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Exploitation of heterosis for growth related traits in African marigold (*Tagetes erecta*)

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ABSTRACT

A line × tester set of 15 parents involving three male sterile lines and 12 pollen parents of (*Tagetes erecta* L.) African marigold and their 36 hybrids were analyzed for heterosis with respect to various growth related traits. The hybrids MS 8 × Af.Sel.11, MS-5 × Af.Sel.16 and MS 8 × Af.Sel.11 exhibited maximum heterosis over better parent, mid parent and commercial check respectively for plant height. The maximium heterosis value for low plant spread were observed in the hybrid MS 7 × Af.Sel.1 over better, mid and commercial check, respectively, however hybrids (MS 5 × Af.Sel.10), MS 5 × Af.Sel.14 and MS 7 × Af.Sel.10 reported highest values of heterosis for stalk length over better, mid and commercial check respectively. The hybrids (MS 7 × Af.Sel.5, MS 5 × Pusa Narangi Gainda and MS 5 × Pusa Narangi Gainda exhibited maximum heterosis for stem diameter over better, mid and commercial check, respectively. For number of primary branches, the maximum heterosis over better, mid and commercial check were observed in hybrids MS 7 × Af.Sel.14, MS 7 × Af.Sel.14 and MS 7 × Af.Sel.12 respectively. The hybrids MS 7 × Af.Sel.11, MS 8 × Af.Sel.12 and MS-5 × Pusa Narangi Gainda exhibited highest heterosis for number of secondary branches over better, mid and commercial check, respectively.

Key words: Better parent, Commercial check, Heterosis, Mid parent, *Tagetes erecta*

African marigold (*Tagetes erecta* L.) is one of the most important ornamental species grown worldwide. It belongs to the family Asteraceae. Besides, the pristine use as loose flowers and the bedding plants, marigold is also widely used in perfume and cosmetic industry. Nowdays it is being utilized in urban landscape and most extensively used in landscape architecture due to their delightful appearance, myriads of sizes, shapes, forms, etc. This plant contains bioactive compounds that exhibit nematicidal, fungicidal and insecticidal activity. It is highly effective in keeping the nematode population in soil under control. Moreover, it is also grown as a mixed crop on the borders with other plants. Marigold has the advantage that it can be cultivated under a broad range of climatic conditions and also possess some resistance to saline and other adverse conditions (Foy and Wheeler 1979, Girwani *et al*. 1990, Goh and Haynes 1978, Huang and Cox 1988). Heterosis has contributed significantly towards increased production of the various crops and it has become the basis of multibillion dollar agribusiness in the world (Phillips 1999).

In spite of its economic importance and availability of considerable genetic diversity in plant characters, the genetic potentialities of marigold are practically unexplored and little efforts have been made for its genetic improvement. The crop improvement programmes should aim for the development of varieties or hybrids which suits to the human needs as well environmental friendly. The development of F_1 hybrids with varied growth characters is of prime importance as they form an important component of urban landscape and also growth characters determines the ultimate production potential of the crop. For instance, the hybrids with variable plant heights will be utilized by landscape architecture. The plants having more plant height are being utilized as screening component, whereas plants with dwarf stature are utilized as pot plants or in the form of edges. Being an ornamental crop, it has potential of being used as cut flower crop so the hybrids with high stalk length can be utilized for this purpose. Similarly heterosis for high stem diameter will provide more strength to the plants and plants do not require staking and become tolerant to lodging. Heterosis for more number of primary and secondary branches is desirable since plant containing more number of branches provide more

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opportunity for flower yields. Keeping these points in view, the present studies were undertaken to exploit heterosis for various growth related traits in African marigold.

