), L2 x T3 (19.35) and L5 x T5 (16.14). Panwar *et al*. (2013) observed both significantly negative and positive heterobeltiosis for plant height in marigold. In the present study, the heterobeltiosis for number of leaves per plant in China aster ranged from -33.61 (L5 x T2) to 45.23 (L1 x T4). Among 30 crosses, 9 recorded significantly positive heterobeltiosis.

Plant spread is another trait which decides the utility of the crop. Erect plants suitable for cut flowers, however, spreading types for bedding and pot purpose. Heterobeltiosis for plant spread varied from -34.72 (L5 x T2) to 61.39 (L1 x T5); 6 crosses shown significantly positive heterobeltiosis and 20 crosses showed significantly negative heterobeltiosis. The cross L1 x T5 (61.39) displayed highest followed by L6 x T5 (56.29). Heterobeltiosis for more number of branches per plant is desirable as more branches produces more number of flowers per plant. Heterobeltiosis ranged from -57.58 (L5 x T2) to 42.06 (L5 x T1). Among 30 crosses, three crosses revealed positively significant heterobeltiosis and 12 crosses showed significantly negative heterobeltiosis. The cross L5 x T1 (42.06) recorded the best followed by L5 x T5 (31.97) and L2 x T3 (23.16). Kumari *et al*. (2018) reported good amount of heterobeltiosis for number of branches per plant in the cross of Arka Aadya x Local violet (L3 x T2) in China aster. The exhibition of heterosis is also depends upon the genetic constitution of the parents used in the cross combinations.

Heterobeltiosis estimates in 30 crosses for flowering, flower quality, flower yield and vase life are presented in Table 4. Days to first flowering is a negative trait as earliness is preferred over lateness. Plant earliness is an important character, which helps farmers to fetch more price in early market. Heterobeltiosis for this trait ranged from -47.41 (L1 x T3) to -6.50 (L5 x T4). All the 30 crosses showed significantly negative heterosis at 5% level of sigificnce for days taken for first flowering. The cross L1 x T3 (-47.41) displayed minimum heterobeltiosis followed by L1 x T2 (-46.36). Kanwar *et al*. (2016) have also reported earliness in marigold hybrids.

Flower stalk length and flower head diameter are decisive traits for selection of a genotype for commercial cultivation. The heterobeltiosis for flower stalk length among the crosses varied from -48.62 (L3 x T4) to 73.76 (L6 x T5). Among 30 crosses, 3

Table 3. Estimates of heterobeltiosis in China aster for vegetative traits.

Sl. No.	Cross	Plant height (cm)	Number of leaves/ plant	Plant spread (cm)	Number of branches/plant
1.	L1 × T1	-7.85	-7.90	-33.12**	-9.23
2.	L1 × T2	-23.27**	-23.44**	-16.18**	-36.69**
3.	L1 ×T3	-5.46	4.78	-20.49**	-29.16**
4.	L1 ×T4	-8.68*	45.23**	-10.90	5.32
5.	L1 ×T5	-6.90	-20.07**	61.39**	15.00
6.	L2 × T1	-29.61**	-4.87	-32.49**	-3.33
7.	L2 × T2	-9.87*	-32.76**	-13.59**	-27.84**
8.	L2 ×T3	19.35**	16.73*	-13.33**	23.16*
9.	L2 ×T4	-30.21**	20.00*	-29.46**	-20.45
10.	L2 ×T5	-5.52	-13.71*	14.09	3.96
11.	L3 × T1	-24.51**	-16.15*	-29.97**	-34.44**
12.	L3 × T2	-17.69**	-30.51**	-7.25	-34.79**
13.	L3 ×T3	-2.26	20.73**	-12.68*	-22.53*
14.	L3 ×T4	-23.33**	12.86	-24.86**	-17.41
15.	L3 ×T5	-3.18	-1.69	28.39**	7.98
16.	L4 × T1	-8.82*	0.77	-13.15**	-6.71
17.	L4 × T2	-9.87*	-31.92**	-7.83	-40.49**
18.	L4 ×T3	-23.68**	12.77	-24.23**	-31.15**
19.	L4 ×T4	-41.96**	15.23	-18.41**	-40.14**
20.	L4 ×T5	-29.52**	-8.35	15.87*	-5.61
21.	L5 × T1	31.64**	19.17**	-13.88**	42.06**
22.	L5 × T2	-30.73**	-33.61**	-34.72**	-57.58**
23.	L5 ×T3	2.26	23.12**	-16.74**	18.51*
24.	L5 ×T4	-1.81	-17.63*	-13.26*	-35.59**
25.	L5 ×T5	16.14**	3.01	40.18**	31.97*
26.	L6 × T1	2.94	-12.02	14.20**	-2.52
27.	L6 × T2	-10.84**	-22.59**	-28.08**	-43.68**
28.	L6 ×T3	7.33	16.73*	-18.38**	-7.31
29.	L6 ×T4	-23.87**	30.99**	-30.56**	-1.50
30.	L6 ×T5	33.85**	20.41**	56.29**	11.73
	SEm ±	1.70	1.47	1.21	1.14
	C.D. (P=0.05)	3.47	3.00	2.48	2.32
	C.D. (P=0.01)	4.67	4.04	3.34	3.13

