

Original Research Article

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Exploitation of Commercial Heterosis for Economic Traits in China Aster [*Callistephus chinensis* (L.) Nees.]

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ABSTRACT

Diallel set involving ten parents (without reciprocals) and forty five hybrids of China aster (*Callistephus chinensis* [L.] Nees) were evaluated to analyse for the magnitude commercial heterosis for economic traits at the Department of Floriculture and Landscape Architecture, College of Horticulture, Mudigere. Appreciable heterosis was observed for all the characters and the performance of F₁ hybrids was better than top parent. The overall maximum positive significant heterosis for yield in terms of number of flowers per plant was observed in Local Pink × Local White (18.27), Local Violet × AAC-1 (15.28) for cut flowers, weight of flowers per plant PG Violet × Arka Poornima for loose flower overcommercial heterosis. Negatively heterotic crosses like Local Pink × Local Violet (-14.69), for days to 50% flowering are important to exploit heterosis for earliness in China aster. The F₁ hybrids Local Violet x AAC-1, Local Pink × Local White and PG Violet × Arka Poornima with high yield potential has the potential for commercial cultivation after further evaluation

Keywords

Commercial heterosis, Economic traits, China aster, Quality, Yield

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Introduction

China aster [*Callistephus chinensis* (L.) Nees.] is one of the most important commercial flower crops belonging to the family Asteraceae. The genus *Callistephus* is derived from two Greek words ‘*Kalistos*’

meaning ‘most beautiful’ and ‘*Stephus*’ ‘a crown’ is referring to the flower head (Bailey 1963). The present day asters have been developed from a single form of wild species known as *Callistephus chinensis*. In India, it is grown traditionally for its loose flowers, cut flowers, arranging in vase, floral decorations,

making garlands and *veni* and it is largely grown on commercial scale in states like Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra and West Bengal. It ranks third next to chrysanthemum and marigold among the traditional flowers. In Karnataka, grown in an area of 1693 ha with a productivity of 9.39 t/ha (Anan. 2016) mainly in the districts Bengaluru, Chitradurga, Tumkur, Belagavi, Gadag, Bagalkot and Kolar districts (Ramya *et al.*, 2019).

North (1979) and Watts (1980) grouped China aster under self-pollinated crop, the genus *Callistephus* consists of a single species, *chinensis* with diploid chromosome number of $2n=18$. Floral biology of China aster flower consists of both pistillate ray and perfect disc florets, protoandry is seen in perfect flowers and as whole flower the condition is protogyny as ray flowers open first, maturity stigma and stamen at different time hence geitonogamous condition Strube (1965). Stigma receptivity will be between 11.00 hrs to 13.00 hrs and 10 per cent out crossing is seen. Hybrids in China aster is need of an hour for various quantitative traits like uniform flowering, plant height with erect branching, early flowering, higher yield in terms of number of flowers per plant, weight of individual as well as per plant basis and quality as more stalk length, shelf and vase life to exploit hybrid vigour was first attempted by SS Negi and SPS Raghava 1984-85 at ICAR-IIHR, Bengaluru. High yielding genotype may or may not transfer the superiority indicating amount of heterosis is not predictable to offspring's so selection of promising parent and diallel crossing techniques is one of the most common biometrical procedures to study the combining ability and assess heterosis.

Materials and Methods

The present study was conducted at research block of Floriculture and Landscape

Architecture, College of Horticulture, Mudigere during 2016-19. The experimental site was geographically located at $13^{\circ}7'$ North latitude, $75^{\circ}57'$ East longitude and is situated at an altitude of 982 m above the Mean Sea Level. A total of 45 China aster F_1 hybrids were developed through diallelemating design (without reciprocals) among ten parents *viz.*, Arka Kamini, Arka Aadya, Arka Archana, Local Pink, Local Violet, Local White, AAC-1, PG Purple, PG Violet and Arka Poornima were used for crossing. Forty five F_1 hybrids, along with the parents were evaluated using RCBD with two replications along with check Arka Kamini. Thirty two plants per genotype/hybrid per replication were planted at a spacing of 30cm x 30 cm under open field conditions. Five plants per replication were selected for recording observations. Uniform cultural practices were followed to raise the successful crop. The observations were recorded for quantitative and qualitative traits.

Statistical analysis

Data recorded were as per Griffing (1956) model II and was analyzed by using statistical package 'SAS VT.3' available at Statistical Laboratory of ICAR-IIHR, Bengaluru.

