HETEROSIS AND COMBINING ABILITY STUDIES IN CHINA ASTER (*Callistephus chinensis* [L.] Nees)

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HETEROSIS AND COMBINING ABILITY STUDIES IN CHINA ASTER (***Callistephus chinensis*** [L.] Nees)

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By
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CERTIFICATE

This is to certify that the thesis entitled **"***Heterosis and combining ability studies in China aster (Callistephus chinensis [L.] Nees)***"** *submitted in partial fulfillment of the requirements for the degree of* **MASTER OF SCIENCE (HORTICULTURE)** *in* **FLORICULTURE AND LANDSCAPE ARCHITECTURE** *to the University of Horticultural Sciences, Bagalkot, is a record of bonafide research work carried out by* **Ms. ANJALI KULKARNI** *under my guidance and supervision and that no part of the thesis has been submitted for the award of any other degree, diploma, associateship, fellowship or other similar titles.*

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Date: JUNE, 2015

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JUNE, 2015 **(ANJALI KULKARNI)**

Affectionately Dedicated to

My Grandpa

Lt. Laxmanrao K. Nadiger

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1. INTRODUCTION

China aster (*Callistephus chinensis* Nees) is a half hardy annual and commercial flower crop belonging to the family Asteraceae. It is an important annual flower crop of our country and grown throughout the world. The crop is native to China and spread to European countries and other tropical countries during 1731 AD (Desai, 1967). The genus *Callistephus* is derived from two Greek words *Kalistos* meaning ‘most beautiful’ and *Stephos* ‘a crown’ referring to the flower head.

The present day China aster has been developed from a single wild species *Callistephus chinensis.* The evolution of China aster was a history of remarkable variation. According to Emsweller *et al.* (1937), the original plant had single flower with two to four rows of blue, violet or white ray florets. The first change in the flower type had been the prolongation or development of central florets and the production of quilled flowers. Germans developed double forms during 18^{th} century. Hence, the asters are also referred as German aster. This was because of the advancement of the aster evolution and large scale seed production by Germans. Introduction of branching types, including tall, medium tall and dwarf types made the great evolution improvement in aster. Branching types were introduced in USA, which was main center of development of this plant as well as for the production of seeds.

Natural crossing is approximately 10 per cent as reported by Fleming (1937). Strube (1965) described floral biology of China aster. Flower head consists of both pistillate ray florets and perfect disc florets. The proportion of ray florets and disc florets is a measure of doubleness of the flower. North (1979) and Watts (1980) grouped China aster under self-pollinated crops.

It is one of the important cut flower grown in Maharashtra, while this is very popular as a cut and loose flower in Mumbai, Pune and Nashik market. In Karnataka, it is widely grown around Bengaluru, Chitradurga and Kolar districts. It is also cultivated in Tamil Nadu and West Bengal. The statistics on exact area and production of the crop in India are not available. It is estimated to be grown in about 400 ha in Puna alone. In Karnataka, it is cultivated in an area of 2083 hectare with the production of 1920 mt and productivity of 9.18 t/ha (Anon. 2010). It is grown successfully in open condition for year round production in *kharif, rabi* and summer seasons to have continuous supply of flower to the market. The flower have long vase life and are used for various purposes. It is used for the preparation of garlands, in bouquets as fillers, flower arrangements, in flower shows and exhibitions. It is popular as bedding plant and also used in herbaceous borders in gardens. It is grown as a potted plant and its dwarf cultivars are suitable for edges.

Considering the importance of this crop, there is a prime need for its improvement through breeding as the existing commercial cultivars in India have either single or semi-double flowers showing prominent disc and have short flower stalks. An understanding of the genetics of various characters is a basic requirement for the efficient utilization of genetic variability. Like other crops in China aster also, most of the economic traits are governed by polygenes for which the conventional Mendelian analysis is inadequate. Many biometrical methods have been developed to obtain genetic information about such characters. Among the various methods, diallel analysis is used widely in different crops. The diallel analysis furnishes useful information on the study of the genetic mechanism of the inheritance of quantitative characters, particularly in respect of gene action and combining ability. Full diallel design in all possible mating among the selected parents are made in both directions *i.e.,* direct and reciprocals. In full diallel, each parent is used as male and female for each mating. This information is helpful to a breeder in selecting the parents for hybridization and in formulating appropriate breeding procedure to be adopted for achieving the desired objectives in the improvement of a crop.

In addition to quantitative characters, studies on qualitative characters are also important for improvement of a crop, especially in an ornamental crop. Reports on the inheritance of qualitative characters in China aster are scanty although, it is a commercially important crop.

Keeping the above points in view, the present investigation on “Heterosis and combining ability in China aster” was undertaken by using diallel crossing (with reciprocal) techniques with the following objectives:

1. To estimate the magnitude and direction of heterosis for growth, yield and quality parameters in China aster.

2. To identify good general combiners among parents for growth, yield and quality parameters.

3. To identify good specific and reciprocal combiner among the crosses for growth, yield and quality parameters.

2. REVIEW OF LITERATURE

The study on combining ability and heterosis breeding carried out in China aster is meager. Hence the work carried out in other ornamental crops is also reviewed and presented hereunder.

2.1 Combining ability

The knowledge of combining ability first proposed by Spargue and Tatum (1942) in corn. It is useful in selection of parents, which can produce superior hybrids. It is also useful in measuring hybrid performance and genetic architecture of metric traits of parents. They coined two terms; General combining ability (GCA) and specific combining ability (SCA). The general combining ability is the deviation of the mean performance of all the crosses involving a parents from overall mean. Specific combining ability was defined as the deviation in the performance of the specific cross from the performance expected on the basis of general combining ability effects of parents involved in the cross. They also confirmed that the GCA was largely the result of additive gene action, while the SCA was the result of the dominance, epistatis and genotype environment interactions. The most commonly used design are diallel and line x tester.

Review pertaining to combining ability on various qualitative and quantitative parameters in China aster and related crops are presented below.

2.1.1 Plant height (cm)

Highly significant GCA variance than SCA variance in China aster has been reported for plant height by Raghava (1984) and Patil and Rane (1994b). Raghava and Negi (1993) also reported variance component due to specific combining ability was greater than that of general combining ability which showed predominant role of non-additive gene action.

Singh and Swarup (1971), reported higher component of variance for SCA (9862.93) than those of GCA (1848.27) in balsam.

Higher components of variance for SCA than that of GCA was recorded in marigold by Nagabhusanam *et al.* (1989). Suresh kumar *et al.* (2004) observed predominance of GCA variance was reported for this character and the SCA component of variance was higher than that of GCA variance of component in China aster.

Hemanth kumar *et al.* (2008) for gladiolus, Singh and Mishra (2010) for marigold, Bayat *et al.* (2012) for petunia and Kattera *et al.* (2014) in annual chrysanthemum reported higher SCA variance than that of GCA variance.

2.1.2 Number of leaves per plant

Higher GCA variance than SCA variance was reported by Hemanth kumar *et al.* (2008) in gladiolus and Singh and Mishra (2010) in marigold.

2.1.3 Stem girth (cm)

De Leo and Ottaviano (1978) and Raghava (1984) observed higher GCA variance than SCA variance for this trait in gerbera and China aster respectively.

Hemanth kumar *et al.* (2008) for gladiolus, Singh and Mishra (2010) for marigold and Kattera *et al.* (2014) for annual chrysanthemum also observed same results with higher amount of variance in for GCA than SCA.

2.1.4 Plant spread (cm^2)

Higher GCA variance than SCA variance was reported by Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994b) in China aster and Singh and Mishra (2010) in marigold. The component of variance due to specific combining ability was higher than the component of general combining ability variance.

2.1.5 Leaf area per plant (cm^2)

Singh and Mishra (2010) and Kattera *et al.* (2014) observed higher GCA variance than SCA variance for this trait in marigold and annual chrysanthemum respectively.

2.1.6 Number of branches per plant

Predominance of GCA variance was reported for this character and the SCA component of variance was higher than that of GCA variance of component in China aster by Raghava (1984), Raghava and Negi (1993) and Patil and Rane (1994b).

In a 5 x 5 diallel in balsam, Swarup *et al.* (1975) reported higher component of variance for SCA than that of GCA variance. Singh and Mishra (2010) and Nagabhusanam *et al.* (1989) for marigold, Suresh Kumar *et al.* (2003) for China aster and Kattera *et al.* (2014) for annual chrysanthemum observed higher GCA variance than SCA variance for this trait.

2.1.7 Days for first flower bud initiation

Anita *et al.* (2003a) and Suresh kumar *et al.* (2004a) studied the combining ability effects in marigold and annual China aster respectively, found that the GCA variance was more than SCA variance, where as the SCA component of variance was higher than GCA variance.

Kattera *et al.* (2014) also reported similar results of higher GCA variance of 309.38 than SCA variance of 14.18 in annual chrysanthemum.

2.1.8 Days for first flowering

Predominance of GCA variance over SCA variance was found this character and the component of variance due to SCA was higher than the component of GCA variance in China aster (Raghava, 1984), Raghava and Negi (1993), Patil and Rane (1994b) and Suresh kumar *et al.* (2004a); Anita *et al.* (2003a) in marigold.

On the contrarily, Singh and Swarup (1971) in African marigold reported that, the GCA components of variance (326.94) was higher than that of SCA (114.90), inferring that predominant role of additive gene action for this character.

2.1.9 Days for fifty per cent flowering

Significant GCA and SCA variance (negative) were observed for 50 per cent of flowering in African marigold by Nagabhusanam *et al.* (1989), China aster by Suresh Kumar *et al.* (2004a) and in annual chrysanthemum by Kattera *et al.* (2014).

2.1.10 Duration of flowering

Raghava (1984) in China aster found the higher SCA component of variance over GCA component of variance indicating the predominant role of non-additive gene action in the inheritance of this character.

Raghava and Negi (1993), Patil and Rane (1994b) and Suresh kumar *et al.* (2004a) in China aster and Kattera *et al.* (2014) in annual chrysanthemum also reported similar results of higher component of variance for SCA than that of GCA.

2.1.11 Number of flowers per plant

Raghava (1984) reported that higher GCA variance than SCA variance and variance component due to SCA was higher than that of GCA.

Raghava and Negi (1993), Patil and Rane (1994b) and Suresh kumar *et al.* (2004a) in China aster, Singh and Swarup (1971), Nagabhsanam *et al.* (1989), Anita *et al.* (2003a) in marigold and Swarup *et al.* (1975) in balsam reported higher GCA variance than SCA variance. In contrary, Kattera *et al.* (2014) observed higher SCA variance than GCA variance in annual chrysanthemum.

2.1.12 Individual flower weight (g)

GCA variance was found to be greater than SCA variance for flower weight in China aster as reported by Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994b) and Suresh kumar *et al.* (2004a), Singh and Swarup (1971), Nagabhusanam *et al.* (1989), Anita *et al.* (2003a) for marigold and Sachiva (1976) and De Leo and Ottaviano (1978) in gerbera.

Kattera *et al.* (2014) observed higher SCA for the above trait and the component of variance due to SCA was higher than that of GCA.

2.1.13 Flower yield per plant (g)

Suresh kumar *et al.* (2004a) reported higher component of variance due to GCA (8665.75) than due to SCA (6487.25).

2.1.14 Flower stalk length (cm)

Raghava (1984) reported high and significant GCA variance and SCA variance for this trait. The component of variance due to SCA was higher than GCA.

Raghava and Negi (1993), Patil and Rane (1994b) and Suresh kumar *et al.* (2003) in China aster, Sachiva (1976) and De Leo and Ottaviano (1978) in gerbera and Anita *et al.* (2003a) for marigold also reported that of GCA variance was higher and significant than SCA variance.

2.1.15 Flower diameter (cm)

Higher GCA as compared to SCA variance was reported by Raghava (1984), Raghava and Negi (1993) and Suresh kumar *et al.* (2003) in China aster. The component of variance due to SCA was higher in magnitude in comparison to the component of variance due to GCA.

Results showed higher component of variance for SCA than that of GCA for this character in marigold (Singh and Swarup, 1971 and Anita *et al.* 2003a), balsam (Swarup *et al.* 1975) and in gerbera (Sachiva, 1976 and De Leo and Ottaviano, 1978).

Kattera *et al.* (2014) reported higher GCA variance (00.17) than SCA variance (00.11) in annual chrysanthemum. In contrary Bayat *et al.* (2012) reported higher GCA variance than SCA variance for this trait.

2.1.16 Vase life

Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994b) and Suresh kumar *et al.* (2004a) reported predominance of GCA variance over SCA variance and the component of variance due to SCA was found to be higher than that of GCA for vase life in China aster.

Kattera *et al.* (2014) also noticed similar effects in annual chrysanthemum. The GCA variance reported was 01.20, whereas SCA variance exhibited was 00.88.

2.1.17 Seed yield per ha

Singh and Mishra (2010) reported component of variance due to GCA was higher in magnitude in comparison to the component of variance due to SCA in marigold.

2.1.18 Seed test weight

The component of variance due to SCA was higher than the component of variance due to GCA for this trait in marigold, as reported by Singh and Mishra (2010).

2.2 Heterosis

The term heterosis refers to phenomenon in which F_1 population shows increased or decreased vigor over mid-parent (mid-parent heterosis) or better parent (heterobeltiosis) or check (economic heterosis). Heterosis is the result of action and interaction of dissimilar gametes in the heterozygotes. Hence, Shull (1908) referred this as the phenomenon of stimulus of heterozygosis and manifest effect was called “hybrid vigor”. In flower crops heterosis breeding become prominent and useful in the improvement of yield potential of self as well as cross pollinated crops like China aster, petunia, marigold etc. Hybrids offer opportunities for improvement in productivity, earliness, uniformity, wider adoptability, quality and for the rapid development of dominant genes for resistance to diseases and pests (Riggs, 1988).

The study on heterosis breeding and combining ability carried out in China aster is meager. Hence, the work carried out in other ornamental crops is also reviewed and presented hereunder.

2.2.1 Plant height (cm)

Singh and Swarup (1971) in a 7 x 7 diallel in African marigold obtained heterosis over better parent which was ranging from 0.22 to 44.13 per cent. The maximum heterobeltiosis per cent for this character was recorded by the hybrid Alaska x Local variety from Katrain (44.13%) followed by Sun Giant x Orange Puff Single (43.62%).

In a 5 x 5 diallel of balsam, Swarup *et al.* (1975) reported the heterosis range of 14.87 to 40.44 per cent over better parent. Among the crosses, the cross between Neco Mammoth x Tall Double White and Rose Flowered x Camellia Flowered showed best heterosis of 40.44 per cent and 39.95 per cent over better parent, respectively.

Heterosis range of -56.36 to 21.30 per cent was reported in a 5 x 5 diallel in petunia by Hussein and Misiha (1979).

Raghava (1984) observed heterosis range of -3.61 to 48.98 per cent over mid-parent and from -18.51 to 46.80 per cent over better parent. The crosses AST-16 x Azura Blue and Giant Branching Comet x AST-16 showed highest heterosis percentages over mid-parent and better parent in China aster, respectively.

Raghava *et al.* (1988) in 12 x 12 diallel (without reciprocals) in China aster obtained heterosis range of 2.08 to 46.80 per cent over better parent. The hybrid Giant Branching Comet x AST-16 recorded maximum heterobeltiosis per cent.

Nagbhushanam *et al.* (1989) recorded -15.46 to 36.96 per cent range of heterosis over its parents. The hybrid African Double Yellow x Spun Gold exhibited maximum per cent of heterosis (36.96%) followed by the hybrid Spun Gold x Gold Coin Yellow (25.30%) in African marigold.

The maximum heterosis in marigold over better parent was recorded in the hybrid L4 x T_1 (32.50%) followed by L7 x T_1 (20.05%) (Kumar *et al.*1989).

Significant heterosis over better parent and mid parent was observed in all the important characters of gladiolus. The maximum value of heterosis for plant height was recorded in the hybrid Friendship x Vinks Golry over mid parent (20.09 per cent) and better parent (22.45 per cent) by Pant and Lal (1992).

Patil and Rane (1994a) observed heterosis range of -50.98 to 9.81 per cent over better parent, while,-59.77 to -1.63 per cent heterosis range was recorded for top parent in China aster.

The maximum heterosis over better parent was varied from -8.9 to 31.1 per cent and -15.5 to 34.6 per cent in African marigold during winter and summer, respectively.

The highest heterobeltiosis of 31.1 per cent observed in the hybrid MS7 x Sel-14 followed by MS7 x Sel-27 (28.7%) in winter. While, the cross MS7 x Sel-14 recorded maximum of 34.6 per cent heterosis over better parent during summer (Gupta *et al.,* 2001).

In gladiolus the maximum heterosis over better parent was recorded in the cross Moss Green Lilac x Heady Wine (15.72%) with the range of heterosis varies from -3.4 to 15.72 per cent for plant height (Misra *et al.,* 2001).

Suresh kumar *et al.* (2004b) reported a heterosis range of -24.62 to 13.94 per cent and -9.03 to 19.15 per cent for better parent and mid parent respectively in China aster.

Hemanth kumar *et al.* (2008) reported heterobeltiosis range of -20.54 to 14.72 per cent in gladiolus, which was highest in the hybrid Sylvia x Priscilla (14.72 per cent) and lowest in the hybrid Sylvia x Summer Sunshine (-14.72 per cent).

2.2.2 Number of leaves per plant

Pant and Lal (1992) reported heterosis over better and mid-parent which ranged from -16.935 to 14.795 and -17.362 to 16.183 in gladiolus. The maximum heterosis was observed in the hybrid Friendship x Vink's Glory (14.795 per cent) followed by Tropic Sea x Oscar (11.286 per cent). While, minimum heterosis was observed in Apple Bloom x Tropic Sea (-16.935 per cent).

In gladiolus, heterosis over better parent was varied from -24.55 to 0.43 per cent where as the hybrid Mayur x Heady Wine showed higher per cent of heterosis over better parent (Misra *et al.,* 2001).

Suresh kumar *et al.* (2003) in China aster reported the magnitude of heterosis over mid parent varied from -8.31 per cent (P.G.Purple x P.G.Pink) to 27.09 per cent (Kamini x Violet Cushion). While, for better parent it ranged from -18.24 per cent (Kamini x Violet Cushion) to 19.46 per cent (P.G.Pink x P.G.Violet).

Heterobeltiosis for the above trait was observed by Hemanth kumar *et al.* (2008) in gladiolus and the results ranged from -13.86 to 18.91 per cent. Highest heterobeltiosis was recorded in the hybrid Melody x Magic (18.91 per cent), followed by Sylvia x Magic. Minimum heterobeltiosis was seen in Sylvia x Vedanapoli (-13.86 per cent).

2.2.3 Stem girth (cm)

Raghava (1989) reported mid-parent heterosis range of -22.39 to 72.92 per cent, while better parent heterosis ranged between -36.30 to 59.61 per cent. Among 12 x 12 diallel cross only 6 and 2 crosses exhibited positive and significant heterotic over mid and better parent in China aster.

Suresh kumar *et al.* (2003) in china aster reported maximum stem girth from the cross Kamini x Violet Cushion (17.93%) followed by Violet Cushion (15.04%).

A heterobeltiosis range of -23.93 to 13.66 per cent was reported for the above trait in gladiolus by Hemanth kumar *et al.* (2008).

2.2.4 Plant spread (cm^2)

Heterosis for plant spread ranged from -19.56 to 84.82 per cent over mid-parent and from 25.18 to 70.10 per cent over better parent. The hybrid AST-1 x Giant Branching Comet registered highest heterosis over mid as well as better parent in China aster (Raghava, 1984).

Raghava *et al.* (1988) noticed the range of heterosis from 1.90 to 70.10 per cent over better parent in China aster.

The heterosis over mid parent ranged from -39.66 per cent to 56.50 per cent, while for better parents it ranged from -49.07 to 23.47 per cent and for standard check heterosis varied from 62.85 per cent (Suresh kumar *et al.*, 2003).

2.2.5 Leaf area per plant (cm^2)

In China aster -40.68 to 31.39 per cent and from -60.39 to 11.39 per cent heterosis range was observed over better and top parent, respectively. The cross P_1x P_2 showed highly significant positive heterosis over both the parents (Patil and Rane, 1994a).

The heterosis range of -8.9 to 38.0 per cent and -6.6 to 39.5 per cent in winter and summer season respectively was observed in marigold. Among the cross MS7 x Sel-36 and MS7 x Sel-28 recorded maximum heterosis over better parent for winter and summer season, respectively (Gupta *et al.,* 2001). The magnitude of heterosis ranged from -15.94 per cent to 52.93 per cent, -32.60 per cent to 49.43 per cent and from 68.34 per cent to 248.87 per cent over MP, BP and standard check, respectively.

2.2.6 Number of branches per plant

Heterosis over better parent in balsam ranged from 18.03 to 62.52 per cent for number of branches per plant. Among the crosses, the cross Neco mammoth x Tall double white recorded maximum heterosis per cent (62.52), followed by Rose flowered x Neco mammoth (59.55%) (Swarup *et al.,* 1975).

Raghava (1984) observed the heterosis range of -10.79 to 109.89 per cent over mid-parent and the range of heterosis over better parent was from -18.86 to 106.25 per cent for the character number of primary branches per plant. The hybrid AST-8 X Shell Pink had the best heterotic effects over both mid and better parent. While, the heterosis for number of secondary branches per plant ranged from -32.40 to 116.59 per cent and -36.72 to 104.50 per cent over mid and better parent respectively. The hybrids Giant Branching Comet x Azure Blue and AST-20 x AST-16 showed the best heterotic effects over mid parent and better parent respectively in China aster.

The heterosis range varied from 0.49 to 106.25 per cent over better parent for number of primary branches and from 1.94 to 104.50 per cent for number of secondary branches per plant. Among the crosses, AST-8 x Shell pink and AST-20 x AST-16 exhibited maximum heterotic effects over better parents for number of primary and secondary branches respectively in China aster (Raghava *et al.,* 1988).

Nagabhusanam *et al.* (1989) observed the heterosis range of -21.00 to 23.20 per cent over its parent in African marigold. The hybrids African double yellow x Gold Coin Yellow showed highest per cent of heterosis (23.20%), while Giant double African Marigold x Spungold ranked second with 19.79 per cent of heterosis.

The highest percentage of heterosis over better parent for this character was exhibited by the hybrid L8 x T_2 (34.41%) followed by L8 x T_1 (31.16%). The heterosis over better parent was ranged from -42.04 to 34.41 in marigold (Kumar *et al.*, 1989).

Patil and Rane (1994a) recorded the heterosis range of -38.12 to 83.22 per cent and -50.63 to 13.39 per cent over better and top parent, respectively. The cross P_4 x P_8 showed maximum significant positive heterosis over both the parents in China aster.

Suresh kumar *et al.* (2004b) reported a heterosis range of -8.19 to 26.50 per cent and -8.37 to 17.87 per cent for mid parent and better parent, repectively for China aster.

2.2.7 Days for first flower bud initiation

Anita *et al.* (2003b) reported the heterosis range of -34 to 14 per cent and -32 to 19 per cent over mid parent and better parent respectively. The hybrid Bhubaneshwar local orange x Royal Bengal and Suttan's double orange x New tech orange showed maximum of -34.00 and -32.00 per cent heterosis over mid parent and better parent, repectively in African marigold.

Suresh Kumar *et al.* (2004b) reported an heterosis range of -14.84 to 11.37 per cent and -0.32 to 20.78 per cent for mid parent and better parent, repectively in China aster.

2.2.8 Days for first flowering

Uemoto (1964) obtained 92.5 per cent heterosis over mid-parent for early flowering in antirrhinum.

In African marigold, Singh and Swarup (1971) observed 0.82 to 11.02 per cent heterosis over better parent for early flowering. The hybrid Alaska x Sun Giant showed maximum heterobeltiosis with 0.82 per cent.

Singh and Swarup (1973) in African marigold recorded 4.00 to 12.17 per cent positive heterosis over better parent. The cross Alaska x Cupid Orange Mum exhibited maximum heterobeltiosis with 4.00 per cent delay in flowering.

Hussaein and Misiha (1979) reported that in petunia that the heterosis range of -31.41 to 13.33 per cent over better parent.

Raghava (1984) recorded negative heterosis for days taken for flowering opening with heterosis range from -14.48 to 5.83 per cent and from -14.54 to 14.36 per cent over mid parent and better parent, repectively. Azure Blue x AST-5 and Shell Pink x AST-7 showed the highest negative heterosis over mid-parent and better parent, respectively in China aster.

The positive heterosis range of 0.42 to 14.49 per cent was obtained for days to flower opening over better parent in China aster. The cross Shell Pink x AST-5 recorded 0.42 per cent positive heterobeltiosis (Raghava *et al.*, 1988).

The negative heterosis over better parent was ranged from -9.95 to 12.21 per cent for days to first flowering. The hybrid L9 x T_1 registered maximum negative heterosis over better parent in marigold (Kumar *et al.*, 1989).

Patil and Rane (1994a) reported negative range of about -38.41 to 26.48 per cent and -35.94 to 51.62 per cent over better parent and top parent, respectively. Heterosis for days to flowering was highest in cross P_3 x P_8 (-38.41%) over better parent and P_2 x P_1 (-35.91%) over top parent in China aster.

Gupta *et al.* (2001) observed -39.2 to 29.8 per cent range of negative heterosis over better parent in African marigold during winter. The hybrid MS8 x Sel-7 exhibited maximum per cent heterobeltiosis with -39.3 followed by the hybrid MS7 x Sel-19 (-34.20%), while in summer, the heterosis over better parent was varied from -40.8 to 27.0 per cent. The cross MS7 x Sel-21 and MS8 x Sel-27 was found to be earliest once with heterobeltiosis of -40.8 per cent.

In African marigold, Anita *et al.* (2003b) obtained the negative heterosis with the range of -26 to 15 and -2 to 19 per cent over mid-parent and better parent, respectively. The hybrid Bhubaneshwar Local Orange x Royal Bengal registered significant negative heterosis over both mid and top parent.

Suresh kumar *et al.* (2004b) reported a heterosis range of -13.02 to 11.55 per cent and -0.06 to 15.17 per cent for mid parent and better parent, repectively for China aster.

2.2.9 Days for fifty per cent flowering

Nagabhusanam *et al.* (1989) recorded -8.91 to 21.11 per cent negative heterosis range in African marigold. The hybrid, African Sunset Giant x Spun Gold exhibited early flowering of -8.91 per cent heterosis followed by the hybrid African sunset Giant x Gold Coin Yellow Coin (-5.05%) for 50 per cent flowering. The maximum negative heterosis was shown by the cross Kamini x P.G.Violet (-13.38%) followed by Kamini x P.G.White (-9.83%) and Kamini x P.G.Pink (-6.97%) indicating their earliness.

2.2.10 Duration of flowering

Heterosis for duration of flowering showed a range of 5.79 to 114.31 per cent over better parent in African marigold. The maximum heterosis over better parent was recorded by the hybrid Alaska x Orange puff single (114.31%) followed by Alaska x Local variety from Katrain (57.93%) (Singh and Swarup, 1971).

Raghava (1984) investigated the heterosis for duration of flowering in China aster which ranged from -23.71 to 68.10 per cent over mid parent and from -27.45 to 60.36 per cent over better parent. Hybrid AST-8 x AST-20 registered the best heterotic effects both over mid and better parents.

Raghava *et al.* (1988) observed significant desirable heterosis from 0.59 to 60.39 per cent over mid-parent in China aster.

The heterosis range of -17.17 to 13.76 per cent was registered over better parent in marigold. The cross L9 x T_3 exhibited the maximum heterosis of 13.76 per cent over the better parent (Kumar *et al.*, 1989).

Patil and Rane (1994a) obtained -42.35 to 3.08 and -28.57 to 26.98 per cent heterosis range over better and top parent, respectively in China aster.

Gupta *et al.* (2001) studied the heterosis over better parent and reported the range which varied from 0.2 to 414 per cent and 11.7 to 535.7 per cent in African marigold during winter and summer, respectively. The highest heterobeltiosis per cent was recorded by the hybrids MS7 x Sel-7 and MS8 x Sel-31 during winter and summer respectively.

Anita *et al.* (2003b) observed significant desirable heterosis over mid-parent and better parent with the range of -59 to 94 and -48 to 38 per cent, respectively in African marigold. The hybrid Early Yellow x New Tech Orange showed positive and significant heterosis over both mid-parent and better parents.

Suresh kumar *et al.* (2004b) reported a heterosis range of -9.46 to 26.37 per cent and -16.20 to 21.84 per cent for mid parent and better parent, repectively for China aster.

2.2.11 Number of flower per plant

In African marigold Singh and Swarup (1971) obtained a range of 9.56 to 327.55 per cent heterosis over better parent. The maximum heterosis over better parent was recorded by the hybrid local variety from Katrain x Cupid Orange Mum (327.55%) followed by Hawaii x Cupid Orange Mum.

Singh and Swarup (1973) recorded a range of 27.34 to 114.42 per cent heterosis over better parent in African marigold. The hybrid Sun Giant x Orange Puff recorded maximum heterobeltiosis per cent with (114.42%).

The heterosis over better parent ranged from 44.03 to 145.21 per cent in balsam. The hybrid Rose flowered x Scarlet double showed maximum heterosis per cent with 145.21 per cent followed by Rose Flowered x Camellia Flowered (138.41%) (Swarup *et al.,* 1975).

The mid-parent heterosis for number of flowers ranged from -23.01 to 138.96 per cent and the better parent heterosis ranged from -28.47 to 126.96 per cent. Positive and significant heterosis was observed for maximum number of crosses. The highest heterotic effect over better was shown by the cross AST-16 x AST-7 in China aster (Raghava, 1984).

The range of heterosis over better parent in marigold was recorded from 0.93 to 57.67 per cent. The hybrid L9 x T_1 exhibited maximum heterobeltiosis per cent with 57.67 per cent (Kumar *et al.*, 1989).

Gupta *et al.* (2001) found 13.4 to 150.4 and 30.5 to 198.4 per cent heterosis over better parent in African marigold for winter and summer season, respectively. The hybrid MS8 x Sel-7 showed maximum heterosis over better parent with 150.4 per cent followed by hybrid MS8 x Sel-7 (126.1%) for winter season. While, for summer season the hybrid MS-8 x Sel-8 showed maximum heterobeltiosis followed by MS12 x Sel-8 (171.71%).

Anita *et al.* (2003b) obtained significant desirable heterosis over mid-parent and better parent with range of -8 to 98 and -25 to 43 per cent, respectively in African marigold. Among crosses, Sutton's Double orange x Early Yellow Single and Bhubaneshwar Local Orange x Giant Orange Single showed significant positive heterosis over both mid and better parents.

Suresh kumar *et al.* (2004b) reported a heterosis range of 6.35 to 59.22 per cent and 2.09 to 42.07 per cent for mid parent and better parent, repectively for China aster.

2.2.12 Individual flower weight (g)

Singh and Swarup (1971) obtained the heterosis range of 2.03 to 171.49 per cent over better parent in African marigold. The maximum heterobeltiosis per cent was recorded by the hybrid Alaska x Hawaii (171.49%), followed by hybrid from Katrain x Orange Puff Single (152.90%).

In African marigold Singh and Swarup (1973) found a heterosis range of 3.44 to 7.12 per cent over better parent. The hybrid which exhibited maximum heterobeltiosis were Giant x Local variety from Katrain (7.12%) followed by Alaska x Cupid Orange Mum (5.84%).

Raghava (1984) reported mid-parent heterosis range of -59.43 to 89.91 per cent and better parent heterosis range of -73.42 to 60.33 per cent for flower weight in China aster. The hybrid Crego Giant Pink x AST-5 and AST-20 x AST-12 exhibited the best heterotic effects over mid-parent and better parent, respectively.

In China aster the heterosis range varied from 2.53 to 60.33 per cent over better parent for flower weight (Raghava *et al.*, 1988).

