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

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Abstract
Heterosis over commercial check, cv. Arka Kamini 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. Results revealed that the cross L5 × T1 exhibited highest positive significant standard heterosis for plant height, number of leaves per plant, weight of flowers per plant and flower yield per hectare. The cross L1 x T3 exhibited maximum negative standard heterosis for days to first flowering. L5 x T4 recorded the maximum positive standard heterosis for flower head diameter and 100 flower weight.

Keywords: China aster, standard heterosis, line, tester, yield

Introduction
China aster belongs to the family Asteraceae and is native of Northern China (Navalinskien *et al*., 2005) [5]. 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) [3]. It is grown commercially as cut flower for flower arrangement, interior decoration and loose flower garland making, worshipping (Munikrishnappa, 2013) [7]. 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 (Kumari *et al*., 2017) [5]. In Karnataka alone, it is grown in an area of 1693 ha with productivity of 9.39 t/ha (Anon., 2016) [1].
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 carry out to estimate standard heterosis in 30 crosses for vegetative, flowering, yield and vase life traits in China aster to exploit the commercial cultivation of hybrids.

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 13º 58' N Latitude, 78ºE Longitude and at 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 cv. Arka Kamini, a popular variety released from ICAR-IIHR is used as commercial check. The recommended agronomical practices were adopted to raise the successful crop.

Table 1: Cross combinations of lines (L) x testers (T) evaluated for standard heterosis

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

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) [11]. Standard heterosis was estimated using the following formula (Hallauer and Mirinda, 1988) [4]:

$$\text{Standard heterosis (\%)} = \frac{F_1\text{-CC x 100}}{CC}$$

Where,
F_1 = Mean of F_1 hybrid
CC = Commercial check

Results and Discussion

Standard heterosis estimates in 30 crosses for vegetative traits are presented in Table 2. Plant height is an important character which determines the 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 standard heterosis over Arka Kamini ranged from -40.16 (L4 x T4) to 25.16 (L5 x T1). Among 30 hybrids, three crosses showed significant positive standard heterosis and 19 crosses showed significant negative standard heterosis. The cross L5 x T1 showed highest significant standard heterosis followed by L2 x T3 and L6 x T. Panwar *et al.* (2013) [9] observed both significantly negative and positive standard heterosis for plant height in marigold. The standard heterosis for number of leaves per plant ranged from -40.16 (L4 x T4) to 25.16 (L5 x T1). Among 30 crosses, 24 crosses have shown significantly positive standard heterosis, best recorded by L6 x T5.

Table 2: Estimates of standard heterosis 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	-12.38**	21.16*	26.49**	-6.74
2.	L1 × T2	-23.19**	34.04**	12.86*	-13.63
3.	L1 ×T3	-6.23	30.06**	-2.74	-7.62
4.	L1 ×T4	-5.85	50.83**	-3.77	20.05
5.	L1 ×T5	-18.26**	18.19*	25.49**	-0.67
6.	L2 × T1	-33.08**	25.13**	27.68**	-0.67
7.	L2 × T2	-9.77*	17.72	16.35**	-1.55
8.	L2 ×T3	18.38**	44.90**	6.01	60.62**
9.	L2 ×T4	-28.04**	24.63**	-23.82**	-9.33
10.	L2 ×T5	-17.04**	27.60**	-11.29	-10.21
11.	L3 × T1	-28.22**	10.30	32.46**	-32.64**
12.	L3 × T2	-17.60**	21.66*	24.89**	-11.04
13.	L3 ×T3	-3.05	49.85**	6.80	1.04
14.	L3 ×T4	-20.95**	17.21	-18.85**	-5.85
15.	L3 ×T5	-14.99**	45.37**	-0.17	-6.74
16.	L4 × T1	-13.31**	32.55**	64.27**	-4.15
17.	L4 × T2	-9.77*	19.20*	24.11**	-18.81
18.	L4 ×T3	-24.31**	39.97**	-7.33	-10.21
19.	L4 ×T4	-40.16**	19.67*	-11.89*	-31.76*
20.	L4 ×T5	-38.11**	35.52**	-9.90	-12.80
21.	L5 × T1	25.16**	56.77**	62.89**	45.96**
22.	L5 × T2	-30.65**	16.23	-12.10*	-42.12**
23.	L5 ×T3	1.42	52.82**	1.84	54.56**
24.	L5 ×T4	1.23	-14.45	-6.32	-26.58*
25.	L5 ×T5	1.98	52.31**	9.00	13.99
26.	L6 × T1	-2.13	15.73	115.99**	0.16
27.	L6 × T2	-10.74**	35.52**	-3.15	-23.16
28.	L6 ×T3	6.45	44.90**	-0.17	20.88
29.	L6 ×T4	-21.51**	48.37**	-25.01**	12.28
30.	L6 ×T5	17.53**	78.04**	21.53**	7.10
	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