Results and Discussion

The present investigation revealed that mean values of crosses were in higher magnitude than that of parents (Table 1) for plant height (56.10cm), Plant spread East-West (45.90cm), number of primary branches (12.32), number of florets per flower head (124.57), flower head diameter (5.08g), flower stalk length (17.37cm), vase life (10.01), number of flowers per plant (55.59), number of flowers per branch (11.99), individual flower weight (3.14g), weight of flowers per plant (156.32g) and seed yield per plant (8.07). On the other hand the mean values were lower than the crosses for plant spread North-South (42.99), days to 50% flowering (65.76), flowering

duration (33.26), disc diameter (1.33cm) and shelf life (3.16 days).

Commercial heterosis over Arka Kamini was estimated for growth, flowering, quality and yield contributing traits among 45 hybrids of China aster and results are found significant among all traits (Table 2, 3 and 4).

Present heterosis investigation, it is evident that none of the 45 F₁ hybrids of China aster showed consistency in direction and degree of heterosis over three bases for all the characters studied. Some of them manifested positive heterosis while others exhibited negative heterosis, mainly due to varying extent of genetic diversity among parents of different cross combinations for the yield attributing traits. Significant heterosis was observed for all the growth, earliness and yield attributes. It is inferred that the magnitude of economic heterosis was higher for most of the growth and earliness characters under study. Kulkarni *et al.*, (2015), Kumari *et al.*, (2018) and Bhargav *et al.*, (2019b) also reported such a variation in heterosis for different characters and manifestation of negative heterosis observed in some of the crosses for different traits may be due to the combination of the unfavourable genes of the parents.

Plant height, plant spread and number of primary branches are the important vegetative traits, plants with higher plant height with erect branches and more number of primary branches can accommodate more flowers and are ideal as cut flower, while dwarf ones for potted plant and spreading branches are ideal for landscape and loose flower with higher yield. Hence, positive direction of heterosis is desirable for these traits and appreciable amount of positive significant commercial heterosis is observed plant height (up to 72.51%) (Table 2), plant spread NS (up to 90.75%), plant spread EW (up to 93.08%) and

number of primary branches per plant (up to 45.97%) direction.

Days to 50 % flowering and flowering duration are traits directly get profit to the farmers by catching early market, the F₁ hybrids which bloom early with least days to 50 % flowering and the F₁ hybrids with longer flower duration bear the flowers for longer period. Hence they are also suitable for flower commercial production and landscape use, the heterosis in negative direction is desirable which indicates earliness. All 45 hybrids exhibited negative significant heterosis over Arka Kamini for days to 50% flowering, the crosses Local Pink × Local Violet Local Pink × Local White and Arka Kamini × PG Violet noticed -14.69, -13.29 and -11.19% (Table 2) significant negative heterosis over commercial check Arka Kamini. Similarly flowering duration in positive direction is desirable and nine crosses exhibited superior positive significant commercial heterosis over check Arka Kamini, the crosses PG Violet × Arka Poornima (17.19), Arka Kamini × Local Violet (15.63) and Local Violet × AAC-1 and Arka Archana × AAC-1 (each 14.06). Exploitation of earliness in China aster is important step in improvement of China aster, commercial heterosis for days to flower was estimated over early flowering parent earlier by Raghava *et al.*, (1988), Kulkarni *et al.*, (2015) and Kumari *et al.*, (2018) in China aster and negative heterobeltosis for earliness by Bhargav *et al.*, (2019b) in China aster. Positive heterosis for flowering duration by Pavani (2014), Kulkarni *et al.*, (2015) superior heterosis for duration of flowering Kumari *et al.*, (2018) in China aster.

The quality of the China aster enhanced by flower head diameter, disc diameter, flower stalk length, vase life and shelf life.

Table.1 Range, mean of parents, crosses and range of standard heterosis in China aster