The heterosis range of -54.26 to 27.53 per cent was observed in African marigold. The highest per cent heterosis was found in the hybrid African sunset x Spun Gold (27.33%) followed by African Sunset x Coimbatore Local (24.46%) (Nagabhusanam *et al.*, 1989).

Kumar *et al.* (1989) reported that eight hybrids exhibited positive and significant heterosis over better parent in marigold, of which L2 x T_2 showed the highest (96.76%) heterosis over the better parent.

The heterosis range of -52.74 to 99.25 per cent and -69.46 to 29.67 per cent was observed over better parent and top parent, respectively in China aster. The combination of P_9 x P_2 recorded the highest magnitude of heterosis over better parent (99.25%) followed by P_4 x P_7 (63.48%) (Patil and Rane, 1994a).

Gupta *et al.* (2001) studied the heterosis over better parent in African marigold. The heterobeltiosis range varied from 48.4 to 180.0 and -1.9 to 91.1 per cent during winter and summer season, respectively. The maximum heterobeltiosis range was recorded by the hybrid viz., MS8 x Sel-7 and MS8 x Sel-31 during winter and summer season, respectively.

Anita *et al.* (2003b) recorded the significant desirable heterosis over mid-parent and better parent with -37 to 133 and -59 to 94 per cent, respectively in marigold. Among the crosses, Bhubaneshwar Local Orange x New Tech Orange and African Gold Yellow x New Tech Orange had the highest positive heterosis over mid-parent and better parent.

Suresh kumar *et al.* (2004b) reported a heterosis range of -34.51 to 6.68 per cent and -41.84 to 6.54 per cent for mid parent and better parent, repectively in China aster.

2.2.13 Flower yield per plant (g)

The heterosis range of -65.06 to 53.36 per cent was observed for this character in African marigold. The highest heterosis per cent of 53.36 was recorded for the hybrid

African Double Yellow x Sun Gold followed by African Sunset x Spun Gold (52.39%) (Nagabhusanam *et al.*, 1989).

Kumar *et al.* (1989) reported the maximum heterosis of 748.55 per cent over better parent for the hybrid L2 x T_2 in marigold.

The heterosis range over better parent varied from 36.3 to 310.2 per cent and 5.9 to 65.0 per cent in African marigold during winter and summer, respectively. The maximum heterobeltiosis of 310.2 per cent was recorded in MS8 x Sel-7 and MS8 x Sel-8 during winter. While, 65.0 per cent heterosis over better parent was noticed in hybrid MS8 x Sel-4 followed by the hybrid MS7 x Sel-14 (55%) during summer (Gupta *et al.*, 2001)

Anita *et al.* (2003b) obtained significant desirable heterosis over both mid-parent and better parent with -5 to 260 and -76 to 211 per cent, respectively in African marigold. The cross combinations *viz.,* Sutton's Double Orange x New Tech Orange and Sutton's Double Orange x Giant Orange Single showed significant heterosis over both mid and better parent.

Suresh kumar *et al.* (2004b) reported a heterosis range of -18.85 to 60.13 per cent and -34.65 to 18.73 per cent for mid parent and better parent, repectively in China aster.

2.2.14 Flower yield per hectare (t/ha)

Suresh kumar *et al.,* (2003) reported a wide range of mid parent heterosis from -18.95 per cent (Violet Cushion x P.G.Pink) to 60.25 per cent (Kamini x P.G.Violet) was observed for the trait. Better parent heterosis ranged from -34.44 to 18.83 per cent, whereas, Heterosis over standard check was highest in P.G.Pink x P.G.White (345.89%) followed by P.G.Pink x P.G.Violet (343.84%).

2.2.15 Flower stalk length (cm)

Raghava (1984) observed heterosis for flower stalk length which varied from -33.04 to 95.10 per cent over mid-parental value and from -46.37 to 83.26 per cent over better parental value. Hybrid AST-8 x Crego Giant Pink exhibited highest heterotic effects over both mid and better parental values in China aster.

Raghava *et al.* (1988) found significant desirable heterosis over better parent with the range of 1.72 to 83.26 per cent in China aster.

The heterosis range of -55 to 39.39 per cent and -65.90 to 24.63 per cent was recorded over better and top parent respectively in China aster (Patil and Rane, 1994a).

Gupta *et al.* (2001) recorded cross combinations of MS7 x Sel-19 (-18.3 to 43.90 per cent) and MS7 x Sel-29 (-17.9 to 42.9 per cent) maximum heterosis over better parent in African marigold during winter and summer seasons, respectively.

The heterosis range of -58 to 40 and -65 to 34 per cent over mid parent and better parent, respectively was observed in African marigold. The hybrid Giant Orange x Early Yellow single recorded maximum heterosis over mid and better parents (Anita *et al.*, 2003b).

Suresh kumar *et al.* (2003) reported a heterosis range of -14.50 to 11.58 per cent and -27.20 to 10.40 per cent for mid parent and better parent, repectively for China aster.

2.2.16 Flower diameter (cm)

Matous (1962) reported that, flower size (diameter) was not increased in hybrids and in most of the cases it was similar than that of better parent in *Cyclamen persicum.*

In African marigold, heterosis range of 1.32 to 79.59 per cent over better parent was reported. The hybrid Alaska x Hawaii recorded maximum heterosis over better parent followed by local variety from Katrain x Orange Puff Single (68.36%) (Singh and Swarup, 1971).

Swarup *et al.* (1975) observed a range of 22.71 to 38.86 per cent heterosis over better parent in balsam. The cross Camellia Flowered x Neco Mammoth exhibited maximum heterobeltiosis per cent followed by Rose Flowered x Camellia Flowered (38.08%).

The range of heterosis for flower size over mid parent was from -18.06 to 41.56 per cent and over better parent it was from -20.63 to 30.17 per cent. The cross AST-20 x AST-16 registered the best heterotic effects over mid-parent as well as better parents in China aster (Raghava, 1984).

In China aster, Raghava *et al.* (1988) found a heterosis range of 0.37 to 30.17 per cent over better parent for flower diameter.

Nagabhusanam *et al.* (1989) recorded the heterosis range from -27.89 to 18.90 per cent in African marigold. The highest heterosis was found in the hybrid African Double Yellow x Spun Gold followed by African Sunset x Spun Gold.

In marigold the heterosis over better parent ranged from -74.75 to 63.97 per cent. The highest heterobeltiosis was found in the hybrid L2 x T_3 (Kumar *et al.,* 1989).

In China aster the heterosis range varied from -12.50 to 21.74 per cent and -21.67 to 8.75 per cent over better parent and top parent, respectively. The cross combinations P_6 x P_4 and P_2 x P_8 exhibited maximum heterobeltiosis per cent over better and top parent, respectively (Patil and Rane, 1994a).

Gupta *et al.* (2001) recorded -3.7 to 52.7 per cent and -3.0 to 48.8 per cent heterosis over better parent in African marigold during winter and summer season, respectively. The hybrids MS8 x Sel-76 and MS7 x Sel-8 showed maximum heterobeltiosis per cent for winter and summer season, respectively.

Anita *et al.* (2003a) obtained the range of heterosis from -19 to 34 per cent and -9 to 27 per cent over mid parent and better parent, respectively in African marigold. The hybrid Bhubaneshwar Local Orange x New Tech Orange had larger flower size and showed significant positive heterosis over mid-parent and better parent.

2.2.17 Ray floret length (cm)

Suresh kumar *et al.,* (2003) reported mid parent heterosis range from -32.57 per cent to 9.15 per cent, whereas, Over standard check it varied from -10.09 per cent to 76.15 per cent.

2.2.18 Vase life

Mid parent heterosis for vase life ranged from -24.03 to 181.25 per cent and better parent heterosis varied from -38.75 to 125.0 per cent. Highest positive and significant heterosis was observed in the hybrid Shell Pink x Azure Blue in China aster (Raghava, 1984).

Raghava *et al.* (1988) studied heterosis over better parent in China aster and reported the heterobeltiosis of 1.49 to 125.0 per cent. The heterosis range varied from -17.14 to 16.13 per cent and -19.44 to 8.33 per cent over better and best parent, respectively (Patil and Rane, 1994a).

Suresh kumar *et al.* (2004b) reported a heterosis range of -4.23 to 55.74 per cent and -13.51 to 55.74 per cent for mid parent and better parent, repectively for China aster.

2.1.19 Seed yield per plant (g)

In African marigold, heterosis range of 1.69 to 42.85 per cent over better parent was reported. The hybrid Spun gold x Hawaii recorded maximum heterosis over better parent. (Singh and Swarup, 1971).

Gupta *et al.* (2001) recorded -8.5 to 32.40 per cent heterosis over better parent in African marigold during winter. The hybrids MS7 x Sel-14 and MS12 x Sel-21 showed maximum heterobeltiosis per cent for winter season.

2.2.20 Inheritance of flower color

Fleming (1937) reported that purple color was dominant to pink; pink to white and white was recessive to all.

Violet color was dominant over purple, pink and white. While, purple to pink and white and pink was dominant over white. White was recessive to all (Raghava, 1994). Similar results were obtained by Negi and Raghava (1990) and Suresh kumar *et al*. (2003).

2.3 Scoring for *Alternaria* leaf spot

Sreenivasulu *et al.* (2004) screened six genotypes of China aster against *Alternaria* leaf spot under field condition by following 0-5 scale, results revealed least score by Phule Ganesh Pink (18.26) for leaf area infection, whereas it was maximum in Kamini (28.63) for the same.

Thammaiah *et al.* (2004) conducted an experiment in screening of chrysanthemum cultivars for *Alternaria* leaf spot disease under natural condition. Among the twelve cultivars, Chandini recorded the highest *Alternaria* leaf sopt index (39.12%), followed by Raja (38.67%), Bangalore (28.34%), Sarval (26.29%), No-9 (26.23%), Golden Red (22.57%), Dundi (22.88%). Cultivar Indira (2.33%) recorded the lowest leaf spot index followed by Co-2 (3.06%) and Co-1 (6.49%).

Rachappa (2014) reported field screening for *Alternaria* leaf spot disease, minimum score was obtained in genotype AAC-1. Whereas, the high score obtained genotypes were susceptible (Poornima). The degree of variation occurred with respect to the response of genotypes to *Alternaria* leaf spot disease was expected since, any resistance or susceptibility of the cultivar to the disease is controlled by the genetic constituent of genotype.

3. MATERIAL AND METHODS

Field experiment was undertaken during the year 2014-2015 to study the combining ability and heterosis in China aster (*Callistephus chinensis* L. Nees) crosses. The details of the material used and the experimental techniques adopted for the study are presented in this chapter.

3.1 Experimental site

The experiment was carried out in the research field of Department of Floriculture and Landscape Architecture, Kittur Rani Chennamma College of Horticulture, Arabhavi (University of Horticultural Sciences, Bagalkot), Belgaum district, Karnataka (Plate 1).

3.2 Geographical location of experimental site and climate

Arabhavi is situated in northern dry zone of Karnataka state at 16º15´ north latitude, 74º45´ east longitude and at an altitude of 612.03 meter above the mean sea level.

Arabhavi which comes under Zone-3 of Region-2 of agro-climatic zones of Karnataka, has the benefit of both South-West and North-East monsoons. The average rainfall of this area is 530 mm which is distributed over the period of seven months (May to October) with prominent peak during August to October.

The command area receives water from Ghataprabha Left Bank Canal from mid July to mid March. During the experimental period, the mean minimum temperature varied from 18.05ºC to 24.05ºC whereas the mean maximum temperature varied from 28.40ºC to 37.50ºC (April-2014 to March-2015). The highest rainfall during the experimentation period was in December-2014 (19.30 mm) followed by August-2014 (11.00). The meteorological data for the period of experimentation was recorded at the meteorological observatory of the Agricultural Research Station, Arabhavi and is presented in the Appendix I.

Plate 1: General view of experimental plot

3.3 Soil characteristics of experimental site

The experiment was conducted in red soil. The data of the soil analysis is presented in Appendix II.

3.4 Experimental material

Five prominent genotypes including one line were selected from the China aster germplasm maintained at the Department of Floriculture and Landscape Architecture, Kittur Rani Chennamma College of Horticulture, Arabhavi were used as parents (Plate 2). These parents were crossed in all possible cross combinations including reciprocals to develop 20 F_1 hybrids (Plate 3). The salient features of the five parents used in this investigation are presented in Table 1.

Table 1. Salient features of the parents

Sl. No.	Parents	Features
1.	AAC-1	This is locally cultivated genotype, flowers are pink in color, flower diameter is 6 cm and flower weigh 2 g, plant height is 60 cm, stalk length of 30 cm and takes about 138 days to flower. The plant produces 50 flowers/plant. The plants are highly resistant to *Alternaria* leaf spot.
2.	Kamini	This variety was released from IIHR, Bengaluru and commercially cultivated throughout Kanataka state. The variety produces attractive pink colored flowers. It grows to about 60 cm. It has stalk length of 30 cm and vase life of 8 days. Flower are 6 cm in diameter and weigh 2 g each. The plant produce about 50 flowers.
3.	Phule Ganesh Purple	It is semi-erect plant with bright purple color flowers which is preferred in the artistic floral managements and pasting works. It produces 46.82 lakh flower/ha.
4.	Poornima	This variety is released from IIHR, Bengaluru. It bears white colored flowers, diameter of each flower is 5 cm, flower weigh 3.5 g, duration of flowering is 105 days and yields 25 flowers/plant. Plants are susceptible to *Alternaria* leaf spot.
5.	Violet Cushion	This variety was also released from IIHR, Bengaluru. It produces pompon type of flowers having 4 to 5 rows of ray florets with tubular disc florets. Flowers are 4 to 5 cm in diameter and weigh 2 g each. It has stalk length of 20 cm and vase life of 8 days. It produces 70 flowers a plant.


AAC-1


KAMINI


P.G.PURPLE

Plate 2(a): Parents used in hybridization

POORNIMA

VIOLET CUSHION

Plate 2(b): Parents used in hybridization

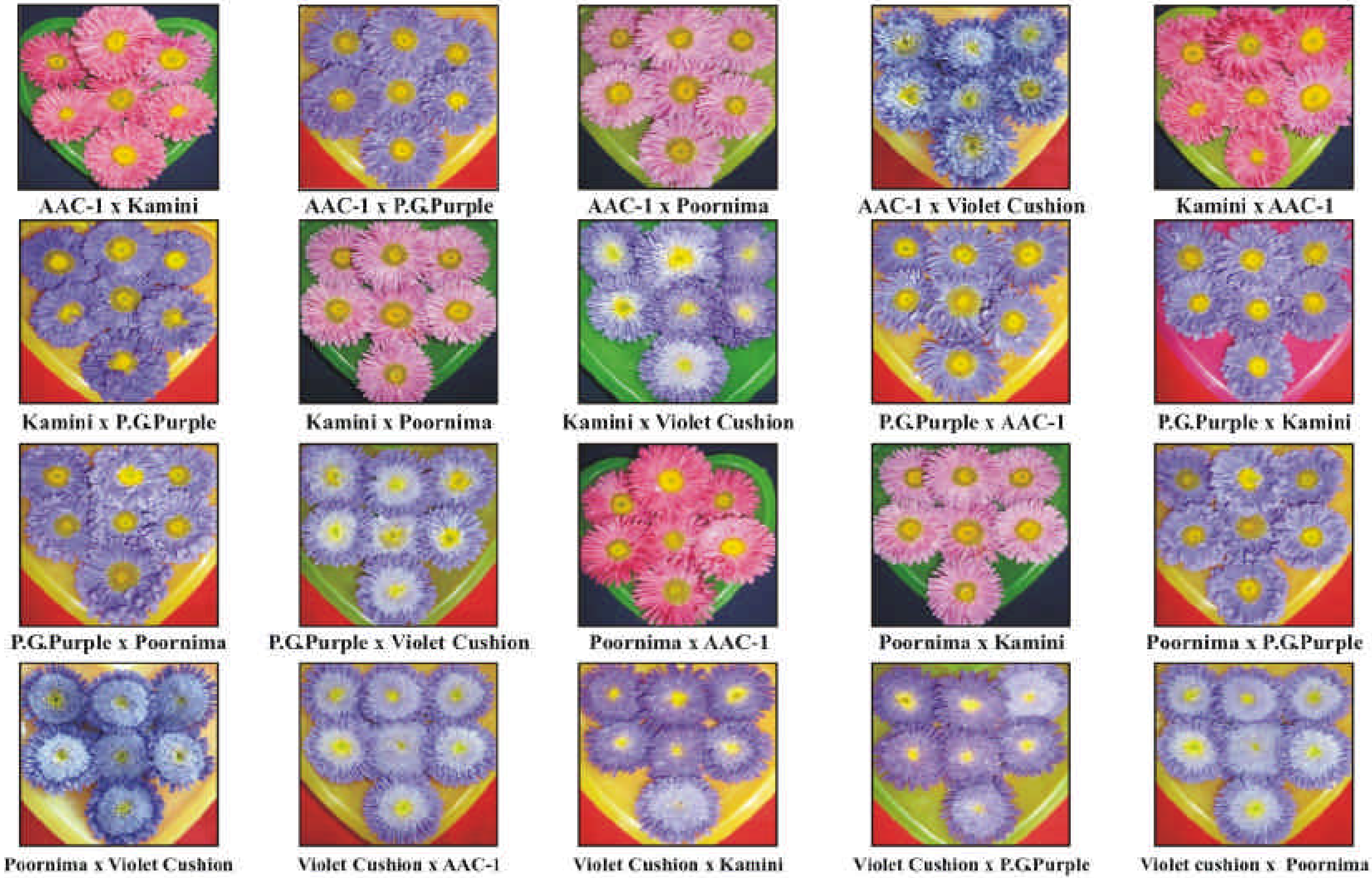

Plate 3: Twenty hybrids developed from five parents

3.5 Hybridization technique

China aster is a self-pollinated crop with approximately 10 per cent natural crossing. Its flower head consists of both pistillate ray florets and perfect disc florets. The stamens and pistils do not mature simultaneously in the individual flowers. The stigma of the individual flower unfolds after the pollen is discharged from the flower. The Chin aster was, therefore, mentioned as geitonogamous.

During hybridization, the florets in the capitulum become sexually mature from outside towards inside. The outer marginal flowers are only female and are therefore used for artificial pollination. Emasculation was done when the flower bud was fully developed. For this, the ray florets were trimmed up to the level of stigma with scissors or sharp blade and disc florets were removed completely. Third day after emasculation pollination was done. The flowers which provide the pollen were kept under sun for 1 to 2 hours for easy discharge of pollen and beaten out on the trimmed flower. The flowers were covered with butter paper bag soon after the emasculation and pollination. Then the flower were tagged to identify the hybrids. Simultaneously the parental lines were selfed and bagged. The seeds were collected from the matured / dried heads (Plate 4).

3.6 Design and layout of experiment

The experiment with 25 entries (5 parents and 20 F_1s) was laid out in a randomized block design with two replications. The other details are as follows:

Treatments	: 25
Number of replications	: 2
Spacing	: 30 cm X 30 cm
Total plants per row	: 25 (Twenty five)
No. of observation plants per row	: 5 (Five)
Standard check	: Kamini

a. Selection of flower bud

b. Emasculation of anthers

c. Emasculated flower

d. Trimming ray florets

e. Trimmed ray florets

f. Selecting flower with mature pollen

g. Pollination

h. Bagging and tagging

Plate 4: Steps involved in the hybridization technique

Standard check variety ‘Kamini’ was used because as no public sector commercial hybrids are available and as Kamini is one of the ruling variety in Karnataka, it was used as standard check variety.

Treatment details

Parents used for hybridization programme

1. AAC-1
2. Kamini
3. Phule Ganesh Purple
4. Poornima
5. Violet Cushion

Hybrids developed by hybridization programme

Direct crosses	Reciprocal crosses
1. AAC-1 x Kamini	1. Kamini x AAC-1
2. AAC-1 x P.G. Purple	2. P.G.Purple x AAC-1
3. AAC-1 x Poornima	3. Poornima x AAC-1
4. AAC-1 x Violet Cushion	4. Violet Cushion x AAC-1
5. Kamini x P.G.Purple	5. P.G.Purple x Kamini
6. Kamini x Poornima	6. Poornima x Kamini
7. Kamini x Violet Cushion	7. Violet Cushion x Kamini
8. P.G.Purple x Poornima	8. Poornima x P.G.Purple
9. P.G.Purple x Violet Cushion	9. Violet Cushion x P.G.Purple
10. Poornima x Violet Cushion	10. Violet Cushion x Poornima

3.7 Cultural operations

The details regarding the various cultural operations carried out in the course of investigations are furnished hereunder.

3.7.1 Nursery operations

Raised nursery beds of size 3.0 m x 1.0 m x 0.1 m were prepared by incorporating of FYM. Seeds of parents and hybrids first also treated with captan (2 g / kg seeds) and then sown in nursery beds. The nursery beds were judiciously watered daily twice for first 10 days and later on daily once for the remaining period. Hand weeding was done thrice when the seedling were 15 days, 25 days and 35 days old. The seedlings were ready for transplanting at 45 days after sowing. During nursery stage seedling damping off controlled by drenching with Captan 0.02 per cent.

3.7.2 Preparation of experimental land and plots

The land was brought to a fine tilth by repeated ploughing and harrowing. A spacing of 30 cm was maintained between the rows / lines. A space of 0.5m was left between two replications.

3.7.3 Transplanting

Forty five days old healthy and uniformly grown seedlings were used for transplanting. The seedling were transplanted at spacing of 30 cm x 30 cm with rate of one seedling per hill.

3.7.4 Fertilizer application

Nitrogen, phosphorus and potassium were applied with the dosage of 180:120:160 kg NPK/ha as per University of Horticultural Sciences, Bagalkot package of practice for horticultural crops. In the form of urea, single super phosphate and muriate of potash, respectively. At the time of transplanting, half the dose of N and full dose of P and K were applied in a circular band of about 3-4 cm around each plant and the crop was top dressed with remaining half dose of N after 30 days of transplanting.

3.7.5 Weeding and irrigation

The plots were kept free from weeds by periodic hand weeding. Irrigation was given at an interval of 5-6 days throughout the period of experimentation depending on the soil moisture status and climatic condition.

3.8 Collection of experimental data

The data were collected on various parameter of vegetative and flowering from the five randomly tagged plants in each replication.

3.8.1 Growth parameter

3.8.1.1 Plant height (cm)

The plant height was measured from the ground level to the growing tip of the plant at 30 and 60 days after transplanting from tagged plants and average was worked out and expressed in centimeters.

3.8.1.2 Number of leaves per plant

Number of leaves were recorded at 30 and 60 days after transplanting from tagged plants and average number of leaves per plant was worked out.

3.8.1.3 Stem girth (cm)

Stem girth was measured at the collar region by using vernier calipers at 30 and 60 days after transplanting and expressed in centimeters.

3.8.1.4 Plant spread (cm^2)

It is measure of canopy width in North-South and East-West directions of tagged plants at 30 and 60 days after transplanting and values were multiplied to obtain plant spread and expressed in square centimeters.

3.8.1.5 Leaf area per plant (cm^2)

The leaf area (cm^2) was estimated by punch method *i.e.,* Five leaves evenly from the bottom, middle and top portion of the plant were taken and twenty punches were made leaving out the mid rib of leaf. Then, the punched and outpunched leaves were dried in hot air oven, later weighed and worked out as per below formulae. (Vivekanandan *et al.* 1972)

$$\text{Leaf area} = \frac{a \times w}{b} \times \text{Number of leaves}$$

Where,

a = Leaf area of twenty leaf discs

b = Dry weight of twenty leaf disc

w = Dry weight of all leaves including twenty leaf discs

3.8.1.6 Number of branches

Number of branches were counted at grand growth stage *i.e.*, 60 days after transplanting from tagged plants and average number of braches per plant was worked out.

3.8.2 Floral characters

3.8.2.1 Days for first flower bud initiation

This was recorded by counting the days from the date of transplanting to the day on which the first flower bud appeared.

3.8.2.2 Days for first flowering

This was recorded by counting the number of days from the date of transplanting to the day on which the first flower bloomed.

3.8.2.3 Days for fifty per cent flowering

Number of days taken from transplanting to the day on which 50 per cent of the plants flowered was recorded.

3.8.2.4 Duration of flowering

Number of days taken from the first flowering to the last flowering was recorded as the total duration of flowering in each treatment.

3.8.3 Yield and other parameters

3.8.3.1 Number of flowers per plant

Numbers of flowers produced per plant from the five tagged plants were recorded and the average number of flowers produced per plant was worked out.

3.8.3.2 Individual flower weight (g)

Individual flower was selected randomly at full bloom stage and weight of individual flower from the five tagged plants were recorded and the average individual flower weight was worked out.

3.8.3.3 Weight of ten flowers (g)

Ten flowers were selected randomly at full bloom stage and weight of these flowers were recorded and the average weight of a flower was worked out.

3.8.3.4 Flower yield per plant (g)

From the tagged plants, yield per plant was worked out by recording the fresh weight of flowers and the mean value was worked out and expressed in grams.

3.8.3.5 Flower yield per hectare (t/ha)

Yield per hectare was calculated based on the yield per plant multiplied by the number of plants per hectare and expressed in tonnes.

3.8.4 Flower quality parameters

3.8.4.1 Stalk length (cm)

The stalk length of the flower was measured from the origin of that stalk from the main stem to the neck of the flower and expressed in centimeters.

3.8.4.2 Flower diameter (cm)

Diameter of the flower was measured at the point of maximum breadth. This was measured by using vernier callipers and average diameter in centimeters was worked out.

3.8.4.3 Ray florets length (cm)

Breadth and length of ray florets were measured and size of floret was worked by multiplying length with breadth and expressed in square centimeters.

3.8.4.4 Disc floret length (cm)

Diameter of disc of the flower was measured at the point of maximum breadth. This was measured by using vernier calipers and average diameter in centimeters was worked out.

3.8.4.5 Vase life

The point of termination of vase life varies from the first sign of wilting or fading to the death of flower. For this purpose, flowers were harvested when one whorl of outer ray florets was opened. The stems were cut to a uniform length in all the lines and lower leaves were removed leaving only few upper leaves. Immediately after cutting, the stems were put into the bucket having clean water. Then the two cut stems were put in 250 ml of distilled water in conical flasks. Wilting of one or two petals was taken as the end of vase life. Number of days at which flower in different lines were found unfit for continuing in the vase was recorded as vase life and the average vase life of each flower was worked.

3.8.4.6 Seed yield per plant (g)

Seeds from each tagged plants were extracted, dried under shade condition and weight was measured expressed in terms of grams.

3.4.4.7 Seed test weight (g)

The thousand seed weight was taken from each plant and expressed in terms of grams

3.8.4.6 Inheritance of flower color

In this flower color of different F_1 progeny were recorded to know the dominant flower color.

3.9 Statistical analysis and interpretation of data

3.9.1 Analysis of variance

Analysis of variance for individual character was done on the basis of mean values per treatment per replication as suggested by Panse and Sukhatme (1967) for Randomized Block Design (RBD). The model of analysis of variance table adopted is given below:

Source	D.F.	S.S	M.S.S	F Ratio
Replication	(r-1)	RSS	Mr	Mr/E
Treatment	(t-1)	TSS	Mt	Mt/E
Error	(r-1) (t-1)	ESS	E	

Where,

r = Number of replications

t = Number of treatments (entries)

Significance of treatments was tested at 5 per cent probability

3.9.2 Combining ability analysis

General combining ability (GCA) variance and specific combining ability (SCA) variance and effects were analyzed by adopting model-1 method-1 of Griffing (1956), since the present study includes parents and F_1 (with reciprocals). The statistical procedure assumes the following mathematical model.

$$Yij = m + gi + gj + sij + rij + \frac{1}{bc} \quad SS_{eijkl}$$

Where,

i, j	= 1, 2,……..,n
k	= 1, 2,……..,n
l	= 1, 2,……..,n
µ	= Population mean
Y_{ij}	= Mean of i^{th} x j^{th} genotype over k and l.
g_i	= General combining ability (gca) effect of the i^{th} parent
g_j	= GCA effect of j^{th} parent
s_{ij}	= Interaction, *i.e.,* specific combining ability effect
r_{ij}	= Reciprocal effect
b	= Number of replication
c	= Number of individuals in each replication

3.9.2.1 Combining ability variance

The analysis of variance table for combining ability as follows:

Source	D. F.	S. S	M. S.S	F Ratio
GCA	(n-1)	S_g	M_g	$s\,e^2 + \frac{2n}{n-1}\ S\ g_i^2$
SCA	n(n-1)/2	S_s	M_s	$s\,e^2 + \frac{2}{n(n-1)}\ SS\ s^2_{ij}$
RCA	n(n-1)/2	S_r	M_r	$s\,e^2 + \frac{2}{n(n-1)}\ SS\ r^2_{ij}$
Error	M	S_e	M_e	$s\,e^2$

Where,

$S_g = \frac{1}{2n}\Sigma(Yi.+Y.j)^2 - \frac{2}{n^2}Y^2 ...$

$S_s = \frac{1}{2}\Sigma\Sigma\, Yij(Yij + Yji) - \frac{1}{2n}\,\Sigma\,(Y.j + Yi.)^2 + \frac{1}{n^2}Y^2$

$S_r = \frac{1}{2}\Sigma\Sigma(Yij - Yji)^2$

$Y_{i.}$ = Row total of i[th] parent

$Y_{.j}$ = Column total of j[th] parent

Y… = Grand total of all hybrids

Y_{ij} = Mean value of ij[th] hybrid

Y_{ji} = Reciprocal value of ij[th] hybrid

n = Number of parents.

The estimates of M`e, the error in above table was obtained as M`e = Me/b, where Me is the error variance estimated in the analysis of variance of the experiment, b is the number of replications. The general, specific and reciprocal combining ability variances were calculated based on the mean sum of squares as follows.

$$\sigma g^2 = \frac{(M_g - M_e)[n-1]}{(n+2)}$$

$$\sigma s^2 = \frac{(M_s - M_e)n\,[n-1]}{2}$$

$$\sigma r^2 = \frac{(M_r - M_e)n\,[n-1]}{2}$$

The test of significance was tested by the ‘F’ ratio against M`e.

3.9.2.2 Estimation of combining ability effects

The general combining ability effects (gca effects), specific combining ability effects (sca effects) and reciprocal combining effects (rca effects) were estimated as follows.

$$gca\ effects = g_i = \frac{1}{2n}(Yi. + Y.j) - \frac{1}{n^2}Y\ldots$$

$$sca\ effects = s_{ij} = \frac{1}{2}(Yij + Yji) - \frac{1}{2n}(Yi. + Y.i + Y.j + Yj.) + \frac{1}{n^2}Y\ldots$$

$$rca\ effects = r_{ij} = \frac{1}{2(Yij - Yji)}$$

Where,

Y.i = Column total of i^{th} parent

Yj. = Row total of j^{th} parent

Remaining n, Yi., Y.j, Yij, Yji, Y… are same as mentioned earlier.

3.9.2.3 Test of significance for the combining ability effects

Standard error (SE) for different estimates were obtained from the formulae

$$S.E.(g_i) = \sqrt{\frac{n-1}{2n^2}\sigma^2 e}$$

$$S.E.(s_{ij}) = \sqrt{\frac{1}{2n^2(n^2[+2n + s)\sigma]^2 e}}$$

$$S.E.(r_{ij}) = \sqrt{\frac{1}{2}\sigma^2 e}$$

Critical difference (C.D.) for testing the significance of the combining ability estimates was obtained by multiplying the respective standard error with table ‘t’ value at error degrees of freedom.

3.9.3 Heterosis

The magnitude of heterosis was estimated in relation to mid parent (MP), better parent (BP) and standard check (SC) as percentage increase or decrease of F_1s over the respective parents.

Average values over replications were used for estimating the heterosis over mid parent, better parent and standard check (SC).

Emphasis to say heterotic cross depended upon the trait that may be desired in any one of the directions, higher or lower. Therefore, the cross showing positive values was judged as a better cross for plant height, number of leaves, number of branches, number of flowers, flower weight, diameter of flower, number of flower per plant, yield per plant and yield per hectare. Similarly, the cross showing lower values was selected as better cross for days to flower bud initiation days to flower bud opening, days to 50 per cent flowering etc.