Plant spread is an trait which decides the utility of the crop. Erect plants suitable for cut flowers, however, spreading types for bedding and pot purpose. Standard heterosis over Arka Kamini for plant spread ranged from -25.01 (L6 x T4) to 115.99 (L6 x T1). Among the 30 crosses, 12 have shown significantly positive standard heterosis and 5 have shown significantly negative. The cross L6 x T1 recorded highest positive standard heterosis over commercial check. Standard heterosis for number of branches per plant ranged from-42.12 (L5 × T2) to 60.62 (L2 × T3). Among 30 crosses, only three cross have showed significantly positive standard heterosis and 4 were shown significantly negative standard heterosis. The highest positive significant standard heterosis was receded in L2 x T3 followed by L5 x T3 and L5 x T1 Kumari *et al.* (2018) [6] reported good amount of standard heterosis for number of branches per plant in China aster.

Standard heterosis estimates in 30 crosses for flowering, flower quality, flower yield and vase life are presented in

Table 3. 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. Standard heterosis for this trait ranged from -39.13 (L1 x T3) to 13.35 (L6 x T2). Among the 30 hybrids, 27 crosses showed significantly negative heterosis and 3 crosses showed significantly positive heterosis. The cross L1 x T3 showed highest negative heterosis, followed by L5 x T3 and L1 x T5. Kumari *et al*. (2018) [6] have also reported earliness in China aster hybrids.

Table 3: Estimates of standard heterosis 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)	Weight of flowers /plant (g)	Flower yield/ hectare (q)	Vase life (days)
1.	L1 × T1	-30.50**	-16.38*	-13.42**	-2.11	-15.08**	12.69	-16.85**	-16.85**	-28.57 **
2.	L1 × T2	-32.06 **	-13.79*	-1.36	10.34**	-31.22**	-11.38	-24.17**	-24.17**	-28.57 **
3.	L1 ×T3	-39.13**	-26.16**	-15.87**	-6.16**	-40.56**	-24.88**	-44.23**	-44.23**	-28.57 **
4.	L1 ×T4	-32.04 **	-6.60	-13.15**	-12.05**	-34.05**	-18.67*	-42.00**	-42.01**	-4.79
5.	L1 ×T5	-35.06 **	-25.00**	-12.24**	-2.24	-56.98**	-29.26**	-57.94**	-57.94**	-38.07 **
6.	L2 × T1	-16.48 **	-13.93*	-11.33**	-0.89	-44.24**	-15.03*	-44.71**	-44.71**	-33.36 **
7.	L2 × T2	-18.17 **	4.88	-15.87**	-8.16**	-11.68*	5.75	-18.95**	-18.96**	-23.79 **
8.	L2 ×T3	-30.75 **	-0.29	-8.70**	8.71**	3.60	21.07**	12.58*	12.57*	-4.79
9.	L2 ×T4	-2.83*	-32.33**	-12.33**	-2.55*	-40.00**	-15.03*	-41.54**	-41.53**	-23.79 **
10.	L2 ×T5	-20.68**	-23.57**	-8.88**	7.32**	-45.65**	1.38	-41.67**	-41.67**	-33.36 **
11.	L3 × T1	-13.73**	15.52*	-13.60**	-2.47*	-48.49**	23.63**	-49.75**	-49.76**	-26.21 **
12.	L3 × T2	-23.92**	1.72	-12.51**	0.89	-27.82**	-11.01	-27.20**	-27.20**	-23.36 **
13.	L3 ×T3	-31.70**	-4.02	-9.61**	-7.58**	-24.42**	2.47	-30.18**	-30.18**	-4.79
14.	L3 ×T4	-16.73**	-41.09**	-10.52**	-13.50**	-53.86**	-10.28	-60.07**	-60.06 **	9.50**
15.	L3 ×T5	-27.75**	-13.22*	-8.88**	-8.47**	-35.75**	16.35*	-41.18**	-41.18**	-4.79
16.	L4 × T1	-22.24 **	14.95*	-17.95**	-10.87**	-13.09*	-0.81	-22.65**	-22.65**	-14.29 **
17.	L4 × T2	-22.60 **	2.29	-4.62	-16.21**	-9.14	59.02**	-23.91**	-23.91**	-38.07 **
18.	L4 ×T3	-30.14**	-15.81*	-15.23**	-11.29**	-24.98**	-16.13*	-33.46**	-33.46**	0.00
19.	L4 ×T4	-22.12 **	-18.97**	-4.62	7.37**	-54.70**	-33.26**	-51.36**	-51.36**	-33.36 **
20.	L4 ×T5	-33.74**	-23.84**	-15.23**	-22.32**	-35.75**	-19.76**	-50.10**	-50.11**	-23.57 **
21.	L5 × T1	-26.31 **	0.29	-0.27	7.50**	17.19**	27.64**	25.89**	25.89**	-19.07 **
22.	L5 × T2	-20.80 **	-16.67*	-9.07**	0.89	-67.44**	-31.79**	-67.18**	-67.19**	-28.57 **
23.	L5 ×T3	-37.10**	-8.62	-5.98*	0.58	-28.38**	-4.81	-27.98**	-27.99 **	9.50**
24.	L5 ×T4	6.76**	2.59	13.15**	21.79**	-17.92**	4.31	-0.08	-0.09	19.07**
25.	L5 ×T5	-30.03**	13.50*	0.82	3.76**	-10.55	-2.25	-7.25	-7.24	4.79
26.	L6 × T1	7.60**	26.16**	5.44	9.45**	5.86	21.82**	15.87*	15.87*	23.79**
27.	L6 × T2	13.35**	14.66*	-9.07**	4.05**	-6.59	36.39**	-2.90	-2.90	-9.50 **
28.	L6 ×T3	-12.53**	3.16	-11.33**	-12.47**	-15.64**	7.22	-26.15**	-26.15**	-19.07 **
29.	L6 ×T4	-5.82**	-27.88**	-12.69**	-16.84**	-6.88	14.88 *	-22.57**	-22.59**	-4.79
30.	L6 ×T5	-11.93**	21.84**	-11.42**	-17.68**	48.05**	42.60**	21.88**	21.87**	-33.36 **
	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