| Characters | Parents | | Crosses | | Check mean | Range of standard heterosis (%) | No. of crosses in positive direction |
|-----------------------------------|---------------|--------|---------------|--------|------------|---------------------------------|--------------------------------------|
| | Range | Mean | Range | Mean | | | |
| Plant height (cm) | 41.00-63.10 | 53.92 | 37.20-97.90 | 56.10 | 56.50 | -34.45-72.51 | 14 |
| Plant spread North-South (cm) | 24.90-69.30 | 44.14 | 24.60-66.00 | 42.99 | 34.60 | -28.90-90.75 | 27 |
| Plant spread East-West (cm) | 26.50-60.60 | 42.65 | 24.10-69.80 | 45.90 | 36.15 | -33.33-93.08 | 33 |
| Number of primary branches /plant | 6.90-13.90 | 11.06 | 6.35-18.10 | 12.32 | 12.40 | -48.79-45.97 | 5 |
| Days to 50 % flowering | 79.90-59.00 | 67.99 | 73.50-61.00 | 65.76 | 71.50 | -4.20- (-14.69) | 27 |
| Number of florets/flower head | 84.40-143.40 | 112.44 | 82.20-169.10 | 124.57 | 92.90 | -11.52-82.20 | 40 |
| Flowering duration | 27.00-40.50 | 34.10 | 28.50-37.50 | 33.26 | 32.00 | -10.594-17.19 | 9 |
| Flower head diameter (cm) | 4.40-5.64 | 5.07 | 4.08-6.29 | 5.08 | 5.05 | -19.21-24.55 | 8 |
| Disc diameter (cm) | 1.08-1.50 | 1.33 | 2.62-2.07 | 0.95 | 1.28 | -48.44-61.72 | 3 |
| Flower stalk length (cm) | 7.70-19.40 | 14.81 | 11.80-32.50 | 17.37 | 17.50 | -36.00-95.43 | 6 |
| Vase life (days) | 5.90-10.30 | 8.37 | 8.00-11.90 | 10.01 | 8.00 | -15-63-48.75 | 34 |
| Shelf life (days) | 2.30-3.90 | 3.16 | 2.10-3.95 | 2.97 | 3.05 | -31.15-29.51 | 4 |
| Number of flowers/plants | 42.00-55.60 | 51.36 | 47.30-71.20 | 55.59 | 55.50 | -22.92-28.29 | 12 |
| Number of flowers/branches | 6.30-12.60 | 8.62 | 6.50-16.90 | 11.99 | 8.40 | -22.62-98.81 | 41 |
| Individual flower weight (g) | 2.02-4.55 | 2.87 | 2.31-4.45 | 3.14 | 3.05 | -24.92-45.90 | 11 |
| Weight of 100 flowers (g) | 227.56-400.00 | 284.51 | 273.50-508.00 | 313.63 | 270.05 | -20.20-88.11 | 11 |
| Weight of flowers/plant (g) | 123.55-235.15 | 155.85 | 114.00-328.50 | 156.32 | 148.50 | -18.86-121.21 | 16 |
| Seed yield/plant (g) | 3.87-8.85 | 6.60 | 6.75-10.75 | 8.07 | 7.75 | -12.90-38.71 | 13 |

Table.3 Estimates of standard heterosis (%) over commercial check Arka Kamini for flowering traits in China aster