The estimate of heterosis was carried out by following the methods suggested by Turner (1953) and Hayes *et al.* (1955).

$$\text{Mid parent value (MP)} = \frac{P_1+P_2}{2}$$

a) Heterosis over mid parent (MP) (Relative heterosis %)

$$= \frac{\overline{F}_1 - \overline{MP}}{\overline{MP}} \times 100$$

b) Heterosis over better parent (BP) (Heterobeltiosis %)

$$= \frac{\overline{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

c) Heterosis for standard check (SC) (Standard heterosis %)

$$= \frac{\overline{F}_1 - \overline{SC}}{\overline{SC}} \times 100$$

Where,

P_1 = Female parent

P_2 = Male parent

$\overline{F}_1$ = Hybrid

$\overline{MP}$ = Mean of mid parent

$\overline{BP}$ = Mean of better parent

$\overline{SC}$ = Mean of standard check ‘Kamini’

Test whether the observed magnitude of heterosis was significant or not was done by comparing the mean deviations with values of critical difference (CD) obtained separately from MP, BP and SC by using the formulae.

CD = S.Em x ‘t’ value

Where,

$$\text{S.Em (BP or SC)} = \sqrt{\frac{2 \times \text{Error MSS}}{r}}$$

$$\text{S.Em (MP)} = \sqrt{\frac{3/2 \times \text{Error MSS}}{r}}$$

Where,

r = Number of replications

t = Table ‘t’ values at error degrees of freedom

Emss = Error mean sum of squares

SC = Standard check

BP = Better parent

MP = Mid parent

3.10 Field evaluation of China aster parents and crosses against *Alternaria* leaf spot disease under natural disease pressure condition

Evaluation of China aster parents and crosses against leaf spot caused by *Alternaria alternate* was conducted at during *Rabi* 2014 in medium black soil under irrigated conditions in order to find out the source of resistance. The disease scale intensity was recorded at the every alternate month, using disease score (0-5 scale).

$$PDI = \frac{Sum\ of\ numerical\ ratings}{Number\ of\ plants\ assessed\ X\ Maximum\ ratings} X\ 100$$

The details of the scale are:

Grading of ratings	**Reaction**	**Disease intensity**
0	Immune	<1
1	Resistant	1-15
2	Moderately resistant	16-25
3	Moderately susceptible	26-50
4	Susceptible	51-75
5	Highly susceptible	Above 76

Five plants were selected randomly in each treatment and intensity of the disease was recorded by following 0-5 scale as mentioned earlier. Per cent disease index was calculated by using the formula given by Wheeler (1969).

4. EXPERIMENTAL RESULTS

The results of the experiment conducted during 2014-15 at the Department of Floriculture and Landscape Architecture, K. R. C. College of Horticulture, Arabhavi on "Heterosis and Combining ability studies in China aster (*Callistephus chinensis* L. Nees) are presented below.

1. Analysis of variance (ANOVA)
2. Heterosis
3. Combining ability analysis

4.1 Analysis of variance (ANOVA)

Analysis of variance using diallel analysis showed significant treatment differences for all the characters studied Table 2.

The ANOVA indicated that mean sum of squares (mss) due to treatment were highly significant for all the twenty three characters except stem girth which showed significant results.

4.2 Heterosis

The estimates of heterosis over mid parent, better parent and standard check are presented in the Table 3 to Table 24.

4.2.1 *Per se* performance, nature and magnitude of heterosis

The pertinent data on *per se* performance of 25 entries (5 parents + 20 F_1 s) and magnitude of heterosis are presented hereunder.

4.2.1.1 Plant height (cm)

Among the parents the plant height ranged from 24.00 (Kamini) to 46.30 (P.G.Purple). However, for the F_1 s, it ranged from 28.00 (Poornima x Kamini) to 55.40 (Poornima x P.G.Purple).

Table 2. Analysis of variance for twenty three characters in China aster

Sl. No.	Source	Mean sum of square		
		Replication	**Treatment**	**Error**
	Degrees of freedom	1	24	24
1	Plant height	75.39	101.23**	17.02
2	No. of leaves	113.10	47.73**	11.86
3	Stem girth	0.02	0.01*	0.006
4	Plant spread	565104	92352**	24489
5	Leaf area	2957315.04	1817274.03**	394268.39
6	No. of branches	0.01	24.40**	1.69
7	Days for 1st flower bud initiation	1.37	43.11**	3.93
8	Days for 1st flowering	0.50	59.20**	4.43
9	Days for 50% flowering	1.09	63.66**	4.22
10	Duration of flowering	3.28	11.99**	0.99
11	No. of flowers/plant	0.22	193.44**	2.52
12	Individual flower weight	0.04	0.2**	0.03
13	Weight of ten flowers	8.12	35.54**	8.41
14	Flower yield/plant	209.69	4489.60**	154.93
15	Flower yield/ha	2.59	55.43**	1.91
16	Flower stalk length	5.12	6.64**	2.48
17	Flower diameter	0.57	0.39**	0.03
18	Ray floret length	0.41	0.21**	0.07
19	Disc floret length	0.49	1.17**	0.31
20	Vase life	0.02	3.10**	0.09
21	Seed yield/plant	0.0002	0.20**	0.02
22	Seed test weight	0.000107	0.03**	0.001922
23	*Alternaria* Leaf spot incidence	3.48	1106.05**	62.77

*Significant at 5 per cent level **Significant at 1 per cent level

The mid parent heterosis ranged from -11.11 per cent (P.G.Purple x Violet Cushion) to 31.59 per cent (Poornima x P.G.Purple) for the trait. Nine crosses exhibited positive significant heterosis while, none of crosses showed negative significant heterosis over mid parent.

The heterosis over the better parent ranged was from -26.12 per cent (Poornima x Kamini) to 22.77 per cent (AAC-1 x Poornima). Two crosses showed positive significance heterosis while, eight crosses recorded negative significant heterosis over better parent.

The heterosis over standard check Kamini ranged from 16.67 per cent (Poornima x Kamini) to 130.83 per cent (Poornima x P.G.Purple). Out of twenty crosses, eighteen crosses showed positive significant heterosis over standard check Kamini (Table 3).

4.2.1.2 Number of leaves

The number of leaves per plant varied from 28.70 (Kamini) to 39.40 (Violet Cushion) for parents and 30.10 (Poornima x Kamini) to 49.90 (AAC-1 x Violet Cushion) for F_1 s.

The magnitude of heterosis over mid parent varied from -7.87 per cent (P.G.Purple x Poornima) to 37.97 per cent (Poornima x AAC-1). Four crosses showed positive significant heterosis while, none of crosses showed negative significant heterosis over mid parent.

For better parent heterosis ranged from -14.36 per cent (P.G.Purple x Poornima) to 32.55 per cent (Poornima x AAC-1). Three crosses showed positive significant heterosis while, two crosses recorded negative significance heterosis over better parent.

The standard heterosis over check Kamini ranged from 4.87 per cent (Poornima x Kamini) to 73.86 per cent (AAC-1 x Violet Cushion). Seventeen crosses exhibited positive significant heterosis over standard check in the desirable direction (Table 4).

Table 3. *Per se* performance and nature of heterosis for plant height (60 Days after transplanting)

Sl. No.	Cross	Plant height (cm)					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	38.20	24.00	39.70	27.65**	3.93	65.42**
2	AAC-1 x P.G.Purple	38.20	46.30	48.10	13.85*	3.89	100.42**
3	AAC-1 x Poornima	38.20	37.90	46.90	23.26**	22.77**	95.42**
4	AAC-1 x Violet Cushion	38.20	45.50	49.00	17.05**	7.69	104.17**
5	Kamini x AAC-1	24.00	38.20	37.00	18.97*	-3.14	54.17**
6	Kamini x P.G.Purple	24.00	49.30	43.70	24.32**	-5.62	82.08**
7	Kamini x Poornima	24.00	37.90	28.90	-6.62	-23.75**	20.42
8	Kamini x Violet Cushion	24.00	45.50	39.80	14.53	-12.53*	65.83**
9	P.G.Purple x AAC-1	46.30	38.20	40.50	-4.14	-12.53*	68.75**
10	P.G.Purple x Kamini	46.30	24.00	39.60	12.66	-14.47*	65.00**
11	P.G.Purple x Poornima	46.30	37.90	50.10	19.00**	8.21	108.75**
12	P.G.Purple x Violet Cushion	46.30	45.50	40.80	-11.11	-11.88*	70.00**
13	Poornima x AAC-1	37.90	38.20	34.40	-9.53	-9.25	43.33**
14	Poornima x Kamini	37.90	24.00	28.00	-9.53	-26.12**	16.67
15	Poornima x P.G.Purple	37.90	46.30	55.40	31.59**	19.65**	130.83**
16	Poornima x Violet Cushion	37.90	45.50	40.50	-2.88	-10.99	68.75**
17	Violet Cushion x AAC-1	45.50	38.20	37.90	-9.44	-16.70**	57.92**
18	Violet Cushion x Kamini	45.50	24.00	40.10	15.40*	-11.87*	67.08**
19	Violet Cushion x P.G.Purple	45.50	46.30	42.40	-7.63	-8.42	76.67**
20	Violet Cushion x Poornima	45.50	37.90	45.60	9.35	0.22	90.00**
S.Em ±		**2.12**	**2.12**	**3.10**	**3.57**	**4.12**	**4.12**
C.D 5%		**6.30**	**6.30**	**9.17**	**7.46**	**8.52**	**8.52**
C.D 1%		**8.61**	**8.61**	**12.54**	**10.10**	**11.60**	**11.60**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

Table 4. *Per se* performance and nature of heterosis for number of leaves (60 Days after transplanting)

Sl. No.	Cross	Number of leaves					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	34.40	28.70	38.90	23.29**	13.08*	35.54**
2	AAC-1 x P.G.Purple	34.40	36.90	44.80	25.66**	21.40**	56.09**
3	AAC-1 x Poornima	34.40	31.70	33.80	2.26	-1.74	17.77*
4	AAC-1 x Violet Cushion	34.40	39.40	49.90	35.23**	26.64	73.86**
5	Kamini x AAC-1	28.70	34.40	35.20	11.56	2.32	22.64**
6	Kamini x P.G.Purple	28.70	36.90	35.40	7.92	-4.06	23.34**
7	Kamini x Poornima	28.70	31.70	30.30	0.33	-4.41	5.57
8	Kamini x Violet Cushion	28.70	39.40	37.80	11.01	-4.06	31.70**
9	P.G.Purple x AAC-1	36.90	34.40	35.30	-0.98	-4.33	23.00**
10	P.G.Purple x Kamini	36.90	28.70	36.20	10.36	-1.89	26.13**
11	P.G.Purple x Poornima	36.90	31.70	31.60	-7.87	-14.36*	10.10
12	P.G.Purple x Violet Cushion	36.90	39.40	39.20	2.75	-0.50	36.58**
13	Poornima x AAC-1	31.70	34.40	45.60	37.97*	32.55**	58.88**
14	Poornima x Kamini	31.70	28.70	30.10	-0.33	-5.04	4.87
15	Poornima x P.G.Purple	31.70	36.90	38.70	12.82	4.87	34.84**
16	Poornima x Violet Cushion	31.70	39.40	35.20	-0.98	-10.65	22.64**
17	Violet Cushion x AAC-1	39.40	34.40	34.70	-5.96	-11.92*	20.90**
18	Violet Cushion x Kamini	39.40	28.70	36.80	8.07	-6.59	28.22**
19	Violet Cushion x P.G.Purple	39.40	36.90	38.80	1.70	-1.52	35.19**
20	Violet Cushion x Poornima	39.40	31.70	37.00	4.07	-6.09	28.91**
S.Em ±		**2.34**	**2.34**	**2.46**	**3.10**	**3.44**	**3.44**
C.D 5%		**6.92**	**6.92**	**7.29**	**6.20**	**7.11**	**7.11**
C.D 1%		**9.46**	**9.46**	**9.96**	**8.38**	**9.68**	**9.68**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

4.2.1.3 Stem girth (cm)

The stem girth ranged from 1.07 (Kamini) to 1.24 (Violet Cushion) and 1.07 (Kamini x Poornima) to 1.40 (P.G.Purple x AAC-1) for parents and crosses, repectively.

Two crosses exhibited positive significant heterosis while one cross showed negative significant heterosis over mid parent. The maximum heterosis was shown by the cross P.G.Purple x AAC-1 (15.67%) followed by Poornima x Kamini (9.45%).

The range of heterosis over better parent was from -16.02 per cent (Violet Cushion x P.G.Purple) to 15.45 per cent (P.G.Purple x AAC-1) for the trait. One cross showed positive significant heterosis while, five crosses recorded negative significant heterosis over better parent.

The heterosis over standard check Kamini ranged from -3.16 per cent (Violet Cushion x P.G.Purple) to 31.02 per cent (P.G.Purple x AAC-1). Twelve crosses exhibited positive significant heterosis over standard check (Table 5).

4.2.1.4 Plant spread (cm^2)

The range of variation recorded from 727.08 cm^2 (Poornima) to 1190.94 cm^2 (AAC-1) and from 747.92 cm^2 (Violet Cushion x Poornima) to 1498.08 cm^2 (AAC-1 x P.G.Purple) for parents and hybrids, repectively.

Five crosses exhibited positive significant and two crosses showed negative significant heterosis over mid parent and range varied from -25.25 per cent (Violet Cushion x P.G.Purple) to 58.07 per cent (P.G.Purple x Poornima). Better parent heterosis varied from -29.94 per cent (Violet Cushion x Poornima) to 33.04 per cent (P.G.Purple x Poornima). Three crosses showed positive significant heterosis and three crosses exhibited negative significant heterosis over better parent.

For standard check, heterosis varied from 4.99 per cent (Violet Cushion x P.G.Purple) to 97.43 per cent (AAC-1 x P.G.Purple). Thirteen crosses showed positive significant count for the trait (Table 6).

Table 5. ***Per se*** **performance and nature of heterosis for stem girth (60 Days after transplanting)**

Sl. No.	Cross	Stem girth (cm)					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	1.22	1.07	1.08	-5.09	-10.73*	1.31
2	AAC-1 x P.G.Purple	1.22	1.21	1.25	2.83	2.63	16.48**
3	AAC-1 x Poornima	1.22	1.17	1.10	-7.65	-9.40*	2.81
4	AAC-1 x Violet Cushion	1.22	1.24	1.20	-1.79	-2.57	12.34*
5	Kamini x AAC-1	1.07	1.22	1.20	5.28	-0.97	12.38*
6	Kamini x P.G.Purple	1.07	1.21	1.12	-2.19	-7.84	4.18
7	Kamini x Poornima	1.07	1.17	1.07	-4.71	-8.72*	-0.33
8	Kamini x Violet Cushion	1.07	1.24	1.25	8.29	1.10	16.58**
9	P.G.Purple x AAC-1	1.21	1.22	1.40	15.67**	15.45**	31.02**
10	P.G.Purple x Kamini	1.21	1.07	1.20	5.57	-0.51	12.46
11	P.G.Purple x Poornima	1.21	1.17	1.09	-8.38	-9.95*	1.80
12	P.G.Purple x Violet Cushion	1.21	1.24	1.22	-0.59	-1.57	13.50**
13	Poornima x AAC-1	1.17	1.22	1.25	4.71	2.72	16.58**
14	Poornima x Kamini	1.17	1.07	1.23	9.45*	4.85	14.48**
15	Poornima x P.G.Purple	1.17	1.21	1.19	0.35	-1.35	11.52*
16	Poornima x Violet Cushion	1.17	1.24	1.28	6.19	3.37	19.20**
17	Violet Cushion x AAC-1	1.24	1.22	1.21	-1.50	-2.28	12.68*
18	Violet Cushion x Kamini	1.24	1.07	1.18	2.07	-4.70	9.89*
19	Violet Cushion x P.G.Purple	1.24	1.21	1.04	-15.19**	-16.02**	-3.16
20	Violet Cushion x Poornima	1.24	1.17	1.17	-2.67	-5.26	9.24
S.Em ±		**0.04**	**0.04**	**0.05**	**0.07**	**0.08**	**0.08**
C.D 5%		**0.13**	**0.13**	**0.17**	**0.14**	**0.16**	**0.16**
C.D 1%		**0.18**	**0.18**	**0.23**	**0.21**	**0.22**	**0.22**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

Table 6. *Per se* performance and nature of heterosis for plant spread (60 Days after transplanting)

Sl. No.	Cross	Plant spread (cm^2)					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	1190.94	758.80	1318.96	35.30**	10.75	73.82**
2	AAC-1 x P.G.Purple	1190.94	1064.10	1498.08	32.87**	25.79**	97.43**
3	AAC-1 x Poornima	1190.94	727.08	1092.52	13.92	-8.26	43.98**
4	AAC-1 x Violet Cushion	1190.94	1067.52	1162.68	2.96	-2.37	53.23**
5	Kamini x AAC-1	758.80	1190.94	1039.04	6.58	-12.75	36.93**
6	Kamini x P.G.Purple	758.80	1064.10	1067.72	17.15	0.34	40.71**
7	Kamini x Poornima	758.80	727.08	859.84	15.73	13.32	13.32
8	Kamini x Violet Cushion	758.80	1067.52	967.16	5.91	-9.40	27.46*
9	P.G.Purple x AAC-1	1064.10	1190.94	1096.32	-2.77	-7.94	44.48**
10	P.G.Purple x Kamini	1064.10	758.80	975.20	6.99	-8.35	28.52*
11	P.G.Purple x Poornima	1064.10	727.08	1415.68	58.07**	33.04**	86.57**
12	P.G.Purple x Violet Cushion	1064.10	1067.52	823.04	-22.78*	-22.90*	8.47
13	Poornima x AAC-1	727.08	1190.94	1247.46	30.08**	4.75	64.40**
14	Poornima x Kamini	727.08	758.80	881.60	18.66	16.18	16.18
15	Poornima x P.G.Purple	727.08	1064.10	1321.64	47.57**	24.20*	74.18**
16	Poornima x Violet Cushion	727.08	1067.52	922.96	2.86	-13.54	21.63
17	Violet Cushion x AAC-1	1067.52	1190.94	1236.72	9.52	3.84	62.98**
18	Violet Cushion x Kamini	1067.52	758.80	884.28	-3.16	-17.17	16.54
19	Violet Cushion x P.G.Purple	1067.52	1064.10	796.68	-25.25*	-25.37**	4.99
20	Violet Cushion x Poornima	1067.52	727.08	747.92	-16.65	-29.94**	-1.43
S.Em ±		**55.85**	**55.85**	**119.31**	**135.63**	**156.50**	**156.50**
C.D 5%		**165.32**	**165.32**	**353.17**	**278.00**	**323.00**	**323.00**
C.D 1%		**225.97**	**225.97**	**482.74**	**381.20**	**381.20**	**381.20**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

4.2.1.5 Leaf area per plant (cm^2)

Among the parents the leaf area per plant ranged from 3239.08 (Kamini) to 4496.28 (P.G.Purple). However, for the F_1 s, it ranged from 2248.73 (Kamini x Poornima) to 7443.14 (AAC-1 x Violet Cushion).

The mid parent heterosis ranged from -28.38 per cent (Kamini x P.G.Purple) to 98.45 per cent (AAC-1 x Poornima) for the trait. Five crosses exhibited positive significant heterosis while, one of cross showed negative significant heterosis over mid parent.

The heterosis over the better parent was ranged from -35.56 per cent (Kamini x P.G.Purple) to 76.53 per cent (AAC-1 x Poornima). Three crosses showed positive significance heterosis while, three crosses recorded negative significant heterosis over better parent.

The heterosis over standard check Kamini ranged from -19.40 per cent (Kamini x P.G.Purple) to 166.79 per cent (AAC-1 x Poornima). Out of twenty crosses, thirteen crosses showed positive significant heterosis over standard check Kamini (Table 7).

4.2.1.6 Number of branches

The number of branches varied from 12.20 (Kamini) to 23.70 (Violet Cushion) for parents and 12.40 (Kamini x Poornima) to 21.40 (P.G.Purple x Violet Cushion) for F_1 s.

The magnitude of heterosis over mid parent varied from -6.42 per cent (Kamini x Poornima) to 21.39 per cent (P.G.Purple x Poornima). Eleven crosses showed positive significant heterosis while, none of crosses showed negative significance heterosis over mid parent.

For better parent heterosis, it ranged from -19.70 per cent (Kamini x P.G.Purple) to 18.75 per cent (Poornima x AAC-1). One cross showed positive significant heterosis while, ten crosses recorded negative significant heterosis over better parent.

The standard heterosis over check Kamini ranged from 1.64 per cent (Kamini x Poornima) to 75.41 per cent (P.G.Purple x Violet Cushion). Seventeen crosses exhibited positive significant heterosis over standard check in the desirable direction (Table 8).

Table 7. *Per se* performance and nature of heterosis for leaf area per plant (60 Days after transplanting)

Sl. No.	Cross	Leaf area per plant(cm^2)					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	3384.47	3239.08	3284.97	70.48**	57.63**	85.60*
2	AAC-1 x P.G.Purple	3384.47	4496.28	5178.13	13.12	9.80	37.34*
3	AAC-1 x Poornima	3384.47	4253.75	3831.77	98.45**	76.53**	166.79**
4	AAC-1 x Violet Cushion	3384.47	4104.50	7443.14	-8.40	-17.54	21.31
5	Kamini x AAC-1	3239.08	3384.47	4105.86	35.17*	24.99*	47.17**
6	Kamini x P.G.Purple	3239.08	4496.28	2789.92	-28.38*	-35.56**	-19.40
7	Kamini x Poornima	3239.08	4253.75	2248.73	6.36	-11.64	33.55*
8	Kamini x Violet Cushion	3239.08	4104.50	3725.84	-6.04	-21.08*	16.10
9	P.G.Purple x AAC-1	4496.28	3384.47	4191.12	23.73*	20.10	50.22**
10	P.G.Purple x Kamini	4496.28	3239.08	3549.32	13.04	1.71	27.22
11	P.G.Purple x Poornima	4496.28	4253.75	3489.66	-15.17	-22.48*	17.16
12	P.G.Purple x Violet Cushion	4496.28	4104.50	3268.60	18.41	9.55	61.16**
13	Poornima x AAC-1	4253.75	3384.47	3573.16	-4.73	-15.26	28.07
14	Poornima x Kamini	4253.75	3239.08	4156.73	18.66	-1.42	48.99**
15	Poornima x P.G.Purple	4253.75	4469.28	4177.18	8.41	-0.93	49.72**
16	Poornima x Violet Cushion	4253.75	4104.50	4216.43	2.24	0.88	52.47**
17	Violet Cushion x AAC-1	4104.50	3384.47	3940.45	6.65	-4.00	41.24**
18	Violet Cushion x Kamini	4104.50	3239.08	4697.04	36.26**	14.44	68.36**
19	Violet Cushion x P.G.Purple	4104.50	4496.28	3706.73	-2.38	-9.69	32.86*
20	Violet Cushion x Poornima	4104.50	4253.75	3430.88	-17.54	-18.63	22.97
S.Em ±		**450.94**	**450.94**	**430.971**	**585.54**	**676.12**	**676.12**
C.D 5%		**1334.77**	**1334.77**	**1275.66**	**1208.5**	**1395.46**	**1395.46**
C.D 1%		**1824.49**	**1824.49**	**1743.69**	**1646.84**	**1901.61**	**1901.61**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

Table 8. *Per se* performance and nature of heterosis for number of branches (60 Days after transplanting)

Sl. No.	Cross	Number of branches					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	14.40	12.20	15.60	17.29**	8.33	27.87**
2	AAC-1 x P.G.Purple	14.40	20.30	20.70	19.31**	1.97	69.67**
3	AAC-1 x Poornima	14.40	14.30	15.30	6.62	6.25	25.41**
4	AAC-1 x Violet Cushion	14.40	23.70	20.60	8.14	-13.08**	68.85**
5	Kamini x AAC-1	12.20	14.40	13.40	0.75	-6.94	9.84
6	Kamini x P.G.Purple	12.20	20.30	16.30	0.31	-19.70**	33.61**
7	Kamini x Poornima	12.20	14.30	12.40	-6.42	-13.29*	1.64
8	Kamini x Violet Cushion	12.20	23.70	20.90	16.43**	-11.81**	71.31**
9	P.G.Purple x AAC-1	20.30	14.40	20.50	18.16**	0.99	68.03**
10	P.G.Purple x Kamini	20.30	12.20	19.70	21.23**	-2.96	61.48**
11	P.G.Purple x Poornima	20.30	14.30	21.00	21.39**	3.45	72.13**
12	P.G.Purple x Violet Cushion	20.30	23.70	21.40	-2.73	-9.70**	75.41**
13	Poornima x AAC-1	14.30	14.40	17.10	19.16**	18.75**	40.16**
14	Poornima x Kamini	14.30	12.20	13.00	-1.89	-9.09	6.56
15	Poornima x P.G.Purple	14.30	20.30	20.30	17.34**	0.00	66.39**
16	Poornima x Violet Cushion	14.30	23.70	21.10	11.05*	-10.97**	72.95**
17	Violet Cushion x AAC-1	23.70	14.40	21.10	10.76	-10.97**	72.95**
18	Violet Cushion x Kamini	23.70	12.20	20.70	15.32**	-12.66**	69.67**
19	Violet Cushion x P.G.Purple	23.70	20.30	21.30	-3.18	-10.13**	74.59**
20	Violet Cushion x Poornima	23.70	14.30	20.90	10.00*	-11.81**	71.31**
S.Em ±		**0.62**	**0.62**	**0.95**	**1.13**	**1.30**	**1.30**
C.D 5%		**1.85**	**1.85**	**2.82**	**2.32**	**2.68**	**2.68**
C.D 1%		**2.53**	**2.53**	**3.86**	**3.17**	**3.66**	**3.66**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

4.2.1.7 Days for first flower bud initiation

The range of variation recorded from 58.60 (Kamini) to 69.80 (Poonima) and from 57.20 (Poornima x Kamini) to 69.90 (AAC-1 x Violet Cushion and Poornima x Violet Cushion) for parents and hybrids, respectively.

Five crosses exhibited positive significant heterosis and four crosses showed negative significant heterosis over mid parent and its range varied from -13.83 per cent (Poornima x P.G.Purple) to 11.68 per cent (Violet Cushion x Kamini). Better parent heterosis varied from -18.05 per cent (Poornima x Kamini) to 6.98 per cent (Violet Cushion x P.G.Purple). Three crosses showed positive significant heterosis and seven crosses exhibited negative significant heterosis over better parent.

For standard check, heterosis varied from -2.39 per cent (Poornima x Kamini) to 22.87 per cent (Violet Cushion x P.G.Purple). Eighteen crosses showed positive significant count for the trait (Table 9).

4.2.1.8 Days for first flowering

The days for first flowering ranged from 71.10 (Kamini) to 84.20 (Poornima and Violet Cushion) and 71.30 (Poornima x P.G.Purple) to 88.60 (Violet Cushion x P.G.Purple) for parents and crosses, repectively.

Six crosses exhibited positive significant heterosis, while five crosses showed negative significant heterosis over mid parent. The maximum heterosis was shown by the cross Violet Cushion x Kamini (11.53%) followed by Violet Cushion x P.G.Purple (9.79%).

The range of heterosis over better parent was from -15.32 per cent (Poornima x P.G.Purple) to 5.23 per cent (Violet Cushion x P.G.Purple) for the trait. One cross showed positive significant heterosis while, seven crosses recorded negative significant heterosis over better parent.

The heterosis over standard check Kamini ranged from 0.28 per cent (Poornima x P.G.Purple) to 24.61 per cent (Violet Cushion x P.G.Purple). Twenty crosses exhibited positive significant heterosis over standard check (Table 10).

Table 9. ***Per se*** **performance and nature of heterosis for days for flower bud initiation**

Sl. No.	Cross	Days for first flower bud initiation					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	69.30	58.60	65.30	2.11	-5.77**	11.43**
2	AAC-1 x P.G.Purple	69.30	63.20	65.10	-1.74	-6.06**	11.09**
3	AAC-1 x Poornima	69.30	69.80	69.10	-0.65	-1.00	17.92**
4	AAC-1 x Violet Cushion	69.30	67.30	69.90	2.34	3.86	19.28**
5	Kamini x AAC-1	58.60	69.30	70.20	9.77**	1.30	19.80**
6	Kamini x P.G.Purple	58.60	63.20	61.30	0.66	-3.01	4.61*
7	Kamini x Poornima	58.60	69.80	61.90	-3.58	-11.32**	5.63*
8	Kamini x Violet Cushion	58.60	67.30	65.60	4.21*	-2.53	11.95**
9	P.G.Purple x AAC-1	63.20	69.30	63.10	-4.75*	-8.95**	7.68**
10	P.G.Purple x Kamini	63.20	58.60	61.90	1.64	-2.06	5.63*
11	P.G.Purple x Poornima	63.20	69.80	61.10	-8.12**	-12.46**	4.27
12	P.G.Purple x Violet Cushion	63.20	67.30	70.60	8.20**	4.90*	20.48**
13	Poornima x AAC-1	69.80	69.30	69.20	-0.50	-0.86	18.09**
14	Poornima x Kamini	69.80	58.60	57.20	-10.90**	-18.05**	-2.39
15	Poornima x P.G.Purple	69.80	63.20	57.30	-13.83**	-17.91**	-2.22
16	Poornima x Violet Cushion	69.80	67.30	69.90	1.97	0.14	19.28**
17	Violet Cushion x AAC-1	67.30	69.30	70.80	3.66	2.16	20.82**
18	Violet Cushion x Kamini	67.30	58.60	70.30	11.68**	4.46*	19.97**
19	Violet Cushion x P.G.Purple	67.30	63.20	72.00	10.34**	6.98**	22.87**
20	Violet Cushion x Poornima	67.30	69.30	70.30	2.93	1.44	19.97**
S.Em ±		**1.95**	**1.95**	**1.17**	**1.71**	**1.98**	**1.98**
C.D 5%		**5.79**	**5.79**	**3.49**	**3.54**	**4.09**	**4.09**
C.D 1%		**7.91**	**7.91**	**4.77**	**4.83**	**5.57**	**5.57**

*Significant at 5 per cent level   ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent   MP- Mid parent   BP- Better parent   SC- Standard check (Kamini)

Table 10. *Per se* performance and nature of heterosis for days for first flowering

Sl. No.	Cross	Days for first flowering					
		***Per se* performance**			**% Heterosis over**		
		P_1	**P_2**	**F_1**	**MP**	**BP**	**SC**
1	AAC-1 x Kamini	82.60	71.10	77.70	1.11	-5.93**	9.28**
2	AAC-1 x P.G.Purple	82.60	77.20	78.20	-2.13	-5.33**	9.99**
3	AAC-1 x Poornima	82.60	84.20	81.90	-1.80	-2.73	15.19**
4	AAC-1 x Violet Cushion	82.60	84.20	82.80	-0.72	-1.66	16.46**
5	Kamini x AAC-1	71.10	82.60	83.70	8.91**	1.33	17.72**
6	Kamini x P.G.Purple	71.10	77.20	75.40	1.69	-2.33	6.05**
7	Kamini x Poornima	71.10	84.20	74.90	-3.54*	-11.05**	5.34**
8	Kamini x Violet Cushion	71.10	84.20	81.60	5.09**	-3.09	14.77**
9	P.G.Purple x AAC-1	77.20	82.60	76.00	-4.88**	-7.99**	6.89**
10	P.G.Purple x Kamini	77.20	74.10	75.90	2.36	-1.68	6.75**
11	P.G.Purple x Poornima	77.20	84.20	73.70	-8.67**	-12.47**	3.66
12	P.G.Purple x Violet Cushion	77.20	84.20	86.60	7.31**	2.85	21.80**
13	Poornima x AAC-1	84.20	82.60	82.20	-1.44	-2.38	15.61**
14	Poornima x Kamini	84.20	71.10	72.10	-7.15**	-14.37**	1.41
15	Poornima x P.G.Purple	84.20	77.20	71.30	-11.65**	-15.32**	0.28
16	Poornima x Violet Cushion	84.20	84.20	85.60	1.66	1.66	20.39**
17	Violet Cushion x AAC-1	84.20	82.60	86.80	4.08*	3.09	22.08**
18	Violet Cushion x Kamini	84.20	71.10	86.60	11.53**	2.85	21.80**
19	Violet Cushion x P.G.Purple	84.20	77.20	88.60	9.79**	5.23**	24.61**
20	Violet Cushion x Poornima	84.20	84.20	86.80	3.09	3.09	22.08**
	S.Em ±	**2.14**	**2.14**	**1.17**	**1.82**	**2.10**	**2.10**
	C.D 5%	**6.34**	**6.34**	**3.46**	**3.76**	**4.34**	**4.34**
	C.D 1%	**8.66**	**8.66**	**4.74**	**5.12**	**5.92**	**5.92**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

4.2.1.9 Days for 50% flowering

The days for fifty per cent flowering varied from 83.30 (Kamini) to 97.20 (Violet Cushion) for parents and 84.00 (Poornima x Kamini) to 102.10 (Violet Cushion x P.G.Purple) for F_1 s.

