Studies on Genetic Variability in China aster
Callistephus chinensis

Manzoor Ahmad Wantoo
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Thesis

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The Faculty of Post-graduate Studies

Sher-e-Kashmir University of Agricultural Sciences and
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in partial fulfillment of requirement for the award of the degree of

Master of Science in Agriculture
(Floriculture and Landscaping)

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DEDICATED TO MY REVERED PARENTS

Sher-e-Kashmir
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Campus Srinagar 191 121

Certificate – I

This is to certify that the thesis entitled, "**Studies on Genetic Variability in China Aster *Callistephus chinensis*"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science in Agriculture (Floriculture and Landscaping),** to the **Faculty of Post-graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Mr. Manzoor Ahmad Wantoo (Regd. No. 2004-A-736-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has been duly acknowledged.

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Certificate – II

We, the members of the Advisory Committee of **Mr. Manzoor Ahmad Wantoo (Regd. No. 2004-A-736-M),** a candidate for the degree of **Master of Science in Agriculture (Floriculture and Landscaping)** have gone through the manuscript of the thesis entitled, "**Studies on Genetic Variability in China Aster *Callistephus chinensis*"** and recommended that it may be submitted by the student in partial fulfillment of the requirements for the award of the degree.

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Certificate – III

This is to certify that the thesis entitled "**Studies on Genetic Variability in China Aster *Callistephus chinensis*"** submitted by **Mr. Manzoor Ahmad Wantoo (Regd.No.2004-A-736-M)** to the **Faculty of Post–graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** in partial fulfillment of the requirements for the award of the degree of **Master of Science in Agriculture (Floriculture and Landscaping)** was examined and approved by the Advisory Committee and External Examiner on ……………….

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ABSTRACT

The present investigation entitled “Studies on Genetic Variability in China aster *Callistephus chinensis*” was undertaken to obtain information on the genetic variability with respect to metric traits among 30 China aster genotypes.The analysis of variance, revealed highly significant differences for all the traits studied. The highest range was recorded for flower yield plant^{-1} which varied from 63.88 to 166.19 followed by number of leaves plant^{-1} (96.05 to 130.38); plant height (36.12 to 64.52) and days taken to first flower bud opening (54.00 to 79.15).The highest magnitudes of phenotypic and genotypic coefficients of variability were recorded for number of main branches plant^{-1}, length of flower stalk, flower yield plant^{-1}, number of lateral branches plant^{-1} and number of flowers plant^{-1}.The estimates of broad sense heritability were found higher for all the traits under study which varied from 71.73 to 97.03 per cent. However, the traits like flower yield plant^{-1}, length of flower stalk, main stem diameter, number of flowers plant^{-1}, flower diameter, flower weight and vase life of cut flower exhibited higher estimates of heritability and medium to high estimates of genetic gain, indicating the role of additive genes in their inheritance. The most important economic trait flower yield plant^{-1} displayed significant positive correlation with number of main branches plant^{-1}, number of lateral branches plant^{-1}, number of flowers plant^{-1}, flower diameter, flower weight, number of leaves plant^{-1} and plant height revealing their importance in selection.Similarly, principal component analysis revealed that about 82 per cent of total variability, present among the 30 genotypes of China aster, was contained in first two principal components. However, estimates of variates (loadings) depicted the contribution of traits towards the principal components, it revealed that two characters viz., number of flowers plant^{-1} and number of leaves plant^{-1} significantly contributed to the first principal component. The selection of best genotypes was made on the basis of absolute principal components analysis scores which revealed that genotypes viz., Ast-25, Ast-24, Ast-18 Ast- 9 and Ast-10 were found best in terms of economic traits (number of flowers plant^{-1}, flower yield plant^{-1}, length of flower stalk).

Key words: China aster, Heritability, Principal components, Variability

Signature of Student	Signature of Advisor
Dated………………	Dated…………………

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Place:Shalimar ***Manzoor Ahmad Wantoo***
Date……………

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Chapter-1

INTRODUCTION

China aster *Callistephus chinensis* is a self pollinated crop (Strube, 1965), belonging to the family compositae (Asteraceae), and is native to China. But the literature showed that the single and semi-double varieties are predominantly cross-pollinated, whereas the double ones are generally self pollinated (Janakiram, 2005). The Genus *Callistephus* derived its name from two Greek words “Kalistos” meaning most beautiful and “Stephos” meaning a crown, referring to the flowers. It was first named by Linnaeus as *Aster chinensis* and Nees subsequently changed this name to *Callistephus chinensis.* Considering the close association of flowers with our daily life, records of commercial flower production in country are few. However, with changing life styles and increasing urban affluence, floriculture has assumed a commercial status. Floriculture industry has now become one of the rapidly expanding and dynamic global activities.

Floriculture is a fast growing agri-industry in India. Commercial potential of floriculture as a viable agri-business enterprise received attention of Government of India during Eighth Plan. Liberalization of economic policies encouraged corporate houses and first generation enterpreneurs to invest in setting up export oriented units. The global trade in floriculture is estimated at U.S.D. fifty billion and trade of over six billion in cut flowers and pot plants with an annual growth rate of 17 percent. The major destinations for fresh cut flowers from India are Japan, Netherlands, Germany, U.K, Hong-Kong and Gulf countries.

Indian floriculture industry has more or less established itself in the national and international market in last two decades. The quantum jump witnessed in production and trade of floricultural products is due to sound research system, focussed attention of Government coupled with innovative entrepreneurs. The export of floricultural products has increased from Rs.8 crores in 90-91 to Rs.87 crores in the years 1997-98.

The year 2000-2001 witnessed the export of about Rs123.12 crores worth of floricultural products, out of which nearly two-third of the trade is actually the dried flowers and less known plants. As far as consumption of flowers is concerned, it has increased manifold. The total world export of floricultural products in 2000 was US $ 7662922400. The Netherland remained world's largest exporter of floricultural products with a share of 50 percent total export. Among the importers, Germany is the largest importing country for floricultural products. It imports floricultural products worth $ 1,457,696000 (Dadlani, 2002).

India is endowed with diverse agro-climatic conditions, which is conducive, for growing all kinds of flowers throughout the year. In cut flower trade, it has made an impact in the global market. In India, area under different flower crops all over the country during 2002-03 was 70419 hectare and production of loose and cutflower was 734912 tonnes and 2060.5 million, respectively. But in our state the area under floricultural crops during 2002-03 was 69 hectare and production of loose and cut flowers was 38 tonnes and 0.7 million, respectively (Anonymous, 2005).

China aster is an important cut flower throughout the world, which can be easily grown in open fields and green houses for production of cut flowers and loose flowers. The flowers are used as cut flowers for interior decoration and as loose flowers for worship and informal beds. The flower is in great demand during the festivals like christmas, diwali, dashera etc.   The crop is also grown as herbaceous border in gardens. China aster is half hardy annual and the both flowers as well as plants are damaged by frost. Plants are erect and braches are having hispid hair. Branches bear alternate broadly ovate or triangular ovate and irregularly toothed leaves. Flowers are solitary and blue, lavender, rose and white and these are prominent colours. In India, it is an important flower for winter plantings in the plains, while in the hills it produces flowers in late summer and autumn.

The present varieties were developed from *Callistephus chinensis.* Majority of improvement work is being carried out in Europe. However, not much attention was given for its improvement in our country. Although work on its genetic improvement in India started during early seventies, with major objectives to increase number of flowers per plant and stalk length; to improve size, shape and colour of flowers and to breed for cut flower varieties with good keeping quality. Fleming (1937) estimated approximately 10 percent natural crossing in China aster. However, Strube (1965) mentioned that in China aster, care and precaution is needed to avoid occasional cross pollination due to insects or other pollinating agents. Negi *et al.* (1983) reported that, the magnitude of variability and heritability of desirable characters in the crop are important considerations for planning breeding programme. Jankiram and Rao (1994) mentioned that, knowledge about the magnitude of genetic variability and heritability of characters is essential for a successful breeding programme in case of China aster. The success of phenotypic selection depends upon the range of genetic variability available in the population. Burton and Devane (1953) emphasized that, the genetic variance and heritability along with genetic advance are useful in informing the genetic facts. Further, they emphasized that genetic advance and the estimates of correlation coefficient, between various characters should be considered for the assessment of maximum and accurate effect of selection. However, selection of parents based on individual attributes may not be as good and advantageous as the ones based on a number of components collectively. The information on these aspects in China aster under the climatic conditions of Kashmir Valley is lacking. Hence, the present investigation was undertaken with following objectives:

1. To assess the extent of genetic variability with respect to vegetative and floral traits.
2. To study the nature of heritable components.
3. To identify important genotypes using principal components analysis.

4. To study the interrelationship among various economically important characters.

Chapter-2

REVIEW OF LITERATURE

The success of any breeding programme depends on the presence of sufficient genetic variability to help in effective selection. It is important to assess the relative magnitude of components of variability in order to use such information, together with other selection parameters for improvement of the plant type through adoption of effective breeding methods (Johnson *et al.*, 1955; Hanson *et al.*, 1956; Briggs and Knowle's 1967). It is necessary to divide the total phenotypic variance of the entire characters into its components, as these are the basis for a genetic analysis and the dimensions of these components divide the breeding behaviour of the populations. Such selection parameters, particularly genetic variability (GCV), helps to choose a potential genotype, whereas heritability (h^2) along with genetic advance as percentage of mean are more useful in predicting the resultant effect from selections of best genotypes. A brief account of pertinent literature on different aspects of the present study is addressed under the following headings.

2.1 Variability
2.2 Heritability and genetic advance
2.3 Correlations
2.4 Principal components analysis

2.1 Variability

For effective selection and utilization of genotypes for breeding programme, a thorough study of genetic variability is essential. Genotypic coefficient of variation indicates the relative magnitude of genetic diversity, present in the material and helps to compare the genetic variability present for different characters.

Singh *et al.* (1977) carried out genetic variability studies in sunflower and observed high genotypic coefficient of variation for yield and plant height which indicated that there was greater variability for these characters as compared to others among the varieties studied.

Negi *et al.* (1983) studied genetic variability in 19 varieties of China aster and reported that the varietal differences in respect of all the characters were highly significant. Variation was high for number of flowers plant^{-1}, flower weight and stalk length. The genotypic coefficient of variation was highest for flower weight followed by stalk length and number of flowers plant^{-1}. Also reported that PCV were higher than GCV for all the characters studied.

Raghava *et al.* (1992) worked out genetic variability estimates in chrysanthemum and reported that variation was high for number of flowers plant^{-1} and flower yield plant^{-1}. However, the genotypic coefficient of variation was the highest for flower yield plant-^{1} followed by number of flowers plant^{-1} and flower size.

Jhon *et al.* (1994) reported that, genetic variability in 11 varieties of *Zinnia elegans* was highly significant in respect of eight characters. The highest coefficient of variation was shown by number of branches plant^{-1} followed by flower weight and number of flowers plant^{-1} whereas, the least values were shown by days to flower followed by duration of flowering. The genotypic coefficient of variation was highest for the number of flowers plant^{-1} followed by number of branches and flower weight.