MATERIALS AND METHODS

The experimental material comprised 15 genotypes of African marigold. It included three male sterile lines namely, MS 5, MS 7 and MS 8 and a set of 12 diverse pollinators which included 10 selections numbered as African Selection1 (Af.Sel.1), Af.Sel.4, Af.Sel.5, Af.Sel.6, Af Sel.8, Af Sel.10, Af.Sel.11, Af.Sel.12, Af.Sel.14 and Af.Sel.16 and 2 varieties Pusa Narangi Gainda (PNG) and Pusa Basanti Gainda (PBG) and further these were used as testers for crossing with MS lines. This genetic material utilized as parents in the line × tester cross were grown, maintained and evaluated at Division of Floriculture and Landscaping, Indian Agricultural Research Institute, New Delhi. The field trials were conducted during winter season 2009-11 for the production of F_1 hybrid seeds and their evaluation. For producing F_1 hybrid seed, pollination of three male sterile lines was done with all 12 testers in 36 combinations using line × tester design when their flowers were fully opened. The genotypes were planted in randomized block design (RBD) with three replications to evaluate intervarietal F_1 hybrids and their parental lines. The experiment was conducted in open field at spacing of 45 cm × 45 cm. All the selected genotypes were given uniform cultural practices for healthy growth and development. The biometrical observations were recorded on five random competitive plants from each replication after discarding border plants. The genotypes were assessed for various growth related traits, i e plant height (cm), plant spread (cm), stalk length (cm), stem diameter (cm), number of primary branches and number of secondary branches.

Heterosis over mid-parent heterosis (MPH), better-parent heterosis (BPH) and economic heterosis for each cross were calculated as percentage deviation from the mid-parent (MP) and better-parent (BP) values and commercial check, respectively (Turner 1953, Hays *et al*. 1955).The commercial check used was variety Pusa Narangi Gainda.

RESULTS AND DISCUSSION

Heterosis of 36 intervarietal F_1 hybrids for growth related traits were studied. Plant height is an important parameter which determines the usefulness of the crop for varied purposes. Since marigold being an ornamental crop is largely used in urban landscape so this parameter is one of the most important determining factor. The plants with tall stature are being utilized as a screening component, whereas dwarf ones are used as pot plants or in the form of edges. For plant height, the range of heterosis varied from –24.29% (MS 5 × Af.Sel.14) to 24.60% (MS 8 × Af.Sel.11) over better parent, –16.46% (MS 5 × Af.Sel.14) to 39.27 % (MS 5 × Af.Sel.16) over mid parent and -34.99% (MS 7 × Af.Sel.16) to 5.52% (MS 8 × Af.Sel.11) over commercial check (Table 1). Out of 36 hybrids, 10 hybrids exhibited significant and positive heterosis over better parent. Similarly, 17 hybrids exhibited significant and positive heterosis over mid parent and 1 hybrid exhibited significant and positive heterosis over commercial check. The highest significant positive better parent heterosis was observed in hybrid MS 8 × Af.Sel.11 (24.60) followed by MS 5 × Af.Sel.16 (23.90) and MS 5 × Af.Sel.10 (19.40). The highest significant positive mid parent heterosis was observed in hybrid MS 5 × Af.Sel.16 (39.27) followed by MS 8 × Af.Sel.11 (25.68) and MS 7 × Af.Sel.5 (25.46). The highest significant positive heterosis over commercial check was observed in hybrid MS 8 × Af.Sel.11 (5.52). Therefore, these hybrid combinations can be utilized for the production of taller plants if desired. For the trait plant height both significantly negative and positive heterosis were observed in marigold. Pant and Lal (1992) reported range of heterois from -14.891 to 20.089% over better parent in gladiolus suggested that hybrid combinations can be utilized for the production of taller/dwarf plants. The results are also in accordance with Hassan *et al*. (2012) in petunia and Kumar and Ganesan (2004) in sesame.