The magnitude of heterosis over mid parent varied from -9.58 per cent (Poornima x P.G.Purple) to 10.14 per cent (Violet Cushion x Kamini). Six crosses showed positive significant heterosis while, six of crosses showed negative significance heterosis over mid parent.

For better parent heterosis ranged from -13.20 per cent (Poornima x P.G.Purple) to 5.04 per cent (Violet Cushion x P.G.Purple). One cross showed positive significance heterosis while, eleven crosses recorded negative significance heterosis over better parent.

The standard heterosis over check Kamini ranged from 0.24 per cent (Poornima x P.G.Purple) to 22.57 per cent (Violet Cushion x P.G.Purple). Seventeen crosses exhibited positive significant heterosis over the standard check in the desirable direction (Table 11).

4.2.1.10 Duration of flowering

Among the parents duration of flowering ranged from 30.11 (Poornima) to 39.04 (Violet Cushion). However, for the F_1 s, it ranged from 31.68 (Poornima x Violet Cushion) to 38.36 (AAC-1 x P.G.Purple).

The mid parent heterosis ranged from -11.47 per cent (Violet Cushion x P.G.Purple) to 17.21 per cent (AAC-1 x Poornima) for the trait. Nine crosses exhibited positive significant heterosis while, four crosses showed negative significant heterosis over mid parent.

The range of heterosis over the better parent was from -20.42 per cent (Poornima x Violet Cushion) to 12.71 per cent (Poornima x Kamini). Two crosses showed positive significance heterosis while, thirteen crosses recorded negative significance heterosis over better parent.

Table 11. *Per se* performance and nature of heterosis for days for 50 per cent flowering

Sl. No.	Cross	Days for 50 per cent flowering					
		***Per se* performance**			**% Heterosis over**		
		P_1	**P_2**	**F_1**	**MP**	**BP**	**SC**
1	AAC-1 x Kamini	92.40	83.30	87.80	-0.06	-4.98**	5.40**
2	AAC-1 x P.G.Purple	92.40	88.50	88.60	-2.05	-4.11**	6.36**
3	AAC-1 x Poornima	92.40	96.20	91.20	-3.29*	-5.20**	9.48**
4	AAC-1 x Violet Cushion	92.40	97.20	92.90	-2.00	-4.42**	11.52**
5	Kamini x AAC-1	83.30	92.40	93.80	6.77**	1.52	12.61**
6	Kamini x P.G.Purple	83.30	88.50	86.80	1.05	-1.92	4.20*
7	Kamini x Poornima	83.30	96.20	84.40	-5.96**	-12.27**	1.32
8	Kamini x Violet Cushion	83.30	97.20	92.30	2.27	-5.04**	10.80**
9	P.G.Purple x AAC-1	88.50	92.40	87.80	-2.93*	-4.98**	5.40**
10	P.G.Purple x Kamini	88.50	83.30	87.90	2.33	-0.68	5.52**
11	P.G.Purple x Poornima	88.50	96.20	86.50	-6.33**	-10.08**	3.84*
12	P.G.Purple x Violet Cushion	88.50	97.20	96.90	4.36**	-0.31	16.33**
13	Poornima x AAC-1	96.20	92.40	93.40	-0.95	-2.91*	12.12**
14	Poornima x Kamini	96.20	83.30	84.00	-6.41**	-12.68**	0.84
15	Poornima x P.G.Purple	96.20	88.50	83.50	-9.58**	-13.20**	0.24
16	Poornima x Violet Cushion	96.20	97.20	97.30	0.62	0.10	16.81**
17	Violet Cushion x AAC-1	97.20	92.40	98.60	4.01**	1.44	18.37**
18	Violet Cushion x Kamini	97.20	83.30	99.40	10.14**	2.26	19.33**
19	Violet Cushion x P.G.Purple	97.20	88.50	102.10	9.96**	5.04**	22.57**
20	Violet Cushion x Poornima	97.20	96.20	99.70	3.10*	2.57	19.69**
S.Em ±		**1.94**	**1.94**	**1.23**	**3.16**	**2.05**	**2.05**
C.D 5%		**5.76**	**5.76**	**3.64**	**3.67**	**4.23**	**4.23**
C.D 1%		**7.87**	**7.87**	**4.97**	**5.00**	**5.77**	**5.77**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

The heterosis over standard check Kamini ranged from 1.71 per cent (Poornima x Violet Cushion) to 23.16 per cent (AAC-1 x P.G.Purple). Out of twenty crosses, eighteen crosses showed positive significant heterosis over standard check Kamini (Table 12).

4.2.1.11 Number of flowers per plant

Among the parents the number of flowers per plant ranged from 32.60 (Poornima) to 68.20 (Violet Cushion). However, for the F_1 s, it ranged from 48.00 (Kamini x Poornima) to 67.30 (Violet Cushion x AAC-1).

The mid parent heterosis ranged from -17.38 per cent (Poornima x Kamini) to 38.42 per cent (AAC-1 x Poornima) for the trait. Seventeen crosses exhibited positive significant heterosis while, One of cross showed negative significant heterosis over mid parent. The range of heterosis over the better parent was varied from -29.91 per cent (Poornima x Kamini) to 21.81 per cent (Kamini x AAC-1). Four crosses showed positive significance heterosis while, seven crosses recorded negative significance heterosis over better parent.

The heterosis over standard check Kamini ranged from -29.91 per cent (Poornima x Kamini) to 43.80 per cent (Violet Cushion x AAC-1). Out of twenty crosses, nineteen crosses showed positive significant heterosis over standard check (Table 13).

4.2.1.12 Individual flower weight (g)

The individual flower weight ranged from 2.98 (Kamini) to 4.00 (Violet Cushion) and 2.86 (Poornima x Kamini) to 4.21 (AAC-1 x P.G.Purple) for parents and crosses, repectively.

Seven crosses exhibited positive significant heterosis while two crosses showed negative significant heterosis over mid parent. The maximum heterosis was shown by the cross AAC-1 x P.G.Purple (34.27%) followed by Kamini x P.G.Purple (14.84%).

The range of heterosis over better parent was from -18.84 per cent (Poornima x Kamini) to 33.44 per cent (AAC-1 x P.G.Purple) for the trait. Three crosses showed

Table 12. *Per se* performance and nature of heterosis for duration of flowering

Sl. No.	Cross	Duration of flowering					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	34.47	31.15	34.98	6.61**	1.46	12.30**
2	AAC-1 x P.G.Purple	34.47	39.33	38.36	3.96*	-2.46	23.16**
3	AAC-1 x Poornima	34.47	30.11	37.85	17.21**	9.79**	21.51**
4	AAC-1 x Violet Cushion	34.47	39.04	37.55	1.11	-5.67**	20.56**
5	Kamini x AAC-1	31.15	34.47	34.60	5.44**	0.36	11.07**
6	Kamini x P.G.Purple	31.15	39.33	37.45	6.27**	-4.78**	20.23**
7	Kamini x Poornima	31.15	30.11	31.82	3.89	2.16	2.16
8	Kamini x Violet Cushion	31.15	39.04	37.65	6.13**	-5.41**	20.89**
9	P.G.Purple x AAC-1	39.33	34.47	35.27	-4.41*	-10.31**	13.25**
10	P.G.Purple x Kamini	39.33	31.15	35.33	0.27	-10.16**	13.44**
11	P.G.Purple x Poornima	39.33	30.11	35.04	0.91	-10.92**	12.48**
12	P.G.Purple x Violet Cushion	39.33	39.04	35.32	-10.74**	-11.28**	13.39**
13	Poornima x AAC-1	30.11	34.47	33.86	4.87*	-1.77	8.72**
14	Poornima x Kamini	30.11	31.15	35.11	14.63**	12.71**	12.71**
15	Poornima x P.G.Purple	30.11	39.33	36.88	6.23**	-6.22**	18.41**
16	Poornima x Violet Cushion	30.11	39.04	31.68	-9.38**	-20.42**	1.71
17	Violet Cushion x AAC-1	39.04	34.47	36.36	-2.11	-8.67**	16.72**
18	Violet Cushion x Kamini	39.04	31.15	35.62	0.41	-10.51**	14.37**
19	Violet Cushion x P.G.Purple	39.04	39.33	34.92	-11.74**	-12.27**	12.12**
20	Violet Cushion x Poornima	39.04	30.11	35.65	1.97	-10.45**	14.44**
	S.Em ±	**0.48**	**0.48**	**0.75**	**0.86**	**0.99**	**0.99**
	C.D 5%	**1.42**	**1.42**	**2.23**	**1.78**	**2.06**	**2.06**
	C.D 1%	**1.94**	**1.94**	**1.62**	**2.43**	**2.80**	**2.80**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

Table 13. *Per se* performance and nature of heterosis for number of flowers per plant

Sl. No.	Cross	Number of flowers/plant					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	48.60	46.80	50.70	6.29*	4.32*	8.33**
2	AAC-1 x P.G.Purple	48.60	58.50	52.50	-1.96	-10.26**	12.18**
3	AAC-1 x Poornima	48.60	32.60	56.20	38.42**	15.64**	20.09**
4	AAC-1 x Violet Cushion	48.60	68.20	63.40	8.56**	-7.04**	35.47**
5	Kamini x AAC-1	46.80	48.60	59.20	24.11**	21.81**	26.50**
6	Kamini x P.G.Purple	46.80	58.50	58.40	10.92**	-0.17	24.79**
7	Kamini x Poornima	46.80	32.60	48.00	20.91**	2.56	2.56
8	Kamini x Violet Cushion	46.80	68.20	66.60	15.83**	-2.35	42.31**
9	P.G.Purple x AAC-1	58.50	48.60	52.20	-2.52	-10.77**	11.54**
10	P.G.Purple x Kamini	58.50	46.80	56.60	7.50**	-3.25	20.94**
11	P.G.Purple x Poornima	58.50	32.60	57.20	25.58**	-2.22	22.22**
12	P.G.Purple x Violet Cushion	58.50	68.20	66.60	5.13**	-2.35	42.31**
13	Poornima x AAC-1	32.60	48.60	54.70	34.73**	12.55**	16.88**
14	Poornima x Kamini	32.60	46.80	32.80	-17.38**	-29.91**	-29.91**
15	Poornima x P.G.Purple	32.60	58.50	53.60	17.67**	-8.38**	14.53**
16	Poornima x Violet Cushion	32.60	68.20	65.60	30.16**	-3.81*	40.17**
17	Violet Cushion x AAC-1	68.20	48.60	67.30	15.24**	-1.32	43.80**
18	Violet Cushion x Kamini	68.20	46.80	66.20	15.13**	-2.93	41.45**
19	Violet Cushion x P.G.Purple	68.20	58.50	66.20	4.50**	-2.93	41.45**
20	Violet Cushion x Poornima	68.20	32.60	65.90	30.75**	-3.37*	40.81**
S.Em ±		**0.68**	**0.68**	**1.11**	**1.37**	**1.58**	**1.58**
C.D 5%		**2.03**	**2.03**	**3.30**	**2.84**	**3.27**	**3.27**
C.D 1%		**2.78**	**2.78**	**4.51**	**3.87**	**4.46**	**4.46**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

positive significance heterosis while, eleven crosses recorded negative significant heterosis over better parent.

The heterosis over standard check Kamini ranged from -3.93 per cent (Poornima x Kamini) to 41.50 per cent (AAC-1 x P.G.Purple). Twelve crosses exhibited positive significant heterosis over standard check Kamini (Table 14).

4.2.1.13 Weight of ten flowers (g)

The range of variation recorded from 29.23 (Kamini) to 45.26 (Violet Cushion) and from 28.66 (Poornima x Kamini) to 40.78 (AAC-1 x Poornima and AAC-1 x Violet Cushion) for parents and hybrids, repectively.

Four crosses exhibited positive significant and none of the crosses showed negative significant heterosis over mid parent and the range varied from -9.55 per cent (P.G.Purple x Violet Cushion) to 26.57 per cent (AAC-1 x Poornima). Better parent heterosis varied from -23.82 per cent (P.G.Purple x Violet Cushion) to 23.87 per cent (AAC-1 x Poornima). Three parents showed positive significant heterosis and nine parents exhibited negative significant heterosis over better parent.

For standard check, heterosis varied from -1.95 per cent (Poornima x Kamini) to 39.51 per cent (AAC-1 x Poornima). Twelve parents showed positive significant count for the trait (Table 15)

4.2.1.14 Flower yield per plant (g)

The flower yield per plant varied from 114.77 (Poornima) to 272.51 (Violet Cushion) for parents and 93.83 (Poornima x Kamini) to 257.01 (AAC-1 x Violet Cushion) for F_1 s.

The magnitude of heterosis over mid parent varied from -26.17 per cent (Poornima x Kamini) to 55.85 per cent (AAC-1 x Poornima). Seventeen parents showed positive significant heterosis while, one of cross (Poornima x Kamini) showed negative significance heterosis over mid parent.

Table 14. *Per se* performance and nature of heterosis for individual flower weight

Sl. No.	Cross	Individual flower weight (g)					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	3.16	2.98	3.49	13.79**	10.54**	17.23**
2	AAC-1 x P.G.Purple	3.16	3.12	4.21	34.27**	33.44**	41.50**
3	AAC-1 x Poornima	3.16	3.53	3.72	11.36**	5.56	24.95**
4	AAC-1 x Violet Cushion	3.16	4.00	4.06	13.36**	1.48	36.17**
5	Kamini x AAC-1	2.98	3.16	3.18	3.52	0.57	6.65
6	Kamini x P.G.Purple	2.98	3.12	3.50	14.84**	12.25**	17.56**
7	Kamini x Poornima	2.98	3.53	3.12	-4.08	-11.52**	4.73
8	Kamini x Violet Cushion	2.98	4.00	3.74	7.23*	-6.43*	25.55**
9	P.G.Purple x AAC-1	3.12	3.16	3.13	-0.24	-0.85	5.14
10	P.G.Purple x Kamini	3.12	2.98	3.12	2.48	0.16	4.90
11	P.G.Purple x Poornima	3.12	3.53	3.17	-4.73	-10.21**	6.28
12	P.G.Purple x Violet Cushion	3.12	4.00	3.43	-3.47	-14.06**	15.31**
13	Poornima x AAC-1	3.53	3.16	3.21	-4.00	-8.99**	7.72
14	Poornima x Kamini	3.53	2.98	2.86	-12.01**	-18.84**	-3.93
15	Poornima x P.G.Purple	3.53	3.12	3.19	-3.85	-9.39**	7.25
16	Poornima x Violet Cushion	3.53	4.00	3.52	-6.48*	-11.99**	18.10**
17	Violet Cushion x AAC-1	4.00	3.16	3.65	2.04	-8.66**	22.57**
18	Violet Cushion x Kamini	4.00	2.98	3.71	6.25	-7.28*	24.41**
19	Violet Cushion x P.G.Purple	4.00	3.12	3.87	8.73*	-3.20	29.89**
20	Violet Cushion x Poornima	4.00	3.53	3.71	-1.29	-7.11*	24.65**
S.Em ±		**0.10**	**0.10**	**0.14**	**0.16**	**0.18**	**0.18**
C.D 5%		**0.32**	**0.32**	**0.41**	**0.33**	**0.38**	**0.38**
C.D 1%		**0.43**	**0.43**	**0.57**	**0.45**	**0.52**	**0.52**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

Table 15. *Per se* performance and nature of heterosis for weight of ten flowers

Sl. No.	Cross	Weight of ten flowers (g)					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	31.42	29.23	34.20	12.78*	8.85	17.00*
2	AAC-1 x P.G.Purple	31.42	30.98	38.92	24.74**	23.50**	33.15**
3	AAC-1 x Poornima	31.42	33.02	40.78	26.57**	23.87**	39.51**
4	AAC-1 x Violet Cushion	31.42	45.26	40.78	6.36	-9.90*	39.51**
5	Kamini x AAC-1	29.23	31.42	31.72	4.60	0.95	8.52
6	Kamini x P.G.Purple	29.23	30.98	35.24	17.06**	13.75**	20.56**
7	Kamini x Poornima	29.23	33.02	30.01	-3.58	-9.12	2.67
8	Kamini x Violet Cushion	29.23	45.26	37.97	1.95	-16.11**	29.90**
9	P.G.Purple x AAC-1	30.98	31.42	31.74	1.73	1.02	8.59
10	P.G.Purple x Kamini	30.98	29.23	31.76	5.50	2.52	8.66
11	P.G.Purple x Poornima	30.98	33.02	31.21	-2.47	-5.48	6.77
12	P.G.Purple x Violet Cushion	30.98	45.26	34.48	-9.55	-23.82**	17.96**
13	Poornima x AAC-1	33.02	31.42	32.59	1.15	-1.30	11.50
14	Poornima x Kamini	33.02	29.23	28.66	-7.92	-13.20*	-1.95
15	Poornima x P.G.Purple	33.02	30.98	30.48	-4.75	-7.69	4.28
16	Poornima x Violet Cushion	33.02	45.02	37.61	-3.61	-16.46**	28.67**
17	Violet Cushion x AAC-1	45.26	31.42	37.10	-3.23	-18.03**	26.92**
18	Violet Cushion x Kamini	45.26	29.23	36.80	-1.19	-18.69**	25.90**
19	Violet Cushion x P.G.Purple	45.26	30.98	38.63	1.34	-14.65**	32.16**
20	Violet Cushion x Poornima	45.26	33.02	35.87	-8.35	-20.75**	22.72**
S.Em ±		**2.74**	**2.74**	**1.84**	**2.51**	**2.90**	**2.90**
C.D 5%		**8.12**	**8.12**	**5.46**	**5.18**	**5.98**	**5.89**
C.D 1%		**11.10**	**11.10**	**7.46**	**7.06**	**8.15**	**8.15**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

For better parent heterosis ranged from -32.69 per cent (Poornima x Kamini) to 36.15 per cent (AAC-1 x Poornima). Six crosses showed positive significance heterosis while, nine crosses recorded negative significance heterosis over better parent.

The standard heterosis over check Kamini ranged from -32.69 per cent (Poornima x Kamini) to 84.37 per cent (AAC-1 x Violet Cushion). Eighteen crosses exhibited positive significant heterosis over standard check in the desirable direction (Table 16 and Plate 5).

4.2.1.15 Flower yield per hectare (t/ha)

The range of variation recorded from 12.75 (Poornima) to 30.28 (Violet Cushion) and from 10.43 (Poornima x Kamini) to 28.56 (AAC-1 x Violet Cushion) for parents and hybrids, repectively.

Seventeen crosses exhibited positive significant and one cross showed negative significant heterosis over mid parent and range varied from -56.85 per cent (Poornima x Kamini) to 26.06 per cent (AAC-1 x Poornima). Better parent heterosis varied from -59.30 per cent (Poornima x Kamini) to 15.48 per cent (AAC-1 x P.G.Purple). Four crosses showed positive significant heterosis and fifteen crosses exhibited negative significant heterosis over better parent.

For standard check, heterosis varied from -54.10 per cent (Poornima x Kamini) to 25.76 per cent (AAC-1 x Poornima). Eight crosses showed positive significant count for the trait (Table 17).

4.2.1.16 Flower stalk length (cm)

Among the parents flower stalk length ranged from 17.55 (AAC-1) to 20.40 (Kamini). However, for the F_1 s, it ranged from 14.50 (P.G.Purple x Violet Cushion) to 23.80 (Violet Cushion x AAC-1).

The mid parent heterosis ranged from -24.48 per cent (P.G.Purple x Poornima) to 27.96 per cent (Violet Cushion x AAC-1) for the triat. Three crosses exhibited positive significant heterosis while, three of crosses showed negative significant heterosis over mid parent.

Table 16. ***Per se*** **performance and nature of heterosis for flower yield per plant**

Sl. No.	Cross	Flower yield/plant (g)					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	153.60	139.40	177.24	20.98**	15.39**	27.14**
2	AAC-1 x P.G.Purple	153.60	182.47	221.24	31.67**	21.25**	58.71**
3	AAC-1 x Poornima	153.60	114.77	209.12	55.85**	36.15**	50.01**
4	AAC-1 x Violet Cushion	153.60	272.51	257.01	20.63**	-5.69	84.37**
5	Kamini x AAC-1	139.40	153.60	188.10	28.39**	22.46**	34.93**
6	Kamini x P.G.Purple	139.40	182.47	204.39	27.00**	12.02**	46.62**
7	Kamini x Poornima	139.40	114.77	149.74	17.83**	7.42	7.42
8	Kamini x Violet Cushion	139.40	272.51	249.02	20.91**	-8.62**	78.63**
9	P.G.Purple x AAC-1	182.47	153.60	163.35	-2.79	-10.48*	17.17**
10	P.G.Purple x Kamini	182.47	139.40	176.73	9.82*	-3.14	26.78**
11	P.G.Purple x Poornima	182.47	114.77	181.13	21.88**	-0.73	29.93**
12	P.G.Purple x Violet Cushion	182.47	272.51	228.76	0.56	-16.06**	64.10**
13	Poornima x AAC-1	114.77	153.60	175.40	30.72**	14.20**	25.82**
14	Poornima x Kamini	114.77	139.40	93.83	-26.17**	-32.69**	-32.69**
15	Poornima x P.G.Purple	114.77	182.47	170.93	15.01**	-6.32	22.62**
16	Poornima x Violet Cushion	114.77	272.51	230.53	19.05**	-15.41**	65.37**
17	Violet Cushion x AAC-1	272.51	153.60	245.80	15.37**	-9.80**	76.32**
18	Violet Cushion x Kamini	272.51	139.40	245.28	19.09**	-9.99**	75.95**
19	Violet Cushion x P.G.Purple	272.51	182.47	255.95	12.51**	-6.08*	83.60**
20	Violet Cushion x Poornima	272.51	114.77	244.89	26.47**	-10.14**	75.67**
S.Em ±		**5.29**	**5.29**	**9.33**	**10.77**	**12.44**	**12.44**
C.D 5%		**15.66**	**15.66**	**27.62**	**22.54**	**25.68**	**25.68**
C.D 1%		**21.41**	**21.41**	**37.75**	**30.31**	**35.00**	**35.00**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

Table 17. ***Per se*** **performance and nature of heterosis for flower yield per hectare**

Sl. No.	Cross	Flower yield/ha(t)					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	17.07	15.49	19.69	15.95**	8.26*	8.26*
2	AAC-1 x P.G.Purple	17.07	20.27	24.58	16.73**	15.48**	2.33
3	AAC-1 x Poornima	17.07	12.75	23.24	26.06**	11.50**	25.76**
4	AAC-1 x Violet Cushion	17.07	30.28	28.56	-31.71**	-43.64**	-24.86**
5	Kamini x AAC-1	15.49	17.07	20.90	-1.43	-7.97*	-7.97*
6	Kamini x P.G.Purple	15.49	20.27	22.71	-22.33**	-26.75**	-26.75**
7	Kamini x Poornima	15.49	12.75	16.64	14.52**	8.02*	21.84**
8	Kamini x Violet Cushion	15.49	30.28	27.67	-41.54**	-48.84**	-31.79**
9	P.G.Purple x AAC-1	20.27	17.07	18.15	-8.84*	-9.81*	-20.08**
10	P.G.Purple x Kamini	20.27	15.49	19.64	-8.30*	-13.52**	-13.52**
11	P.G.Purple x Poornima	20.27	12.75	20.13	11.13**	-0.78	11.91**
12	P.G.Purple x Violet Cushion	20.27	30.28	25.42	-19.57**	-33.06**	-10.74**
13	Poornima x AAC-1	12.75	17.07	19.49	-13.97**	-23.91**	-14.18**
14	Poornima x Kamini	12.75	15.49	10.43	-56.85**	-59.30**	-54.10**
15	Poornima x P.G.Purple	12.75	20.27	18.99	-16.97**	-25.86**	-16.38**
16	Poornima x Violet Cushion	12.75	30.28	25.61	-54.38**	-57.89**	-43.86**
17	Violet Cushion x AAC-1	30.28	17.07	27.31	9.29*	-9.81**	20.26**
18	Violet Cushion x Kamini	30.28	15.49	27.25	2.87	-9.99**	20.01**
19	Violet Cushion x P.G.Purple	30.28	20.27	28.44	12.83**	-6.09*	25.21**
20	Violet Cushion x Poornima	30.28	12.75	27.21	-2.64	-10.14**	19.82**
	S.Em ±	**0.58**	**0.58**	**1.03**	**1.19**	**1.38**	**1.38**
	C.D 5%	**1.74**	**1.74**	**3.06**	**2.45**	**2.84**	**2.84**
	C.D 1%	**2.37**	**2.37**	**4.19**	**3.32**	**3.85**	**3.85**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)


AAC-1 x Violet Cushion


Violet Cushion x P.G.Purple


Standard check Kamini

Plate 5: Top two crosses and standard check Kamini for yield

The range of heterosis over the better parent was from -26.40 per cent (P.G.Purple x Poornima) to 22.37 per cent (Violet Cushion x AAC-1). One cross showed positive significance heterosis while, five crosses recorded negative significance heterosis over better parent.

The heterosis over standard check Kamini ranged from -13.69 per cent (P.G.Purple x Poornima) to 41.67 per cent (Violet Cushion x AAC-1). Out of twenty crosses, four crosses showed positive significant heterosis over standard check (Table 18).

4.2.1.17 Flower diameter (cm)

The flower diameter varied from 5.54 (Kamini) to 6.98 (Violet Cushion) for parents and 5.16 (Violet Cushion x Kamini) to 6.47 (AAC-1 x Kamini) for F_1 s.

The magnitude of heterosis over mid parent varied from -22.38 per cent (P.G.Purple x Violet Cushion) to 8.07 per cent (Kamini x Poornima). Two parents showed positive significant heterosis while, fifteen of crosses showed negative significant heterosis over mid parent.

For better parent heterosis, it ranged from -27.94 per cent (P.G.Purple x Violet Cushion) to 4.01 per cent (Kamini x Poornima). None of crosses showed positive significance heterosis while, seventeen crosses recorded negative significance heterosis over better parent.

The standard heterosis over check Kamini ranged from -9.21 per cent (P.G.Purple x Violet Cushion) to 16.79 per cent (AAC-1 x Kamini). Six crosses exhibited positive significance and two crosses exhibited negative significant heterosis over standard check in the desirable direction (Table 19).

4.2.1.18 Ray floret length (cm)

The ray floret length ranged from 2.67 (Kamini) to 3.60 (AAC-1) and 2.55 (Violet Cushion x AAC-1) to 3.72 (AAC-1 x P.G.Purple) for parents and crosses, repectively.

Table 18. ***Per se*** **performance and nature of heterosis for flower stalk length**

Sl. No.	Cross	Flower stalk length (cm)					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	17.55	20.40	17.75	5.93	3.10	8.93
2	AAC-1 x P.G.Purple	17.55	19.80	18.30	-11.35*	-15.74**	-1.19
3	AAC-1 x Poornima	17.55	18.45	16.60	0.41	-2.14	8.93
4	AAC-1 x Violet Cushion	17.55	19.45	18.30	-5.65	-9.77	4.46
5	Kamini x AAC-1	20.40	17.55	17.30	0.14	-2.54	2.98
6	Kamini x P.G.Purple	20.40	19.80	16.80	1.92	-5.58	10.71
7	Kamini x Poornima	20.40	18.45	18.60	-7.61	-12.30*	-2.38
8	Kamini x Violet Cushion	20.40	19.45	16.40	12.55*	4.88	21.43**
9	P.G.Purple x AAC-1	19.80	17.55	19.20	2.54	-2.54	14.29*
10	P.G.Purple x Kamini	19.80	20.40	17.25	-5.48	-12.44*	2.68
11	P.G.Purple x Poornima	19.80	18.45	19.70	-24.48**	-26.40**	-13.69*
12	P.G.Purple x Violet Cushion	19.80	19.45	14.50	1.15	0.51	17.86
13	Poornima x AAC-1	18.45	17.55	17.10	-6.17	-8.56	1.79
14	Poornima x Kamini	18.45	20.40	18.50	4.23	-1.07	10.12
15	Poornima x P.G.Purple	18.45	19.80	16.75	-12.76*	-14.97**	-0.30
16	Poornima x Violet Cushion	18.45	19.45	18.70	-3.28	-5.14	9.82
17	Violet Cushion x AAC-1	19.45	17.55	23.80	27.96**	22.37**	41.67**
18	Violet Cushion x Kamini	19.45	20.40	21.10	16.41**	8.48	25.60**
19	Violet Cushion x P.G.Purple	19.45	19.80	18.75	-4.21	-4.82	11.61
20	Violet Cushion x Poornima	19.45	18.45	17.65	-7.47	-9.25	5.06
S.Em ±		**0.39**	**0.39**	**1.23**	**1.36**	**1.57**	**1.57**
C.D 5%		**1.17**	**1.17**	**3.66**	**2.81**	**3.25**	**3.25**
C.D 1%		**1.57**	**1.57**	**5.00**	**3.84**	**3.84**	**3.84**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

Table 19. ***Per se*** **performance and nature of heterosis for flower diameter**

Sl. No.	Cross	Flower diameter (cm)					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	6.54	5.54	6.47	7.12**	-1.07	16.79**
2	AAC-1 x P.G.Purple	6.54	5.98	5.88	-6.07**	-10.09**	6.14**
3	AAC-1 x Poornima	6.54	5.99	5.38	-14.13**	-17.74**	-2.89
4	AAC-1 x Violet Cushion	6.54	6.98	5.95	-11.98**	-14.76**	7.40**
5	Kamini x AAC-1	5.54	6.54	5.79	-4.14*	-11.47**	4.51*
6	Kamini x P.G.Purple	5.54	5.98	5.86	1.74	-2.01	5.78*
7	Kamini x Poornima	5.54	5.99	6.23	8.07**	4.01	12.45**
8	Kamini x Violet Cushion	5.54	6.98	5.48	-12.46**	-21.49**	-1.08
9	P.G.Purple x AAC-1	5.98	6.54	5.43	-13.26**	-16.97**	-1.99
10	P.G.Purple x Kamini	5.98	5.54	5.63	-2.26	-5.85**	1.62
11	P.G.Purple x Poornima	5.98	5.99	5.54	-7.44**	-7.51**	0.00
12	P.G.Purple x Violet Cushion	5.98	6.98	5.03	-22.38**	-27.94**	-9.21**
13	Poornima x AAC-1	5.99	6.54	5.70	-9.02**	-12.84**	2.89
14	Poornima x Kamini	5.99	5.54	5.66	-1.82	-5.51**	2.17
15	Poornima x P.G.Purple	5.99	5.98	5.66	-5.43**	-5.51**	2.17
16	Poornima x Violet Cushion	5.99	6.98	5.60	-13.65**	-19.77**	1.08
17	Violet Cushion x AAC-1	6.98	6.54	5.40	-20.12**	-22.64**	-2.53
18	Violet Cushion x Kamini	6.98	5.54	5.16	-17.57**	-26.07**	-6.86**
19	Violet Cushion x P.G.Purple	6.98	5.98	5.52	-14.81**	-20.92**	-0.36
20	Violet Cushion x Poornima	6.98	5.99	5.33	-17.81**	-23.64**	-3.79
	S.Em ±	**0.04**	**0.04**	**0.13**	**0.16**	**0.19**	**0.19**
	C.D 5%	**0.14**	**0.14**	**0.41**	**0.34**	**0.39**	**0.39**
	C.D 1%	**0.19**	**0.19**	**0.56**	**0.46**	**0.53**	**0.53**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

Two crosses exhibited positive significant heterosis while three crosses showed negative significant heterosis over mid parent. The maximum heterosis was shown by the cross AAC-1 x Poornima (16.21%) followed by AAC-1 x Kamini (15.80%).