Janakiram and Rao (1994) carried out variability studies in China aster and reported that variation was high for plant spread; number of laterals plant$^{-1;}$ number of flowers plant^{-1} and flower yield plant^{-1}. Whereas, high genotypic coefficient of variation was recorded for number of flowers plant^{-1}. They also reported that GCV were lower than PCV for all the characters studied.

Singh and Sen (2000) evaluated 12 cultivars of African and French marigold and reported that the phenotypic and genotypic coefficients of variation were high for flower yield followed by number of flowers plant^{-1}, plant spread and least for duration of flowering in case of French marigold. However, in case of

African marigold variability was high for dry weight of flower, medium for fresh weight of flower and low for north-south plant spread.

Sirohi and Behera (2000) studied genetic variability in chrysanthemum and reported that phenotypic coefficient of variation (PCV) were higher than those of genotyphic coefficient of variation (GCV) for all the characters. However, higher GCV x PCV estimates were found for number of flowers plant^{-1} followed by number of branches plant^{-1} and disc diameter.

Kumar and Patel (2003) studied 11 genotypes of China aster for 14 metric traits and the analysis was significant for all the characters. The GCV was higher for plant spread., leaf area plant^{-1}, average weight of fresh flower and flower yield plant^{-1}. Highest genotypic coefficient of variation and phenotypic coefficient of variation was observed for plant spread followed by flower yield plant^{-1}. They also reported that GCV were lower than PCV for all the characters studied

Kishore and Raghava (2001) worked out variability estimates in African marigold and reported that phenotypic coefficients of variation were higher than those of genotypic coefficient of variation, however higher phenotypic and genotypic coefficients of variation were found for flower weight plant^{-1} followed by flower yield plant^{-1} and seed yield flower^{-1}.

Patnaik and Mohanty (2002) studied variability in African marigold and reported that, the phenotypic coefficients of variation were higher than genotypic coefficients of variation for all the traits studied. Higher genotypic and phenotypic coefficients of variation were observed for traits like yield of flowers plant^{-1}, individual flower weight, number of flowers plant^{-1} and plant height while remaining traits exhibited moderate to lower values for these parameters.

Nair and Shiva (2003) carried out variability studies in gerbera and reported that GCV was lower than PCV for all the 11 characters indicating the role of environment in the expression of genotype. Maximum estimate of GCV was recorded for leaf area followed by cut flower yield.

2.2 Heritability and genetic advance

The effectiveness of selection for any character does not depend on the amount of phenotypic variability alone. It is of great interest to the breeder to determine how much of phenotypic variability, which is present in a particular character is heritable. The heritability estimates provide such a measure.

Heritability value alone may not provide clear predictability of the breeding value. Its estimate along with genetic advance are usually more useful than simple heritability values in predicting the resultant effect for selecting the best individuals (Johnson *et al.,* 1955). This is due to the fact, that a character may have very high heritability but very less phenotypic variation. Thus, giving low values of genetic advance.

Pathak (1974) also found high heritability (broad sense) for stem diameter and medium heritability for seed yield plant^{-1} and head diameter in sunflower.

In yet another study, Negi *et al.* (1983) worked out heritability estimates for seven characters in China aster and the characters like flower weight; stalk length; flower size and plant height exhibited high values of heritability, whereas, number of flowers plant^{-1}, days taken to flower and number of branches plant^{-1} had medium heritable values. However, high heritability along with high genetic advance was observed for flower weight and stalk length.

Similarly, Barigidad *et al.* (1992) studied variability in chrysanthemum and worked out heritability and genetic advance estimates for all the characters. However, highest heritability (broad sense) and genetic advance were observed for number of branches plant^{-1} followed by number of flowers plant^{-1}.

Aswath and Parthasarathy (1993) found high heritability and coheritability for all the characters in China aster. Whereas, certain characters like plant spread and stalk length showed medium to low heritability on the basis of higher estimates of heritability and coheritability. Therefore, it was suggested that the characters studied were controlled by additive gene action.

Jhon *et al.* (1994) reported high heritability coupled with high genetic advance for number of branches plant^{-1}, flower weight and number of flowers plant^{-1} in *Zinnia elegans* but high heritability with moderate genetic advance was observed in flower size, plant height and plant spread.

Similarly, Janakiram and Rao (1994) worked out heritability estimates for nine characters in China aster and reported that all the nine characters exhibited high values of heritability. High heritability along with high genetic advance was observed for characters like plant spread; number of laterals plant^{-1}; number of flowers plant^{-1}; flower weight and flower yield.

In yet another study, Raghava and Negi (1994) crossed 12 China aster varieties in a half diallele cross to estimate genetic components of 12 metric traits. Variation due to additive effects were found controlling the traits like flower size and ray florets per flower head. Other traits like plant height, main branches plant^{-1}, lateral branches plant^{-1}, plant spread; flowering duration and cut flower life showed preponderance of dominance components over the additive components in their expression.

Patil and Rane (1995) recorded information on heritability from data on 12 yield and quality components from 09 diverse China aster genotypes and their 72 F_1 hybrids. He further reported that narrow sense heritability estimates were very high for all 12 characters studied. However, it was highest for plant height and ray floret rows flower^{-1} (75.2%).

Singh and Sen (2000) found high heritability with low genetic advance for number of branches and duration of flowering in *Tagetes patula,* and plant height; number of branches; plant spread; days to 50% flowering and duration of flowering in *Tagetes erecta*. However, they also observed high heritability with high genetic advance for flower yield and number of flowers plant^{-1} in case of *Tagetes patula*.

In yet another study, Sirohi and Behera (2000) carried out genetic variability studies in chrysanthemum and reported high heritability with high genetic advance for number of branches plant^{-1}, disc diameter, number of petals flower^{-1} and yield of flower.

Patnaik and Mohanty (2002) carried out heritability studies in *Tagetes erecta* and found that estimates of broad sense heritability for various traits varied from 26.50 percent to 83.90 percent. Very high (>80%) heritability values were recorded for individual flower weight, followed by days to flower and plant height. High heritability with low genetic gain was exhibited by stalk length, plant spread (North-South) and duration of flowering whereas, moderate estimates of genetic advance and moderate to high estimates of heritability were showed by plant spread (East-West), depth of flower and days to flower.

Similarly, Kumar and Patil (2003) studied variability in China aster and reported that the broad sense heritability estimates obtained were generally high for all the characters except for time taken for first flower bud initiation and flower diameter. Higher heritability values were observed for characters like plant height; plant spread; days to first flowering; duration of flowering; number of flowers plant^{-1}; flower yield plant-^{1}; stalk length and vase life. Highest heritability along with highest genetic advance was observed for plant spread followed by flower yield plant^{-1}.

Nair and Shiva (2003) worked out heritability estimates in 25 genotypes of gerbera for 11 quantitative traits and found that, broad sense heritability ranged from 43.92% (weeks to first flowering) to 99.99% (cut flower yield). High heritability values were associated with high value of expected genetic advance as percent mean for cut flower yield, leaf area and number of leaves plant^{-1} and moderate for flower head diameter, length of flower stalk and vase life.

2.3 Correlations

The idea of correlation was presented and elaborated by Fisher (1918) and Wright (1921). The direct observable phenotypic correlations do not indicate the magnitude and direction of genotypic correlations. The genotypic correlation presents a true genetic picture of relationship between the genes controlling the characters. The correlation of characters may be due to either genetic linkage or pleiotropy (Harland, 1939). Besides pleiotropy and linkage, association loci or blocks of loci located on different chromosomes may bring about correlated response. Any kind of non-random segregation might cause temporary correlations (Lerner, 1958).

Oka (1972) carried out correlation studies in sunflower where it was indicated that number of days to flowering and plant height were correlated with each other but, not with head diameter.

In yet another study, Shanmugam *et al.* (1972) worked out correlation coefficient between the flower yield and each of six characters in ‘white’ and ‘yellow’ cvs of chrysanthemum, height at first flowering; total increase in height; number of laterals; duration of flowering; number of days to first flowering and size of flowers. All relationships were significant at 5 per cent except for size of flowers in ‘white’ cv and height at flowering in the ‘yellow’ cv.

Negi *et al.* (1983) studied correlation in China aster and reported that genotypic correlation coefficients were higher than the phenotypic correlation coefficients. Days taken to flower had positive significant correlation with number of branches plant^{-1}; flower size; stalk length and flower weight while plant height showed significant positive association with flower size; flower weight and stalk length. Whereas, flower size had positive significant correlation with flower weight and stalk length but was negatively correlated with number of flowers plant^{-1}.

Raghava *et al.* (1992) carried out correlation studies in chrysanthemum and observed higher genotypic correlation coefficients than phenotypic correlation coefficients for all characters. Positive and significant correlation was observed for days to flower with number of flowers plant^{-1} and flower yield plant^{-1}. However, flower size had negative and significant correlation with number of flowers plant^{-1} but it had positive and significant correlation with flower yield plant^{-1}.

Similarly, Aswath and Parthasarathy (1993) carried out correlation studies in 12 varieties of China aster and observed a wide range of phenotypic correlation for some characters viz., plant height, stem scar diameter and number of flowers.

The lowest genotypic and phenotypic correlation was between height of plants and flower diameter whereas the highest genotypic correlation was observed between height and number of flowers. Height of plants also exhibited significant genotypic and phenotypic correlations with vase life.

Jhon *et al.* (1994) carried out correlation studies in 11 varieties of *Zinnia elegans* and reported that plant height had positive and significant correlation with days to flower, duration of flowering, flower size and flower weight, however, number of branches plant^{-1} exhibited significant association with number of flowers. Flower size showed a positive significant correlation with flower weight.

In yet another study, Janakiram and Rao (1994) carried out correlation studies in China aster and reported that genotypic correlation coefficients were higher than phenotypic correlation coefficient. Days to flowering had positive significant correlation with number of main branches plant^{-1}. While it had negative significant correlation with flower size. Flower size had positive significant correlation with flower weight and negative significant correlation with number of flowers plant^{-1}. Positive significant association was observed between number of flowers and plant height, number of main branches plant^{-1} and number of lateral branches plant^{-1}.

Narayana and Patel (1998) carried out correlation studies in sunflower and observed an appreciable positive significant correlation between seed yield and all the growth and yield attributing characters viz., plant height, stem girth and leaf area index. Head diameter and filled seed percent also indicated significant positive correlation with seed yield.

Sirohi and Behera (1999) in chrysanthemum observed highly significant and positive phenotypic association of yield with number of flowers plant^{-1}, plant spread and number of branches plant^{-1}, but the association of flower diameter and number of flowers plant^{-1} was significantly negative. They also observed that the number of flowers plant^{-1} had high direct effect on yield through number of branches plant^{-1}.

Pratap *et al.* (1999) studied correlation in marigold and revealed that in case of African group, the height of plant exhibited positive significant correlation at genotypic and phenotypic level with spread of plant and number of lateral branches. However, plant spread recorded significant positive correlation with size and yield of flowers plant^{-1}. In case of French group, plant height showed positive significant correlation with number of lateral branches, days to visibility of bud, first picking and last picking of the flowers. Whereas, plant spread showed positive correlation with number and yield of flowers plant^{-1}.