Flower stalk length and flower head diameter are decisive traits for selection of a genotype for commercial cultivation. The standard heterosis over Arka Kamini for flower stalk length ranged from -41.09 (L3 x T4) to 26.16 (L6 x T1). Among 30 crosses, six crosses showed significant positive standard heterosis and 14 were negative. The cross L6 x T1 recorded highest. Flower head diameter is another important character for selecting a hybrid. Standard heterosis for flower head diameter ranged from -17.95 (L4 x T3) to 13.15 (L5 x T4). Among the 30 hybrids, one cross L5 x T4 showed significantly positive heterosis and 24 crosses showed significantly negative standard heterosis Since, the crosses made between the divergent parents, negative standard heterosis 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 standard heterosis for 100 flower weight ranged from -22.32 (L4 x T5) to 21.79 (L5 x T4). Among 30 hybrids, 9 crosses showed significantly positive standard heterosis and 15 crosses showed significantly negative standard heterosis. The cross L5 x T4 recorded maximum significant positive standard heterosis. The standard heterosis for number of flowers per plant varied from -67.44 (L5 x T2) to 48.05 (L6 x T5). Among 30 crosses, two crosses showed significantly positive standard heterosis and 22 showed significantly negative standard heterosis. The cross L6 x T5, recorded the best followed by L5 x T1

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 standard heterosis ranged from -33.26 (L4 x T4) to 59.02 (L4 x T2). Among 30 crosses, 9 crosses showed significantly positive standard heterosis and significantly negative standard heterosis each. The best cross for significantly positive standard heterosis was L4 x T2 followed by L6 x T5 and L6 x T2

The standard heterosis for weight of flowers per plant varied from -67.18 (L5 x T2) to 25.89 (L5 x T1). Among the 30 hybrids, 4 crosses showed significantly positive relative heterosis and 23 crosses showed significantly negative relative heterosis. The cross L5 x T1 recorded as the best. Since, the crosses made between the divergent parents, hence, negative standard heterosis were observed in most of the cross 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) [10] and Kumari *et al*. (2018) [6] 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 standard heterosis for flower yield per hectare varied from -67.19 (L5 x T2) to 25.89 (L5 x T1). Among 30 hybrids, 4 crosses showed significantly positive relative heterosis and 23 crosses showed significantly negative relative heterosis. The cross L5 x T1 recorded as the best followed by L6 x T5, L6 x T1 and L2 x T3. Panwar *et al*. (2013) [9] also observed significantly negative and positive standard heterosis for duration of flowering and flower yield per hectare in marigold and Kumari *et al*. (2018) [6] in China aster.

Vase life is an important postharvest trait for cut flower. Standard heterosis for vase life varied from -38.07 (L4 x T2) to 23.79 (L6 x T1). Among 30 crosses, four crosses showed significantly positive standard heterosis and 19 showed negative standard heterosis. The cross combinations L6 x T1, L5 x T4, L5 x T3 and L3 x T4 showed significantly positive standard heterosis.

Conclusion

It can be concluded that standard heterosis can be exploited for vegetative, flowering, flower quality, yield related traits and vase life by selecting the appropriate cross combinations. The cross L5 × T1 exhibited highest positive significant standard heterosis for plant height, weight of flowers per plant and flower yield per hectare. The cross L1 x T3 exhibited maximum negative standard heterosis for days to first flowering. L5 x T4 recorded the maximum positive standard heterosis for flower head diameter and 100 flower weight. 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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