crosses showed significantly positive heterobeltiosis and 15 crosses were shown significantly negative. The cross L6 x T5 (73.76) recorded as the best. Flower head diameter is an important character for selecting a hybrid. Heterobeltiosis for flower head diameter ranged from -15.81 (L4 x T3) to 26.44 (L5 x T4). Among 30 hybrids, five crosses showed significantly positive heterobeltiosis and 10 crosses showed significantly negative heterobeltiosis. The best cross combination was L5 x T4 (26.44) followed by L5 x T5 (15.47). Since, the crosses made between the divergent parents, negative heterobeltiosis were observed for both stalk length and flower diameter.

One-hundred flowers weight, number of flowers per plant and weight of flowers per plant are contributed directly to flower yield. The heterobeltiosis for 100 flower weight ranged from -54.30 (L4 x T2) to 3.41 (L5 x T4). Among the 30 crosses, except one cross all other showed significantly negative heterobeltiosis. The cross L5 x T4 (3.41) recorded as the best significant positive heterobeltiosis. The heterobeltiosis for number of flowers per plant varied from -73.68 (L5 x T2) to 101.18 (L6 x T5). Among the 30 crosses, 3 crosses showed significantly positive relative heterosis and 23 crosses showed significantly negative relative heterosis. The cross L6 x T5 (101.18) recorded the best followed by L5 x T5 (31.12) and L5 x T1 (10.99).

The duration of flowering is important trait for landscape garden and in commercial cultivation as it facilitates extended number of pickings. For duration of flowering heterobeltiosis ranged from -40.97 (L4 x T4) to 60.14 (L4 x T2). Among 30 crosses, nine crosses showed significantly positive heterobeltiosis and 9 were significantly negative. The cross L4 x T2 (60.14) recorded maximum significantly positive heterobeltiosis followed by L6 x T5 (48.48) and L5 x T1 (42.86).

The heterobeltiosis for weight of flowers per plant varied from -85.52 (L5 x T2) to 47.90 (L6 x T5). Among the 30 hybrids, one cross showed significantly positive heterobeltiosis and 27 crosses showed significantly negative heterobeltiosis. The cross L6 x T5 (47.90) showed highest significant positive heterobeltiosis. Since, the crosses made between the divergent parents, hence, negative heterobeltiosis were observed in most of the cross

Table 4. Estimates of heterobeltiosis in China aster for flowering, flower yield and postharvest traits.