Baweja (2000) studied correlation in China aster and observed that estimates of genotypic correlation coefficients were higher than those of phenotypic correlation coefficients for almost all the characters. However, positive and highly significant phenotypic association of yield was observed with the number of flowers plant^{-1}, plant spread and number of branches plant^{-1}. Whereas, flower diameter and number of flowers plant^{-1} were negatively associated, although duration of flowering had a positive phenotypic association with vase life. He also observed that days to first flower opening had a negative association with the number of branches, number of flowers plant^{-1} and flower yield plant^{-1}, indicating the earliness of flowering.

Similarly, Kumar and Patil (2003) studied correlation in 11 genotypes of China aster and reported that flower yield had positive significant correlation with the flower diameter and number of flowers plant^{-1}, whereas, number of flowers plant^{-1} had a positive significant association with number of laterals plant^{-1} and stalk length. However, stalk length is positively and significantly associated with flower diameter. Whereas, days for first flowering showed a highly significant correlation with plant height.

Hegde and Gopinath (2003) carried out correlation studies in *Gaillardia pulchella* and observed that yield of flowers plant^{-1} had significant positive correlation with leaf area plant^{-1}, number of branches plant^{-1} and number of leaves plant^{-1} but had significant negative correlation with duration of flowering. Diameter of flower had significant positive correlation with number of leaves plant^{-1}, stalk length, number of branches plant^{-1}, number of days taken for first flowering and height of plants.

Nair and Shiva (2003) studied correlation in gerbera and reported that the genetic correlation coefficients were high in magnitude than the corresponding phenotypic correlation coefficients. Cut flower yield had significant positive correlation with plant spread and number of leaves plant^{-1}. Whereas, number of leaves plant^{-1} and leaf area showed positive significant correlation with diameter of flower head at both genotypic and genotypic levels.

2.4 Principal components analysis

It is a tool of multivariate analysis which is used when several correlated characters are studied together. Principal components are independent linear combination of original correlated characters. First principal component (PC_1) contains maximum variability followed by the second (PC_2) and so on. Thus instead of studying many variables, we summarize the whole information into one or two variables which are called principal components.

Asawa *et al.* (1977) observed in unflower that, selection based on plant height and percent seed filling would be more efficient as they account for 82 percent (82%) of the variability in yield.

Similarly, Lakshmanaiah (1978) reported that in sunflower, relative efficiency was the highest in the index consisting of all the 12 characters studied. Among the characters included in the index, capitulum diameter was the best in increasing the efficiency in most of the character combinations followed by 100-seed weight, percent seed filling and plant height.

Bhargava *et al.* (2005) determined the genetic diversity in 44 germplasm lines of *Chenopodium* spp. and reported that first four principal components contributed 88.10 per cent of the variability present among the lines. Three characters contributed positively to all the four components. The first principal component (PC_1) had plant height, inflorescence length and stem diameter as the variables with largest coefficients.

In yet another study, Ghafoor *et al.* (2001) reported genetic diversity in blackgram through principal component analysis and observed positively contribution of traits viz; days to flowering and days to maturity associated with the vegetative growth. Leaf size had moderate positive weight on PC_2 while inflorescence length exhibited negative weight. This suggests that the lines that emphasize vegetative growth tend to have larger leaves but fewer number of inflorescences.

Chapter-3

MATERIALS AND METHODS

A field experiment entitled “Studies on genetic variability in China aster (*Callistephus chinensis)*” was conducted during the year 2005 at experimental farm of the Division of Floriculture, Medicinal and Aromatic Plants, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir. The details of the material used and methods employed have been described in this chapter.

3.1 Experimental site

The investigation was conducted at the experimental farm of Division of Floriculture, Medicinal and Aromatic Plants at main campus of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar which is situated 16 km away from city centre that lies between 34° 05′ N latitude and 74° 98′ longitude at an altitude of 1587 meters above the mean sea level.

3.2 Climate

The climate is temperate-cum-mediterranean and continental type characterized by hot summers and severe winters. During winter the temperature sometimes goes below freezing point and whole of the valley is covered with snow. The average annual precipitation is 944.6 mm (average over past 30 years) and more than 80% of precipitation is received from western disturbances. The mean monthly meteorological data collected during the growing season is appended in Appendix I. It can be observed from the data that mean maximum temperature ranged from 20.30°C to 30.72°C and minimum from 6.24°C to 17.42°C, the relative humidity ranged between 59.17 percent in June to 72.60 percent in July during the entire growing season. The total rainfall received during the entire growing season of 2005 amounted to 348.90 mm. Highest rainfall was received during the month of July i.e. 131.5 mm.

3.3 Soil characteristics

The soil of the experimental plot was silty clay loam in texture having organic carbon 0.98 percent, pH 6.93, available nitrogen 335.71 kg ha^{-1}, phosphorus 15.38 kg ha^{-1} and potassium 198.28 kg ha^{-1}.

3.4 Experimental details

I. Design : Randomized Block Design

II. Treatments : 30 genotypes

S.No.	Accession number of the genotypes
1.	Ast-1
2.	Ast-2
3.	Ast-3
4.	Ast-4
5.	Ast-5
6.	Ast-6
7.	Ast-7
8.	Ast-8
9.	Ast-9
10.	Ast-10
11.	Ast-11
12.	Ast-12
13.	Ast-13
14.	Ast-14
15.	Ast-15
16.	Ast-16
17.	Ast-17
18.	Ast-18
19.	Ast-19
20.	Ast-20
21.	Ast-21

22.	Ast-22
23.	Ast-23
24.	Ast-24
25.	Ast-25
26.	Ast-26
27.	Ast-27
28.	Ast-28
29.	Ast-29
30.	Ast-36

III. Replication(s) : 3

IV. Net plot area : 2.2 m^2

V. Spacing : 30 cm x 20 cm

VI. Number of plants per treatment per replication : 20

3.5 Field/ Cultural operations

3.5.1 Nursery raising

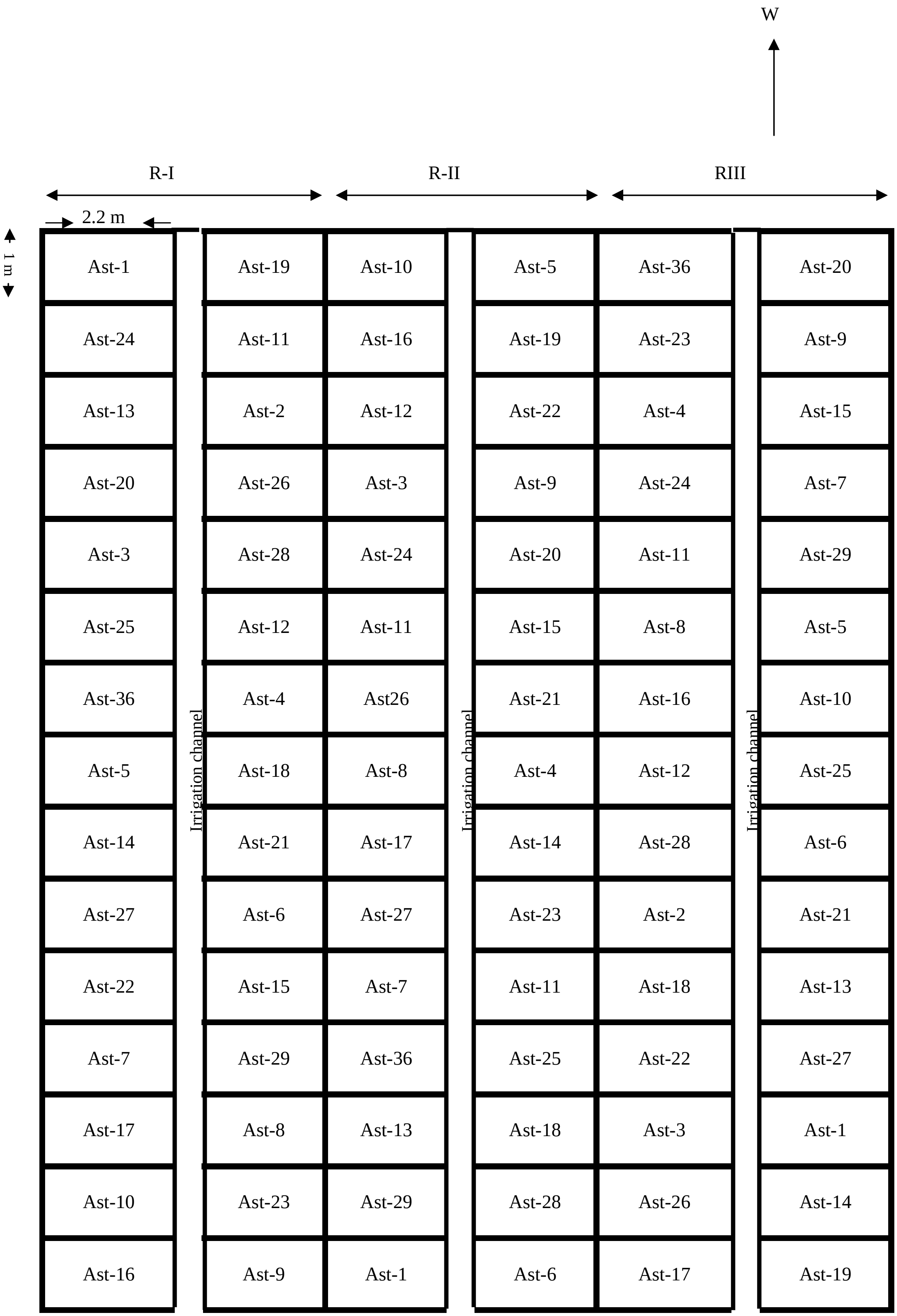
Seeds were sown in clay baked pans which were filled with well proportionate rooting media for obtaining seedlings. The seedlings get ready for transplanting in 40 days.

3.5.2 Land preparation

The land preparation was carried out thoroughly. First of all it involved the digging of land which was followed by clod breaking, deweeding and finally leveling and preparation of plots as per layout plan Fig 1.

3.5.3 Application of manure and fertilizers

The organic manure in the form of well rotten farmyard manure was applied and thoroughly mixed with the soil 20 days before the transplanting of seedlings. The recommended basal dose of N, P and K @ 90, 60 and 60 kg ha^{-1} through urea, diammonium phosphate and muriate of potash, respectively were also given 01 day before transplanting. Top dressing of nitrogen @ 90 kg ha^{-1} was given 45 days after transplanting.



R-I		R-II		RIII	
Ast-1	Ast-19	Ast-10	Ast-5	Ast-36	Ast-20
Ast-24	Ast-11	Ast-16	Ast-19	Ast-23	Ast-9
Ast-13	Ast-2	Ast-12	Ast-22	Ast-4	Ast-15
Ast-20	Ast-26	Ast-3	Ast-9	Ast-24	Ast-7
Ast-3	Ast-28	Ast-24	Ast-20	Ast-11	Ast-29
Ast-25	Ast-12	Ast-11	Ast-15	Ast-8	Ast-5
Ast-36	Ast-4	Ast26	Ast-21	Ast-16	Ast-10
Ast-5	Ast-18	Ast-8	Ast-4	Ast-12	Ast-25
Ast-14	Ast-21	Ast-17	Ast-14	Ast-28	Ast-6
Ast-27	Ast-6	Ast-27	Ast-23	Ast-2	Ast-21
Ast-22	Ast-15	Ast-7	Ast-11	Ast-18	Ast-13
Ast-7	Ast-29	Ast-36	Ast-25	Ast-22	Ast-27
Ast-17	Ast-8	Ast-13	Ast-18	Ast-3	Ast-1
Ast-10	Ast-23	Ast-29	Ast-28	Ast-26	Ast-14
Ast-16	Ast-9	Ast-1	Ast-6	Ast-17	Ast-19

Fig: Layout Plan of the Field Experiment

Net plot size = 2.2 m^2

3.5.4 Transplanting of seedlings

Before transplanting, the seedlings were treated with Bavistin 0.1 percent as a protective measure against the fungal diseases. At the transplanting time, the seedlings had developed three to four leaves and transplanting was done during the evening hours in order to avoid bright sunshine, at a spacing of 30 cm x 20 cm.