The range of heterosis over better parent was from -27.45 per cent (Violet Cushion x AAC-1) to 7.39 per cent (P.G.Purple x Kamini) for the trait. None of crosses showed positive significance heterosis while, five crosses recorded negative significant heterosis over better parent.

The heterosis over standard check Kamini ranged from -12.37 per cent (Violet Cushion x AAC-1) to 27.49 per cent (AAC-1 x Poornima). Five crosses exhibited positive significance and one cross showed negative significant heterosis over standard check Kamini (Table 20).

4.2.1.19 Disc floret length (cm)

The range of variation recorded from 2.18 (Kamini) to 4.08 (Violet Cushion) and from 1.72 (P.G.Purple x AAC-1) to 3.61 (Kamini x Violet Cushion) for parents and hybrids, repectively.

None of crosses exhibited positive significant but seven cross showed negative significant heterosis over mid parent and range varied from -49.49 per cent (P.G.Purple x AAC-1) to 15.41 per cent (Kamini x Violet Cushion). Better parent heterosis varied from -59.14 per cent (P.G.Purple x AAC-1) to 5.38 per cent (AAC-1 x Kamini). None of crosses showed positive significant heterosis and nine crosses exhibited negative significant heterosis over better parent.

For standard check, heterosis varied from -20.96 per cent (P.G.Purple x AAC-1) to 65.90 per cent (Kamini x Violet Cushion). Eight crosses showed positive significant count for the trait (Table 21).

4.2.1.20 Vase life

Among the parents vase life ranged from 7.70 (Kamini) to 11.70 (Violet Cushion). However, for the F_1 s, it ranged from 7.10 (Poornima x Kamini) to 11.10 (Violet Cushion x P.G.Purple).

Table 20. *Per se* performance and nature of heterosis for ray floret length

Sl. No.	Cross	Ray floret length (cm)					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	3.60	2.67	3.52	15.80**	5.83	27.84**
2	AAC-1 x P.G.Purple	3.60	2.89	3.72	6.63	-5.12	14.60*
3	AAC-1 x Poornima	3.60	2.89	3.34	16.21**	5.55	27.49**
4	AAC-1 x Violet Cushion	3.60	3.17	3.71	7.70	2.42	23.71**
5	Kamini x AAC-1	2.67	3.60	2.85	-11.28*	-18.92**	-2.06
6	Kamini x P.G.Purple	2.67	2.89	2.91	-2.30	-5.15	-5.15
7	Kamini x Poornima	2.67	2.89	2.76	1.38	0.69	0.69
8	Kamini x Violet Cushion	2.67	3.17	2.93	-12.17*	-15.77**	-8.25
9	P.G.Purple x AAC-1	2.89	3.60	3.13	-0.08	-11.10*	7.39
10	P.G.Purple x Kamini	2.89	2.67	3.13	10.62	7.39	7.39
11	P.G.Purple x Poornima	2.89	2.89	2.74	2.32	0.00	-1.37
12	P.G.Purple x Violet Cushion	2.89	3.17	2.87	-2.20	-8.83	-0.69
13	Poornima x AAC-1	2.89	3.60	3.29	3.05	-6.40	13.06*
14	Poornima x Kamini	2.89	2.67	2.65	-8.30	-8.93	-8.9
15	Poornima x P.G.Purple	2.89	2.89	2.96	5.53	3.14	1.72
16	Poornima x Violet Cushion	2.89	3.17	2.87	-4.30	-8.83	-0.69
17	Violet Cushion x AAC-1	3.17	3.60	2.55	-23.71**	-27.45**	-12.37*
18	Violet Cushion x Kamini	3.17	2.67	2.71	-10.86	-14.51**	-6.87
19	Violet Cushion x P.G.Purple	3.17	2.89	3.01	1.86	-5.05	3.44
20	Violet Cushion x Poornima	3.17	2.89	3.06	1.32	-3.47	5.15
S.Em ±		**0.28**	**0.28**	**0.15**	**0.23**	**0.26**	**0.26**
C.D 5%		**0.83**	**0.83**	**0.46**	**0.47**	**0.54**	**0.54**
C.D 1%		**1.13**	**1.13**	**0.63**	**0.64**	**0.74**	**0.74**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

Table 21. ***Per se*** **performance and nature of heterosis for disc floret length**

Sl. No.	Cross	Disc floret length (cm)					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	2.60	2.18	2.74	14.74	5.38	25.92
2	AAC-1 x P.G.Purple	2.60	3.21	1.89	-44.49**	-55.11**	-13.14
3	AAC-1 x Poornima	2.60	2.57	1.90	-26.50	-26.92	-12.68
4	AAC-1 x Violet Cushion	2.60	4.08	3.51	5.09	-13.97	61.31**
5	Kamini x AAC-1	2.18	2.60	2.11	-11.64	-18.85	-3.03
6	Kamini x P.G.Purple	2.18	3.21	2.23	-30.16*	-47.03**	2.48
7	Kamini x Poornima	2.18	2.57	2.18	-8.13	-15.18	0.18
8	Kamini x Violet Cushion	2.18	4.08	3.61	15.41	-11.52	65.90**
9	P.G.Purple x AAC-1	3.21	2.60	1.72	-49.49**	-59.14**	-20.96
10	P.G.Purple x Kamini	3.21	2.18	1.93	-39.56**	-54.16**	-11.31
11	P.G.Purple x Poornima	3.21	2.57	2.00	-41.00**	-52.49**	-8.09
12	P.G.Purple x Violet Cushion	3.21	4.08	3.09	-25.45	-26.60**	42.00*
13	Poornima x AAC-1	2.57	2.60	1.92	-25.73	-26.15	-11.76
14	Poornima x Kamini	2.57	2.18	2.17	-8.55	-15.56	-0.28
15	Poornima x P.G.Purple	2.57	3.21	2.33	-31.27**	-44.66**	7.08
16	Poornima x Violet Cushion	2.57	4.08	3.49	4.96	-14.46	60.39**
17	Violet Cushion x AAC-1	4.08	2.60	3.57	6.89	-12.50	64.06**
18	Violet Cushion x Kamini	4.08	2.18	3.35	7.10	-17.89	53.95**
19	Violet Cushion x P.G.Purple	4.08	3.21	3.38	-18.46*	-19.71*	55.33**
20	Violet Cushion x Poornima	4.80	2.57	3.45	3.76	-15.44	58.55**
S.Em ±		**0.37**	**0.37**	**0.10**	**0.48**	**0.56**	**0.56**
C.D 5%		**1.11**	**1.11**	**0.30**	**1.00**	**1.16**	**1.16**
C.D 1%		**1.52**	**1.52**	**0.41**	**1.36**	**1.58**	**1.58**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

The mid parent heterosis ranged from -25.26 per cent (Poornima x Kamini) to 20.47 per cent (Kamini x P.G.Purple) for the trait. Seven crosses exhibited positive significant heterosis while, six crosses showed negative significant heterosis over mid parent.

The heterosis over the better parent ranged from -37.17 per cent (Poornima x Kamini) to 10.64 per cent (P.G.Purple x AAC-1). Five cross showed positive significant heterosis while, fifteen crosses recorded negative significant heterosis over better parent (Table 22)

The heterosis over standard check Kamini ranged from -7.79 per cent (Poornima x Kamini) to 44.16 per cent (Violet Cushion x P.G.Purple). Out of twenty crosses, eighteen crosses showed positive significant heterosis over standard check Kamini.

4.2.1.21 Seed yield per plant (g)

The flower diameter varied from Poornima (1.73) to Violet Cushion (2.60) for parents and Poornima x Kamini (1.29) to Violet Cushion x P.G.Purple (2.28) for F_1 s.

The magnitude of heterosis over mid parent varied from -40.80 per cent (Kamini x Violet Cushion) to 22.51 per cent (AAC-1 x Poornima). Two parents showed positive significant heterosis while, nine of crosses showed negative significance heterosis over mid parent.

For better parent heterosis ranged from -47.12 per cent (Kamini x Violet Cushion) to 12.53 per cent (AAC-1 x Poornima). One cross (AAC-1 x Poornima) showed positive significance heterosis while, fifteen crosses recorded negative significance heterosis over better parent.

The standard heterosis over check Kamini ranged from -37.16 per cent (Kamini x Violet Cushion) to 11.49 per cent (Violet Cushion x P.G.Purple). Two crosses exhibited positive significance and twelve crosses exhibited negative significant heterosis over standard check in the desirable direction (Table 23).

Table 22. *Per se* performance and nature of heterosis for vase life

Sl. No.	Cross	Vase life					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	8.50	7.70	8.10	0.00	-4.71*	5.19*
2	AAC-1 x P.G.Purple	8.50	9.40	9.80	9.50**	4.26*	27.27**
3	AAC-1 x Poornima	8.50	11.30	8.60	-13.13**	-23.89**	11.69**
4	AAC-1 x Violet Cushion	8.50	11.70	10.00	-0.99	-14.53**	29.87**
5	Kamini x AAC-1	7.70	8.50	8.90	9.88**	4.71*	15.58**
6	Kamini x P.G.Purple	7.70	9.40	10.30	20.47**	9.57**	33.77**
7	Kamini x Poornima	7.70	11.30	7.40	-22.11**	-34.51**	-3.90
8	Kamini x Violet Cushion	7.70	11.70	9.70	0.00	-17.09**	25.97**
9	P.G.Purple x AAC-1	9.40	8.50	8.95	16.20**	10.64**	35.06**
10	P.G.Purple x Kamini	9.40	7.70	8.55	18.13**	7.45**	31.17**
11	P.G.Purple x Poornima	9.40	11.30	10.35	-3.38	-11.50**	29.87**
12	P.G.Purple x Violet Cushion	9.40	11.70	10.55	2.37	-7.69**	40.26**
13	Poornima x AAC-1	11.30	8.50	8.40	-15.15**	-25.66**	9.09**
14	Poornima x Kamini	11.30	7.70	7.10	-25.26**	-37.17**	-7.79**
15	Poornima x P.G.Purple	11.30	9.40	10.00	-3.38	-11.50**	29.87**
16	Poornima x Violet Cushion	11.30	11.70	10.60	-7.83**	-9.40**	37.66**
17	Violet Cushion x AAC-1	11.70	8.50	10.30	1.98	-11.97**	33.77**
18	Violet Cushion x Kamini	11.70	7.70	10.50	8.25**	-10.26**	36.36**
19	Violet Cushion x P.G.Purple	11.70	9.40	11.10	5.21**	-5.13**	44.16**
20	Violet Cushion x Poornima	11.70	11.30	10.60	-7.83**	-9.40**	37.66**
	S.Em ±	**0.12**	**0.12**	**0.22**	**0.25**	**0.30**	**0.30**
	C.D 5%	**0.38**	**0.38**	**0.67**	**0.53**	**0.61**	**0.61**
	C.D 1%	**0.52**	**0.52**	**0.92**	**0.73**	**0.84**	**0.84**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

Table 23. ***Per se*** **performance and nature of heterosis for seed yield per plant**

Sl. No.	Cross	Seed yield/plant (g)					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	1.77	1.38	1.67	17.09**	6.36	6.36
2	AAC-1 x P.G.Purple	1.77	1.78	2.18	-13.96*	-17.93**	-26.16**
3	AAC-1 x Poornima	1.77	1.73	1.51	22.51**	12.53*	9.78*
4	AAC-1 x Violet Cushion	1.77	2.60	2.25	-17.33**	-32.12**	-13.69**
5	Kamini x AAC-1	1.38	1.77	1.79	-3.90	-12.71*	-12.71*
6	Kamini x P.G.Purple	1.38	1.78	2.05	-14.54**	-18.83**	-18.83**
7	Kamini x Poornima	1.38	1.73	1.66	-2.23	-3.42	-3.42
8	Kamini x Violet Cushion	1.38	2.60	1.98	-40.80**	-47.12**	-32.76**
9	P.G.Purple x AAC-1	1.78	1.77	1.65	-6.27	-10.60	-19.56**
10	P.G.Purple x Kamini	1.78	1.38	1.67	-14.29**	-18.58**	-18.58**
11	P.G.Purple x Poornima	1.78	1.73	1.84	6.91	2.76	0.24
12	P.G.Purple x Violet Cushion	1.78	2.60	2.05	-19.82**	-31.54**	-12.96*
13	Poornima x AAC-1	1.73	1.77	1.71	-6.68	-14.29**	-16.38**
14	Poornima x Kamini	1.73	1.38	1.29	-36.39**	-37.16**	-37.16**
15	Poornima x P.G.Purple	1.73	1.78	1.57	-18.38**	-21.55**	-23.47**
16	Poornima x Violet Cushion	1.73	2.60	2.00	-24.70**	-33.46**	-15.40**
17	Violet Cushion x AAC-1	2.60	1.77	2.10	-1.87	-19.42**	2.44
18	Violet Cushion x Kamini	2.60	1.38	2.15	-7.64	-17.50**	4.89
19	Violet Cushion x P.G.Purple	2.60	1.78	2.28	2.70	-12.50**	11.49*
20	Violet Cushion x Poornima	2.60	1.73	2.19	-4.68	-15.77**	7.09
	S.Em ±	**0.09**	**0.09**	**0.11**	**0.12**	**0.14**	**0.14**
	C.D 5%	**0.27**	**0.27**	**0.33**	**0.24**	**0.30**	**0.30**
	C.D 1%	**0.37**	**0.37**	**0.46**	**0.33**	**0.39**	**0.39**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

4.2.1.22 Seed test weight

The individual flower weight ranged from 4.06 (Kamini) to 4.65 (Violet cushion) and 4.23 (Kamini x Violet Cushion) to 5.04 (AAC-1 x Violet Cushion) for parents and crosses, respectively.

Four crosses exhibited positive significant heterosis while, nine crosses showed negative significant heterosis over mid parent. The maximum heterosis was shown by the cross Violet Cushion x AAC-1 (4.87%) followed by AAC-1 x Poornima (3.92%).

The range of heterosis over better parent was from -14.61 per cent (AAC-1 x Violet Cushion) to 3.34 per cent (Violet Cushion x AAC-1) for the trait. Two crosses showed positive significance heterosis while, twelve crosses recorded negative significance heterosis over better parent.

The heterosis over standard check Kamini ranged from -12.12 per cent (Kamini x Violet Cushion) to 9.09 per cent (AAC-1 x Poornima). Six crosses exhibited positive significance and nine crosses showed negative significant heterosis over standard check Kamini (Table 24).

4.3 Combining ability analysis

4.3.1 Combining ability variance

The partition of variance due to general combining ability (gca), specific combining ability (sca) and reciprocal combing ability (rca) was done for twenty-two characters studied and is presented in Table 25.

The data revealed that the mean sum squares due to general combining ability were significant to all characters except stem girth, individual flower weight, flower diameter, ray floret length, seed yield and test weight. The mean sum of squares due to specific combining ability was significant to all characters except stem girth, individual flower weight, flower diameter, ray floret length, disc floret length, vase life, seed yield and test weight. Similarly, mean sum of squares due to reciprocal combining ability was significant to all characters except stem girth, number of branches, individual flower weight, flower diameter, ray floret length, disc floret length, vase life, seed yield and test weight. The mean squares for gca were of higher magnitude than those of sca and rca except for flower diameter.

Table 24. *Per se* performance and nature of heterosis for seed test weight

Sl. No.	Cross	Seed test weight (g)					
		Per se performance			% Heterosis over		
		P_1	P_2	F_1	MP	BP	SC
1	AAC-1 x Kamini	2.10	1.99	2.40	-1.17	-2.92*	0.65
2	AAC-1 x P.G.Purple	2.10	1.99	2.33	-8.64**	-10.65**	-7.36**
3	AAC-1 x Poornima	2.10	1.99	2.14	3.92**	2.65*	9.09**
4	AAC-1 x Violet Cushion	2.10	1.99	2.52	-13.35**	-14.61**	-11.47**
5	Kamini x AAC-1	1.96	2.10	2.42	2.87*	1.04	4.76**
6	Kamini x P.G.Purple	1.96	2.10	2.31	-7.39**	-7.76**	-7.79**
7	Kamini x Poornima	1.96	2.10	2.13	-11.23**	-13.85**	-8.44**
8	Kamini x Violet Cushion	1.96	2.10	2.12	-12.41**	-12.69**	-12.12**
9	P.G.Purple x AAC-1	2.30	2.22	2.40	2.24	0.00	3.68**
10	P.G.Purple x Kamini	2.30	2.22	2.23	-3.04*	-3.46**	-3.46**
11	P.G.Purple x Poornima	2.30	2.22	2.29	-0.74	-4.07**	1.95
12	P.G.Purple x Violet Cushion	2.30	2.22	2.36	-2.06	-2.80*	-2.16
13	Poornima x AAC-1	2.12	2.13	2.41	-0.82	-2.04	4.11**
14	Poornima x Kamini	2.12	2.13	2.15	-9.97**	-12.63**	-7.14**
15	Poornima x P.G.Purple	2.12	2.13	2.43	2.42*	-1.02	5.19**
16	Poornima x Violet Cushion	2.12	2.13	2.46	-11.09**	-13.44**	-8.01**
17	Violet Cushion x AAC-1	2.34	2.31	2.48	4.87**	3.34**	7.14**
18	Violet Cushion x Kamini	2.34	2.31	2.30	-0.76	-1.08	-0.43
19	Violet Cushion x P.G.Purple	2.34	2.31	2.35	1.84	1.08	1.73
20	Violet Cushion x Poornima	2.34	2.31	2.18	-8.79**	-11.20**	-5.63**
S.Em ±		**0.04**	**0.04**	**0.02**	**0.03**	**0.04**	**0.04**
C.D 5%		**0.13**	**0.13**	**0.07**	**0.07**	**0.09**	**0.09**
C.D 1%		**0.18**	**0.18**	**0.10**	**0.10**	**0.12**	**0.12**

*Significant at 5 per cent level ** Significant at 1 per cent level

P_1- Female parent P_2- Male parent MP- Mid parent BP- Better parent SC- Standard check (Kamini)

Table 25. Variance due to general, specific and reciprocal combining ability and their ratio for twenty two characters in China aster

Sl. No.	Source	Mean sum of square				Component of variance			
	Degrees of freedom	GCA	SCA	RCA	Error	s^2g	s^2s	s^2r	gca:sca
		4	10	10	24				
1	Plant height	160.28**	36.41**	20.94**	8.51	86.72	278.97	124.27	0.31
2	No. of leaves	54.59**	8.96**	26.48**	5.93	27.81	30.30	205.50	0.91
3	Stem girth	0.0068	0.0053	0.0076	0.0031	0.00	0.02	0.05	0.09
4	Plant spread	120573.68**	46326.43**	16266.72**	12244.71	61902.27	340817.20	40220.10	0.18
5	Leaf area per plant	863819.39**	700527.20**	1134680.88**	197134.19	380962.97	5033930.10	9375466.90	0.07
6	No. of branches	59.63**	4.39**	1.04	0.84	33.59	35.42	1.96	0.94
7	Days for 1st flower bud initiation	73.11**	17.99**	4.49**	1.96	40.66	160.30	25.30	0.25
8	Days for 1st flower	108.92**	22.41**	5.06**	2.21	60.98	202.00	28.50	0.30
9	Days for 50 per cent flowering	119.51**	20.21**	8.37**	2.10	67.09	181.10	62.70	0.37
10	Duration of flowering	15.80**	4.78**	3.28**	0.4992	8.74	42.81	27.81	0.20
11	No. of flower/plant	390.45**	59.07**	16.87**	1.26	222.39	578.10	156.10	0.38
12	Individual flower weight	0.37	0.05	0.10	0.01	0.20	0.40	0.89	0.51
13	Weight of 10 flower	67.00**	7.12**	8.72**	4.20	35.89	29.20	45.20	1.22
14	Flower yield/Plant	10197.34**	824.18**	484.35**	77.46	5782.79	7467.20	4068.90	0.77
15	Flower yield/ha	12.31**	49.42**	12.16**	0.95	6.49	484.70	112.10	0.01
16	Flower stalk length	6.22**	2.39**	3.08**	1.24	2.85	11.50	18.40	0.24
17	Flower diameter	0.09	0.34	0.09	0.01	0.04	3.25	0.76	0.01
18	Ray floret length	0.26	0.03	0.11	0.03	0.13	0.03	0.82	3.82
19	Disc floret length	2.27**	0.46	0.03	0.15	1.21	3.07	-1.19	0.39
20	Vase life	6.01**	1.21	0.09	0.04	3.41	11.65	0.55	0.29
21	Seed yield/ plant	0.11	0.12	0.06	0.01	0.06	1.05	0.48	0.12
22	Seed test weight	0.02	0.01	0.01	0.0010	0.01	0.17	0.18	0.08

*Significant at 5 per cent level **Significant at 1 per cent level

4.3.2 Combining ability effects (gca, sca and rca)

The gca effects of five parents, sca effects of ten crosses and rca effects of ten crosses for various characters detailed in Table 26, Table 27 and Table 28, repectively.

4.3.2.1 Plant height (cm)

The gca effects were found positive in three parents (AAC-1, P.G.Purple and Violet Cushion), where as negative in two parents (Kamini and Poornima). Among which, the parents P.G.Purple and Violet Cushion were positively significant and Kamini was negative significant for gca effects.

Among the crosses, six crosses had positive sca effects, of which three crosses (AAC-1 x Kamini, Kamini x Violet Cushion and P.G.Purple x Poornima) exhibited positive significant sca effects. Out of four negative sca effects, two crosses (Kamini x Poornima and P.G.Purple x Violet Cushion) were significant.

The rca effects showed positive for four crosses, none of the crosses were significant. Among the six negative rca effects, two crosses Poornima x AAC-1 (-6.25) and Violet Cushion x AAC-1 (-5.55) were significant for the trait.

4.3.2.2 Number of leaves

Three parents (AAC-1, P.G.Purple and Violet Cushion) exhibited positive gca effects and others (Kamini and Poornima) recorded negative gca effects. All parents were significant except P.G.Purple.

The sca effects were positive for six crosses, out of which one cross (AAC-1 x Poornima) was significant. All the other crosses with negative sca effects were non-significant.

Among ten crosses, four crosses were positively related, out of which cross Poornima x AAC-1 (5.90) was significant. Six parents were negatively related and two crosses P.G.Purple x AAC-1 (-4.75) and Violet Cushion x AAC-1 (-7.60) were significant.

Table 26. General combining ability (gca) effects for different traits in China aster

Sl. No.	Characters	AAC-1	Kamini	P.G. Purple	Poornima	Violet Cushion	SEgi	C.D. 5%	C.D. 1%
1	Plant height	0.18	-6.63**	4.51**	-0.25	1.90**	00.82	1.7	2.31
2	No. of leaves	2.04**	-2.85**	0.72	-2.09**	2.16**	00.68	1.42	1.93
3	Stem girth	0.03	-0.04	0.01	-0.01	0.02	01.59	3.28	4.45
4	Plant spread	160.81*	-95.42**	65.70*	-52.18	-78.91*	31.29	64.6	87.54
5	Leaf area	282.64*	-291.29*	-294.44*	306.87*	-3.58	125.58	259.19	351.24
6	No. of branches	-1.02**	-2.69**	1.85**	-1.36**	3.21**	0.26	0.54	0.73
7	Days for 1st flower bud initiation	2.12**	-2.92**	-2.13**	-0.45	3.39**	0.39	0.82	1.11
8	Days for 1st flowering	1.14*	-3.30**	-2.30**	-0.62	5.07**	0.42	0.87	1.18
9	Days for 50% flowering	0.19	-3.40**	-1.99**	-0.46	5.66**	0.41	0.85	1.15
10	Duration of flowering	0.33	-0.96**	1.28**	-1.64**	0.99**	0.19	0.41	0.56
11	No. of flower/Plant	-1.24**	-3.37**	1.45**	-6.66**	9.84**	0.31	0.66	0.89
12	Individual flower weight	0.04	-0.19**	-0.07	-0.10	0.31**	3.73	0.07	0.10
13	Weight of 10 flowers	0.41	-2.18**	-1.22*	-1.33*	4.32**	0.58	1.2	1.62
14	Flower yield/plant	-2.80	-20.93**	-0.51	-28.74**	52.98**	2.48	5.14	6.96
15	Flower yield/ha	-0.05	-1.11**	-0.81**	0.26	1.72**	0.27	513.75	696.21
16	Flower stalk length	0.02	-0.20	-0.26	-0.84*	1.29**	0.31	0.65	0.88
17	Flower diameter	0.16**	-0.01	-0.10*	-0.04	-0.01	3.82	0.08	0.11
18	Ray floret length	0.28**	-0.11**	-0.08	-0.03	-0.06	0.05	0.11	0.15
19	Disc floret length	-0.27*	-0.26*	-0.03	-0.27*	0.83**	0.11	0.23	0.31
20	Vase life	-0.50**	-0.90**	0.48**	-0.12	1.05**	0.60	0.37	0.50
21	Seed yield/plant	-0.04	-0.06	-0.09**	0.00	0.18**	0.031	0.06	0.09
22	Seed test weight	0.07**	-0.05**	0.00	0.03**	-0.04**	0.008	0.02	0.02

*Significant at 5 per cent level **Significant at 1 per cent level

Table 27. Specific combining ability (sca) effects for different traits in China aster

Sl. No	Cross	Plant height (cm)	No. of leaves (no.)	Stem girth (cm)	Plant spread (cm^2)	Leaf area per plant (cm^2)	No. of branches (no.)	Days for first flower bud initiation	Days for 1st flowering	Days for 50% flowering	Duration of flowering	No. of flowers/ Plant (no.)
1	AAC-1 x Kamini	3.69*	1.20	-0.03	67.05	711.48*	-0.12	2.54**	2.55**	2.31*	-0.03	2.98**
2	AAC-1 x P.G. Purple	-1.20	0.63	0.10**	24.14	84.08	1.44*	-1.90*	-2.05*	-1.70	-0.24	-4.44**
3	AAC-1 x Poornima	-0.09	3.09*	-0.02	14.80	979.48**	0.25	1.47	1.22	0.87	1.71**	6.77**
4	AAC-1 x Violet Cushion	0.56	1.44	-0.02	71.24	-555.77*	0.33	-1.17	-1.72	-1.80*	0.19	0.17
5	Kamini x P.G. Purple	2.66	1.27	0.01	4.62	-454.59	0.51	0.64	0.94	1.04	0.63	2.84**
6	Kamini x Poornima	-5.78**	-1.52	0.01	-28.24	-13.63	-1.58**	-3.09**	-2.89**	-3.64**	0.61	-6.15**
7	Kamini x Violet Cushion	3.57*	1.33	0.05	53.49	323.59	1.95**	1.47	2.02*	1.89*	1.16**	3.35**
8	P.G. Purple x Poornima	7.68**	-0.14	-0.04	308.58**	-228.88	1.83**	-4.23**	-4.89**	-4.25**	0.87*	4.03**
9	P.G. Purple x Violet Cushion	-5.62**	-0.54	-0.08*	-223.49**	460.18	-2.04**	4.03**	4.52**	4.13**	-2.59**	-1.47*
10	Poornima x Violet Cushion	0.59	-0.63	0.04	80.03	-400.32	0.82	1.15	1.44	1.60	-1.14*	5.99**
S.Esij		1.70	1.42	0.03	64.52	258.89	0.53	0.81	0.86	0.84	0.41	0.65
C.D. 5%		3.51	2.93	0.07	133.17	534.32	1.11	1.69	1.79	1.75	0.85	1.35
C.D. 1%		4.76	3.97	0.09	180.46	724.10	1.50	2.29	2.43	2.37	1.15	1.83

*Significant at 5 per cent   **Significant at 1 per cent

Contd…

Sl. No.	Cross	Individual flower weight (g)	Weight of 10 flowers (g)	Flower yield/ plant (g)	Flower yield/ ha (t/ha)	Flower stalk length (cm)	Flower diameter (cm)	Ray floret length (cm)	Disc floret length (cm)	Vase life (days)	Seed yield per plant (g)	Seed test weight (g)
1	AAC-1 x Kamini	0.02	0.07	9.16	1.99**	-0.36	0.24**	0.08	0.23	0.25	0.21**	0.08**
2	AAC-1 x P.G. Purple	0.24**	1.48	-1.65	-0.36	-0.20	-0.15	-0.01	-0.62*	0.47**	-0.16*	-0.09**
3	AAC-1 x Poornima	0.07	2.95*	26.55*	1.90**	0.18	-0.33**	0.21	-0.28	-0.53**	0.15*	0.08**
4	AAC-1 x Violet Cushion	0.04	-0.44	3.98	-1.40*	1.02	-0.23**	-0.18	0.25	-0.05	-0.08	-0.05*
5	Kamini x P.G. Purple	0.11	2.23	14.76**	-1.85**	0.04	0.11	0.10	-0.36	0.97**	-0.07	-0.05**
6	Kamini x Poornima	-0.18*	-1.81	-25.79**	-2.01**	0.15	0.25**	-0.11	-0.02	-1.38**	-0.19**	-0.13**
7	Kamini x Violet Cushion	0.14	0.59	17.86**	-1.15	1.31	-0.41**	-0.17	0.18	0.30*	-0.24**	-0.02
8	P.G. Purple x Poornima	-0.11	-1.26	8.03	0.84	-1.62*	-0.01	-0.01	-0.26	-0.01	0.02	0.07**
9	P.G. Purple x Violet Cushion	-0.05	-1.20	-7.37	1.53*	-0.10	-0.37**	0.06	-0.30	-0.23	0.06	0.06**
10	Poornima x Violet Cushion	-0.05	-0.90	16.22**	-3.91**	-0.75	-0.24**	0.03	0.18	0.02	-0.10	-0.12**
S.Esij		0.08	1.19	5.13	0.57	0.65	0.07	0.10	0.23	0.12	0.06	0.01
C.D. 5%		0.17	2.47	10.59	1.18	1.34	0.16	0.23	0.48	0.26	0.12	0.04
C.D. 1%		0.22	3.35	14.35	1.59	1.82	0.22	0.31	0.65	0.35	0.17	0.05

*Significant at 5 per cent **Significant at 1 per cent

Table 28. Reciprocal combining ability (rca) effects for different traits in China aster

Sl. No	Cross	Plant height (cm)	No. of leaves (no.)	Stem girth (cm)	Plant spread (cm^2)	Leaf area per plant (cm^2)	No. of branches (no.)	Days for first flower bud initiation	Days for 1st flowering	Days for 50% flowering	Duration of flowering	No. of flowers/ plant
1	Kamini x AAC-1	-1.35	-1.85	0.06	-139.96	-536.14	-1.10	2.45**	3.00**	3.00**	-0.19	4.25**
2	P.G. Purple x AAC-1	-3.80	-4.75*	0.08*	-200.88*	179.68	-0.10	-1.00	-1.10	-0.40	-1.54**	-0.15
3	Poornima x AAC-1	-6.25**	5.90**	0.07	77.47	-1934.99**	0.90	0.05	0.15	1.10	-1.99**	-0.75
4	Violet Cushion x AAC-1	-5.55*	-7.60**	0.00	37.02	277.99	0.25	0.45	2.00	2.85*	-0.60	1.95*
5	P.G. Purple x Kamini	-2.05	0.40	0.04	-46.26	650.30*	1.70*	0.30	0.25	0.55	-1.06*	-0.90
6	Poornima x Kamini	-0.45	-0.10	0.08*	10.88	215.44	0.30	-2.35*	-1.40	-0.20	1.64**	-7.60**
7	Violet Cushion x Kamini	0.15	-0.50	-0.04	-41.44	728.98*	-0.10	2.35*	2.50*	3.55**	-1.01	-0.20
8	Poornima x P.G. Purple	2.65	3.55	0.05	-47.02	454.29	-0.35	-1.90	-1.20	-1.50	0.92	-1.80*
9	Violet Cushion x P.G. Purple	0.80	-0.20	-0.09*	-13.12	-394.77	-0.05	0.70	1.00	2.60*	-0.20	-0.20
10	Violet Cushion x Poornima	2.55	0.90	-0.05	-87.52	-411.44	-0.10	0.20	0.60	1.20	1.98**	0.15
S.Erij		2.06	1.72	3.97	78.24	313.95	0.65	0.99	1.05	1.02	0.49	0.79
C.D. 5%		4.26	3.55	0.07	61.49	647.97	1.34	2.05	2.17	2.12	1.03	1.64
C.D. 1%		5.77	4.82	0.09	218.84	878.11	1.82	2.77	2.94	2.87	1.40	2.22

*Significant at 5 per cent **Significant at 1 per cent

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Sl. No	Cross	Individual flower weight (g)	Weight of 10 flowers (g)	Flower yield/ plant (g)	Flower yield/ ha (t/ha)	Flower stalk length (cm)	Flower diameter (cm)	Ray floret length (cm)	Disc floret length (cm)	Vase life (days)	Seed yield per plant (g)	Seed test weight (g)
1	Kamini x AAC-1	-0.16	-1.24	5.43	-1.84*	-0.50	-0.34**	-0.44**	-0.32	0.40*	-0.19*	0.05*
2	P.G. Purple x AAC-1	-0.54**	-3.59*	-28.95**	-2.55**	1.30	-0.22*	-0.11	-0.09	0.30	0.07	0.13**
3	Poornima x AAC-1	-0.26*	-4.09**	-16.86*	-4.54**	-0.60	0.16	-0.21	0.01	-0.10	-0.27**	-0.06*
4	Violet Cushion x AAC-1	-0.20*	-1.84	-5.61	5.12**	3.13**	-0.28**	-0.52**	0.03	0.15	0.17*	0.21**
5	P.G. Purple x Kamini	-0.19	-1.74	-13.83*	1.50*	-0.68	-0.11	0.18	-0.15	-0.10	0.00	0.05*
6	Poornima x Kamini	-0.13	-0.68	-27.95**	-8.62**	1.05	-0.29**	-0.14	-0.00	-0.15	-0.34**	0.01
7	Violet Cushion x Kamini	-0.02	-0.59	-1.87	5.88**	0.35	-0.16	0.02	-0.13	0.40*	0.38**	0.13**
8	Poornima x P.G. Purple	0.01	-0.36	-5.10	-3.21**	1.13	0.06	0.05	0.16	0.00	-0.24**	0.04
9	Violet Cushion x P.G. Purple	0.22*	2.08	13.60*	4.08**	-0.52	0.25*	0.06	0.15	0.15	0.25**	0.04
10	Violet Cushion x Poornima	0.10	-0.87	7.18	7.23**	-0.40	-0.13	0.08	-0.02	0.00	0.23**	0.03
S.Erij		0.1000	1.1960	6.2234	0.69	0.7884	0.1000	0.1331	0.2810	0.1499	0.07	0.0219
C.D. 5%		0.21	2.47	12.84	1.42	1.63	0.21	0.27	0.58	0.31	0.14	0.05
C.D. 1%		0.28	3.35	17.41	1.93	2.21	0.28	0.37	0.79	0.42	0.20	0.06

*Significant at 5 per cent **Significant at 1 per cent

4.3.2.3 Stem girth (cm)

The parents AAC-1, P.G.Purple and Violet Cushion showed positive gca effects, while the parents Kamini and Poornima recorded negative gca effects.