| Sl. No. | Crosses | Plant height (cm) | Plant spread (cm) | | No. of primary branches/plant | Days to 50% flowering | No. of florets/flower head |
|---------|------------------------------|-------------------|-------------------|-------------|-------------------------------|-----------------------|----------------------------|
| | | | NS | EW | | | |
| 1 | Arka Kamini × Arka Aadya | 4.67 | 31.50* | 31.40* | 30.65* | -6.99* | 15.23* |
| 2 | Arka Kamini × Arka Archana | -18.94* | 20.23* | 23.10* | 16.13 | -9.09* | 17.55* |
| 3 | Arka Kamini × Local Pink | -24.58* | 5.20 | 3.46 | -32.26* | -6.99* | -7.53 |
| 4 | Arka Kamini × Local Violet | -25.99* | 10.12 | -13.97 | -23.39 | -6.29* | 48.33* |
| 5 | Arka Kamini × Local White | 1.15 | 71.97* | 47.72* | 11.69 | -1.40 | 37.14* |
| 6 | Arka Kamini × AAC-1 | 4.67 | 27.46* | 28.35* | 5.65 | -4.90* | 2.37 |
| 7 | Arka Kamini × PG Purple | 13.48* | 32.95* | 41.36* | 2.42 | -3.50 | 41.98* |
| 8 | Arka Kamini × PG Violet | 6.61 | 68.21* | 57.68* | 12.10 | -11.19* | 41.98* |
| 9 | Arka Kamini × Arka Poornima | -22.11* | 34.68* | 37.34* | -9.68 | 2.80 | 42.52* |
| 10 | Arka Aadya × Arka Archana | 31.28* | 10.69 | 11.48 | 45.97* | -2.10 | 47.26* |
| 11 | Arka Aadya × Local Pink | -34.45* | -13.29 | -6.74* | 23.39 | 1.40 | 38.21* |
| 12 | Arka Aadya × Local Violet | -26.70* | 48.84* | 42.74* | 8.06 | -4.20* | 35.52* |
| 13 | Arka Aadya × Local White | -32.86* | 18.50* | 24.48* | 29.84* | -5.59* | 19.38* |
| 14 | Arka Aadya × AAC-1 | -24.93* | 7.23 | 22.54* | 10.48 | -4.90* | -0.86 |
| 15 | Arka Aadya × PG Purple | -26.43* | 9.25 | 6.50 | 18.55 | -3.50 | 35.52* |
| 16 | Arka Aadya × PG Violet | 11.19* | 9.25 | 17.57* | -8.06 | -5.59* | 44.46* |
| 17 | Arka Aadya × Arka Poornima | 2.91 | 32.66* | 39.42* | 6.45 | -6.99* | 49.41* |
| 18 | Arka Archana × Local Pink | -14.36* | -2.02 | -0.41 | -29.84* | -0.70 | 34.88* |
| 19 | Arka Archana × Local Violet | -0.97 | 36.85* | 43.85* | -13.71 | -2.80 | 33.26* |
| 20 | Arka Archana × Local White | -3.35 | 9.25 | 12.86 | 29.84* | -7.69* | 33.58* |
| 21 | Arka Archana × AAC-1 | -27.58* | 17.34* | 17.01* | 0.81 | -7.69* | 29.92* |
| 22 | Arka Archana × PG Purple | -30.75* | 22.25* | 20.06* | -2.42 | -6.99* | 37.46* |
| 23 | Arka Archana × PG Violet | -6.78 | 22.25* | 34.44* | -2.42 | -1.40 | 43.60* |
| 24 | Arka Archana × Arka Poornima | -19.65* | 29.19* | 37.21* | 16.94 | -4.90* | 42.95* |
| 25 | Local Pink × Local Violet | -5.55 | 27.75* | 22.82* | 3.23 | -14.69* | -11.50* |
| 26 | Local Pink × Local White | 5.02 | 38.15* | 58.23* | 25.81 | -13.29* | 30.46* |
| 27 | Local Pink × AAC-1 | -14.19* | 11.56 | 10.10 | -4.84 | -9.79* | -3.12 |
| 28 | Local Pink × PG Purple | -1.50 | 62.14* | 58.23* | -12.10 | 2.80 | 24.87* |
| 29 | Local Pink × PG Violet | 15.59* | 53.76* | 57.68* | -17.74 | -3.50 | 73.74* |
| 30 | Local Pink × Arka Poornima | 9.07* | 7.23 | -1.80 | 4.84 | -9.79* | 82.02* |
| 31 | Local Violet × Local White | -3.96 | -2.02 | -2.63 | -3.23 | -2.80 | 82.02* |
| 32 | Local Violet × AAC-1 | 12.07* | -16.62* | -33.33* | 16.94 | -13.99* | 15.93* |
| 33 | Local Violet × PG Purple | 9.87* | -2.02 | -15.63 | -19.35 | -10.49* | 16.68* |
| 34 | Local Violet × PG Violet | -19.56* | -16.62* | 59.06* | 2.02 | -2.10 | 27.02* |
| 35 | Local Violet × Arka Poornima | 3.61 | -11.71 | -28.35* | -27.42* | -4.90* | 25.62* |
| 36 | Local White × AAC-1 | 21.06* | 71.97* | -8.99 | 2.42 | -0.70 | 48.98* |
| 37 | Local White × PG Purple | 17.71* | -28.90* | 36.38* | -11.29 | -4.90* | 24.43* |
| 38 | Local White × PG Violet | 16.30* | 0.29 | 66.11* | -12.90 | -7.69* | 49.62* |
| 39 | Local White × Arka Poornima | 36.74* | 29.19* | 37.48* | -48.79* | -4.20* | 21.42* |
| 40 | AAC-1 × PG Purple | 72.51* | 75.43* | 13.69 | -26.21* | -3.50 | 49.19* |
| 41 | AAC-1 × PG Violet | 71.54* | 42.77* | 71.51* | -16.94 | -2.80 | 52.10* |
| 42 | AAC-1 × Arka Poornima | 9.87* | 22.83* | 26.14* | -1.61 | -2.80 | 25.73* |
| 43 | PG Purple × PG Violet | -19.56* | 53.03* | 78.70* | -20.97 | -0.70 | 48.33* |
| 44 | PG Purple × Arka Poornima | 3.61 | 22.25* | 46.61* | -9.68 | -4.20* | 44.13* |
| 45 | PG Violet × Arka Poornima | 21.06* | 90.75* | 93.08* | 1.61 | -9.79* | 42.41* |
| | Check-Arka Kamini | 56.50 | 34.60 | 36.15 | 12.40 | 71.50 | 92.90 |
| | S.Em± | 2.49 | 2.7 | 2.96 | 1.60 | 1.44 | 3.71 |
| | CD@5% | 5.00 | 5.44 | 5.97 | 3.23 | 2.90 | 7.48 |