Today, in many western countries, marigold is being utilized as a bedding plant, so for that purpose, plant spread is of utmost importance since it is among the major factors which decides the planting distance. Less is the plant spread, more number of plants will be accommodated in the given space as compared to the plants with more plant spread. The range of heterosis for plant spread varied from –40.52% (MS 7 × Af.Sel.1) to 8.77 % (MS 5 × Pusa Narangi Gainda) over better parent, –33.94% (MS 7 × Af.Sel.1) to 16.72 % (MS 5 × Pusa Narangi Gainda) over mid parent and -44.29% (MS 7 × Af.Sel.1) to 9.93% (MS 8 × Pusa Narangi Gainda) over commercial check (Table 1). The negative heterosis for plant spread in hybrids is also a desirable trait. The significant negative heterosis over better parent was observed in 21 hybrids. Similarly, the significant negative heterosis over mid parent was observed in 19 hybrids, whereas significant negative heterosis over commercial check was observed in 30 hybrids. The highest significant negative better parent heterosis was observed in hybrid MS 7 × Af.Sel.1 (–40.52) followed by MS 8 × Af.Sel.1(–40.22) and MS 8 × Af.Sel.14 (–32.59). The highest significant negative mid parent heterosis was observed in hybrid MS 7 × Af.Sel.1 (–33.94) followed by MS 8 × Af.Sel.14 (–31.70) and MS-8 × Af.Sel.1 (–31.33). The highest significant negative heterosis over commercial check was observed in hybrid MS 7 × Af.Sel.1 (–44.29) followed by MS-8 × Af. Sel.1 (–39.49) and MS 5 × Af.Sel.10 (–36.35). Ganeshreddy *et al.* (2008) also observed both negative and positive heterosis for plant spread in chilli.

Stalk length is one of the important characters as African marigold has a potential of being utilized as a cut flower crop**.** Hence, positive heterosis for stalk length is also of prime importance. Heterosis for stalk length varied from

Table 1 Magnitude of heterosis (%) over better parent, mid parent and commercial check for plant height and plant spread

Crosses	Plant height			Plant spread		
	BP	MP	CC	BP	MP	CC
MS 5 × PNG	–11.65**	–4.30	–11.65**	8.77*	16.72**	8.77**
MS 5 × PBG	2.35	6.46*	–6.12*	–1.01	2.34	–8.49**
MS 5 × Af.Sel.1	–5.16	5.61	–19.73**	–9.77*	–3.42	–22.06**
MS 5 × Af.Sel.4	7.78*	9.35**	–6.07*	6.07	6.71	–8.38**
MS 5 × Af.Sel.5	0.18	13.70**	–15.21**	1.27	1.75	–11.69**
MS 5 × Af.Sel.6	–15.67**	–9.36**	–17.07**	5.94	9.29**	–8.49**
MS 5 × Af.Sel.8	3.64	6.60*	–7.13*	–24.62**	–19.49**	–25.37**
MS 5 × Af.Sel.10	19.40**	22.11**	1.05	–29.16**	–27.76**	–36.35**
MS 5 × Af.Sel.11	5.57	5.60	–10.59**	–19.83**	–17.52**	–26.64**
MS 5 × Af.Sel.12	2.25	2.53	–13.45**	–21.27**	–18.32**	–26.70**
MS 5 × Af.Sel.14	–24.29**	–16.46**	–21.13**	–32.38**	–26.14**	–29.73**
MS 5 × Af.Sel.16	23.90**	39.27**	4.87	–17.11**	–11.85**	–28.41**
MS 7 × PNG	–2.11	8.51**	–2.11	7.28	10.79**	7.28**
MS 7 × PBG	0.60	7.20*	–7.73**	–1.65	–1.01	–7.89**
MS 7 × Af.Sel.1	–5.18	3.19	–23.74**	–40.52**	–33.94**	–44.29**
MS 7 × Af.Sel.4	13.48**	18.03**	–1.10	7.07	12.05**	0.28
MS 7 × Af.Sel.5	13.05**	25.46**	–9.09**	–2.65	0.82	–8.83**
MS 7 × Af.Sel.6	–20.16**	–12.16**	–21.49**	–5.12	1.70	–11.14**
MS 7 × Af.Sel.8	4.76	10.42**	–6.12*	–27.24**	–25.22**	–27.96**
MS 7 × Af.Sel.10	18.68**	19.02**	–4.02	–9.54*	–7.66*	–15.28**
MS 7 × Af.Sel.11	3.26	5.93	–12.55**	–14.02**	–13.02**	–19.47**
MS 7 × Af.Sel.12	7.87*	10.34**	–9.19**	2.77	3.07	–3.75
MS 7 × Af.Sel.14	–16.72**	–6.01	–13.25**	–18.79**	–14.57**	–15.61**
MS 7 × Af.Sel.16	–19.16**	–11.18**	–34.99**	–21.20**	–13.03**	–26.20**
MS 8 × PNG	–10.24**	–2.03	–10.24**	8.61*	9.27**	9.93**
MS 8 × PBG	–0.27	4.56	–8.53**	1.25	5.84	2.48
MS 8 × Af.Sel.1	–5.85	4.07	–21.64**	–40.22**	–31.33**	–39.49**
MS 8 × Af.Sel.4	3.74	6.13	–9.59**	–7.79	0.06	–6.67*
MS 8 × Af.Sel.5	–3.86	8.32**	–19.98**	–13.90**	–7.49*	–12.85**
MS 8 × Af.Sel.6	–14.19**	–7.05*	–15.61**	–12.43**	–2.75	–11.36**
MS 8 × Af.Sel.8	10.98**	15.07**	–0.55	–19.35**	–18.46**	–18.37**
MS 8 × Af.Sel10	4.34	5.84	–13.15**	–29.97**	–25.81**	–29.12**
MS 8 × Af.Sel.11	24.60**	25.68**	5.52*	–23.38**	–19.52**	–22.45**
MS 8 × Af.Sel.12	16.40**	17.06**	–2.01	–3.76	0.26	–2.59
MS 8 × Af.Sel.14	–18.75**	–9.67**	–15.36**	–32.59**	–31.70**	–29.95**
MS 8 × Af.Sel.16	–7.18	3.57	–22.74**	–25.01**	–14.37**	–24.10**