3.5.5 Cultural operations

The experimental plots were kept free from weeds by regular hoeing-cum-weeding and experimental field was sprayed with water for 10 days after transplanting and afterwards flood irrigation was initiated as per the requirement. Timely pest and disease control measures were adopted and the details about the different cultural operations adopted throughout the growth period are presented in Table-1.

Table -1: Calendar of operations

S.No.	Operation	2005
1	FYM application	May, 5
2.	Land preparation and layout	May, 22
3.	Fertilizer application	
	Basal dose (N, P, K)	May, 24
	Top dressing (N)	July, 9
4.	Transplanting	May, 25
5.	Hoeing-cum-weeding	
	Ist	June, 9
	2nd	June, 22
	3rd	July, 9
6.	Irrigation	
	Ist	June, 5
	2nd	June, 15
	3rd	June, 25

	4th	July, 5
7.	Plant protection measures	June, 12
	Fungicide drenching (Bavistin @ 0.1%)	
8.	Harvesting of cut flower	July, 28 to August, 30

3.6 Biometric observations

In each experimental plot from the middle rows, to avoid border effect, five randomly selected plants were tagged for recording the following biometric observations and the mean values for different characters were subjected to statistical analysis.

3.6.1 Vegetative and floral characters

3.6.1.1 Plant height (cm)

Plant height of five representative plants was recorded in centimeters with a metre rod from the ground level to the top most flower and mean values were worked out.

3.6.1.2 Number of leaves plant^{-1}

Number of leaves from each representative plant in each genotype was counted and average was worked out.

3.6.1.3 Number of main branches plant^{-1}

Number of main branches from each representative plant was counted and mean values were worked out.

3.6.1.4 Number of lateral branches plant^{-1}

Number of laterals from each representative plant was counted and average was worked out.

3.6.1.5 Leaf area index

The leaf area index was worked out with the help of Canopy Analyser.

3.6.1.6 Main stem diameter (cm)

Main stem diameter of each representative plant was measured with vernier calipper and the mean values were worked out.

3.6.1.7 Days taken to appearance of first flower bud (DAT)

Days taken from transplanting to appearance of first flower bud were recorded from representative plants of each genotype and average was worked out.

3.6.1.8 Days taken to first flower bud opening (DAT)

Days taken from transplanting to first flower bud opening were recorded from representative plants each genotype and average was worked out.

3.6.1.9 Number of flowers plant^{-1}

Number of flowers from each representative plant was counted and average was worked out.

3.6.1.10 Flower weight (gm)

The weight of flower from each representative plant in each genotype from each replication was recorded on a balance and the average was worked out in grams.

3.6.1.11 Flower diameter (cm)

The flower diameter from each representative plant was measured with the help of a measuring scale when it was full open and mean values were worked out.

3.6.1.12 Length of flower stalk (cm)

Stalk length of flowers harvested from representative plants in each genotype was measured with measuring scale and the average was worked out.

3.6.1.13 Duration of flowering (days)

Each representative plant in each genotype was tagged on the day of anthesis and the days taken from anthesis till the flower lost its decorative value were recorded and the mean days were worked out.

3.6.1.14 Flower yield (g) plant^{-1}

Flower yield from representative plants in each genotype was recorded through multiplication of their flower weight with number of flowers they bear and average was worked out.

3.6.1.15 Vase life of cut flower (days)

The cut flowers were harvested from the plants other than those used for recording biometric observations. The uniform cutflowers in terms of developmental stage were harvested from each genotype and carried dry to the laboratory within half an hour. The cutflowers were placed in conical flask containing 100 ml tap water. Vase life in days was determined at room temperature under natural light conditions. The water was being changed at one day interval. The end of the vase life was depicted when the flower lost its decorative value.

3.6.1.16 Stalk diameter (cm)

Stalk diameter of cut flowers harvested for measurement of stalk length was measured with Vernier Calipper and the mean values were worked out.

3.7 Biometrical analysis

Data collected were subjected to biometrical analysis as per the procedure presented by Singh and Chaudhary (1985); Johnson *et al.* (1955) and Mardia *et al.* (1979).

A brief outline of the procedures adopted for the estimation of different statistical parameters is given as follows:

3.7.1 Genetic variability

This was estimated from the analysis of variance as under:

ANOVA

Source of variation	**Df**	**MSS**	**VR (F)**	**E (MS)**
Replication(s)	(r-1)			
Genotypes(s)	(g-1)	Mg	Mg/Me	$\sigma^2_e + r. \sigma^2_g$
Error	(r-1) (g-1)	Me		σ^2_e
Total	**(rg-1)**			

Where

df = Degree of freedom

MSS = Mean sum of squares

VR = Variance ratio (F)

Mg = Mean sum of squares due to genotypes

Me = Mean sum of squares due to error

E(MS) = Expected mean sum of squares

σ^2_e = Variance due to environment

σ^2_g = Variance due to genotype

r = Number of replications

g = Number of genotypes

3.7.2 Coefficient of variability

The phenotypic and genotypic coefficients of variability were calculated for each character by applying the formula given by Burton and Devane (1953) as follows:

3.7.2.1 Phenotypic coefficient of variability (PCV)

$$PCV = \frac{(\sigma^2_p)^{1/2}}{\overline{X}} \times 100$$

Where $\overline{X}$ = general mean of the population

σ^2_p = (Phenotypic variance) = $\sigma^2_g + \sigma^2_e$

σ^2_e = environmental variance

σ^2_g = genotypic variance

3.7.2.2 Genotypic coefficient of variability (GCV)

$$GCV = \frac{(\sigma^2_g)^{1/2}}{\overline{X}} \times 100$$

Where, σ^2_g = genotypic variance

$\overline{X}$ = general mean of the population

3.7.3 Heritability

Heritability (h^2) in broad sense was computed by the formulae suggested by Burton and Devane (1953), Johnson *et al.* (1955) and Hanson *et al.* (1956) as given below:

$$h^2 = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

where,

h^2 = Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

3.7.4 Genetic advance

The expected genetic advance expected in a population was calculated by the formula suggested by Johnson *et al*. (1955) as under:

$$GS = \frac{\sigma^2_g}{\sigma^2_p} \times (\sigma^2_p)^{1/2} \times K$$

Where

GS = expected genetic advance under selection

K = selection differential at 5 percent selection intensity i.e. K value of 2.06

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

3.7.5 Genetic gain

Expected genetic gain expressed as percent of mean, was calculated by the formula given by Johnson *et al.* (1955) as under:

$$\text{Expected genetic gain} = \frac{G.S}{\overline{X}} \times 100$$

Where $\overline{X}$ = population mean

G.S. = Genetic advance

3.7.6 Correlation coefficients

The correlation at genotypic, phenotypic and environmental levels between all possible pairs of characters was calculated from variance and covariance components as given by Al-Jibouri *et al.* (1958). The components of variance have been calculated as per the procedure given under 3.7.2 whereas the components of covariance were calculated as per the procedure given as under:

ANOVA

Source	**d.f.**	**Mean sum of products**	**Expected mean sum of products**
Replication	(r-1)		
Genotypes	(g-1)	MP_1	cov x y (e) + r cov x y(g)
Error	(r-1) (g-1)	MP_2	cov x y(e)
Total	**(r.g-1)**		

Where,

$$\text{Genotypic covariance g cov x y} = \frac{MP_1 - MP_2}{r}$$

phenotypic covariance ph cov x y = g cov x y + e.cov x y

3.7.6.1 Genotypic correlation

Genotypic correlation coefficient between (x) and (y) =

$$\frac{\text{g cov (x.y)}}{[\text{g.v. (x) X g v. (y)}]^{1/2}}$$

3.7.6.2 Phenotypic correlation

Phenotypic correlation coefficient between (x) and (y) =

$$\frac{\text{ph cov (x.y)}}{[\text{ph v. (x) X ph v. (y)}]^{1/2}}$$

3.7.6.3 Environmental correlation

Environmental correlation coefficient between (x) and (y) =

$$\frac{\text{e.cov (x.y)}}{[\text{e.v (x) X e.v (y)}]^{1/2}}$$

The significance of phenotypic correlation coefficient was tested against the tabulated r values given by Fisher and Yates (1948) for v-2 degree of freedom at $p = 0.05$ and $p = 0.01$.

3.7.7 Principal components analysis

Principal components analysis is among the oldest of multivariate techniques having been introduced originally by Pearson (1901) and independently by Hotelling (1933). It remains, however, one of the most widely employed methods of multivartiate analysis useful both for providing a convenient method of displaying multivariate data in a lower dimensional space and for possibly simplifying other analyses of the data.

The basic aim of principal components analysis is to describe the variation in a set of correlated variables, x_1, x_2, x_3, ………………., x_q, in terms of a new set of uncorrelated variables y_1, y_2, y_3, ………….., y_q, each of which is a linear combination of the x variables. The new variables are derived in decreasing order of “importance” in the sense that y_1 accounts for a much of the variation in the original data amongst all linear combinations of x_1, x_2, x_3, ………., x_q. Then y_2 is chosen to account for as much as possible of the remaining variation, subject to being uncorrelated with y_1 and so on. The new variables defined by this process, y_1, y_2, y_3, ………, y_q are the principal components. The general hope of principal components analysis is that the first few components will account for a substantial proportion of the variation in the original variables x_1, x_2, x_3, …………, x_q and can, consequently, be used to provide a convenient lower dimensional summary of these variables that might prove useful for a variety of reasons (Brian, 2005). The observations recorded on 16 metric traits were analysed by the use of principal components analysis technique in the R-software.

Chapter-4

EXPERIMENTAL FINDINGS

During the present investigation entitled “Studies on genetic variability in China aster *Callistephus chinensis* ”, the 30 genotypes were assessed for various vegetative and floral characters. The characters studies were:

a) Vegetative characters

1. Plant height (cm)
2. Number of leaves plant^{-1}
3. Number of main branches plant^{-1}
4. Number of lateral branches plant^{-1}
5. Leaf area index
6. Main stem diameter (cm)

b) Floral characters

1. Days taken to appearance of first flower bud (DAT)
2. Days taken to first flower bud opening (DAT)
3. Number of flowers plant^{-1}
4. Flower weight (g)
5. Flower diameter (cm)
6. Length of flower stalk (cm)
7. Duration of flowering (days)
8. Flower yield (g) plant^{-1}
9. Vase life of cut flower (days)
10. Stalk diameter (cm)

Data collected were subjected to statistical analysis for the above mentioned metric characters using mean values of five randomly selected plants in each of the three replications. The results of the statistical analysis of the data recorded for these characteristics are presented in Table 2-13. The salient features of various characters are presented here under:

4.1 Coefficient of variation
4.2 Heritability and genetic advance
4.3 Association among characters
4.4 Principal component analysis

Analysis of variance

Perusal of the data presented in Table 2 and 3 revealed that the genotypes tested expressed significant variability for all the traits studied and confirmed that, the genotypes selected were diverse and possessed pool of genes for the economic traits.