* - Significant at 5% level

Table.3 Estimates of standard heterosis (%) over commercial check Arka Kamini for Flowering traits in China aster

| Sl. No. | Crosses | Flowering duration (days) | Flower head diameter (cm) | Disc diameter (cm) | Flower stalk length (cm) | Vase life (days) | Shelf life (days) |
|---------|------------------------------|---------------------------|---------------------------|--------------------|--------------------------|------------------|-------------------|
| 1 | Arka Kamini × Arka Aadya | 12.50* | -5.54 | -30.47* | -16.57* | 46.25* | -3.28 |
| 2 | Arka Kamini × Arka Archana | -10.94 | 6.14 | -27.34* | -6.29 | 48.75* | 0.00 |
| 3 | Arka Kamini × Local Pink | -9.38 | -0.99 | -38.28* | -25.71* | 31.25 * | 1.64 |
| 4 | Arka Kamini × Local Violet | 15.63* | -5.15 | -35.16* | -24.57* | 37.50 * | -3.28 |
| 5 | Arka Kamini × Local White | -1.56 | -2.18 | -40.63* | 1086 | 18.75 * | 11.48 |
| 6 | Arka Kamini × AAC-1 | -6.25 | 4.95 | -35.94* | -36.00* | 47.50* | 13.11 |
| 7 | Arka Kamini × PG Purple | 15.63* | 17.82* | 0.78 | 95.43* | 34.38* | -9.84 |
| 8 | Arka Kamini × PG Violet | 15.63* | -6.93 | -42.97* | 0.57 | 34.38 * | -6.56 |
| 9 | Arka Kamini × Arka Poornima | 1.56 | -14.46* | -48.44* | -30.29* | 40.63* | -16.39 |
| 10 | Arka Aadya × Arka Archana | 0.00 | 9.11* | 61.72* | 13.14 | 40.63* | -3.28 |
| 11 | Arka Aadya × Local Pink | -9.38 | 3.37 | -32.81* | 11.43 | 34.38* | 11.48 |
| 12 | Arka Aadya × Local Violet | 0.00 | 0.59 | -27.34* | -29.14* | 31.25* | 1.64 |
| 13 | Arka Aadya × Local White | -3.13 | -4.16 | -25.78* | -27.43* | 33.75* | -14.75 |
| 14 | Arka Aadya × AAC-1 | 3.13 | 4.36 | 10.16* | -13.71 | 31.25* | 22.95* |
| 15 | Arka Aadya × PG Purple | 9.38 | -9.50* | -6.25 | -2.86 | 34.38* | -26.23* |
| 16 | Arka Aadya × PG Violet | 6.25 | 16.44* | -3.91 | -18.29* | 42.50* | 1.64 |
| 17 | Arka Aadya × Arka Poornima | 10.94 | -9.50* | -35.94* | -3.43 | 33.75* | 6.56 |
| 18 | Arka Archana × Local Pink | 4.69 | -1.58 | -42.97* | -19.43* | 6.25 | -14.75 |
| 19 | Arka Archana × Local Violet | 0.00 | -12.08* | -47.66* | -24.57* | 27.50* | -3.28 |
| 20 | Arka Archana × Local White | 9.38 | -14.06* | -51.56* | -32.57* | 17.50* | -16.39 |
| 21 | Arka Archana × AAC-1 | 14.06* | -5.54 | -39.84* | 13.71 | 34.38* | 9.84 |
| 22 | Arka Archana × PG Purple | 6.25 | -5.35 | -36.72* | -15.66 | 18.75* | -31.15* |
| 23 | Arka Archana × PG Violet | -1.56 | 20.00* | -35.94* | 5.71 | 31.25* | -13.11 |
| 24 | Arka Archana × Arka Poornima | 4.69 | 6.34 | -20.31* | -13.71 | 31.25* | -1.64 |
| 25 | Local Pink × Local Violet | -10.94 | 0.59 | -29.69* | -18.86* | 6.25 | -13.11 |
| 26 | Local Pink × Local White | 12.50* | -1.58 | -33.59* | 2.86 | 30.00* | 18.03 |
| 27 | Local Pink × AAC-1 | 4.69 | 2.77 | -37.50* | -13.71 | 18.75* | -21.31* |
| 28 | Local Pink × PG Purple | 3.13 | -5.15 | -21.88* | -11.43 | 21.88* | -14.75 |
| 29 | Local Pink × PG Violet | 1.56 | -5.74 | -22.66* | 13.71 | 18.75* | 22.95* |
| 30 | Local Pink × Arka Poornima | 0.00 | -6.73 | -40.63* | 19.43* | 23.75* | 19.67 |
| 31 | Local Violet × Local White | 1.56 | -7.72* | 6.25 | -22.29* | 12.50 | 1.64 |
| 32 | Local Violet × AAC-1 | 14.06* | 2.18 | -38.28* | 34.29* | 15.63* | 29.51* |
| 33 | Local Violet × PG Purple | 4.69 | 6.53 | -39.06* | -15.43 | 6.25 | -6.56 |
| 34 | Local Violet × PG Violet | -3.13 | 1.19 | -25.00* | 8.57 | 6.25 | -18.03 |
| 35 | Local Violet × Arka Poornima | -3.13 | -19.21* | -34.38* | -19.43* | 6.25 | -13.00 |
| 36 | Local White × AAC-1 | 6.25 | 4.16 | -35.16* | -7.43 | 12.50 | -1.64 |
| 37 | Local White × PG Purple | 14.06* | -4.75 | -40.63* | 10.00 | 6.25 | -4.92 |
| 38 | Local White × PG Violet | -3.13 | -0.40 | -11.72* | 14.86 | 6.25 | -3.28 |
| 39 | Local White × Arka Poornima | 12.50* | 24.55* | -10.94* | -12.00 | 6.25 | -18.03 |
| 40 | AAC-1 × PG Purple | 3.13 | 1.78 | -35.16* | 6.29 | 18.75* | 9.84 |
| 41 | AAC-1 × PG Violet | 10.94 | 4.16 | -45.31* | -8.57 | 18.75* | 3.28 |
| 42 | AAC-1 × Arka Poornima | 4.69 | 7.33* | 9.38* | -22.86* | 0.00 | -19.67 |
| 43 | PG Purple × PG Violet | 1.56 | 4.95 | -6.25 | 33.71* | 34.38 * | -14.75 |
| 44 | PG Purple × Arka Poornima | -1.56 | 12.08* | 0.00 | 78.86* | 40.63* | -1.64 |
| 45 | PG Violet × Arka Poornima | 17.19* | 21.78* | -5.47 | 85.71* | 34.38 * | 22.95* |
| | Check-Arka Kamini | 32.00 | 5.05 | 1.28 | 17.50 | 8.00 | 3.05 |
| | S.Em± | 1.97 | 0.17 | 0.05 | 1.38 | 0.57 | 0.30 |
| | CD@5% | 3.98 | 0.35 | 0.10 | 2.79 | 1.16 | 0.61 |