* Significant at 5% level, ** significant at 1% level

9.09% (MS 8 × Af.Sel.10) to 162.88% (MS 5 × Af.Sel.10), 0.44% (MS 8 × Af.Sel.10) to 103.19% (MS 5 × Af.Sel.14) and 13.43% (MS 8 × Af.Sel.10) to 101.99% (MS 7 × Af.Sel.10) over better parent, mid parent and commercial check, respectively (Table 2). Out of 36 hybrids, 36 F_1 hybrids displayed significant positive heterosis over better parent and commercial check, whereas 35 crosses exhibited significantly positive mid parent heterosis. The highest significant positive better parent heterosis was observed in hybrid MS 5 × Af.Sel.10 (162.88) followed MS 5 × Af.Sel.16 (150.00) and MS 7 × Af.Sel.10 (144.58). The highest significant positive mid parent heterosis was observed in hybrid MS 5 × Af.Sel.14 (103.19) followed by MS 7 × Af.Sel.10 (97.57) and MS 5 × Af.Sel.10 (84.08). The highest significant positive heterosis over commercial check was observed in hybrid MS 7 × Af.Sel.10 (101.91) followed by MS 8 × Af.Sel.14 (76.62) and MS-8 × Pusa Narangi Gainda (74.13). For stalk length maximum exhibited significantly positive heterosis over better parent, mid parent and commercial check.

Table 2 Magnitude of heterosis (%) over better parent, mid parent and commercial check for stalk length and stem diameter