4.1 Estimates of mean, range, phenotypic and genotypic coefficients of variation

The estimates were computed from the data (Table 4 and 5) for different vegetative and floral characters. Mean plant height of the genotypes was 50.54 cm with a range of 36.12-64.52 cm, average number of leaves plant^{-1} ranged from 96.05-130.38 with a mean of 101.71; number of main branches plant^{-1} ranged from 5.98-12.38 with a mean of 8.36; number of lateral branches plant^{-1} ranged from 9.98-19.89 with a mean of 14.26; leaf area index ranged from 1.55-2.38 with a mean of 1.76 and main stem diameter ranged from 1.27-2.10 cm with a mean of 1.60 cm.

Similarly, for days taken to appearance of first flower bud ranged from 49.39-72.34 with a mean of 54.80 days; days taken to first flower bud opening ranged from 54.00-29.15 with a mean of 61.57 days; number of flowers plant^{-1} ranged from 22.14 to 37.05 with a mean of 28.77; flower weight ranged from 2.10-4.61 (g) with a mean of 3.86 (g); flower diameter ranged from 3.87 – 7.52 cm with a mean of 5.80 cm; length of flower stalk ranged from 12.82-25.59 cm with a mean of 19.91 cm; duration of flowering ranged from 29.40-45.10 days with a mean of 36.70 days; flower yield (g) plant^{-1} ranged from 63.88-66.19 (g) with a mean of 110.12 (g); vase life of cut flower ranged from 8.01 –11.87 days

Table 2: Analysis of variance for various vegetative characters in China aster (*Callistephus chinensis*) under temperate climatic conditions of Kashmir

Source of variation	Degrees of freedom	Mean sum of squares					
		Plant height (cm)	No. of leaves plant^{-1}	No. of main branches plant^{-1}	No. of lateral branches plant^{-1}	Leaf area index	Main stem diameter (cm)
Replication	2	33.343	50.508	0.479	1.653	0.003	0.004
Treatment	29	196.161**	158.954*	9.000**	17.135**	0.150*	0.168*
Error	58	18.485*	8.461*	1.259*	1.989*	0.002**	0.002**

*,**=Significant and highly significant, respectively

Table 3: Analysis of variance for various floral characters in China aster (*Callistephus chinensis*) under temperate climatic conditions of Kashmir

		Mean sum of squares									
Source of variation	**Degrees of freedom**	**Days taken to appearance of first flower bud (DAT)**	**Days taken to first flower bud opening (DAT)**	**No. of flowers plant^{-1}**	**Flower weight (g)**	**Flower diameter (cm)**	**Length of flower stalk (cm)**	**Duration of flowering (days)**	**Flower yield (g) plant^{-1}**	**Vase life of cutflower (days)**	**Stalk diameter (cm)**
Replication	2	0.366	5.631	3.138	0.004	0.130	7.616	13.655	37.384	3.433	0.000
Treatment	29	59.580**	63.455**	48.318	0.866**	2.255*	45.832**	57.620*	1050.958**	5.866*	0.001*
Error	58	5.512*	6.675*	5.009*	0.012**	0.112*	2.919*	4.094*	10.627**	0.101**	0.0002*

*,**=Significant and highly significant, respectively

Table-4: **Magnitude of variability for different vegetative characters in China aster (*Callistephus chinensis*) genotypes under temperate climatic conditions of Kashmir**

Character	Genotypes		Range	Mean	Standard error of mean (S.E)m	Critical Difference (p=0.05)
	Lowest	Highest				
Plant height (cm)	Ast-3	Ast-19	36.12 – 64.52	50.54	2.48	7.03
Number of leaves plant^{-1}	Ast-4	Ast-25	96.05 – 130.38	101.71	1.67	4.76
Number of main branches plant^{-1}	Ast-14	Ast-19	5.98 – 12.38	8.36	0.64	1.83
Number of lateral branches plant^{-1}	Ast-19	Ast-25	9.98 – 19.89	14.26	0.97	2.83
Leaf area index	Ast-28	Ast-25	1.55 – 2.38	1.76	0.02	0.07
Main stem diameter (cm)	Ast-17	Ast-25	1.27 – 2.10	1.60	0.02	0.08

Table-5: Magnitude of variability for different floral characters in China aster (*Callistephus chinensis*) genotypes under temperate climatic conditions of Kashmir

Character	Genotypes		Range	Mean	Standard error of mean (S.E)m	Critical Difference (p=0.05)
	Lowest	Highest				
Days taken to appearance of first flower bud (DAT)	Ast-5	Ast-14	49.39 – 72.34	54.80	1.32	2.94
Days taken to first flower bud opening (DAT)	Ast-5	Ast-14	54.00 – 79.15	61.57	1.45	4.31
Number of flower plant^{-1}	Ast-28	Ast-25	22.14 – 37.05	28.77	1.15	3.42
Flower weight (cm)	Ast-8	Ast-25	2.10 – 4.61	3.86	0.06	0.18
Flower diameter (cm)	Ast-8	Ast-25	3.87 – 7.52	5.80	0.19	0.55
Length of flower stalk (cm)	Ast-5	Ast-19	12.82 – 25.59	19.91	0.97	2.81
Duration of flowering (days)	Ast-23	Ast-8	29.40 – 45.10	36.70	1.15	3.32
Flower yield (g) plant^{-1}	Ast-8	Ast-25	63.88 – 166.19	110.12	2.48	7.32
Vase life of cut flower (days)	Ast-14	Ast-8	8.01 – 11.87	9.34	0.72	2.05
Stalk diameter (cm)	Ast-5	Ast-25	0.13 – 0.22	0.16	0.01	0.04

DAT = Days after transplanting

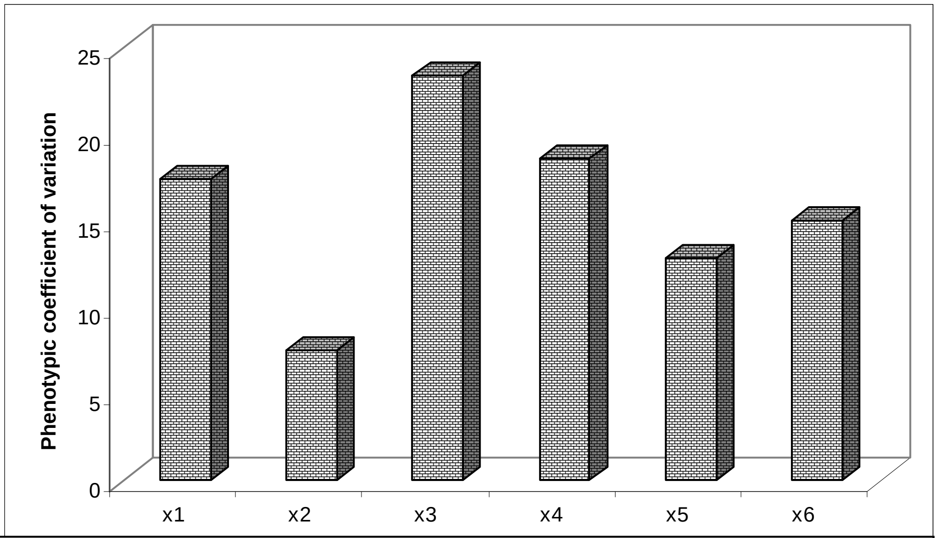


Fig 2: Phenotypic coefficient of variation for various vegetative characters in China aster

Legend

X_1 = Plant height (cm)

X_2 = Number of leaves plant^{-1}

X_3 = Number of main branches plant^{-1}

X_4 = Number of lateral branches plant^{-1}

X_5 = Leaf area index

X_6 = Main stem diameter (cm)

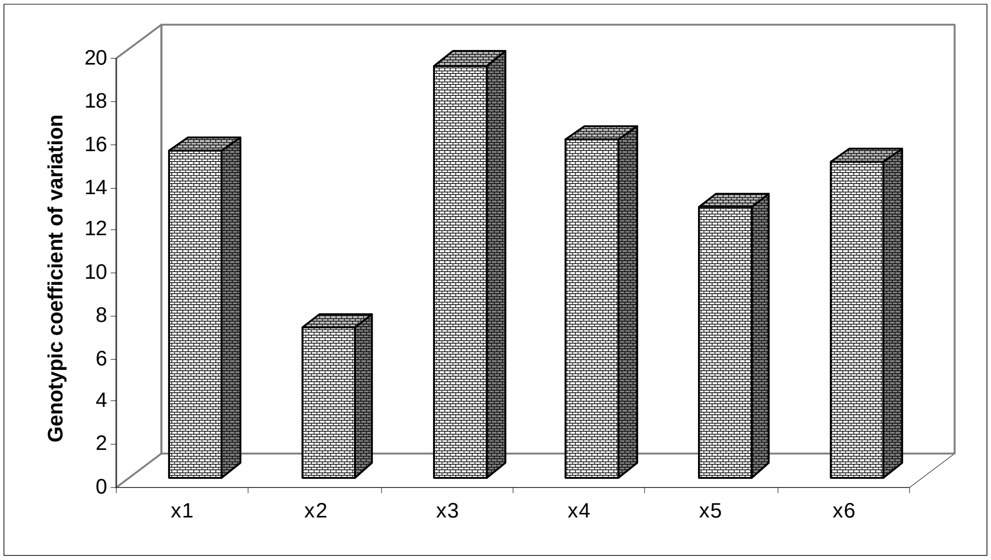


Fig 3: Genotypic coefficient of variation for various vegetative characters in China aster

Legend

X_1 = Plant height (cm)

X_2 = Number of leaves plant^{-1}

X_3 = Number of main branches plant^{-1}

X_4 = Number of lateral branches plant^{-1}

X_5 = Leaf area index

X_6 = Main stem diameter (cm)

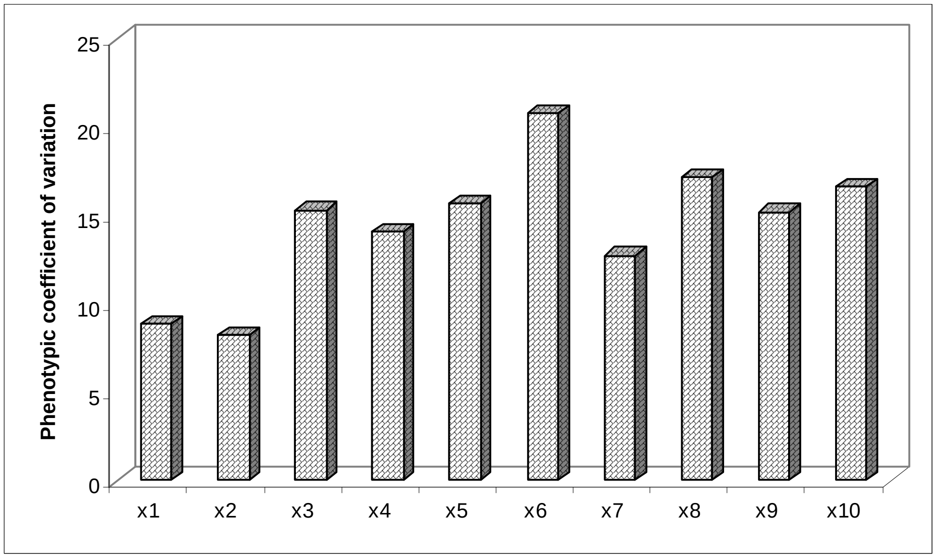


Fig 4: Phenotypic coefficient of variation for various floral characters in China aster