* - Significant at 5% level

Table.4 Estimates of standard heterosis (%) over commercial check Arka Kamini for yield traits in China aster

| Sl. No. | Crosses | Number of flowers/ plant | Number of flowers/ branch | Individual flower weight (g) | Weight of 100 flowers (g) | Flowers weight / plant (g) | Seed yield (g) |
|---------|------------------------------|--------------------------|---------------------------|------------------------------|---------------------------|----------------------------|----------------|
| 1 | Arka Kamini × Arka Aadya | 7.48* | 98.81* | -1.97 | 5.72 | -7.41* | 9.68 |
| 2 | Arka Kamini × Arka Archana | 7.48* | 89.29* | -1.64 | 12.57 | -1.68 | 12.90* |
| 3 | Arka Kamini × Local Pink | -3.82 | 5.95 | -12.79* | 1.46 | -23.2 * | 1.29 |
| 4 | Arka Kamini × Local Violet | -14.62* | 25.00* | -0.33 | 10.35 | -10.77* | 1.94 |
| 5 | Arka Kamini × Local White | 4.82 | 73.81* | 0.66 | 16.83 | -8.08* | 1.94 |
| 6 | Arka Kamini × AAC-1 | -21.43* | 73.81* | -5.25 | 2.76 | -6.40 | 13.55* |
| 7 | Arka Kamini × PG Purple | -17.11* | 69.05* | 12.46* | 16.09 | 7.07* | 12.26* |
| 8 | Arka Kamini × PG Violet | -22.92* | 80.95* | 10.49* | 22.38* | -28.96* | 6.45 |
| 9 | Arka Kamini × Arka Poornima | -4.98 | 39.29* | -4.59 | 5.91 | -18.86* | 0.00 |
| 10 | Arka Aadya × Arka Archana | -20.27* | 97.62* | 33.77* | 49.79* | -5.05 | -12.90* |
| 11 | Arka Aadya × Local Pink | -16.11* | 88.10* | 15.74* | 22.94* | 4.04 | 25.81* |
| 12 | Arka Aadya × Local Violet | -19.93* | 59.52* | 7.87 | 10.54 | -6.40 | 38.71* |
| 13 | Arka Aadya × Local White | -16.45* | 107.14* | 9.18* | 19.98 | -3.37 | 25.81* |
| 14 | Arka Aadya × AAC-1 | -13.29* | 72.62* | -4.26 | 8.87 | 3.70 | -6.45 |
| 15 | Arka Aadya × PG Purple | -21.26* | 80.95* | -0.66 | 9.79 | -7.07 * | 12.90* |
| 16 | Arka Aadya × PG Violet | -1.66 | 41.67* | -2.95 | 6.65 | 16.50* | 0.00 |
| 17 | Arka Aadya × Arka Poornima | -11.79* | 69.05* | -4.26 | 3.31 | 9.43* | 0.00 |
| 18 | Arka Archana × Local Pink | -12.13* | 15.48* | -24.92* | -14.28 | -13.47* | 0.00 |
| 19 | Arka Archana × Local Violet | 0.00 | 39.29* | 0.33 | 9.24 | -16.50* | 0.00 |
| 20 | Arka Archana × Local White | 0.66 | 91.67* | 4.26 | 17.20 | 20.54* | 12.90* |