Crosses	Stalk length			Stem diameter		
	BP	MP	CC	BP	MP	CC
MS 5 × PNG	125.00**	78.38**	47.76**	45.91**	55.83**	45.74**
MS 5 × PBG	127.27**	49.63**	49.25**	16.09**	23.32**	14.45**
MS 5 × Af.Sel.1	87.88**	48.50**	23.38**	31.01**	31.52**	15.09**
MS 5 × Af.Sel.4	106.06**	44.68**	35.32**	23.96**	26.26**	8.01**
MS 5 × Af.Sel.5	136.36**	70.49**	55.22**	45.83**	46.41**	27.20**
MS 5 × Af.Sel.6	93.94**	34.38**	27.36**	–3.37**	9.79**	10.93**
MS 5 × Af.Sel.8	118.18**	38.13**	43.28**	–14.87**	0.85	7.69**
MS 5 × Af.Sel.10	162.88**	84.08**	72.64**	–0.36	18.22**	26.59**
MS 5 × Af.Sel.11	106.06**	24.20**	35.32**	6.92**	18.47**	15.90**
MS 5 × Af.Sel.12	93.18**	21.72**	26.87**	9.69**	22.44**	20.89**
MS 5 × Af.Sel.14	140.91**	103.19**	58.21**	14.55**	29.01**	28.74**
MS 5 × Af.Sel.16	150.00**	70.10**	64.18**	47.66**	49.41**	28.63**
MS 7 × PNG	84.94**	67.30**	52.74**	42.05**	51.15**	41.88**
MS 7 × PBG	89.76**	44.83**	56.72**	27.36**	34.79**	25.88**
MS 7 × Af.Sel.1	76.51**	59.24**	45.77**	16.54**	16.54**	2.20**
MS 7 × Af.Sel.4	56.02**	26.34**	28.86**	25.58**	28.40**	10.19**
MS 7 × Af.Sel.5	71.08**	42.00**	41.29**	49.10**	50.26**	30.97**
MS 7 × Af.Sel.6	87.95**	50.36**	55.22**	–13.66**	–2.24**	–1.13**
MS 7 × Af.Sel.8	71.69**	26.39**	41.79**	–2.69**	14.92**	23.28**
MS 7 × Af.Sel.10	144.58**	97.57**	101.99**	2.86**	21.65**	30.88**
MS 7 × Af.Sel.11	60.24**	12.71**	32.34**	4.40**	15.28**	13.18**
MS 7 × Af.Sel.12	65.66**	21.41**	36.82**	21.86**	35.55**	34.10**
MS 7 × Af.Sel.14	90.96**	82.71**	57.71**	16.97**	31.29**	31.26**
MS 7 × Af.Sel.16	76.51**	38.86**	45.77**	–4.39**	–2.89**	–16.2**
MS 8 × PNG	74.13**	70.73**	74.13**	25.91**	35.29**	25.86**
MS 8 × PBG	55.50**	35.98**	61.69**	18.39**	26.54**	16.95**
MS 8 × Af.Sel.1	16.83**	14.84**	17.41**	18.86**	20.10**	4.47**
MS 8 × Af.Sel.4	21.53**	12.14**	26.37**	23.48**	24.97**	6.08**
MS 8 × Af.Sel.5	48.80**	40.41**	54.73**	27.03**	27.37**	9.80**
MS 8 × Af.Sel.6	42.11**	29.69**	47.76**	–5.94**	7.47**	7.96**
MS 8 × Af.Sel.8	59.33**	34.82**	65.67**	2.69**	22.31**	30.20**
MS 8 × Af.Sel10	9.09**	0.44	13.43**	–3.57**	15.02**	22.71**
MS 8 × Af.Sel.11	65.07**	33.98**	71.64**	25.58**	39.95**	36.12**
MS 8 × Af.Sel.12	37.32**	15.73**	42.79**	21.65**	36.57**	33.71**
MS 8 × Af.Sel.14	96.13**	82.05**	76.62**	18.79**	34.55**	33.51**
MS 8 × Af.Sel.16	60.29**	44.09**	66.67**	31.40**	32.10**	13.20**

* Significant at 5% level, ** significant at 1% level

Stem diameter is the trait which provides support and strength to the plants, because more is the stem diameter more will be thickness of the main branch. The range of heterosis for stem diameter ranged –14.87% (MS 5 × Af.Sel.8) to 49.10 % (MS 7 × Af.Sel.5) over better parent, –2.89% (MS 7 × Af.Sel.16) to 55.83% (MS 5 × Pusa Narangi Gainda) over mid parent heterosis and –16.2% (MS 7 × Af.Sel.16) to 45.74% (MS 5 × Pusa Narangi Gainda) over commercial check (Table 2). Out of 36 hybrids, 28 crosses showed significant positive better parent heterosis, 33 crosses showed significant positive mid parent heterosis and 34 crosses showed significant positive heterosis over commercial check. The highest significant positive better parent heterosis was observed in hybrid MS 7 × Af.Sel.5 (49.10) followed by MS 5 × Af.Sel.16 (47.66) and MS 5 × Pusa Narangi Gainda (45.91). The highest significant positive mid parent heterosis was observed in hybrid MS 5 × Pusa Narangi Gainda (55.83) followed by MS 7 × Pusa Narangi Gainda (51.15) and MS 7 × Af.Sel.5 (50.26). The highest significant positive heterosis over commercial check was observed in hybrid MS 5 × Pusa

Table 3 Magnitude of heterosis (%) over better parent, mid parent and commercial check for number of primary branches and number of secondary branches