Legend

X_1 = Days taken to appearance of first flower bud

X_2 = Days taken to first flower bud opening

X_3 = Number of flowers plant^{-1}

X_4 = Flower weight (g)

X_5 = Flower diameter (cm)

X_6 = Length of flower stalk (cm)

X_7 = Duration of flowering (days)

X_8 = Flower yield (g) plant^{-1}

X_9 = Vase life of cutflower (days)

X_{10} = Stalk diameter (cm)

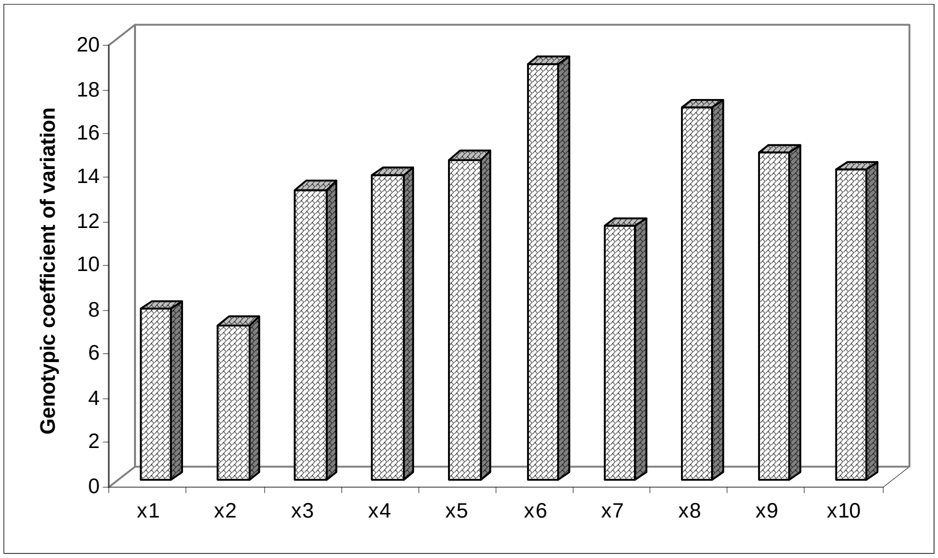


Fig 5: Genotypic coefficient of variation for various floral characters in China aster

Legend

X_1 = Days taken to appearance of first flower bud

X_2 = Days taken to first flower bud opening

X_3 = Number of flowers plant^{-1}

X_4 = Flower weight (g)

X_5 = Flower diameter (cm)

X_6 = Length of flower stalk (cm)

X_7 = Duration of flowering (days)

X_8 = Flower yield (g) plant^{-1}

X_9 = Vase life of cutflower (days)

X_{10} = Stalk diameter (cm)

with a mean of 9.34 days and stalk diameter ranged from 0.13-0.22 cm with a mean of 0.16 cm.

The perusal of the data presented in Table 6 and 7 revealed that magnitude of genetic and phenotypic coefficient of variation for various vegetative and floral characters studied, expressed significant variations at both the levels. However, magnitudes of genotypic coefficient of variation for number of leaves plant^{-1}, days taken to appearance of first flower bud and days taken to first flower bud opening was low (< 10.00 per cent); it was moderate (10.00-18.00 per cent) for plant height; number of lateral branches plant^{-1}; leaf area index; main stem diameter; number of flowers plant^{-1}; flower weight; flower diameter; duration of flowering; flower yield plant^{-1}; vase life of cut flower; and stalk diameter and was high (> 18.00 per cent) for number of main branches plant^{-1} and length of flower stalk, while magnitude of phenotypic coefficient of variation for all the above mentioned characters exhibited similar trend except the number of lateral branches plant^{-1} for which it was 19.02 per cent. The graphic representation of phenotypic and genotypic coefficient of variation is also shown in Fig 2-5.

4.2 Heritability and genetic advance

Broad sense heritability estimates, genetic advance and genetic advance as per cent of mean (expected genetic gain) in respect of all the 16 characters are presented in Table 8-9 and are also depicted in Fig 6-7. The estimates of heritability (broad sense) were categorized as high (>60 per cent), medium (30-60 per cent) and low (<30 per cent) whereas expected genetic gain estimates were categorized as high (>30 per cent), medium (20-30 per cent) and low (<20 per cent).

High heritability (broad sense) values were obtained for all the characters viz., flower yield plant^{-1} (97.03 per cent), flower weight (83.33 per cent); leaf area index (80.00 per cent); main stem diameter (93.33 per cent); vase life of cut flower (94.98 per cent); flower diameter (85.54 per cent); number of leaves plant^{-1} (85.57 per cent); length of flower stalk (83.05 per cent); duration of flowering (81.33 per cent); days taken to appearance of first flower bud (76.58 per cent);

Table-6: **Estimates of 'variance', and 'phenotypic and genotypic coefficient of variation' for different vegetative characters in China aster (*Callistephus chinensis*) under temperate climatic conditions of Kashmir**

Character	**Variance**		**Coefficient of variation (%)**	
	σ^2_g	σ^2_p	**GCV**	**PCV**
Plant height (cm)	59.23	77.71	15.23	17.44
Number of leaves plant^{-1}	50.16	58.62	6.96	7.53
Number of main branches plant^{-1}	2.58	3.54	19.22	23.45
Number of lateral branches plant^{-1}	5.05	7.04	15.75	18.60
Leaf area index	0.04	0.05	12.58	12.86
Main stem diameter (cm)	0.05	0.06	14.71	15.07

σ^2_g = genotypic variance
σ^2_p = phenotypic variance
GCV = genotypic coefficient of variation
PCV = phenotypic coefficient of variation

Table-7: **Estimates of 'variance', and 'phenotypic and genotypic coefficient of variation' for different floral characters in China aster (*Callistephus chinensis*) under temperate climatic conditions of Kashmir**

Character	Variance		Coefficient of variation (%)	
	σ^2_g	σ^2_p	GCV	PCV
Days taken to appearance of first flower bud (DAT)	18.02	23.54	7.75	8.85
Days taken to first flower bud opening (DAT)	18.93	25.60	7.06	8.22
Number of flowers plant^{-1}	14.44	19.45	13.21	15.32
Flower weight (g)	0.28	0.29	13.82	14.12
Flower diameter (cm)	0.71	0.83	14.57	15.68
Length of Flower stalk (cm)	14.30	17.22	18.99	20.84
Duration of Flowering (days)	17.84	21.94	11.51	12.77
Flower yield (g) plant^{-1}	346.77	357.40	16.91	17.17
Vase life of cut flower (days)	1.92	2.02	14.84	15.23
Stalk diameter (cm)	0.0005	0.0007	14.11	16.65

σ^2_g = genotypic variance
σ^2_p = phenotypic variance
GCV = genotypic coefficient of variation
PCV = phenotypic coefficient of variation
DAT = Days of transplanting

Table-8: Estimates of ‘heritability’, ‘genetic advance’ and ‘expected genetic gain’ for different vegetative characters in China aster (*Callistephus chinensis*) under temperate climatic conditions of Kashmir

Characters	Heritability (Broad sense) %	Genetic advance	Expected genetic gain (percent of mean)
Plant height (cm)	76.21	13.84	27.38
Number of leaves plant^{-1}	85.57	13.50	13.27
Leaf area index	95.70	0.44	25.35
Number of main branches plant^{-1}	67.19	2.71	32.45
Number of lateral branches plant^{-1}	71.73	3.92	27.51
Main stem diameter (cm)	83.33	0.47	29.59

*Selection intensity at 5% level

Table-9: **Estimate of 'heritability', 'genetic advance' and 'expected genetic gain' for different floral characters in China aster (*Callistephus chinensis*) under temperate climatic conditions of Kashmir**

Characters	Heritability (Broad sense) %	Genetic advance	Expected genetic gain (percent of mean)
Days taken to appearance of first flower bud (DAT)	76.58	7.65	13.96
Days taken to first flower bud opening (DAT)	73.93	7.70	12.51
Number of flowers plant^{-1}	74.24	6.75	23.46
Flower weight (g)	95.82	1.07	27.87
Flower diameter (cm)	86.40	1.61	27.91
Length of flower stalk (cm)	83.05	7.10	35.66
Duration of flowering (days)	81.33	7.84	21.38
Flower yield (g) plant^{-1}	97.03	37.78	34.31
Vase life of cut flower (days)	94.98	2.78	29.79
Stalk diameter (cm)	71.83	0.04	24.64

* = Selection intensity at 5% level
DAT = Days after transplanting

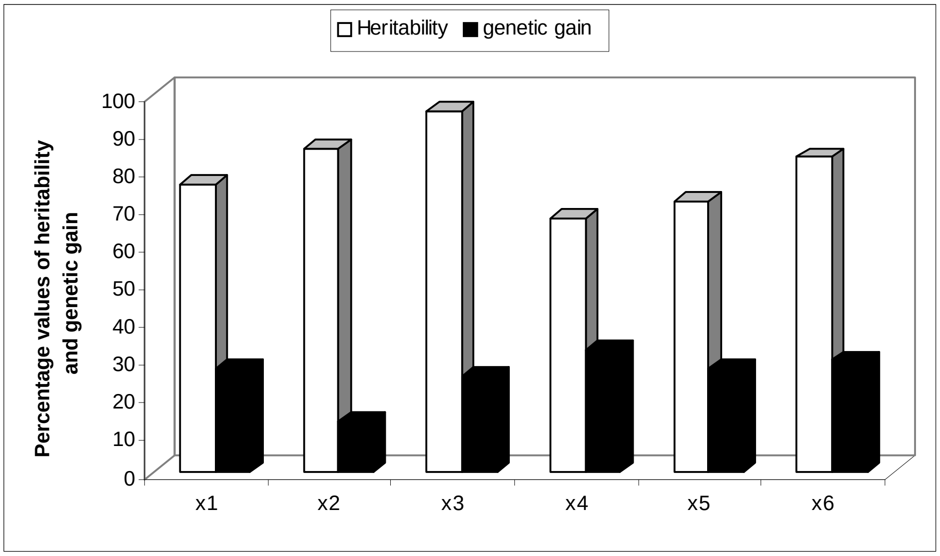


Fig 6: Heritability (broad sense) and genetic advance (as per cent of mean) for various vegetative characters in China aster

Legend

X_1 = Plant height (cm)

X_2 = Number of leaves plant^{-1}

X_3 = Number of main branches plant^{-1}

X_4 = Number of lateral branches plant^{-1}

X_5 = Leaf area index

X_6 = Main stem diameter (cm)