Out of ten crosses, one cross *viz.*, AAC-1 x P.G.Purple showed positive significant sca effect whereas, cross P.G.Purple x Violet Cushion exhibited negative significant effect. Rest of the crosses were non-significant, out of which four crosses (Kamini x P.G. Purple, Kamini x Poornima, Kamini x Violet Cushion and Poornima x Violet cushion) showed positive sca effects and other four crosses (AAC-1 x Kamini, AAC-1 x Poornima, AAC-1 x Violet Cushion and P.G. Purple x Poornima) exhibited negative sca effects.

Among all the ten crosses, seven crosses were in positive direction and three crosses were in negative direction of rca effects. Two crosses P.G. Purple x AAC-1 (0.08) and Poornima x Kamini (0.08) showed positive significant rca effects. Out of negatively related rca, the cross Violet Cushion x P.G.Purple (-0.09) was significant.

4.3.2.4 Plant spread (cm^2)

The parents AAC-1 had highest (160.81) positive significant gca effects followed by P.G.Purple (65.70). While, Kamini (-95.42) showed the lowest negative significant gca effects.

Among the crosses, P.G. Purple x Poornima showed positive significant sca effects and P.G. Purple x Violet Cushion recorded negative significant sca effects. Where as, other seven crosses (AAC-1 x Kamini, AAC-1 x P.G. Purple, AAC-1 x Poornima, AAC-1 x Violet Cushion, Kamini x P.G. Purple, Kamini x Violet Cushion P.G. Purple x Violet Cushion) showed positive sca effects and cross Kamini x Poornima recorded negative sca effects.

The rca effect was negative for seven crosses, among which, significant for cross P.G.Purple x AAC-1 (-200.88) and positive rca effects for another three crosses (Poornima x AAC-1, Violet Cushion x AAC-1 and Poornima x Kamini).

4.3.2.5 Leaf area per plant (cm^2)

Among the five parents, two parents *viz.*, AAC-1 and Poornima recorded positive gca effects and other three parents Kamini, P.G.Purple and Violet Cushion showed negative gca effects. Out of which all the parents except Violet Cushion expressed significance for the trait.

The sca effects were positive for five crosses, out of which two crosses (AAC-1 x Kamini and AAC-1 x Poornima) were significant. All the crosses with negative sca effects were non-significant except the cross AAC-1 x Violet Cushion.

Among all the crosses, six crosses showed positive rca effects, out of which two crosses P.G.Purple x Kamini (650.30) and Violet Cushion x Kamini (728.98) were significant. Four other crosses exhibited negative rca effects, of which cross Poornima x AAC-1 (-1934.99) was significant.

4.3.2.6 Number of branches

All five parents exhibited significant gca effects. Among which, two parents P.G.Purple and Violet Cushion were in positive direction and the other three parents AAC-1, Kamini and Poornima were in negative direction.

Among the crosses, seven crosses had positive sca effects, of which three crosses (AAC-1 x P.G. Purple, P.G.Purple x Poornima and Kamini x Violet Cushion) exhibited positive significant sca effects. Out of three negative sca effects, two crosses (Kamini x Poornima and P.G.Purple x Violet Cushion) were significant.

Four crosses recorded positive rca effects, of which cross P.G.Purple x Kamini (1.70) showed positive significance. Out of six negative rca effects, none of crosses were significant for this trait.

4.3.2.7 Days for first flower bud initiation

Among the five parents, two parents AAC-1 and Violet Cushion recorded positive gca effects and other three parents Kamini, P.G.Purple and Poornima showed negative gca effects. Out of which all the parents except Poornima expressed significance for the trait (Fig. 1)

Six crosses recorded positive sca effects, of which two crosses AAC-1 x Kamini and P.G.Purple x Violet Cushion showed positive significant sca effects. Out of four negative sca effects, three crosses (AAC-1 x P.G.Purple, Kamini x Poornima and P.G.Purple x Poornima) expressed significance for the trait.

Among all ten crosses, seven crosses showed positive rca effects, in which two crosses Kamini x AAC-1 (2.45) and Violet Cushion x Kamini (2.35) were significant. Three crosses recorded negative rca effects, in which cross Poornima x Kamini (-2.35) showed significance.

4.3.2.8 Days for first flowering

The parents Kamini, P.G.Purple and Poornima exhibited negative gca effects among which, Kamini and P.G.Purple were significant. Rest of the two parents AAC-1 and Violet Cushion showed positive significant gca effects (Fig. 1).

The sca effects were significant for six crosses, out of which three crosses AAC-1 x Kamini (2.55), Kamini x Violet Cushion (2.02) and P.G.Purple x Violet Cushion (4.52) exhibited positive significant sca effects and three crosses AAC-1 x P.G.Purple (-2.05), Kamini x Poornima (-2.89) and P.G.Purple x Poornima (-4.89) showed negative significant sca effects.

Seven crosses recorded positive rca effects, of which two crosses Kamini x AAC-1 (3.00) and Violet Cushion x Kamini (2.50) showed positive significance. Out of three negative rca effects, none of crosses were significant for this trait.

4.3.2.9 Days for 50% flowering

Three parents Kamini, P.G.Purple and Poornima showed negative gca effects, of which parents Kamini and P.G.Purple exhibited negative significant gca effects. Where as, the parent Violet Cushion exhibited positive significant gca effect (Fig.1).

Six crosses recorded positive sca effects, of which AAC-1 x Kamini (2.31), Kamini x Violet Cushion (1.89) and P.G.Purple x Violet Cushion (4.13) showed positive significant sca effects. Four crosses showed negative sca effects, of which AAC-1 x Violet Cushion (-1.80), Kamini x Poornima (-3.64) and P.G.Purple x Poornima (-4.25) showed negative significant sca effects.

Among all the crosses, seven parents showed positive rca effects, out of which four crosses Kamini x AAC-1 (3.00), Violet Cushion x AAC-1 (2.85), Violet Cushion x Kamini (3.55) and Violet Cushion x P.G.Purple (2.60) were significant . Three other crosses exhibited negative rca effects, of which none of cross was significant for this trait.

4.3.2.10 Duration of flowering

Among five parents, two (P.G.Purple and Violet Cushion) showed positive significant gca effects except AAC-1. While, other two parents (Kamini and Poornima) exhibited negative significant gca effects (Fig. 1)

Six crosses recorded positive sca effects, of which only three crosses AAC-1 x Poornima (1.71), Kamini x Violet Cushion (1.16) and P.G.Purple x Poornima (0.87) exhibited positive significant sca effects. Two crosses P.G.Purple x Violet Cushion (-2.59) and Poornima x Violet Cushion (-1.14) showed negative significant sca effects.

The rca effect was positive for three crosses, among which, significant for two crosses Poornima x Kamini (1.64) and Violet Cushion x Poornima (1.98). Negative rca effects for another seven crosses was recorded, out of which three crosses P.G.Purple x AAC-1 (-1.54), Poornima x AAC-1 (-1.99) and P.G.Purple x Kamini (-1.06) were significant for the trait.

4.3.2.11 Number of flowers per plant

Two parents (P.G.Purple and Violet Cushion) exhibited positive significant gca effects, whereas other parents (AAC-1, Kamini and Poornima) showed negative significant gca effects (Fig. 2).

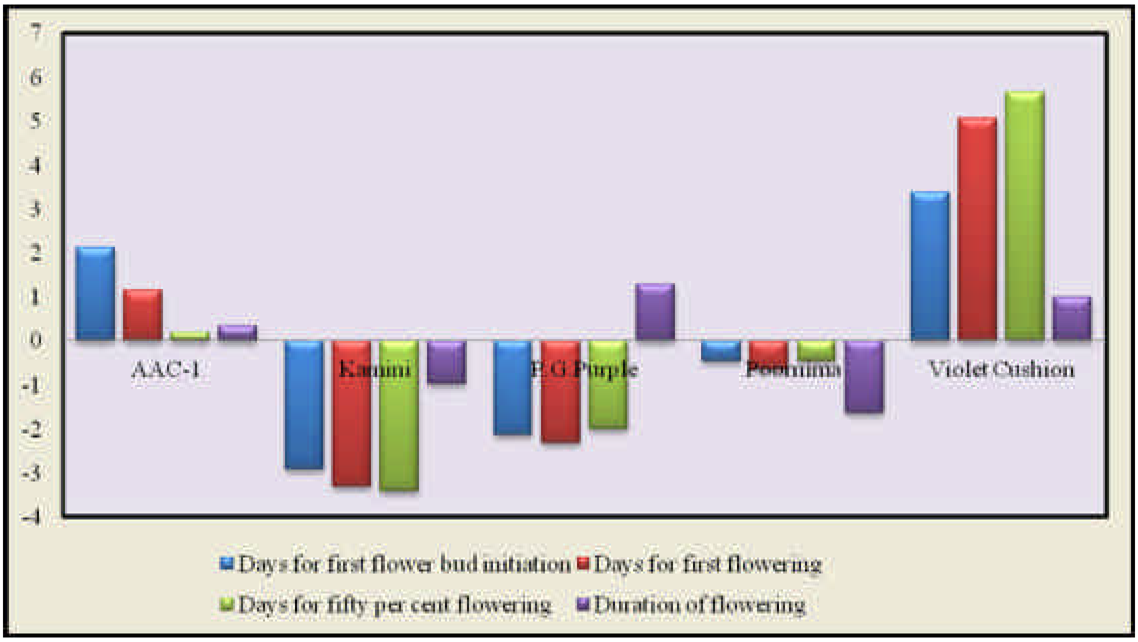


Fig 1 : Estimates of gca effects for floral characters among parents

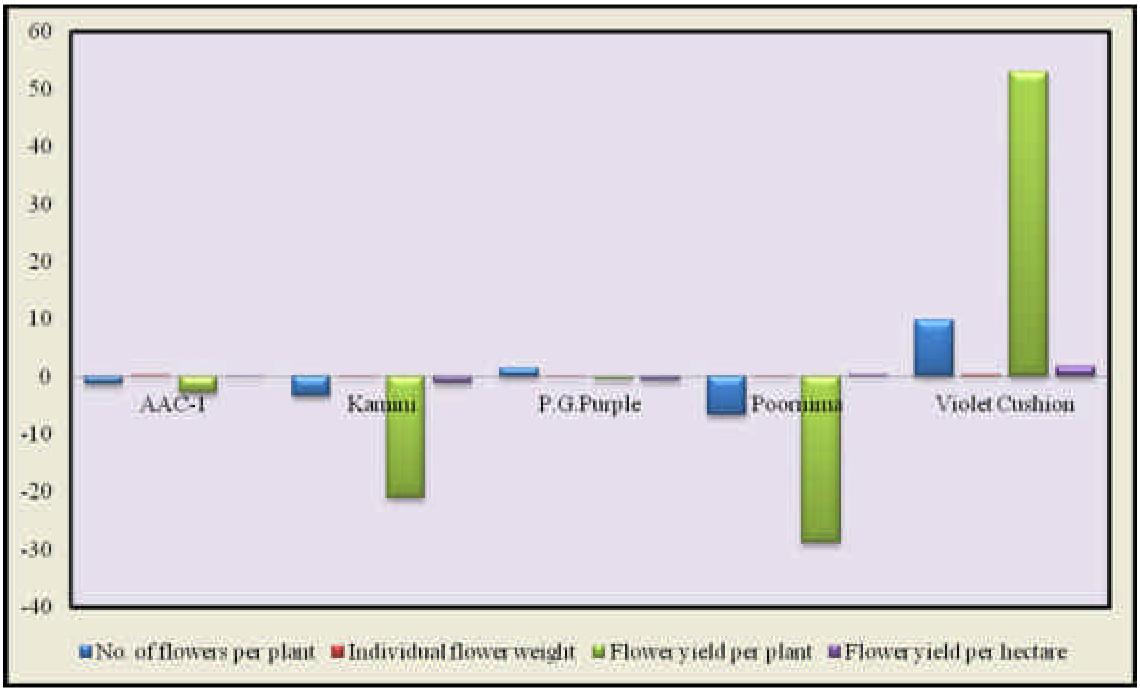


Fig 2: Estimates of gca effects for yield characters among parents

The sca effects were significant for nine crosses, out of which six crosses AAC-1 x Kamini (2.98), AAC-1 x Poornima (6.77), Kamini x P.G.Purple (2.84), Kamini x Violet Cushion (3.35), P.G.Purple x Poornima (4.03) and Poornima x Violet Cushion (5.99) were in significantly positive direction and crosses AAC-1 x P.G.Purple (-4.44), Kamini x Poornima (-6.15) and P.G.Purple x Violet Cushion (-1.47) were in significantly negative direction (Fig. 3).

Among all the crosses, three crosses showed positive rca effects, out of which two crosses Kamini x AAC-1 (4.25) and Violet Cushion x AAC-1 (1.95) were significant . Seven other crosses exhibited negative rca effects, of which two of crosses Poornima x Kamini (-7.60) and Poornima x P.G. purple (-1.80) were significant for this trait (Fig. 4).

4.3.2.12 Individual flower weight (g)

Two of the parents exhibited significant gca effect for the trait, among which, parent Violet Cushion showed positive significance and Kamini exhibited negative significance (Fig. 2).

Among the crosses, six crosses had positive sca effects, of which cross AAC-1 x P.G.Purple (0.24) exhibited positive significant sca effects. Out of four crosses with negative sca effects, the cross Kamini x Poornima (-0.18) was shown significant effects (Fig. 3).

The rca effect was positive for three crosses, among which, significant for cross Violet Cushion x P.G.Purple (0.22). Negative rca effects for another seven crosses was recorded, out of which three crosses P.G.Purple x AAC-1 (-0.54), Poornima x AAC-1 (-0.26) and Violet Cushion x AAC-1 (-0.20) were significant for the trait (Fig. 4).

4.3.2.13 Weight of ten flowers (g)

The significant gca effects were observed for four parents, out of which three parents (Kamini, P.G.Purple and Poornima) exhibited negative gca effects and one parent (Violet Cushion) showed positive gca effect.

Five crosses showed positive sca effects, among which cross AAC-1 x Poornima (2.95) showed significance. Five other crosses recorded negative sca effects and none of the crosses showed significant sca effect.

Cross between Violet Cushion x P.G.Purple (2.08) recorded positive rca effects. Out of nine negative rca effects, two of crosses P.G.Purple x AAC-1 (-3.59) and Poornima x AAC-1(-4.09) were significant for this trait.

4.3.2.14 Flower yield per plant (g)

Four parents (AAC-1, Kamini, P.G.Purple and Poornima) showed negative gca effect and one parent (Violet Cushion) exhibited positive gca effect. Among which, the parent Violet Cushion showed positive significance and two parents *viz.,* Kamini and Poornima were negatively significant (Fig. 2).

The sca effects were positive for seven crosses, out of which four crosses AAC-1 x Poornima (26.55), Kamini x P.G.Purple (14.76), Kamini x Violet Cushion (17.86) and Poornima x Violet Cushion (16.22) were significant. Three crosses with negative sca effects, out of which cross Kamini x Poornima (-25.79) was significant (Fig. 3).

Among all the crosses, three crosses showed positive rca effects, out of which, cross Violet Cushion x P.G.Purple (13.60) was significant. Seven other crosses exhibited negative rca effects, of which four of cross P.G.Purple x AAC-1 (-28.95), Poornima x AAC-1(-16.86), P.G.Purple x Kamini (-13.83) and Poornima x Kamini (-27.95) were significant for this trait (Fig. 4).

4.3.2.15 Flower yield per hectare (t/ha)

The significant gca effects were observed for two parents. Out of which one parent (Violet cushion) exhibited positive significant gca effects and other two parents (Kamini and P.G.Purple) showed negative significant gca effects (Fig. 2).

Among the crosses, four crosses had positive sca effects, of which AAC-1 x Kamini (1.99), AAC-1 x Poornima (1.90) and P.G.Purple x Violet Cushion (1.53) were significant. Out of six crosses with negative sca effects, cross Kamini x Poornima

(-2.01), AAC-1 x Violet cushion (-1.40), Kamini x P.G.Purple (-1.85) and Poornima x Violet Cushion (-3.91) were significant for the trait (Fig. 3)

Out of ten crosses, five cross *viz.,* Violet Cushion x P.G.Purple (4.08), Violet Cushion x Poornima (7.23), Violet Cushion x Kamini (5.88), P.G.Purple x Kamini (1.50) and Violet Cushion x AAC-1 (5.12) showed positive significant rca effect whereas, five crosses P.G.Purple x AAC-1 (-2.55), Poornima x AAC-1 (-4.54), Kamini x AAC-1 (-1.84), Poonima x Kamini (-8.62) and Poornima x P.G.Purple (-3.21) exhibited negative significant effect (Fig. 4).

4.3.2.16 Flower stalk length (cm)

Two out of five parents chosen for the study exhibited significant gca effects, in which, Violet cushion showed positive significant gca and Poornima showed negative significant gca effect.

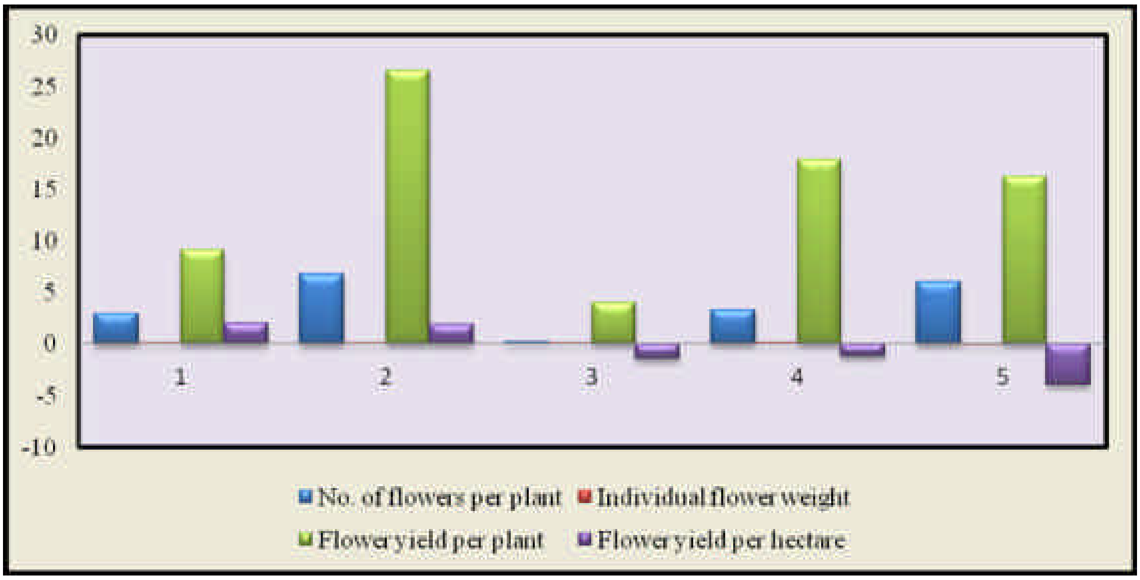
Out of ten crosses, five crosses showed positive sca effects but none were significant. Five parents recorded negative sca effects, out of which cross P.G.Purple x Poornima (-1.62) was significant.

Five crosses recorded positive rca effects, of which cross Violet Cushion x AAC-1 (3.13) showed positive significance. Out of five negative rca effects, none of crosses were significant for this trait.

4.3.2.17 Flower diameter (cm)

All parents except AAC-1 showed negative gca and P.G.Purple was negatively significant.

The sca effects were positive for three crosses, out of which two crosses AAC-1 x Kamini (0.24) and Kamini x Poornima (0.25) were significant. Seven crosses showed negative sca effects, among which five crosses AAC-1 x Poornima (-0.33), AAC-1 x Violet Cushion (-0.23), Kamini x Violet Cushion (-0.41), P.G.Purple x Violet Cushion (-0.37) and Poornima x Violet Cushion (-0.24) were significant.



1 – AAC-1 x Kamini | 2 – AAC-1 x Poornima | 3 – AAC-1 x Violet Cushion | 4 – Kamini x Violet Cushion | 5 – Poornima x Violet Cushion

Fig 3: Estimates of sca effects for yield parameters of top five crosses

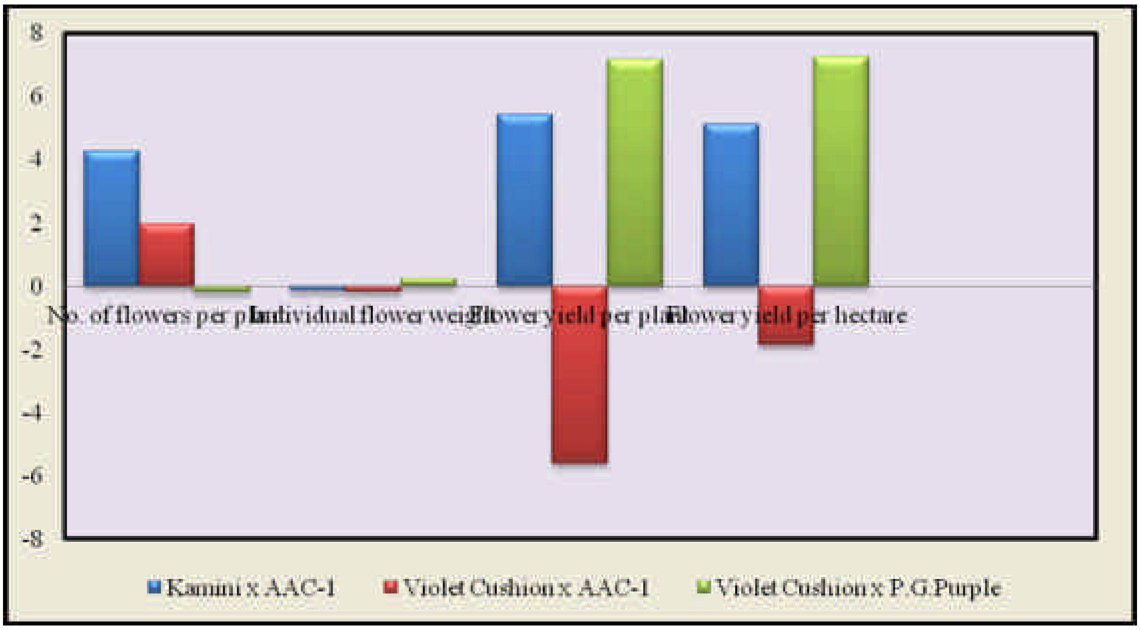


Fig 4: Estimates of rca effects for yield parameters of top three crosses

The rca effect was positive for three crosses, among which, significant for cross Violet Cushion x P.G.Purple (0.25). Negative rca effects for another seven crosses was recorded, out of which four crosses Kamini x AAC-1 (-0.34), P.G.Purple x AAC-1 (-0.22), Poornima x Kamini (-0.29) and Violet Cushion x AAC-1 (-0.28) were significant for the trait.

4.3.2.18 Ray floret length (cm)

Parent AAC-1 was positively significant to this trait, where as other parents (Kamini, P.G.Purple, Poornima and Violet Cushion) were showing negative gca effect. Among them, Kamini exhibited negative significance effect.

Among the crosses, five crosses had positive sca effects and other five crosses had negative sca effects. None of the crosses exhibited significance.

Five crosses recorded positive rca effects, none showed positive significance. Out of five negative rca effects, two of crosses Kamini x AAC-1 (-0.44) and Violet Cushion x AAC-1 (-0.52) were significant for this trait.

4.3.2.19 Disc floret length (cm)

Four parents Kamini (-0.26), P.G.Purple (-0.03), Poornima (-0.27) and AAC-1 (-0.27) showed negative gca effect. While parent Violet Cushion (0.83) exhibited positive significant effect.

The sca effects were positive for four crosses and none of them were significant. Rest of the six crosses were exhibiting negative sca effect, out of which cross AAC-1 x P.G.Purple (-0.62) showed negative significance.

Among all the crosses, four parents showed positive rca effects and six other crosses exhibited negative rca effects, none of the crosses were significant for this trait.

4.3.2.20 Vase life

Four parents AAC-1, Kamini, P.G.Purple and Violet Cushion showed significant gca effects among which parent P.G.Purple and Violet Cushion were positively significant and parent AAC-1 and Kamini were negatively significant.

Among the crosses, five crosses had positive sca effects, of which three crosses AAC-1 x P.G.Purple (0.47), Kamini x P.G.Purple (0.97) and Kamini x Violet Cushion (0.30) exhibited positive significant sca effects. Out of five crosses with negative sca effects, two crosses AAC-1 x Poornima (-0.53) and Kamini x Poornima (-1.38) were significant.

Seven crosses recorded positive rca effects, among them two crosses Kamini x AAC-1 (0.40) and Violet Cushion x Kamini (0.40) showed positive significance. Out of three negative rca effects, none of them were significant for this trait.

4.3.2.21 Seed yield per plant (g)

One out of five parents showed positive significant gca effect for the trait (Violet Cushion) and one parent (P.G.Purple) showed negative significant gca effect.

The sca effects were positive for four crosses, out of which two crosses AAC-1 x Kamini (0.21) and AAC-1 x Poornima (0.15) were significant. Among six crosses with negative sca effects, four crosses AAC-1 x P.G.Purple (-0.16), Kamini x Poornima (-0.19), Kamini x Violet Cushion (-0.24) were significant for the trait.

The rca effect was significantly positive for four crosses. Significantly negative rca effects for another four crosses was recorded.

4.3.2.22 Seed test weight (g)

Among the five parents, four parents *viz.*, AAC-1, Kamini, Poornima and Violet Cushion recorded positive gca effects and P.G.Purple showed negative gca effects. Out of which all parents except P.G.Purple expressed significance for the trait.

Among the crosses, four crosses AAC-1 x Kamini (0.08), AAC-1 x Poornima (0.08), P.G.Purple (0.07) and P.G.Purple x Violet Cushion (0.06) had positive significant effects. Out of six crosses with negative sca effects, five crosses AAC-1 x P.G.Purple (-0.09), AAC-1 x Violet Cushion (-0.05), Kamini x P.G.Purple (-0.05), Kamini x Poornima (-0.13) and Poornima x Violet Cushion (-0.12) were significant.

Among all the crosses, nine parents showed positive rca effects, out of which five crosses Kamini x AAC-1 (0.05), P.G.Purple x AAC-1 (0.13), Violet Cushion x

AAC-1 (0.21), P.G.Purple x Kamini (0.05) and Violet Cushion x Kamini (0.13) was significant . Cross Poornima x AAC-1 (-0.06) was negatively significant for this trait.