Crosses	Number of primary branches			Number of secondary branches		
	BP	MP	CC	BP	MP	CC
MS 5 × PNG	15.79**	29.41**	15.79**	31.30**	54.26**	31.30**
MS 5× PBG	38.71**	40.98**	13.16**	28.16**	35.38**	0.76
MS 5 × Af.Sel.1	–8.57**	–1.54	–15.79**	18.48**	31.33**	–16.79**
MS 5 × Af.Sel.4	2.22	22.67**	21.05**	–29.35**	–25.29**	–50.38**
MS 5 × Af.Sel.5	32.35**	40.63**	18.42**	34.74**	36.90**	–2.29
MS 5 × Af.Sel.6	–9.30**	6.85**	2.63	39.58**	42.55**	2.29
MS 5 × Af.Sel.8	–11.90**	2.78	–2.63	1.00	5.21	–22.90**
MS 5 × Af.Sel.10	3.33**	3.33*	–18.42**	–33.61**	–24.30**	–38.17**
MS 5 × Af.Sel.11	7.50**	22.86**	13.16**	–8.41	–1.51	–25.19**
MS 5 × Af.Sel.12	–21.15**	0.00	7.89**	5.43	15.48**	–25.95**
MS 5 × Af.Sel.14	34.37**	38.71**	13.16**	23.23**	27.75**	–6.87
MS 5 × Af.Sel.16	20.00**	29.23**	10.53**	10.87*	13.33**	–22.14**
MS 7 × PNG	18.42**	34.33**	18.42**	25.19**	43.86**	25.19**
MS 7 × PBG	22.58**	26.67**	0.00	32.04**	36.00**	3.82
MS 7 × Af.Sel.1	0.00	9.38**	–7.89**	14.43**	29.82**	–15.27**
MS 7 × Af.Sel.4	–15.56**	2.70	0.00	–39.18**	–34.08**	–54.96**
MS 7 × Af.Sel.5	23.53**	33.33**	10.53**	19.59**	20.83**	–11.45**
MS 7 × Af.Sel.6	–6.98**	11.11**	5.26**	14.43**	15.03**	–15.27**
MS 7 × Af.Sel.8	–28.57**	–15.49**	–21.05**	8.00	9.64*	–17.56**
MS 7 × Af.Sel.10	10.00**	11.86**	–13.16**	–1.64	9.59*	–8.40*
MS 7 × Af.Sel.11	12.50**	30.43**	18.42**	49.53**	56.86**	22.14**
MS 7 × Af.Sel.12	–5.77**	20.99**	28.95**	7.22	20.23**	–20.61**
MS 7 × Af.Sel.14	43.75**	50.82**	21.05**	43.43**	44.90**	8.40*
MS 7 × Af.Sel.16	–2.86**	6.25**	–10.53**	–17.53**	–13.51**	–38.93**
MS 8 × PNG	7.89**	17.14**	7.89**	25.95**	51.38**	25.95**
MS 8 × PBG	28.12**	30.16**	7.89**	26.21**	36.84**	–0.76
MS 8 × Af.Sel.1	–20.00**	–16.42**	–26.32**	22.99**	32.92**	–18.32**
MS 8 × Af.Sel.4	4.44**	22.08**	23.68**	–27.59**	–25.44**	–51.91**
MS 8 × Af.Sel.5	11.76**	15.15**	0.00	47.37**	53.85**	6.87
MS 8 × Af.Sel.6	–16.28**	–4.00**	–5.26**	25.00**	31.15**	–8.40**
MS 8 × Af.Sel.8	–30.95**	–21.62**	–23.68**	–9.00	–2.67	–30.53**
MS 8 × Af.Sel.10	25.00**	29.03**	5.26**	–17.21**	–3.35	–22.90**
MS 8 × Af.Sel.11	10.00**	22.22**	15.79**	0.93	11.34**	–17.56**
MS 8 × Af.Sel.12	–23.08**	–4.76**	5.26**	47.13**	57.06**	–2.29
MS 8 × Af.Sel.14	15.62**	15.62**	–2.63	38.38**	47.31**	4.58
MS 8 × Af.Sel.16	11.43**	16.42**	2.63	–4.55	–4.00	–35.88**

* Significant at 5% level, ** significant at 1% level

Narangi Gainda (45.74) followed by MS 7 × Pusa Narangi Gainda (41.88) and MS 8 × Af.Sel.11 (36.12). Hassan *et al.* (2012) obtained highly positive significant heterosis estimates (MPH) for stem diameter in all of the hybrid combinations except one. Similarly, Raghava (1984) observed highest heterosis over mid and better parent was exploited in the China aster hybrid Crego Giant Pink × AST 16.