Sl. No.	Cross	Days to first flowering	Flower stalk length (cm)	Flower head diameter (cm)	100 flower weight (g)	Number of flowers/ plant	Duration of flowering (days)	Flower yield/plant (g)	Flower yield/ hectare (q)	Vase life (days)
1.	L1 × T1	-40.02 **	-34.17**	-6.19	-46.04 **	-19.58**	26.13**	-56.59 **	-56.59 **	-21.07 **
2.	L1 × T2	-46.36 **	-23.86**	1.21	-39.82 **	-44.39**	-8.99	-66.55 **	-66.55 **	-31.83 **
3.	L1 ×T3	-47.41 **	-34.94**	-13.67**	-24.29 **	-37.50**	-29.46**	-52.68 **	-52.68 **	-34.77 **
4.	L1 ×T4	-40.48 **	-18.54**	-2.94	-25.33 **	-40.10**	-28.06**	-55.24 **	-55.24 **	-20.04 **
5.	L1 ×T5	-32.42 **	6.96	0.52	-19.05 **	-36.94**	-25.11**	-48.96 **	-48.95 **	-31.57 **
6.	L2 × T1	-27.92 **	-32.24**	-3.93	-45.37 **	-47.19**	-4.90	-71.14 **	-71.14 **	-26.36 **
7.	L2 × T2	-35.39 **	-7.37	-10.98**	-49.91 **	-28.60**	8.61	-64.25 **	-64.25 **	-27.27 **
8.	L2 ×T3	-40.17 **	-12.15*	-9.12**	-12.29 **	8.93	13.68*	-4.47	-4.48	-13.05 **
9.	L2 ×T4	-14.90 **	-40.98**	-5.98	-17.26 **	-45.50**	-24.85**	-54.88 **	-54.87 **	-35.99 **
10.	L2 ×T5	-17.46 **	9.00	4.57	-11.14 **	-20.34*	7.32	-29.22 **	-29.21 **	-22.25 **
11.	L3 × T1	-25.54 **	-9.05	-5.01	-46.24 **	-51.21**	38.38**	-73.77 **	-73.77 **	-22.51 **
12.	L3 × T2	-39.93 **	-10.16	-6.51*	-44.97 **	-41.64**	-8.61	-67.89 **	-67.88 **	-26.86 **
13.	L3 ×T3	-40.99 **	-15.43**	-11.35**	-25.44 **	-20.54**	-3.78	-40.76 **	-40.76 **	-13.05 **
14.	L3 ×T4	-27.07 **	-48.62**	-2.23	-26.55 **	-58.09**	-20.65**	-69.18 **	-69.18 **	-8.04 **
15.	L3 ×T5	-24.81 **	23.75*	3.53	-24.21 **	-5.83	23.16**	-28.62 **	-28.61 **	0.00
16.	L4 × T1	-32.88 **	-9.50	-3.05	-50.87 **	-17.69**	-0.11	-59.62 **	-59.62 **	-5.29
17.	L4 × T2	-38.88 **	-9.65	-6.51*	-54.30 **	-26.54**	60.14**	-66.44 **	-66.43 **	-40.90 **
18.	L4 ×T3	-39.65 **	-25.82**	-15.81**	-28.43 **	-21.12**	-21.25**	-43.54 **	-43.54 **	-8.68 **
19.	L4 ×T4	-31.80 **	-29.32**	6.59*	-8.83 **	-58.86**	-40.97**	-62.46 **	-62.46 **	-44.03 **
20.	L4 ×T5	-31.05 **	8.61	-2.91	-35.67 **	-16.42*	-19.19**	-39.44 **	-39.44 **	-15.55 **
21.	L5 × T1	-36.40 **	-21.04**	8.06*	-40.75 **	10.99*	42.86**	-34.28 **	-34.27 **	-10.58 **
22.	L5 × T2	-37.46 **	-26.40**	-6.70*	-44.97 **	-73.68**	-29.96**	-85.52 **	-85.53 **	-31.83 **
23.	L5 ×T3	-45.65 **	-19.49**	-3.53	-18.85 **	-24.70**	-10.62	-38.89 **	-38.90 **	0.00
24.	L5 ×T4	-6.50 **	-10.53	26.44**	3.41 **	-25.45**	-7.74	-22.88 **	-22.88 **	0.00
25.	L5 ×T5	-27.19 **	61.86**	15.47**	-14.08 **	31.12**	3.47	12.56	12.58	22.25**
26.	L6 × T1	-7.14 **	-0.68	14.24**	-39.67 **	0.26	26.84**	-39.51 **	-39.51 **	36.78**
27.	L6 × T2	-10.50 **	1.26	-6.70*	-43.25 **	-24.48**	40.07**	-57.16 **	-57.16 **	-13.63 **
28.	L6 ×T3	-24.43 **	-9.11	-9.02**	-29.38 **	-11.30	0.68	-37.34 **	-37.34 **	-26.09 **
29.	L6 ×T4	-17.52 **	-37.10**	-2.43	-29.39 **	-15.42**	1.61	-40.24 **	-40.25 **	-20.04 **
30.	L6 ×T5	-8.36 **	73.76**	1.45	-31.84 **	101.18**	48.48**	47.90 **	47.91 **	-22.25 **
	SEm ±	0.80	1.78	0.16	2.15	1.59	1.56	3.23	2.72	0.22
	C.D. (P=0.05)	1.63	3.65	0.32	4.41	3.26	3.20	6.61	5.55	0.44
	C.D. (P=0.01)	2.20	4.92	0.43	5.94	4.39	4.31	8.91	7.49	0.59

combinations for 100 flowers weight, number of flowers/plant and weight of flowers/plant. The results are in accordance with the findings of Pavani (2014) in the crosses attempted with divergent parents in China aster.

Flower yield is the most important trait for commercial cultivation of China aster flowers. Flowers with good quality character along with good yield will always be preferred by growers. The heterobeltiosis for flower yield per hectare varied from -85.53 (L5 x T2) to 47.91 (L6 x T5). Among the 30 hybrids, only one cross showed significantly positive heterobeltiosis i.e. L6 x T5 (47.91). Kumari *et al*. (2018) also observed similar phenomenon for duration of flowering and it ranged from -0.49 (Arka Violet Cushion x Local Violet) to 84.64 (Arka Poornima x Arka Shashank) and flower yield per hectare, ranged from -41.21 (Arka Archana × Arka Shashank) to 47.09 (Arka Aadya × Local Violet) in China aster. Kanwar *et al*. (2016) and Panwar *et al*. (2013) also observed significantly negative and positive heterobeltiosis for duration of flowering and flower yield per hectare in marigold.

Vase life is an important postharvest trait for cut flower. Heterobeltiosis for vase life varied from -44.03 (L4 x T4) to 36.78 (L6 x T1). Among the 30 hybrids, 2 crosses showed significantly positive heterobeltiosis and 24 crosses showed significantly negative heterobeltiosis; hybrids, L6 x T1 (36.78) and L5 x T5 (22.25) showed significant positive heterobeltiosis.

Conclusion

It can be concluded that heterobeltiosis can be exploited for vegetative, flowering, flower quality, yield related traits and vase life by selecting the appropriate cross combinations in China aster. Since, these are the essential traits which directly or indirectly affect the production potential of the crop, therefore, emphasis may be given on development of F_1 hybrids with improved flower quality and yield in China aster.

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