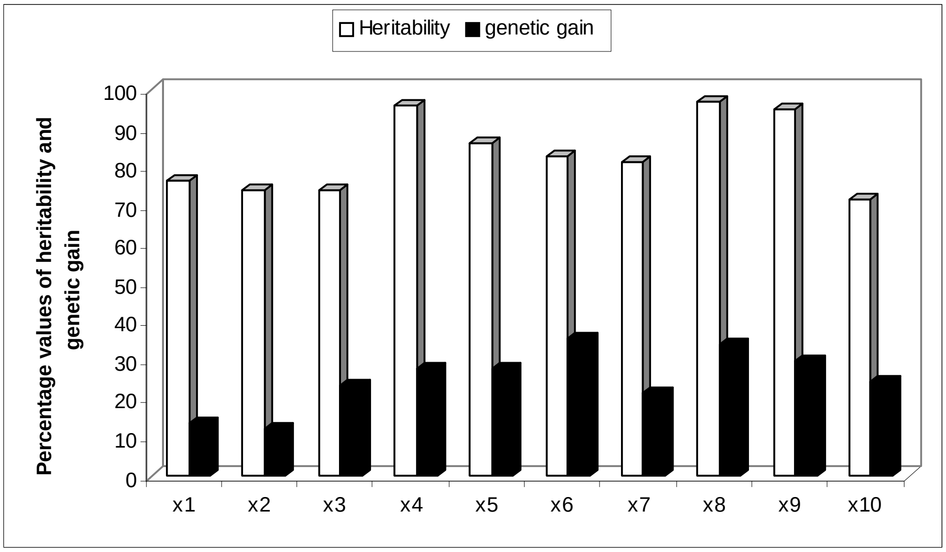


Fig 7: Heritability (broad sense) and genetic advance (as per cent of mean) for various floral characters in China aster

Legend

X_1 = Days taken to appearance of first flower bud

X_2 = Days taken to first flower bud opening

X_3 = Number of flowers plant^{-1}

X_4 = Flower weight (g)

X_5 = Flower diameter (cm)

X_6 = Length of flower stalk (cm)

X_7 = Duration of flowering (days)

X_8 = Flower yield (g) plant^{-1}

X_9 = Vase life of cutflower (days)

X_{10} = Stalk diameter (cm)

plant height (76.21 per cent); number of lateral branches plant^{-1} (71.73 per cent); number of flowers plant^{-1} (74.24 per cent); days taken to first flower bud opening (73.93 per cent); stalk diameter (71.83 per cent) and number of main branches plant^{-1} (72.88 per cent).

Higher estimates of expected genetic gain were recorded for length of flower stalk (35.66 per cent); flower yield plant^{-1} (34.31 per cent) and number of main branches plant^{-1} (33.85 per cent), whereas, medium estimates were recorded for vase life of cut flower (29.79 per cent); main stem diameter (26.25 per cent), flower diameter (27.41 per cent), flower weight (27.87 per cent); plant height (27.38 per cent); leaf area index (20.45 per cent); stalk diameter plant^{-1} (23.28 per cent); duration of flowering (21.38 per cent); number of lateral branches plant^{-1} (27.51 per cent) and number of flowers plant^{-1} (23.46 per cent). The estimates of expected genetic gain were low for days taken to appearance of first flower bud (13.96 per cent); number of leaves plant^{-1} (13.50 per cent) and days taken to first flower bud opening (12.51 per cent).

High heritability coupled with high expected genetic gain was observed for length of flower stalk and flower yield plant^{-1} while high heritability along with moderate expected genetic gain was found for vase life of cut flower; main stem diameter; leaf area index; duration of flowering; flower weight; flower diameter; plant height; number of flowers plant^{-1}; number of lateral branches plant^{-1} and stalk diameter. The characters viz., number of leaves plant^{-1}; days taken to appearance of first flower bud and days taken to first flower bud opening had high heritability along with low expected genetic gain. Medium heritability associated with high expected genetic gain was observed for number of main branches plant^{-1}.

4.3 Association among characters

In order to formulate an efficient breeding programme, a knowledge of the nature and extent of association of characters is considered to be of great significance Allard (1960). Therefore, correlation coefficients were estimated at both phenotypic and

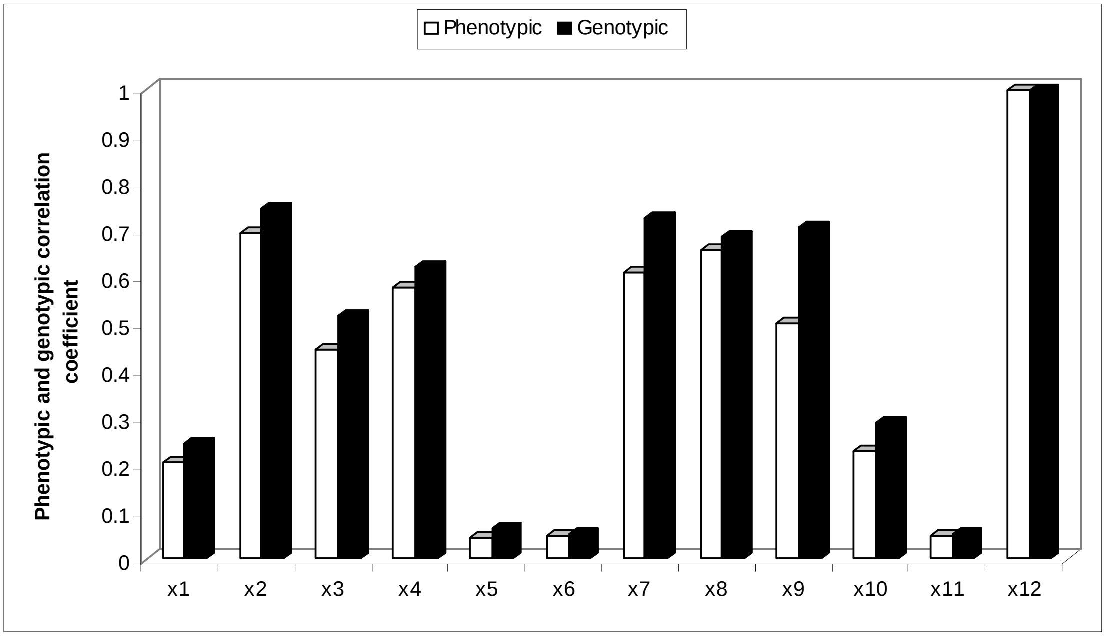


Fig 8: Correlation of flower yield (g) plant^{-1} with other characters in China aster

Legend

X_1= Plant height (cm)

X_2= Number of leaves plant^{-1}

X_3= Number of main branches plant^{-1}

X_4= Number of lateral branches plant^{-1}

X_5 =Days taken to appearance of first flower bud

X_6= Days taken to first flower bud opening

X_7 =Number of flowers plant^{-1}

X_8 = Flower weight (g)

X_9= Flower diameter (cm)

X_{10}= Length of flower stalk (cm)

X_{11} = Duration of flowering (days)

X_{12} = Flower yield (g) plant^{-1}

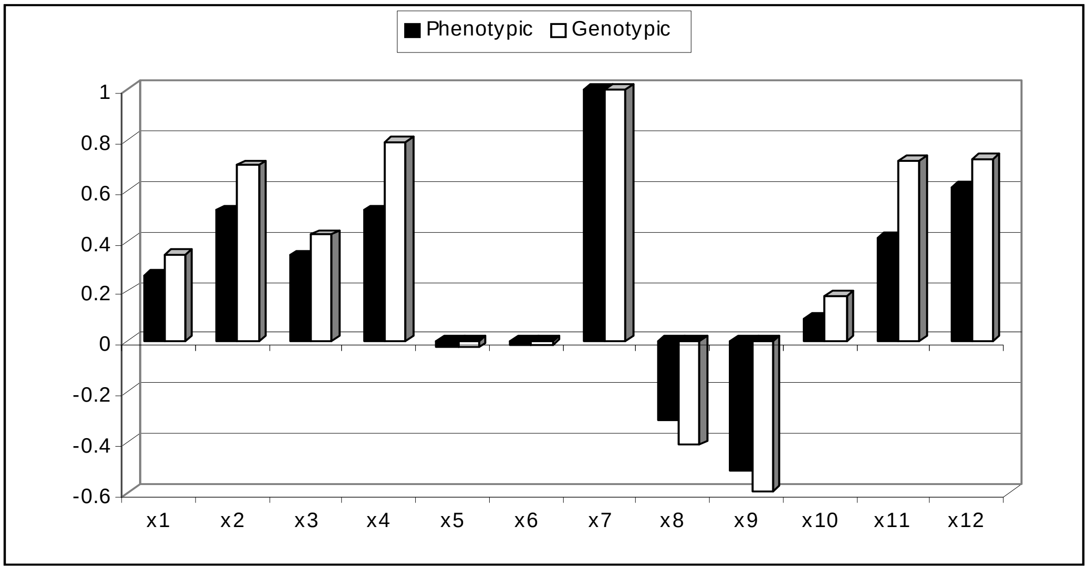


Fig 9: Correlation of number of flowers plant^{-1} with other characters in China aster

Legend

X_1= Plant height (cm)

X_2= Number of leaves plant^{-1}

X_3= Number of main branches plant^{-1}

X_4= Number of lateral branches plant^{-1}

X_5 =Days taken to appearance of first flower bud

X_6= Days taken to first flower bud opening

X_7 =Number of flowers plant^{-1}

X_8 = Flower weight (g)

X_9= Flower diameter (cm)

X_{10}= Length of flower stalk (cm)

X_{11} = Duration of flowering (days)

X_{12} = Flower yield (g) plant^{-1}

genotypic levels among various vegetative and floral characters to know the nature of relationships existing among the characters studied and these coefficients are present in Table 10 and 11, respectively. Graphic representation of correlations between number of flowers plant^{-1}; and flower yield plant^{-1} with various characters are given in Figures 8 and 9, respectively. Genotypic correlation coefficients were, by and large, higher in magnitude, though similar in direction than their corresponding correlation coefficients at the phenotypic level.