| 21 | Arka Archana × AAC-1 | 12.46* | 54.76* | -11.80* | 7.94 | 21.21* | 12.90* |
| 22 | Arka Archana × PG Purple | -12.29* | 55.95* | 1.31 | 5.17 | 10.44* | 6.45 |
| 23 | Arka Archana × PG Violet | -14.12* | 55.95* | 6.56 | 20.53 | 4.38 | 0.00 |
| 24 | Arka Archana × Arka Poornima | -6.48* | 72.62* | -8.20 | 1.28 | -18.18* | -6.45 |
| 25 | Local Pink × Local White | -6.98* | 66.67* | 4.92 | 16.83 | -1.35 | 6.45 |
| 26 | Local Pink × Local Violet | 18.27* | 101.19* | -1.48 | 19.98 | 18.52* | 14.19* |
| 27 | Local Pink × AAC-1 | -0.83 | 46.43* | -2.63 | 5.17 | 8.42* | 19.35* |
| 28 | Local Pink × PG Purple | -4.32 | 29.76* | -4.59 | 7.76 | -18.86* | 6.45 |
| 29 | Local Pink × PG Violet | -16.45* | 21.43* | -6.89 | 0.17 | -25.25* | -6.45 |
| 30 | Local Pink × Arka Poornima | 5.32* | 91.67* | 4.59 | 19.98 | 18.18* | -9.68 |
| 31 | Local Violet × Local White | -4.98 | 54.76* | 7.54 | 4.43 | 19.19* | 0.00 |
| 32 | Local Violet × AAC-1 | 15.28* | 84.52* | -7.87 | 21.64* | 35.02* | 12.90* |
| 33 | Local Violet × PG Purple | -9.47* | 25.00* | 4.26 | -20.20 | -17.17* | -6.45 |
| 34 | Local Violet × PG Violet | -2.99 | 58.33* | -24.26* | 2.94 | -10.44* | 0.00 |
| 35 | Local Violet × Arka Poornima | -19.10* | 13.10 | -9.18* | 8.68 | -17.17* | -6.45 |
| 36 | Local White × AAC-1 | -3.99 | 51.19* | -6.89 | 14.05 | -10.77* | 0.00 |
| 37 | Local White × PG Purple | 1.50 | 30.95* | 1.31 | 24.05* | -10.44* | -12.90* |
| 38 | Local White × PG Violet | -12.96* | 28.57* | 14.10* | 30.16* | -2.69 | 0.00 |
| 39 | Local White × Arka Poornima | -11.46* | -22.62* | 16.07* | 13.87 | -20.88* | -6.45 |
| 40 | AAC-1 × PG Purple | -6.81* | 11.90 | 1.97 | 3.87 | -7.07* | 0.00 |
| 41 | AAC-1 × PG Violet | -13.29* | 35.71* | -3.28 | 88.11* | 18.86* | -6.45 |
| 42 | AAC-1 × Arka Poornima | -12.46* | 51.19* | 15.08* | 32.94* | 38.38* | 0.00 |
| 43 | PG Purple × PG Violet | -14.12* | 22.62* | 33.11* | 39.97* | 43.77* | -6.45 |
| 44 | PG Purple × Arka Poornima | -9.97* | 39.29* | 45.90* | 63.12* | 121.21* | 0.00 |
| 45 | PG Violet × Arka Poornima | 3.65 | 59.52* | 40.98* | 55.71* | 105.39* | 22.58* |
| | Check-Arka Kamini | 55.50 | 8.40 | 3.05 | 270.05 | 148.50 | 7.75 |
| | S.Em± | 1.48 | 0.58 | 0.12 | 27.80 | 5.00 | 0.37 |
| | CD@5% | 2.99 | 1.17 | 0.24 | 56.03 | 10.08 | 0.76 |