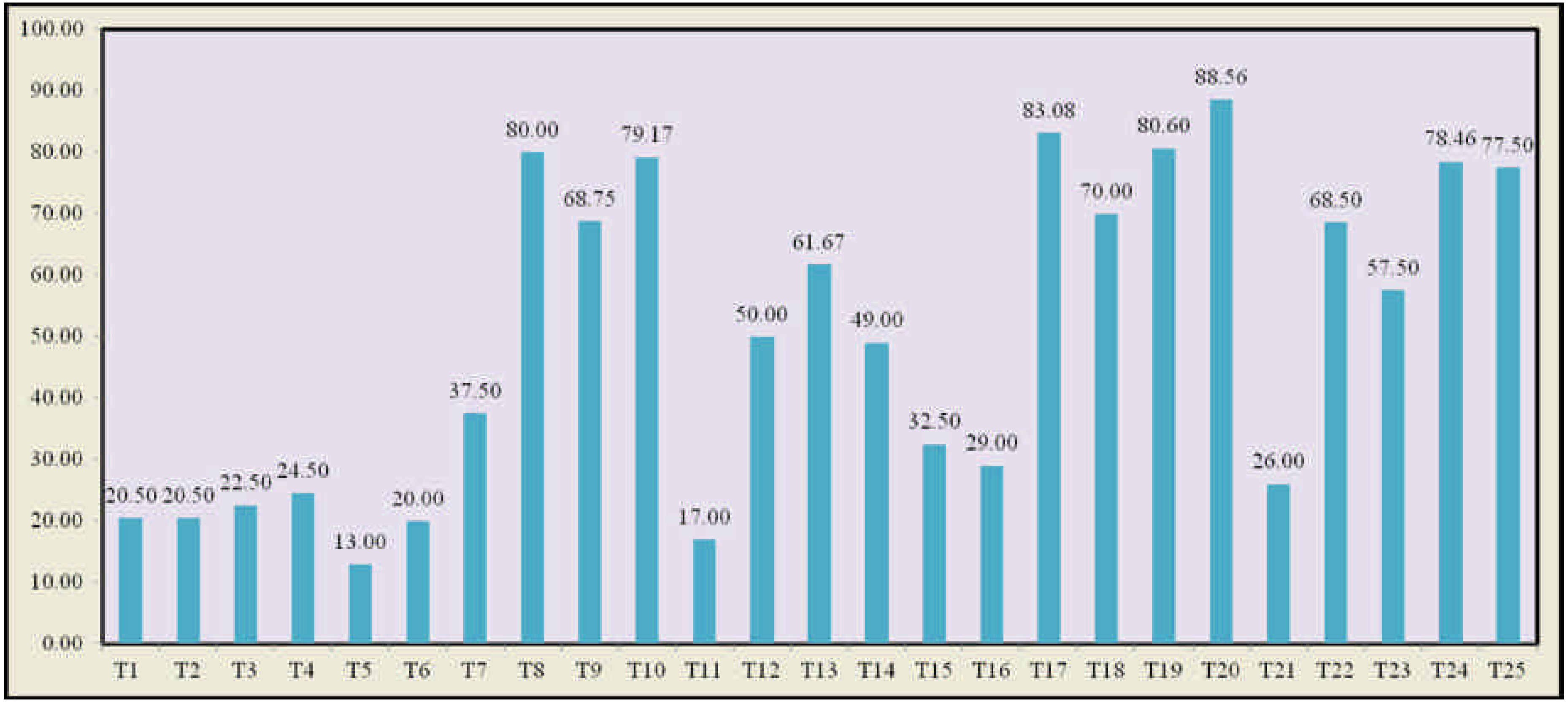
4.4 Evaluation of China aster parents and crosses against *Alternaria* leaf spot disease under natural disease pressure condition.

The evaluation of China aster parents and its crosses against *Alternaria* leaf spot under natural disease pressure condition was undertaken at K. R. C. College of Horticulture, Arabhavi, Department of Floriculture and Landscape Architecture during winter season of 2014-15. Among the parents used, AAC-1 showed high resistance to *Alternaria* leaf spot with an PDI of 13.00 per cent followed by the parent P.G.Purple (32.50 per cent) being moderately susceptible. Violet cushion (77.50 per cent) and Kamini (79.17 per cent) were susceptible whereas, the parent Poornima (88.56 per cent) was highly susceptible.

Among the crosses, P.G.Purple x AAC-1 (17.00%) exhibited high resistance to this disease followed by AAC-1 x Kamini (20.50%), AAC-1 x P.G.Purple (20.50%), AAC-1 x Poornima (22.50%), AAC-1 x Violet Cushion (24.50%), Kamini x AAC-1 (20.00%) showed moderate resistance. The crosses, Kamini x P.G.Purple (37.50 %), P.G.Purple x Kamini (50.00%), Poornima x AAC-1 (29.00%) and Violet Cushion x AAC-1 (26.00%) exhibited moderate susceptibility to *Alternaria* leaf spot. Cross between Kamini x Poornima (80.00%), Poornima x Kamini (83.08%), Poornima x Violet Cushion (80.60%) showed high susceptibility (Table 29 and Fig. 5).

Table 29. Field evaluation of China aster parents and crosses against *Alternaria* leaf spot disease under natural disease pressure condition

Treatments	PDI
AAC-1	13.00
AAC-1 X Kamini	20.50
AAC-1 X P.G.Purple	20.50
AAC-1 X Poornima	22.50
AAC-1 X Violet Cushion	24.50
Kamini	79.17
Kamini X AAC-1	20.00
Kamini X P.G.Purple	37.50
Kamini X Poornima	80.00
Kamini X Violet Cushion	68.75
P.G.Purple	32.50
P.G.Purple X AAC-1	17.00
P.G.Purple X Kamini	50.00
P.G.Purple X Poornima	61.67
P.G.Purple X Violet Cushion	49.00
Poornima	88.56
Poornima X AAC-1	29.00
Poornima X Kamini	83.08
Poornima X P.G.Purple	70.00
Poornima X Violet Cushion	80.60
Violet Cushion	77.50
Violet Cushion X AAC-1	26.00
Violet Cushion X Kamini	68.50
Violet Cushion X P.G.Purple	57.50
Violet Cushion X Poornima	78.46
S.Em ±	**4.57**
C.D. 5 %	**13.35**
C.D. 1 %	**18.09**



T_1 - AAC-1 X K	T_6 -K X AAC-1	T_{11} -PGP X AAC-1	T_{16} -P X AAC-1	T_{21} -VC X AAC-1
T_2 -AAC-1 X PGP	T_7 -K X PGP	T_{12} -PGP X K	T_{17} -P X K	T_{22} -VC X K
T_3 -AAC-1 X P	T_8 -K X P	T_{13} -PGP X P	T_{18} -P X PGP	T_{23} -VC X PGP
T_4 -AAC-1 X VC	T_9 -K X VC	T_{14} -PGP X VC	T_{19} -P X VC	T_{24} -VC X P
T_5 -AAC-1	T_{10} -K	T_{15} -PGP	T_{20} –P	T_{25} -VC

K- Kamini, PGP- P.G.Purple, P- Poornima and VC- Violet Cushion

Fig. 5: Field evaluation of China aster parents and F_1 hybrids against *Alternaria* leaf spot disease under natural disease pressure condition

5. DISCUSSION

Exploitation of hybrid vigor has gained momentum due to its spectacular yield increase in many self pollinated vegetables like onion, chilli, tomato etc.

Heterosis breeding in several flower crops namely rose, and petunia and marigold has been found to be useful in the improvement of yield. Simultaneously, there is ample scope for exploitation of hybrid vigor in China aster.

China aster is one of the important commercial flower crop used as loose flower for garland making, cut flower for interior decoration and as herbaceous borders in the garden. Considering the importance of this crop and looking into the immense potential of heterosis breeding in China aster, the present investigation was carried out. In the present study Diallel analysis, which is one of the important biometrical approach and provides information about general, specific and reciprocal combining ability of parents and crosses repectively, besides the type of gene action was adopted. The experiment consisted of five parents belonging to diverse genetic groups with respect to yield, yield components and quality traits were used to develop 20 hybrids. Kamini is the one important commercial variety in Karnataka, which was used as both parent and standard check for the present study. The study generated information on inheritance of yield, yield attributes and quality traits.

The breeder must possess an adequate knowledge of gene action, combining ability and degrees of dominance to practice selection. Results obtained in the present study are discussed under the following headings.

5.1 Heterosis and combining ability

Heterosis in hybrids over mid parent, better parent and standard check was estimated for twenty two characters. Twenty hybrids developed by using 5 x 5 diallel (including reciprocals) designs were evaluated for combing ability.

5.1.1 Plant height (cm)

Plant height is an important vegetative character determining growth of plant. Among twenty crosses, nine crosses over mid parent, two crosses over BP and eighteen crosses over standard check showed significant positive heterosis and similar observations were made by Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994a) and Suresh Kumar *et al.* (2004) in China aster, Sing and Swarup (1971) in marigold and Hemanth Kumar *et al.* (2010) in gladiolus.

There was also considerable genetic variation existed among parents and crosses. The SCA variance was higher than GCA variance which revealed the predominance of non additive gene action for the trait. Similar findings were reported by Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994b) and Suresh kumar *et al.* (2004) in China aster and Singh and Mishra (2010) in marigold

General combining ability effects of parents varied both in magnitude and direction. The parents P.G.Purple and Violet Cushion were found to be good general combiners for the trait. They seemed to possess additive genes for the trait.

Three crosses, AAC-1 x Kamini, Kamini x Violet Cushion and P.G.Purple x Poornima exhibited positive significant sca effects. These results are in conformity with Raghava and Negi (1993), Patil and Rane (1994b), Suresh Kumar *et al.* (2004) in China aster and Nagabhusanam *et al.* (1989) in marigold. None of the crosses showed positive significant rca effects.

Cross P.G.Purple x Poornima showed positive significant heterosis over MP and standard check and positive significant sca effects. Here, one parent was with high gca and other with low gca combinations, which indicated that additive x dominance type of gene action for the trait. Hence, suggesting that these hybrids can serve as useful genetic material for getting good segregants in the segregating population. Similar findings were obtained by Nagabhusanam *et al.* (1989) in marigold.

5.1.2 Number of leaves

The number of leaves has a positive effect not only on yield but also on the quality of flowers. The cross between Poornima x AAC-1 exhibited positive significant heterosis over standard check and cross Poornima x AAC-1 showed positive significant heterosis over MP, BP and standard check. Among twenty crosses, five crosses over MP, three crosses over BP and seventeen crosses over standard check showed significant positive heterosis. Similar results were obtained by Misra *et al.* (2001), Pant *et al.* (1992) in gladiolus and Kumar *et al.* (1989), Gupta *et al.* (2001) in marigold.

Significant difference was seen for parents verses crosses. Mean sum of squares of GCA, SCA and RCA were found significant. However, the magnitude of RCA variance was higher indicating neither additive nor non-additive gene action played role, but it was due to the Cytoplasmic gene action. Similar findings were reported by Bayat *et al.* (2010).

Whereas, two parents, AAC-1 and Violet Cushion showed positive significant gca effects and appeared to possess additive genes for the trait. However, the cross between AAC-1 x Poornima showed positive significant sca effect and the cross Poornima x AAC-1 exhibited positive significant rca effect. AAC-1 x Poornima and its reciprocal cross (Poornima x AAC-1) had one parent with high gca and other with low gca indicating that additive x dominance type of gene action for the trait, which can be exploited by heterosis breeding or recurrent selection. Similar results were seen by Suresh kumar *et al.* (2004) in China aster.

5.1.3 Stem girth (cm)

Among the crosses, P.G. Purple x AAC-1 exhibited significant positive heterotic effects over mid parent, better parent and standard check Kamini. Two crosses over mid parent, one cross over better parent and thirteen crosses over standard check exhibited positive significant heterosis, similar results were observed by De Leo and Ottaviano (1978) and Raghava (1984) in Gerbera and China aster repectively.

The mean sum of squares for GCA, SCA and RCA were non-significant for this trait. None of the parent showed positive significant GCA effect. Cross AAC-1 x P.G. Purple showed positive significant sca effect. Similar study has been reported by Raghava (1984) in China aster. Two crosses P.G. Purple x AAC-1 and Poornima x Kamini showed positive significant rca effects. The cross P.G. Purple x AAC-1 involved combination of parents with low x low GCA effects which indicated involvement of dominance x dominance type of gene action for the trait, which indicated non additive gene action and these can be exploited by heterosis breeding or recurrent selection.

5.1.4 Plant spread (cm^2)

The cross P.G.Purple x Poornima showed positive significant heterotic effect over mid parent, better parent and standard check. Among twenty crosses, five crosses over mid parent, three crosses over BP and thirteen crosses over standard check showed significant positive heterosis. Similar observations were made by Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994b) and Suresh kumar *et al.* (2004) in China aster and Sing and Swarup (1971) in marigold.

There was considerable genetic variation observed among the parents and crosses. The component of variance due to specific combining ability was higher than general combining ability which indicated predominant role of non additive gene action. These results were in confirmation with Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994b) and Suresh kumar *et al.*(2004) in China aster.

Two parents AAC-1 and P.G.Purple showed positive significant gca effects and appeared to possess additive genes.

The cross P.G.Purple x Poornima recorded positive significant sca effect. Similar results were also obtained by Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994b) and Suresh Kumar *et al.* (2004) in China aster and Nagabhusanam *et al.* (1989) in marigold. None of the crosses showed positive significant rca effect for this trait.

The crosses involved parent with low x high type of gca effects which indicated additive x dominant type of gene action for the trait, which can be exploited by heterosis breeding or recurrent selection.

5.1.5 Leaf area per plant (cm^2)

The crosses AAC-1 x Poornima exhibited significant positive heterotic effects over mid parent, better parent and standard check Kamini and AAC-1 x Kamini and the cross Violet Cushion x Kamini showed significant positive heterotic effect over mid parent and standard check,. Five crosses over mid parent, three cross over better parent and thirteen crosses over standard check exhibited positive significant heterosis. Similar results were recorded by Suresh kumar *et al.* (2004) in China aster.

The results indicated that considerable genetic variation existed among parents and crosses. The magnitude of RCA variance was higher indicating neither additive nor non-additive gene action, but it was the Cytoplasmic gene action which played role.

Two parents AAC-1 and Poornima showed positive significant gca effects and appeared to possess additive genes.

Two crosses AAC-1 x Poornima and AAC-1 x Kamini showed positive significant sca effect. Similar study has been reported by Raghava (1984) in China aster. Two crosses P.G. Purple x Kamini and Violet Cushion x Kamini showed positive significant rca effects.

The cross AAC-1 x Poornima involved combination of parents with high x high gca effects which indicated involvement of additive x additive type of gene action for the trait. The cross Violet Cushion x Kamini had combination of low x low gca effect, which indicate involvement of dominant x dominant type, which indicated non additive gene action and these can be exploited by heterosis breeding or recurrent selection. Similar results were recorded by Suresh kumar *et al.* (2004) in China aster.

5.1.6 Number of branches

The cross AAC-1 x P.G.Purple showed positive significant heterosis over mid parent and standard check. Eleven crosses over mid parent, one crosses over BP and seventeen crosses over standard check showed significant positive heterosis. Similar observations were made by Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994b) and Suresh Kumar *et al.* (2004) in China aster and Sing and Swarup (1971) in marigold.

Significant difference was seen for parents verses crosses. Mean sum of squares of GCA and SCA were found significant. However, the magnitude of SCA variance was higher indicating the predominance of non-additive gene action. As reported by Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994b) and Suresh Kumar *et al.* (2004) in China aster.

General combining ability effects of parents varied both in magnitude and direction. The parents P.G.Purple and Violet Cushion were found to be general combiners for the trait. They seemed to possess additive genes for the trait.

Three crosses AAC-1 x P.G.Purple, Kamini x Violet Cushion and P.G.Purple x Poornima recorded positive significant sca effect. One cross P.G.Purple x Kamini showed positive significant rca effect for this trait. Similar results were recorded by Suresh kumar *et al.* (2004) in China aster.

Majority of the crosses involved combination of low x high gca effect, which indicate involvement of additive x dominant type of gene action, which can be exploited by heterosis breeding or recurrent selection.

5.1.7 Days for first flower bud initiation

Flower bud initiation is an important trait. The crosses AAC-1 x P.G.Purple, Kamini x Poornima and P.G.Purple x Poornima showed negative significant heterosis over MP and BP. Four crosses over mid parent, seven crosses over BP showed significant negative heterosis. Similar observations were made by Anita *et al.* (2003a) in marigold and Suresh kumar *et al.* (2004) in China aster.

The results indicated that considerable genetic variation existed among parents and crosses. The SCA variance was higher than GCA variance which revealed the predominance of non additive gene action for the trait. Similar findings were reported by Anita *et al.* (2003a) in marigold and Suresh kumar *et al.* (2004) in China aster.

General combining ability effects of parents varied both in magnitude and direction. The parents Kamini and P.G.Purple was found to be good general combiners for the trait. They seemed to possess additive genes for the trait.

Three crosses, AAC-1 x P.G.Purple, Kamini x Poornima and P.G.Purple x Poornima exhibited negative significant sca effects. These results are in conformity with Anita *et al.* (2003a) in marigold and Suresh kumar *et al.* (2004) in China aster. Cross Poornima x Kamini showed negative significant rca effects.

The cross Kamini x Poornima had both the parents with low gca and other two crosses had parents with low x high which indicated that dominant x dominance and additive x dominant type of gene action, repectively for the trait and can be exploited by heterosis breeding or recurrent selection.

5.1.8 Days for first flowering

First floret opening is another maturity component. Two crosses Kamini x Poornima and P.G.Purple x Poornima showed negative significant heterosis over mid parent and better parent. Five crosses exhibited negatively significant heterosis over MP and seven crosses over BP. Similar findings were obtained by Raghava and Negi (1993), Patil and Rane (1993), Suresh kumar *et al.* (2004) in China aster and Anita *et al.* (2003b) in marigold.

The results indicated that considerable genetic variation existed among parents and crosses. The component of variance due to SCA found to be higher than GCA which indicated the predominant role of non additive gene action. These findings are in agreement with Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994b) and Suresh kumar *et al.*(2004) in China aster and Anita *et al.* (2003a) in marigold. On the contrary, Singh and Swarup (1971) reported higher GCA component of variance in marigold.

The parents Kamini and P.G.Purple exhibited negative significant gca effect and appeared to possess additive genes for the trait.

Three crosses AAC-1 x P.G.Purple, Kamini x Poornima and P.G. Purple x Poornima showed negative significant sca effect and these findings are in confirmation with study of Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994b) and Suresh kumar *et al.*(2004) in China aster. None of the cross showed negative significant rca effect for the trait.

The crosses had both parents with low gca effect, indicating action of dominance x dominant type, which indicated non additive gene action and these can be exploited by heterosis breeding or recurrent selection.

5.1.9 Days for 50% flowering

The cross Kamini x Poornima showed negative significant heterosis over MP and BP. Six crosses over mid parent, eleven crosses over BP showed significant negative heterosis. Similar observations was made by Suresh kumar *et al.*(2004) in China aster.

The results indicated that considerable genetic variation existed among parents and crosses. The SCA variance was higher than GCA variance which revealed the predominance of non additive gene action for the trait. Similar findings were reported by Nagabhusanam *et al.* (1989) in marigold and Suresh kumar *et al.* (2004) in China aster.

General combining ability effects of parents varied in magnitude of effect and also direction. The parent Kamini and P.G.Purple recorded significant negative gca effects and they seemed to possess additive genes for the trait.

Three crosses, AAC-1 x Violet Cushion, Kamini x Poornima and P.G.Purple x Poornima exhibited negative significant sca effects. These results are in conformity with by Nagabhusanam *et al.* (1989) in marigold and Suresh kumar *et al.*(2004) in China aster. None of the cross showed negative significant rca effects.

The crosses Kamini x Poornima and P.G.Purple x Poornima had both the parents with low gca which indicated that dominant x dominance type of gene action for the trait, which indicated non additive gene action and these can be exploited by heterosis breeding or recurrent selection. Similar results were reported by Nagabhusanam *et al.* (1989) in marigold and Suresh kumar *et al.* (2004) in China aster.

5.1.10 Duration of flowering

Flowering duration is also an important maturity component where the earliness is preferred. Among the crosses, AAC-1 x Poornima exhibited significant positive heterotic effects for MP, BP and standard check, where as the crosses Kamini x Violet Cushion and P.G.Purple x Poornima showed significant positive heterotic effects for MP and standard check. Nine crosses over MP, two crosses over BP and eighteen crosses over standard check showed significant positive heterosis. Similar results were obtained by Raghava (1984) and Suresh kumar *et al.*(2004) in China aster, Singh and Swarup (1971) and Gupta *et al.* (2001) in marigold.

The results indicated significant genetic variation among parents and crosses. The SCA variance was higher than GCA variance which revealed the predominance of non additive gene action for the trait. Similar findings were reported by Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994b) and Suresh kumar *et al.*(2004) in China aster and Anita *et al.*(2003a) in marigold.

Two parents, P.G.Purple and Violet Cushion showed positive significant gca effects and appeared to possess additive genes for the trait.

Three crosses, AAC-1 x Poornima, Kamini x Violet Cushion and P.G.Purple x Poornima exhibited positive significant sca effects. These results are in conformity with Raghava and Negi (1993), Patil and Rane (1994b), Suresh kumar *et al.* (2004) in China aster and Nagabhusanam *et al.* (1989) in marigold. Two crosses Poornima x Kamini and Violet Cushion x Poornima showed positive significant rca effects.

Majority of the crosses showed parents with low x high gca type which indicated additive x dominance type of gene action for the trait and can be exploited by heterosis breeding or recurrent selection.

5.1.11 Number of flowers per plant

The number of flowers per plant is an important yield parameter in China aster. Three crosses AAC-1 x Kamini, AAC-1 x Poornima and Kamini x AAC-1 exhibited positive significant heterotic effect over MP, BP and standard check. Majority of crosses recorded significant positive heterosis over MP, BP and standard check Kamini. Similar findings were reported by Raghava (1988) in China aster, Singh and Swarup (1971), Singh and Swarup (1973), Kumar *et al.* (1989), Gupta *et al.* (2001) in marigold and Swarup *et al.* (1975) in balsam.

Significant differences were seen for parents verses crosses. Mean sum of squares of GCA, SCA and RCA were found significant. However, the magnitude of SCA variance was higher indicating the predominance of non-additive gene action. As reported by Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994b) and

Suresh Kumar *et al.* (2004) in China aster, Singh and Swarup (1971) and Anita *et al.* (2003a) in marigold.

Two parents, P.G.Purple and Violet Cushion showed positive significant gca effects and appeared to possess additive genes for the trait (Plate 6).

Six crosses AAC-1 x Kamini, AAC-1 x Poornima, Kamini x P.G. Purple, Kamini x Violet Cushion, P.G. Purple x Poornima and Poornima x Violet Cushion recorded positive significant sca effect. Two crosses Kamini x AAC-1 and Violet Cushion x AAC-1 showed positive significant rca effect for this trait. Similar results were observed by Bayat *et al.* (2012).

Maximum of the crosses had parents with low x low gca effects which indicated dominance x dominance type of gene action for the trait, which indicated non additive gene action and these can be exploited by heterosis breeding or recurrent selection.

5.1.12 Individual flower weight (g)

The cross AAC-1 x P.G. Purple showed positive significant heterotic effects over mid parent, better parent and standard check Kamini. Seven crosses over mid parent, three crosses over better parent and twelve crosses over standard check exhibited positive significant heterosis, similar results were observed by Singh and Swarup (1971), Kumar *et al.* (1989), Nagabhusanam *et al.* (1989) in marigold, Raghava *et al.* (1988) in China aster.

The mean sum of squares for GCA, SCA and RCA were non significant for this trait. Parent Violet Cushion showed positive significant gca effect. Crosses AAC-1 x P.G. Purple and Violet Cushion x P.G. Purple showed positive significant sca and rca effect, repectively. As reported by Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994b) and Suresh kumar *et al.*(2004) in China aster, Singh and Swarup (1971) and Anita *et al.* (2003a) in marigold.

The cross AAC-1 x P.G. Purple involved combination of parents with low x high gca effects which indicated involvement of additive x dominance type of gene action for the trait and can be exploited by heterosis breeding or recurrent selection.

VIOLET CUSHION

P.G.PURPLE

Plate 6: Good general combiner for yield and its components

5.1.13 Weight of ten flowers (g)

The cross, AAC-1 x Poornima, exhibited significant positive heterotic effects over mid parent, better parent and standard check Kamini. Four crosses over mid parent, three crosses over better parent and twelve crosses over standard check exhibited positive significant heterosis. Similar results were observed by Singh and Swarup (1971), Kumar *et al.* (1989), Nagabhusanam *et al.* (1989) in marigold, Raghava *et al.* (1988) in China aster.

The results indicated that considerable genetic variation existed among parents and crosses. The component of variance due to reciprocal combining ability was higher than general combining ability, indicating neither additive nor non-additive gene action, but it was the Cytoplasmic gene action played major role.

Parent Violet Cushion showed positive significant gca effects and appeared to possess additive genes. Cross AAC-1 x Poornima showed positive significant sca effect. None of the crosses showed positive significant rca effects. Among which, the crosses, AAC-1 x Poornima exhibited significant positive heterotic effects over mid parent, better parent and standard check Kamini.

The cross AAC-1 x Poornima involved combination of parents with low x high gca effects which indicated involvement of additive x dominant type of gene action for the trait and can be exploited by heterosis breeding or recurrent selection.

5.1.14 Flower yield per plant (g)

Flower yield per plant is an important yield parameter. The crosses AAC-1 x Poornima, Kamini x P.G. Purple, Kamini x Violet Cushion and Violet Cushion x P.G. Purple positive significant heterosis over MP and standard check. Seventeen crosses over MP, six crosses over BP and eighteen crosses over standard check showed significant positive heterosis. Results obtained were similar to that of Suresh Kumar *et al.* (2004) in China aster.

Significant differences were seen for parents verses crosses. Mean sum of squares of GCA, SCA and RCA were found significant. However, the magnitude of

SCA variance was higher indicating the predominance of non-additive gene action. Similar results were confirmed by Suresh Kumar *et al.* (2004) in China aster.

Parent Violet Cushion showed positive significant gca effects and appeared to possess additive genes for the trait. Three crosses AAC-1 x Poornima, Kamini x P.G. Purple and Kamini x Violet Cushion showed positive significant sca effect and cross between Violet Cushion x P.G. Purple exhibited positive significant rca effect. As reported by Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994b) and Suresh kumar *et al.*(2004) in China aster, Singh and Swarup (1971) and Anita *et al.* (2003a) in marigold.

The cross, AAC-1 x Poornima had both parents with low gca, indicating dominant x dominant type of gene action. The cross Kamini x Violet Cushion, one parent low gca and another parent with high gca indicating that additive x dominance type of gene action for the trait and can be exploited by heterosis breeding or recurrent selection.

5.1.15 Flower yield per hectare (t/ha)

The crosses AAC-1 x Kamini and AAC-1 x Poornima positive significant heterosis over MP, BP and standard check. The cross Violet Cushion x P.G. Purple exhibited positive significant heterosis over MP and standard check. Seventeen crosses over MP, six crosses over BP and eighteen crosses over standard check showed significant positive heterosis.

Significant differences were seen for parents verses crosses. Mean sum of squares of GCA, SCA and RCA were found significant. However, the magnitude of SCA variance was higher indicating the predominance of non-additive gene action. This result were confirmed with the results of Suresh kumar *et al.* (2004a) in China aster and Kattera *et al.* (2014) in annual chrysanthemum.

Parent Violet Cushion showed positive significant gca effects and appeared to possess additive genes for the trait.

Three crosses AAC-1 x Kamini, AAC-1 x Poornima and P.G.Purple x Violet Cushion showed positive significant sca effect. The cross Violet Cushion x P.G. Purple exhibited positive significant rca effect. Similar results were reported by Suresh Kumar *et al.* (2003).

Cross AAC-1 x Poornima had both parent with low gca indicating dominant x dominant type of gene action. The cross P.G.Purple x Violet Cushion, one parent low gca and another parent with high gca indicating that additive x dominance type of gene action for the trait and can be exploited by heterosis breeding or recurrent selection.

5.1.16 Flower stalk length (cm)

The cross Violet Cushion x AAC-1 showed positive significant heterotic effect over mid parent, better parent and standard check. Three crosses over mid parent, one crosses over BP and four crosses over standard check showed significant positive heterosis. Similar observations were made by Raghava *et al.* (1988) and Suresh kumar *et al.* (2003) in China aster, Gupta *et al.* (2001) and Anita *et al.* (2003b) in marigold.

There was considerable genetic variation observed among the parents and crosses. The component of variance due to reciprocal combining ability was higher than general combining ability which indicated predominant role of Cytoplasmic gene action.

Parent Violet Cushion showed positive significant gca effect and appeared to possess additive genes for the trait. None of the cross recorded positive significant sca effect. Cross Violet Cushion x AAC-1 showed positive significant rca effect for this trait. Similar results were reported by Suresh Kumar *et al.* (2003).

The cross Violet Cushion x AAC-1 involved parent with low x high type of gca effects which indicated additive x dominant type of gene action for the trait and can be exploited by heterosis breeding or recurrent selection.

5.1.17 Flower diameter (cm)

The cross showed AAC-1 x Kamini exhibited positive significant heterotic effect over mid parent, and standard check and cross between Kamini x Poornima showed positive significant heterotic effect over mid parent and standard check. Two crosses over mid parent and six crosses over standard check showed significant positive heterosis. Similar results were reported by Suresh Kumar *et al.* (2003).

The GCA, SCA and RCA variance were found to be non significant for the trait. One parent AAC-1 showed positive significant gca effect and appeared to possess additive genes for the trait. Two crosses AAC-1 x Kamini and Kamini x Poornima recorded positive significant sca effect. Cross Violet Cushion x P.G.Purple showed positive significant rca effect for this trait. Similar results were confirmed by Suresh Kumar *et al.* (2003).

The cross AAC-1 x Kamini involved parent with low x high type of gca effects which indicated additive x dominant type of gene action for the trait. Whereas, the cross Kamini x Poornima involved parent with low x low type of gca effects which indicated dominant x dominant type , which indicated non additive gene action and these can be exploited by heterosis breeding or recurrent selection.

5.1.18 Ray floret length (cm)

The cross showed AAC-1 x Poornima exhibited positive significant heterotic effect over mid parent and standard check. Two crosses over mid parent and five crosses over standard check showed significant positive heterosis. Similar results were reported by Suresh Kumar *et al.* (2003).

GCA, SCA and RCA variance were found to be non significant for the trait. The component of variance due to reciprocal combining ability was higher than general combining ability which indicated role of Cytoplasmic gene action.

One parent AAC-1 showed positive significant gca effect and appeared to possess additive genes for the trait. None of the crosses showed positive significant sca and rca effects.

The cross AAC-1 x Poornima involved parent with low x high type of gca effects which indicated additive x dominant type of gene action for the trait and can be exploited by heterosis breeding or recurrent selection.

5.1.19 Disc floret length (cm)

The cross between Kamini x Violet Cushion showed positive significant heterosis over standard check. Eight crosses over standard check Kamini showed significant positive heterosis.

Significant difference were seen for parents verses crosses. Mean sum of squares of GCA, SCA and RCA were found significant. However, the magnitude of SCA variance was higher indicating the predominance of non-additive gene action. This result was confirmed by Suresh kumar *et al.* (2004) in China aster.

General combining ability effects of parents varied both in magnitude and direction. The parent Violet Cushion was found to be general combiners for the trait and seemed to possess additive genes for the trait. None of the crosses showed positive significant sca and rca effect for this trait.

The crosses involved combination of low x high gca effect, which indicate involvement of additive x dominant type of gene action and can be exploited by heterosis breeding or recurrent selection. Similar result was observed by Suresh kumar *et al.* (2004) in China aster.

5.1.20 Vase life

It is an important quality parameter. Two crosses AAC-1 x P.G.Purple and Kamini x P.G.Purple showed positive significant heterosis over MP, BP and standard check. Seven crosses over mid parent, five crosses over better parent and eighteen crosses over standard check showed significant positive heterosis. Similar observations were made by Raghava (1984), Raghava (1988), Patil and Rane (1994a) and Suresh kumar *et al.* (2004) in China aster.

The results indicated that considerable genetic variation existed among parents and crosses. The SCA variance was higher than GCA variance which revealed the predominance of non additive gene action for the trait. Similar findings were reported by Raghava (1984), Raghava and Negi (1993), Patil and Rane (1994b) and Suresh kumar *et al.*(2004) in China aster.

General combining ability effects of parents varied both in magnitude and direction. The parents P.G.Purple and Violet Cushion were found to be general combiners for the trait. They seemed to possess additive genes for the trait.

Three crosses, AAC-1 x P.G.Purple, Kamini x P.G.Purple and Kamini x Violet Cushion exhibited positive significant sca effects. These results are in conformity with Raghava and Negi (1993), Patil and Rane (1994b), Suresh kumar *et al.* (2004) in China aster. Two crosses Kamini x AAC-1 and Violet Cushion x Kamini showed positive significant rca effects.