The branch number is the trait which is indirectly responsible for increasing the production potential of the crop since plants containing more number of primary and secondary branches provide opportunity for more yields, so positive heterosis is desirable for this trait. For number of primary branches, the range of heterosis varied from –30.95% (MS 8 × Af.Sel.8) to 43.75 % (MS 7 × Af.Sel.14) over better parent, –21.62% (MS 8 × Af.Sel.8) to 50.82% (MS 7 × Af.Sel.14) over mid parent and –26.32% (MS 8 × Af.Sel.1) to 28.95% (MS 7 × Af.Sel.12) over commercial check (Table 3). Out of 36 hybrids, 21 crosses showed significant positive better parent heterosis, 27 crosses showed significant positive mid parent heterosis and 20 crosses showed significant positive heterosis over commercial check. The highest significant positive better parent heterosis was observed in hybrid MS 7 × Af.Sel.14 (43.75) followed by MS 5 × Pusa Basanti Gainda (38.71) and MS 5 × Af.Sel.14 (34.37). The highest significant positive mid parent heterosis was observed in hybrid MS 7 × Af.Sel.14 (50.82) followed by MS 5 × Pusa Basanti Gainda (40.98) and MS 5 × Af.Sel.5 (40.63). The highest significant positive heterosis over commercial check was observed in hybrid MS 7 × Af.Sel.12 (28.95) followed by MS 8 × Af.Sel.4 (23.68), MS 5 × Af.Sel.4 (21.05) and MS 7 × Af.Sel.14 (21.05).The range of heterosis for number of secondary branches from –39.18% (MS 7 × Af.Sel.4) to 49.53% (MS 7 × Af.Sel.11) over better parent, –34.08 (MS 7 × Af.Sel.4) to 57.06 % (MS 8 × Af.Sel.12) over mid parent and -54.96 (MS 7 × Af.Sel.4) to 31.30 (MS 5 × Pusa Narangi Gainda) over commercial check (Table 3). Out of 36 hybrids, 21 crosses showed significant positive better parent heterosis, 26 crosses showed significant positive mid parent heterosis and 5 crosses showed significant positive heterosis over commercial check. The highest significant positive better parent heterosis was observed in hybrid MS 7 × Af.Sel.11 (49.53) followed by MS 8 × Af.Sel.5 (47.37) and MS 8 × Af.Sel.12 (47.13). The highest significant positive mid parent heterosis was observed in hybrid MS 8 × Af.Sel.12 (57.06) followed by MS 7 × Af.Sel.11 (56.86) and MS 5 × Pusa Narangi Gainda (54.26). The highest significant positive heterosis over commercial check was observed in hybrid MS 5 × Pusa Narangi Gainda (31.30) followed by MS 8 × Pusa Narangi Gainda (25.95) and MS 7 × Pusa Narangi Gainda (25.19). The hybrids exhibited negative to positive range in both number of primary and secondary branches, however most of the hybrids exhibited positive heterosis over better, mid and commercial check. Similar results were obtained for number of branches by Kumar *et al.* (1989) in marigold. Hassan *et al*. (2012) also reported highly positive significant heterosis estimates (MPH) in petunia for number of branches per plant in all of the hybrid combinations except for P3 × P1 and P4 × P3. Similar results were reported by Singh and Misra (2010) in marigold and Tiwari and Lal (2004) in tomato. Weerasekara *et al*. (2008) also reported good amount of average heterosis and heterobeltiosis for number of branches per plant in okra.

Hence it is concluded that heterosis can be exploited for growth related traits. Since these were the essential traits which are indirectly influencing the production potential of the crop, therefore breeding programmes can be initiated to evolve F_1 hybrids with varied growth related traits.

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