* - Significant at 5% level

Among 45 crosses 12 crosses exhibited significant positive commercial heterosis for flower head diameter and three crosses for disc diameter, the crosses Local White × Arka Poornima, PG Violet × Arka Poornima and Arka Archana × PG Violet are the crosses with highest positive significant values over check (24.55, 21.18 and 20.00 respectively) for head diameter and disc diameter Arka Aadya × Arka Archana (61.72), Arka Aadya × AAC-1 (10.16). Similarly the magnitude of commercial heterosis for flower stalk length, vase life and shelf life also desirable in positive direction, the crosses PG Violet × Arka Poornima (85.71), Local Violet × AAC-1 (34.29) with six crosses exhibited significant for flower stalk length, for vase life Arka Kamini × Arka Archana (48.75), Arka Kamini × AAC-1 (47.50), PG Violet × Arka Poornima (34.35) with 34 crosses exhibiting superior over commercial check and for shelf life Local Violet × AAC-1 (29.51), PG Violet × Arka Poornima and Arka Aadya × AAC-1 (each 22.95), Local Pink × Local Violet (18.72) with four crosses exhibiting over commercial check. China aster vase or shelf life and weight of flower increased with increase in diameter of flower and disc, as each whorl of ray or disc open every day of anthesis. Similar positive commercial heterosis was also reported for flower head diameter and disc diameter by Pavani (2014) and for flower head diameter, vase life and shelf life by Bhargav *et al.*, (2019a) and Kulkarni *et al.*, (2015) in China aster.

Magnitude of standard heterosis for yield and yield related traits such as number of flowers per plant, number of flowers per branch, individual flower weight (g), flower weight per plant (g) and seed yield per plant (g) desirable in positive direction. Among 45 crosses 12 crosses for number of flowers, 41 for number of branches, 11 individual weight and 16 crosses exhibited positive significant commercial heterosis in positive direction.

The crosses with highest significant commercial heterosis are Local Pink × Local White (18.27), Local Violet × AAC-1 (15.28), Arka Archana × AAC-1 (12.46) for number of flowers per plant, Arka Aadya × Local White (107.14), Local Pink × Local White (101.19) and Local Pink × Arka Poornima (91.67) for number of flowers per branch and PG Purple × Arka Poornima (45.90 & 121.21), PG Violet × Arka Poornima (40.98 & 105.30%), and PG Purple × PG Violet (33.11 & 93.77%) for both individual flower weight and weight of flowers per plant respectively and PG Violet × Arka Poornima (22.58%), Arka Aadya × Local Violet (38.71%), for seed yield per plant. The crosses with erect branches with higher number of flowers per plant and number of flowers per branch ideal for cut flower and individual flower weight and higher yield on weight basis are suitable for loose flowers. Kulkarni *et al.*, (2016) confirmed these findings AAC-1 × Poornima exhibited significant positive heterosis standard check for yield and its components, number of flowers per plant and yield of flowers per plant and seed yield (P.G. Purple × Poornima), Pavani (2014), weight of flowers per plant and seed yield per plant; Bhargav *et al.*, (2019a), number of flowers per plant (101.18), weight of flowers per plant (47.90) and Bhargav *et al.*, (2019b), flower yield commercial check Kumari *et al.*, (2018) in China aster.

China aster displays commercial heterosis for yield and its component traits studied. However, for each trait important differences exist among hybrids for the individual values of heterosis. Yield components should be considered to increase the yield through selections. The overall maximum positive significant heterosis for yield number of flowers per plant was observed in Local Pink × Local White (18.27), Local Violet × AAC-1 (15.28) for cut flowers, weight of flowers per plant PG Violet × Arka Poornima for loose

flower overcommercial heterosis. Negatively heterotic crosses like Local Pink × Local Violet (-14.69), for days to 50% flowering are important to exploit heterosis for earliness in China aster. The F₁ hybrids Local Violet × AAC-1, Local Pink × Local White and PG Violet × Arka Poornima with high yield potential has the potential for commercial cultivation after further evaluation for late kharif season of Karnataka.

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