In the above crosses, one parent was with high gca and other with low gca which indicated that additive x dominance type of gene action for the trait and can be exploited by heterosis breeding or recurrent selection.

5.1.21 Seed yield per plant (g)

The cross showed AAC-1 x Poornima exhibited positive significant heterotic effect over mid parent, better parent and standard check. Two crosses over mid parent, one crosses over better parent and two crosses over standard check showed significant positive heterosis. Similar results were reported by Singh and Mishra (2010) in marigold.

GCA, SCA and RCA variance were found to be non significant for the trait. The parent Violet Cushion showed positive significant gca effect and appeared to possess additive genes for the trait.

Two crosses AAC-1 x Kamini and AAC-1 x Poornima, showed positive significant sca effects. Four crosses Violet Cushion x Kamini, Violet Cushion x AAC-1, Violet Cushion x P.G.Purple and Violet Cushion x Poornima showed positive significant rca effects. Similar results were confirmed by Singh and Mishra (2010) in marigold.

The cross between AAC-1 x Poornima involved parent with low x low type of gca effects which indicated dominance x dominance type of gene action for the trait, which indicated non additive gene action and these can be exploited by heterosis breeding or recurrent selection.

5.1.22 Seed test weight (g)

The cross showed AAC-1 x Poornima exhibited positive significant heterotic effect over mid parent, better parent and standard check. Four crosses over mid parent, two crosses over better parent and six crosses over standard check showed significant positive heterosis.

GCA, SCA and RCA variance were found to be non significant for the trait. Two parent AAC-1 and Poornima showed positive significant gca effect and appeared to possess additive genes for the trait.

Four crosses AAC-1 x Kamini, AAC-1 x Poornima, P.G. Purple x Poornima and P.G. Purple x Violet Cushion showed positive significant sca effects. Two crosses Kamini x AAC-1 and Violet Cushion x Kamini showed positive significant rca effects.

The cross involved parent with high x high type of gca effects which indicated additive x additive type of gene action for the trait and these can be exploited by selection or reciprocal recurrent selection.

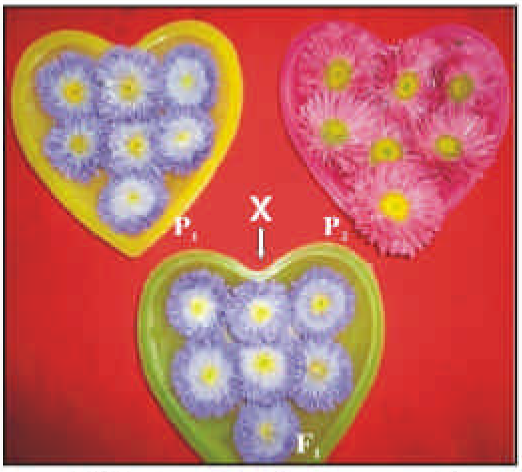
5.1.23 Inheritance of flower color

The cross between violet colored flowers with purple, pink and white colored flowers resulted in F_1 hybrids with violet colored flowers indicating dominance of violet color over all these colors. While purple color was found to be dominant over pink and white color and pink was dominant over white. White color was recessive to all (Plate 7). Similar findings were obtained by Raghava (1984) and Negi and Raghava (1990) in China aster.

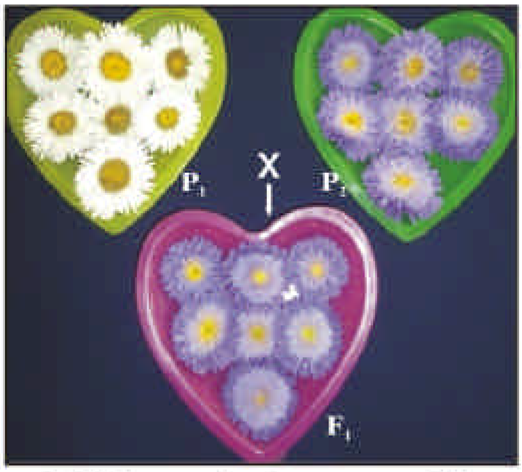
Violet > Purple > Pink > White

5.2 Evaluation of China aster parents and crosses against *Alternaria* leaf spot disease under natural disease pressure condition

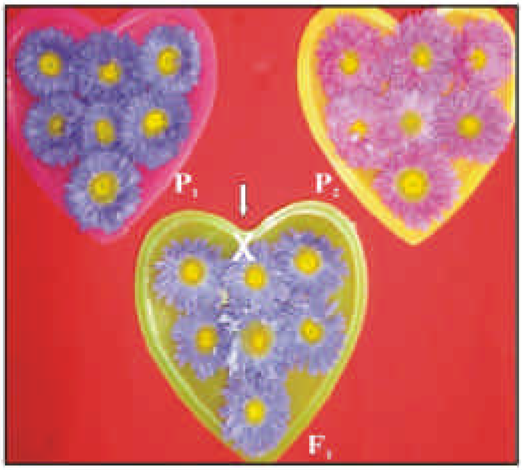
The results revealed that the parent AAC-1 was highly resistance with low score to *Alternaria* leaf spot under natural disease pressure condition. The parent Poornima was found to be the susceptible once with high score. Similar results were seen by Rachappa (2014).



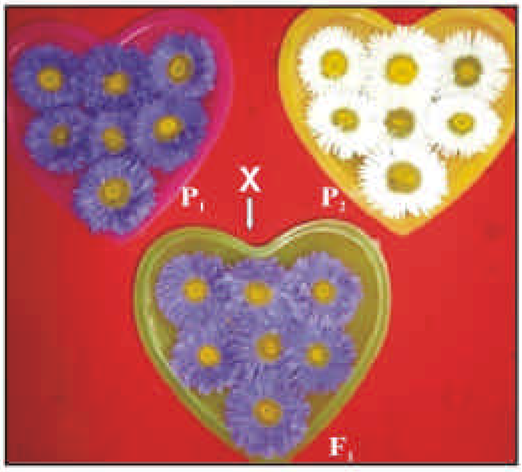
a. Violet was dominant over pink



b. Violet was dominant over white



c. Purple was dominant over pink



d. Purple was dominant over white

e. Pink was dominant over white

Plate 7: Inheritance of flower color in China aster

Among the crosses, P.G.Purple x AAC-1 was found to be the resistant with low score. The degree of variation occurred with respect to the response of crosses to *Alternaria* leaf spot disease was expected since, resistant and susceptibility was controlled by dominant and recessive genes, respectively.

5.3 Pooled gca effects of the parents used in (5x5) full diallel cross of China aster

The information on combining ability was considered to identify potential parents. An assessment was carried out by taking in to account of all the characters simultaneously. For every character a parent was awarded ‘0’ score for non-significant combining ability effects and ‘+1’ for significant gca effects in desirable direction and ‘-1’ for significant gca effects in undesirable direction. All the parents were scored for each character and final score was computed by adding scores obtained in all the twenty two characters and details are presented in Table 30.

Table 30: Overall analysis of general combining ability status for the parents in China aster

Parents	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Total		gca status
																							+ve	-ve	
AAC-1	0	+1	0	+1	+1	-1	+1	+1	0	0	-1	0	0	-1	-1	0	0	0	0	0	0	0	+5	-4	H
Kamini	-1	-1	0	-1	-1	-1	-1	-1	-1	0	-1	0	-1	-1	-1	0	0	0	0	0	0	0	0	-12	L
P.G.Purple	+1	0	0	+1	-1	+1	-1	-1	-1	+1	+1	0	-1	-1	-1	0	0	0	0	0	0	0	+5	-7	L
Poornima	0	-1	0	-1	+1	-1	0	0	0	-1	-1	0	-1	-1	-1	0	0	0	0	0	0	0	+1	-8	L
Violet Cushion	+1	+1	0	-1	-1	+1	+1	+1	+1	0	+1	0	+1	+1	+1	+1	0	0	+1	+1	0	0	+13	-2	H

1. Plant height at
2. No. of leaves
3. Stem girth (cm)
4. Plant spread
5. Leaf area
6. No. of branches
7. Days for 1st flower bud initiation

8- Days for 1st flowering
9- Days for 50% flowering
10- Duration of flowering
11- No. of flowers/plant
12- Individual flower weight
13- Weight of ten flowers

14- Flower yield/plant
15- Flower yield/ha
16- Flower stalk length
17- Flower diameter
18- Ray floret length
19- Disc floret length
20. Vase life
21- Seed yield per plant 22. Seed test weight

0 =Non- significant gca effects
-1 =gca effects in undesirable direction
+1 =gca effects in desirable direction
H = High combiner
L = Low combiner

6. SUMMARY AND CONCLUSIONS

Field experiment to study the combining ability and heterosis in China aster (*Callistephus chinensis* L. Nees) was undertaken with the objective of identifying good combiners among the genotype and to assess the magnitude of heterosis for growth, yield and quality parameters. The experiment was laid out at the research field of Department of Floriculture and Landscape Architecture, K. R. C. College of Horticulture, Arabhavi during 2014-15 in randomized block design and observation were subjected to full diallel analysis. The results of the present investigation are summarized hereunder.

An appreciable amount of variability was obtained for most of the traits in the collection and hybridization materials. Combining ability analysis revealed higher magnitude of SCA variance except number of leaves, leaf area per plant, weight of ten flowers, flower stalk length and ray floret length where RCA variance was higher.

The parent Kamini was a good general combiner for early flowering while, Violet Cushion was found to possess additive genes for plant height, number of leaves, number of branches, duration of flowering, number of flowers/plant, weight of ten flowers, flower yield per plant, flower yield per hectare, flower stalk length and vase life.

The two crosses Kamini x Poornima and P.G.Purple x Poornima exhibited significant negative sca effects and significant negative heterosis over mid parent and better for days for first flower bud initiation, days for first flower opening and days for 50 % flowering. Other two crosses AAC-1 x Kamini and AAC-1 x P.G.Purple showed significant positive sca effects coupled with significant positive heterosis over mid parent and standard check for plant height, number of branches, plant spread, leaf area and number of branches. The cross AAC-1 x Poornima exhibited significant sca effects coupled with significant positive heterosis over mid, better parent and standard check Kamini for duration of flowering, number of flowers per plant, weight of ten flowers and flower yield per plant. Whereas, the cross Kamini x P.G.Purple showed positive significant sca effect coupled with significant positive heterosis over mid, better parent and standard check for vase life and the cross Violet Cushion x AAC-1 exhibited positive significant rca effect and significant positive heterosis over mid, better parent and standard check for flower stalk length.

Based on flower color, the crosses Violet Cushion x P.G.Purple and Violet Cushion x AAC-1 were found to be promising for Violet color flowers. While, for purple colored flowers the cross P.G.Purple x AAC-1 and for pink colored flowers the crosses AAC-1 x Poornima, AAC-1 x Kamini, Kamini x AAC-1 and Kamini x Poornima were found to be the promising hybrids.

Majority of the heterotic crosses had H x L general combining ability parents. Generally, a significant heterotic cross would be of H x L type followed by L x L or H x H combinations. Hence, breeder has to attempt successful hybridization economically in terms of time, cost and number of crosses, it is worthwhile to start with H x L type of crosses followed by L x L for exploiting heterosis.

Inheritance of flower color lead to an conclusion that violet color was dominant over all the other flower colors *i.e.,* purple, pink and white. Violet color was followed by purple, pink and white. White color was recessive to all the other flower colors studied under this aspect.

Evaluation of these parents and F_1's against *Alternaria* leaf spot lead to resistant F_1's among which P.G.Purple x AAC-1 was highly resistant. The crosses which involved AAC-1 as one of its parent, those F_1's were partially or fully resistant to this disease because the parent AAC-1 itself is highly resistant to *Alternaria* leaf spot disease.

Future line of investigations

Since the parents used in the present study are not randomly selected from any population, but are only a chosen set, the results obtained and methods being suggested based on the results, are applicable only to the breeding programmes to be planned with the parents and the materials derived from them. Since, there was predominance of non additive gene action for the majority of the traits, the method which could be suggested for the future breeding programme are heterosis breeding and recurrent selection for specific combining ability.

The cross combination which showed high *per se* performance for flower yield (AAC-1 x Poornima, AAC-1 x P.G.Purple, AAC-1 x Kamini and Kamini x AAC-1), stalk length (Violet Cushion x AAC-1 and Violet Cushion x Kamini) and vase life (AAC-1 x P.G.Purple, Kamini x AAC-1, Kamini x P.G.Purple and P.G.Purple x AAC-1), these crosses also had desirable morphological characters. These cross combinations are most suitable for the exploitation of heterosis for above said traits. Majority of the crosses with high *per se* performance were of H x L type. Therefore, it is worthwhile to start with H x L combination for successful breeding programme.

REFERENCES

Anita, M., Mohanty, C. R. and Mohanpatra, K. C., 2003a, Combining ability for yield and its components in marigold. J. Orn. Hort. **6**(1): 34-38.

Anita, M., Mohanty, C. R. and Mohanpatra, K. C., 2003b, Heterosis studies in African marigold. J. Orn. Hort., **6**(1): 55-57.

Anonymous, 2010-11, www.horticulture.kar.nic.in, Area, production and productivity of cut flower crops.

Arnumachalam, V. and Bandopadhay, A., 1979, Are "Multiple cross multiple pollen" an answer for productive population in *Brassica campestris* var. Braon sarson. Theor. Appl. Genet., **54**: 203-207.

Bayat, H., Neamati, H., Bagheri, A., Tehranifar, A. and Saie, M., 2012, Estimation of heterosis and combining ability in petunia (*Petunia hybrida* Hort.). Not. Sci. Biol., **4**(3): 151-157.

De Leo, V. and Ottaviano, E., 1978, Genetical analysis of morphological traits in *Greber jamesonii* clonal diallel families. Preceedings Eucarpia meeting on genetics and breeding of carnation and gerbera held at Alassio from 24th to 28th April. 1978, pp. 179-191.

Desai, B. L., 1967, Seasonal flowers. ICAR pub., New Delhi, pp. 53-66.

Emsweller, S. L., Brieley, P., Lumsden, D. V. and Mulfred, F. L., 1937, Breeding of ornamental plants. U.S.D.A Year book of Agriculture, U. S.Department of Agriculture, pp. 926-929.

Fleming, W. M., 1937, In: U.S.D.A Year book of agriculture, U.S. Department of Agriculture, p. 985.

Griffing, B., 1956, Concept of general and specific combining ability in relation to diallel crossing system. Aust. J. Biol. Sci, **9**: 463-493.

Gupta, Y. C., Raghava, S. P. S. and Misra, R. L., 2001, Heterosis in African marigold. Indian J. Gen., **61**(1): 65-68.

Hayes, H. K., Immer, F. R. and Smith, P. C., 1995, Methods of plant breeding, Mc Hill Book Co. Inc., New York.

Hemanth kumar, P., Kulkarni, B. S., Jagadeesha, R. C., Reddy, B.S., Shirol, A. M. and Mulge, R., 2008, Combining ability and heterosis for growth characters in gladiolus (*Gladiolus hybrids.* Hort.). Karnataka J. Agric. Sci., **21**(4): 544-547.

Hussein, H.A.S. and Mishiha, A., 1979, Diallel analysis of some quantitative characters in *Petunia hybrida* Hort. Theor. Appl. Genet., **54**: 17-25.

Jackson, M. C., 1967, Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi, pp. 183-193.

Kattera, S., Panchbhai, D. M., Reddy, M. P. and Rajasekhar, B., 2014, Genetic analysis of annual chrysanthemum by diallel mating. Trends in Biosci., **7**(16): 2221-2225.

Kumar, S., Shanmugavelu, K. G. and Irulappan, I., 1989, Hybrid vigour in marigold for economic characters. South Ind. Hort., **38**(3): 173-174.

Matous, J., 1962, Possibilites of using heterosis and the problems of pollen sterility in *Cyclamen persicum* mill. Acta Pruhoniciana, **4**: 13-51.

Misra, R. L., De, R. C. and Saint, H. C., 2001, Manifestation of Heterosis in Exotic x Indigenous crosses of gladiolus. J. Ornl. Hort., New Series, **4** (1): 6-11.

Nagabhusanam Reddy, E., Muthuswami, S., Irulappan, I. and Abdul Khadar, M. D., 1989, Heterosis and combining ability for yield and yield components in African marigold. South Ind. Hort., **36**(1): 51-61.

Negi, S. S. and Raghava, S. P. S., 1990, Genetics of flower color in China aster. Euphytica, **48**: 117-122.

North, C., 1979, Plant breeding and genetics in horticulture. Mac Millan press Ltd. London, pp. 107.

Panse, V. C. and Sukhatme, P. V., 1967, Statistical methods for agricultural workers. ICAR, New Delhi.

Pant, C. C. and Lal, S. D., 1992. Heterosis in Gladiolus (*Gladiolus primulinus* Baker). Prog. Hort., **24** (3-4): 124-127.

Patil, S. S. D. and Rane, D. A., 1994a, Heterosis studies in China aster. J. Maha. Agri. Univ., **19**(3): 372-374.

Patil, S. S. D and Rane, D. A., 1994b, Combining ability studies in China aster. J. Maha. Agri. Univ., **19**(3): 418-420.

Rachappa, K., 2014, Studies on genetic variability and molecular characterization in China aster (*Callistephus chinensis* [L.] Nees.), M.Sc. Thesis, Univ. Hort. Sci., Bagalkot.

Raghava, S. P. S., 1984, Genetical studies in China aster (*Callistephus chinensis* L. Nees) Ph.D. Thesis, Univ. Agri. Sci., Bengaluru.

Raghava, S. P. S. and Negi, S. S., 1993, Combining ability in China aster. Indian J. Hort., **50**(2): 180-186.

Raghava, S. P. S., Negi, S. S. and Ramachander, P. R., 1988, Heterobeltiosis in China aster. Indian J. Hort., **45**: 336-343.

*Riggs, T. J., 1988, Breeding F1 hybrid varieties of vegetables. J. Hort. Sci., **63**: 362-364.

Sachiva, T., 1976, Gerbera breeding: Prelimimary evaluation of genotypes for improved poplations of production. Acta Hort., **63**: 177-185.

*Shull, G. H., 1908, What is heterosis? Genetica, **33**: 430-446

Singh, B. and Swarup, V., 1973, Inheritance of flowering, flower weight and flower number in African marigold. Indian J. Gen. Plant Breeding. **33**(2): 172-175.

Singh, B. and Swarup, V., 1971, Heterosis and combining ability in African marigold. Indian J. Gen. Pl. Breeding. **31**(3): 407-415.

Singh, D. and Mishra, K. K., 2010, Diallel analysis for combining ability in marigold. Karnataka J. Agric. Sci., **23**(2): 298-301.

*Spargus, G. F. and Tatum, L. A., 1942, General v/s specific combining ability in single crosses of corn. J. American Soc. Agron., **34**: 923-932.

Sreenivasulu, G. B., Kulkarni, B. S., Reddy, B. S., Adiga, J. D. and Thammaiah, N., 2004, Evaluavation of China aster genotypes against *Alternaria* leaf spot under field condition. J. Orn. Hort. **7**(3-4): 347-378.

Strube, H., 1965, New ertenntnisse and erfahrungen in der astern suchtung I and II (New knowledge and results in aster breeding I and II). Dtsche gertenb, 12: 134-136, 165-166.

Subbaiah, B. V., and Asija, G. C., 1956, A rapid procedure for the estimation of available nitrogen in soils. Current Sci., **25**:259.

Suresh Kumar, 2003, Combining ability and heterosis studies in China aster (*Callistephus chinensis* (L.) Nees.), M. Sc. Thesis, Univ. Agri. Sci., Dharwad.

Suresh, K., Shirol, A. M., Reddy, B. S., Mulge, R. and Kulkarni, B. S., 2004(a), Combining ability studies in China aster (*Callistephus chinensis* (L.) Nees.). J. Orn. Hort., **7**(3-4): 22-26.

Suresh, K., Shirol, A. M., Reddy, B. S., Mulge, R. and Kulkarni, B. S., 2004(b), Heterosis studies in China aster (*Callistephus chinensis* (L.) Nees.). J. Orn. Hort., **7**(3-4):18-21.

Swarup, V., Raghava, S. P. S. and Balakrishna, K. A., 1975, Heterosis in balsam. Indian J. Gene. Plant Breeding. **35**(1): 69-75.

Turner, J. H., 1953, Study of heterosis in upland cotton, Part II combining ability and inbreeding effects. J. Agron., **43**: 487-490.

Thammaiah, N., Kulkarni, B. S., Reddy, B. S. and Kulkarni, M. S., 2004, Screening of chrysanthemum cultivars against *Alternaria* leaf spot disease under natural conditions, J. Orn. Hort. **7**(3-4): 347-378.

Uemoto, S., 1964, Studies in F1 hybrids of the snapdragon, *Antirrhinum majus* L. I. On several ecological characteristics of various diploid forms. Sci. Bull. Fac. Agri. Kyushu, **21**: 185-213.

Vivekanandan, A. S., Gunasena, H. P. M. and Sivanaygam, T., 1972, Statistical evaluation of the techniques used in estimation of leaf area of crop plant. Indian. J. Agric. Sci. **42**: 857-860.

Watts, L., 1980, Flower and vegetable breeding. Grower Books, London, pp. 182.

*Wheeler, B. E. J., 1969, An Introduction to Plant Diseases. John willey and Sons Ltd., London, pp: 301.

* Originals not seen

Appendix I

Meteorological data recorded for the experimental period (2014-15) at Agricultural Research Station, Arabhavi

Months	Temperature (^oC)		RH (%)		Rain fall (mm)
	Max	Min	Morning	Afternoon	
April-2014	37.50	20.40	82.20	49.00	5.20
May-2014	36.30	24.05	89.70	39.10	8.00
June-2014	33.70	22.30	86.40	60.60	2.00
July-2014	30.60	21.65	87.80	73.70	9.00
August-2014	28.70	22.60	93.10	75.70	11.00
September- 2014	29.00	21.85	87.90	65.80	2.00
October-2014	31.60	19.80	88.90	58.30	3.00
November-2014	29.80	18.20	92.90	48.70	3.00
December-2014	28.40	19.75	91.10	52.70	19.30
January- 2015	28.45	18.85	88.50	48.50	0.00
February- 2015	31.90	18.10	87.50	38.50	0.00
March-2015	34.10	18.05	95.00	62.00	2.00

Appendix- II

Chemical properties of soil from experimental site

Sl. No.	Particulars	Value obtained	Method adopted
1.	Available nitrogen (kg/ha)	231.00	Alkaline permanganate oxidation method (Subbaiah and Asija, 1956)
2.	Available phosphorus (kg/ha)	49.50	Olsen’s method (Jackson, 1967)
3.	Available potassium (kg/ha)	234.00	Flame photometer (Jackson, 1967)
4.	Soil pH	8.10	pH meter (Jackson, 1967)

HETEROSIS AND COMBINING ABILITY STUDIES IN CHINA ASTER (*Callistephus chinensis* [L] Nees.)

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UHS13PGM325 **Major Advisor**

ABSTRACT

The investigation on heterosis and combing ability in China aster (*Callistephus chinensis* [L] Nees.) was carried out at Kittur Rani Channamma College of Horticulture, Arabhavi. The twenty crosses derived from 5 x 5 full diallel (including reciprocal) cross were evaluated along with parents in randomized block design with two replications and data was subjected to full diallel analysis.

The parent, Kamini was a good general combiner for early flowering, while Violet Cushion was found to possess additive genes for growth, flowering, yield and quality parameters. Two crosses Kamini x Poornima and P.G.Purple x Poornima exhibited significant negative heterosis over mid parent and negative SCA effects for early flowering. The cross P.G.Purple x Poornima showed positive significant heterosis over mid parent and standard check 'Kamini', coupled with significant positive SCA effects for plant height, plant spread and number of branches. The cross AAC-1 x Poornima exhibited significant positive heterosis over mid, better parent and standard check coupled with significant positive SCA effects for yield and its components. Whereas, the cross Kamini x P.G.Purple showed positive significant heterosis over mid, better parent and standard check coupled with positive significant SCA effects for vase life. Non-additive gene action was predominant for majority of traits and hence recurrent selection scheme and heterosis breeding is suggested for improvement.

The cross P.G.Purple x AAC-1 was found to be resistant with low disease incidence for *Alternaria* leaf spot. Inheritance pattern for flower color revealed that violet color was dominant over all the other colors *i.e.*, purple, pink and white. Whereas, white was recessive to all the other colors.

ZÉÆÁ D¸ÀÛgï (PÁ¼ï¸ÀgÉÆÃªï ZÉÆÃ¼ï¸ï [°Ã.] ¤Ã¸ï) zÀªÀè¸ÀQgÀªÀvÉÛ ªÀÄvÀÄÛ ¸ÀªÀiÁ£ÀÛdPÀ¸ÁªÀÄxÀåzÀ CzsÀåAiÀÄ£À

CAd° PÀæPÀAÀ **2015** **ªÀÄPÀÌ¼À zÀ²gÀðÀgÀ ¥ÀæÃ£À ªÀÄUÀðzÀ±ÀðPÀgÀÄ**

¸ÁgÁA±À

ZÉÆÁ D¸ÀÛgï zÀªÀè (PÁ¼ï¸ÀgÉÆÃªï ZÉÆÃ¼ï¸ï [°Ã.] ¤Ã¸ï) ¸ÀQgÀªÀvÉ ªÀÄvÀÄÛ ¸ÀªÀiÁ£ÀÛdPÀ ¸ÁªÀÄxÀåzÀ CzsÀåAiÀÄ£ÀªÀ£ÀÄß Q.gÁ.ZÀ vÉÃlUÁjPÁ ªÀÄºÁ«zÁå®AiÀÄzÀ ¥ÁæuÀPÀÌ ªÀÄvÀÄÛ Gzsï£À«£Áå¸À±Á¸ÀÛç«¨sÁUÀzÀªÀè 2014-15 £Éà ¸Á°£ÀªÀèºÀÄPÉÊ½ÃÁVvÀÄÛ ¥ÀæAiÉÆÃUÀ CzsÀåAiÀÄ£ÀªÀèLzÀÄ ¥ÉÃµÀPÀ vÀ½UÀÀ 5 x 5 qÉ°Ã¯ï «±ÉèµÀuÉAiÀÄ ªÀÄ®PÀ ªÀÄr ¥ÀqÉzÀ 20 ¸ÀQgÀ vÀ½UÀ¼À£ÀÄß Dgï. ©. r. ¨ÁPïï «£Áå¸ÀzÀªÀèzÀÄAÀÛ±À «±ÉèµÀuÉUÉ ¥ÉÃµÀPÀ vÀ½UÀ¼À ºÁUÀÆ ¥ÀæÃªÀvÀ vÀ¼ÀAiÀÄ eÉvÉUÉ ªÀÄ®ÀªÀÄ ¥ÀæÀ ªÀÄqÀ¯ÁVvÀÄ. LzÀÄ ¥ÉÃµÀPÀ vÀ½UÀ¼À ¥ÉÊQ, PÁ«Ä¤ vÀ¼ÀAiÀÄ §ºÀÄ ÉÆUÀ ºÀÆ ©qÀÄªÀ UÀÄtUÀ¼ÀUÉ ºÁUÀÆ ªÉÃÉ PÀÆ±ÀÄï vÀ¼ÉAiÀÄ E¼ÀÄªÀj ªÀÄvÀÄÛ §ºÀÄvÉÃPÀ E¼ÀÄªÀjUÉ ¸ÀA§AzsÀ¥ÀlÖ UÀÄtUÀ¼ÀUÉ CvÀåvÀÄÛªÀÄ ¸ÁªÀÄ£À ¸ÀªÀiÁ£ÀÛdPÀ ¸ÁªÀÄxÀå EzÉJAzÀÄ UÀÄgÀÄw¸À¯ÁVzÉ

¸ÀQgÀ vÀ½UÀ¼À ¥ÉÊQ, PÁ«Ä¤ x ¥ÀÆtðªÀÄ ªÀÄvÀÄÛ ¦. f. ¥ÀÆÀ¯ï x ¥ÀÆtðªÀÄ §ºÀÄ ÉÆUÀ ºÀÆ ©qÀÄªÀ UÀÄtUÀ¼ÀUÉ ¸ÀQgÀªÀvÉAiÀÄ ºÁUÀÆ ¤¢ðµÀÖ ¸ÀªÀiÁ£ÀÛdPÀ ¸ÁªÀÄxÀåªÀ CvÀåvÀÄÛªÁVªÉVqÀzÀ GzÀÄVqÀzÀ ºÉÆgÀºÀ«PÉ ªÀÄvÀÄÛ gÉ¨ÉÃ ¸ÀA§AzÀAiÀÄ UÀÄtUÀ¼ÀUÉ ¦. f. ¥ÀÆÀ¯ï x ¥ÀÆtðªÀÄ GvÀÛªÀÄ ¢QÌ£ÀèªÁtÂå ¸ÀQgÀ vÀÀ (PÁ«Ä¤) VAvÀ ºÉZÁÑzÀÄ ¥ÀæªÀÄ VqÀzÀ ºÀ«£À ¸ÀASÉ ¥ÀæÀºÀ«£À vÀÀPÀ ¥ÀæªÀÄ VqÀzÀ ºÀ«£À E¼ÀÄªÀj, ¥ÀæªÀÄ VqÀzÀ ©ÃdzÀ E¼ÀÄªÀj ªÀÄvÀÄÛ 1000 ©ÃdzÀ vÀÆPÀzÀ CA±ÀUÀ¼ÀUÉ ¸ÀQgÀ vÀ¼ÀAiÀÄzÀ JJ¹-1 x ¥ÀÆtðªÀÄ GvÀÛªÀÄ ¤¢ðµÀÖ ¸ÀªÀiÁ£ÀÛdPÀ ¸ÁªÀÄxÀå ºÁUÀÆ ¸ÀQgÀªÀvÉAiÀÄ UÀÄtUÀ¼À£ÀÄß ºÉÆA¢zÉ PÁ«Ä¤ x ¦. f. ¥ÀÆÀ¯ï ¸ÀQgÀzÀ vÀ¼ÀAiÀÄ C¢üPÀ ºÀzÁ¤AiÀÄ°èºÀ ¨Á½PÉ§AzÀÄ CvÀåvÀÄÛ ¤¢ðµÀÖ ¸ÀªÀiÁ£ÀÛdPÀ ºÁUÀÆ ¸ÀQgÀªÀvÉAiÀÄ£ÀÄß ºÉÆA¢zÉ J®è F UÀÄtUÀ¼ÀUÉ C¸ÀÀR°vÀ ªÀÄ±ÀÆ»¤AiÀÄ QæAiÉÄAiÀÄ ºÉZÀÄÑ PÀAqÀÄ §A¢zÀÄÝ ¸ÀªÀiÁ£ÀÛd£À ¸ÁªÀÄxÀåPÁÌV F UÀÄtUÀ¼À£ÀÄß ¥ÀjUÀtÂ¸À®ªÀÄðvÀÄ DAiÀÄÌ¬ÀAzÀ ©rÁªÀ¥À ¸ÀÆPÁVzÉ

¦. f. ¥ÀÆÀ¯ï x JJ¹-1 ¸ÀQgÀ vÀ¼ÀAiÀÄ CvÀåA¢ÃgÀ£ÀÄUÀ¤gÉÃzÀªÀ±À¢ÃÛ¼ÀÀ ºÉÆA¢zÉ ºÀ«£À §tÚzÀ ¦vÀÌðvÀ ¨ÁzsÀPÀvÉAiÀÄ£ÀÄß CzsÀ¬Ä¹zÁUÀ PÀÄëA£ÉÃgÀÄUÉ §tÚJ¯Áè §tÚUÀ¼À VAvÀ ¥ÀæÃ£ÀªÁVzÀÄÝ CzÀPÉ C£ÀÄUÀÄt ªÁV £ÉÃgÀÆ ºÁUÀÆ UÀÄ¯Á© §tÚUÀ¼À vÀzÀ£ÀAvÀgÀzÀ ¸ÁÜ£ÀªÀ£ÀÄß ¥ÀqÉ