4.3.1 Phenotypic correlation coefficient

At phenotypic level, plant height showed highly significant positive correlation with number of main branches plant^{-1}. But it exhibited positive and significant correlation with length of flower stalk. Number of leaves plant^{-1} at phenotypic level displayed significant positive correlation with flower yield plant^{-1}; number of main branches plant^{-1} and number of lateral branches plant^{-1}. Similarly, at phenotypic level, number of main branches plant^{-1} displayed highly significant and positive correlation with number of lateral branches plant^{-1} and length of flower stalk, but it showed positive and significant correlation with number of flowers plant^{-1} and flower yield plant^{-1}. Whereas, number of lateral branches plant^{-1} exhibited highly significant and positive correlation with number of flowers plant^{-1} and flower yield plant^{-1}. However, number of lateral branches plant^{-1} exhibited negative insignificant correlation with flower weight (g). Similarly, number of flowers plant^{-1} displayed highly significant and positive correlation with flower yield plant^{-1} and number of lateral branches plant^{-1}; whereas, it exhibited highly significant and negative correlation with flower diameter. However, a negative and significant correlation was observed between number of flowers plant^{-1} and flower weight. Flower weight, in turn, exhibited highly significant and positive correlation with flower diameter and flower yield plant^{-1}. Flower yield plant^{-1} exhibited highly significant correlation with number of lateral branches plant^{-1}, flower weight and number of flowers plant^{-1}. Its correlation was significantly positive with number of main branches plant^{-1}; number of leaves plant^{-1} and flower diameter. Similarly, length of flower stalk

Table-10: Phenotypic correlation coefficient for different characters of China aster (*Callistephus chinensis*) under temperate climatic conditions of Kashmir

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
X_1	**1.000**	0.327	0.749**	0.151	-0.057	-0.065	0.264	0.014	0.095	0.627**	0.126	0.206
X_2		**1.000**	0.477*	0.492*	-0.027	-0.040	0.521	0.291	0.431	0.343	0.341	0.693*
X_3			**1.000**	0.584**	0.011	-0.010	0.343*	0.061	0.111	0.689**	0.102	0.445*
X_4				**1.000**	0.154	-0.182	0.521**	-0.054	0.024	0.296	0.323	0.580**
X_5					**1.000**	0.855**	-0.021	0.085	-0.101	0.043	-0.152	0.045
X_6						**1.000**	-0.011	0.089	-0.052	0.059	-0.180	0.050
X_7							**1.000**	-0.312*	-0.513**	0.091	0.414	0.612**
X_8								**1.000**	0.868**	0.194	-0.420	0.658**
X_9									**1.000**	0.227	-0.192	0.502*
X_{10}										**1.000**	-0.080	0.231
X_{11}											**1.000**	0.050
X_{12}												**1.000**

*’ **Significant at 5% and 1% level of probability

X_1= Plant height (cm); **X_2**= Number of leaves plant$^{-1;}$ **X_3**= Number of main branches plant^{-1} **X_4**= Number of lateral branches plant^{-1}; **X_5** =Days taken to appearance of first flower bud; **X_6**= Days taken to first flower bud opening; **X_7** =Number of flowers plant^{-1}; **X_8** = Flower weight (g); **X_9**= Flower diameter (cm); **X_{10}**= Length of flower stalk (cm); **X_{11}** = Duration of flowering (days); **X_{12}** = Flower yield (g) plant^{-1}

Table-11: Genotypic correlation coefficient for different characters of China aster (*Callistephus chinensis*) under temperate climatic conditions of Kashmir

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
X_1	**1.000**	0.428	0.898**	0.237	-0.059	-0.090	0.344*	0.019	0.131	0.857**	0.153	0.246*
X_2		**1.000**	0.649*	0.720**	-0.057	-0.063	0.699*	0.330	0.486	0.431	0.400	0.747**
X_3			**1.000**	0.594**	0.013	0.011	0.424*	0.274	0.388	0.885**	0.162	0.519*
X_4				**1.000**	0.256	0.170	0.792**	-0.121	0.057	0.317	0.520	0.623**
X_5					**1.000**	0.871**	-0.023	0.097	0.132	0.049	-0.255	0.065
X_6						**1.000**	-0.113	0.119	0.087	0.106	-0.271	0.052
X_7							**1.000**	-0.412*	-0.596**	0.182	0.719	0.726**
X_8								**1.000**	0.906**	0.220	-0.463	0.687**
X_9									**1.000**	0.289	-0.229	0.706**
X_{10}										**1.000**	-0.066	0.289
X_{11}											**1.000**	0.054
X_{12}												**1.000**

*’ **Significant at 5% and 1% level of probability

X_1= Plant height (cm); **X_2**= Number of leaves plant$^{-1;}$ **X_3**= Number of main branches plant^{-1} **X_4**= Number of lateral branches plant^{-1}; **X_5 =**Days taken to appearance of first flower bud; **X_6**= Days taken to first flower bud opening; **X_7 =**Number of flowers plant^{-1}; **X_8** = Flower weight (g); **X_9**= Flower diameter (cm);
X_{10}= Length of flower stalk (cm);
X_{11} = Duration of flowering (days); **X_{12}** = Flower yield (g) plant^{-1}

exhibited highly significant and positive correlation with plant height and number of main branches plant^{-1}. The two floral characters viz., days taken to appearance of first flower bud and days taken to first flower bud opening, exhibited negative and insignificant correlation with all the characters viz, plant height, number of leaves plant^{-1}; number of flowers plant^{-1}; duration of flowering diameter; number of main branches plant $^{-1}$ and number of lateral branches plant^{-1} but with flower weight, length of flower stalk and flower yield plant^{-1}, its association was positive and insignificant. Whereas, a highly significant and positive correlation existed between days taken to appearance of first flower bud and days taken to first flower bud opening.

4.3.2 Genotypic correlation coefficient

At genotypic level, the flower yield (g) plant^{-1} displayed a highly significant and positive correlation with number of leaves plant^{-1}, number of lateral branches plant^{-1}, number of flowers plant^{-1}; flower diameter and flower weight. Whereas, its association with plant height and number of main branches plant^{-1} was significant and positive. Number of flowers plant^{-1} showed highly significant and positive correlation with number of lateral branches plant^{-1} and flower yield plant^{-1}, whereas, it exhibited highly significant and negative correlation with flower diameter. Similarly, the correlation of number of flowers plant^{-1} was positive and significant with number of leaves plant^{-1}; number of main branches plant^{-1} and plant height, but it showed a significant and negative correlation with flower weight. Although, flower diameter had displayed highly significant and positive correlation with flower weight. However, length of flower stalk exhibited highly significant and positive correlation with plant height and number of main branches plant^{-1}, days taken to first flower bud opening, and days taken to appearance of first flower bud exhibited insignificant and negative correlation with the seven characters viz; plant height, number of leaves plant^{-1}, number of flowers plant^{-1}, duration of flowering, flower diameter, number of main branches plant^{-1} and number of lateral branches plant-1. Whereas, with length of flower stalk, flower weight and flower yield plant^{-1}; its association was positive and insignificant. But a highly significant and positive correlation exhibited between days taken to appearance of first flower bud and days taken to first flower bud opening.

At genotypic level, plant height showed a highly significant and positive correlation with length of flower stalk and number of main branches plant^{-1}, whereas, a significant and positive correlation of plant height was observed with flower yield plant^{-1} and number of flowers plant^{-1}. Number of leaves plant^{-1} displayed a highly significant and positive correlation with number of lateral branches plant^{-1} and flower yield plant^{-1}. Similarly, a significant and positive correlation was observed between number of main branches plant^{-1}, number of flowers plant^{-1}, length of flower stalk and number of leaves plant^{-1}. However, number of main branches plant^{-1} exhibited a highly significant and positive correlation with number of lateral branches plant^{-1}, number of flowers plant^{-1}, length of flower stalk and flower yield plant^{-1}. Flower weight displayed a highly significant and positive correlation with flower diameter.

4.4 Principal components analysis

The principal component analysis provides an excellent opportunity to identify the best genotypes with more accuracy and in short possible time. It is a tool of multivariate analysis which is used when several correlated characters are studied together. Principal components are new variables, which are linear combination of characters, but are independent to each other and are also arranged in order of variances. First principal component (PC_1) contains maximum variability followed by second (PC_2) and so on. Considering the variation in genotypes, the data were subjected to principal components analysis for asserting the linear combination of characters and identify the best genotypes. The first two components contributed 82 per cent of the total variability amongst the 30 genotypes for nine quantitative characters (Table 12). The first principal component (PC_1) contributed to 53.08 per cent of the variance and all the nine characters except flower weight contributed to this factor. The second principal component (PC_2) contributed to 29.194 per cent of variance and all the characters

Table-12 : Loadings (eigenvectors) of some characters in China aster (*Callistephus chinensis*) genotypes under temperate climatic conditions of Kashmir

Components	**PC_1**	**PC_2**
Standard deviation	2.185	1.621
Variance (%)	53.083	29.194
Cumulative variance (%)	53.083	82.232
	Coefficient of variates	
Flower yield (g) plant^{-1}	-0.369	0.306
Number of leaves plant^{-1}	**-0.434**	0.094
Number of main branches plant^{-1}	-0.272	0.142
Number of lateral branches plant^{-1}	-0.292	-0.094
Leaf area index	-0.424	-0.175
Main stem diameter (cm)	-0.389	-0.303
Number of flowers plant^{-1}	-0.392	-0.289
Flower weight (g)	-0.092	**0.590**
Flower diameter (cm)	-0.153	0.560

PC_1 = Principal component 1^{st}
PC_2 = Principal component 2^{nd}

except number of lateral branches plant^{-1} and number of leaves plant^{-1} contributed to this factor. The maximum contribution to the PC_1 and PC_2 in terms of loadings, was from number of flowers plant^{-1} (-0.434) and flower weight (0.590), respectively (Table 11). However, Fig 10 showed that number of flowers plant^{-1} had maximum contribution while flower weight had minimum to PC_1 and Fig 11 revealed that PC_2 is a contrast of number of lateral branches plant^{-1}; leaf area index; main stem diameter; number of flowers plant^{-1} versus the characters viz., flower yield plant^{-1}; number of leaves plant^{-1}; number of main branches plant^{-1}; flower weight and flower diameter. However, magnitude of principal component analysis scores (PCA scores) for all the 30 genotypes were worked out and accordingly the five best genotypes were identified on the basis of magnitude of these scores and it was found that Ast-25 genotype is most superior followed by Ast-24, Ast-8, Ast-9 and so on (Table 13).

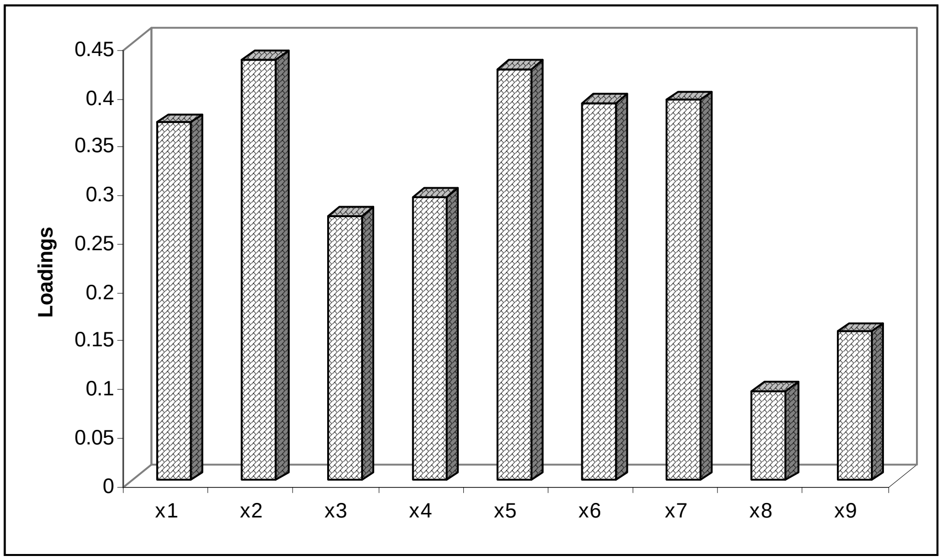


Fig 10: Loadings of first principal component. This plot shows that x_2 has maximum contribution while x_8 has minimum

Legends

X_1= Flower yield (g) plant^{-1}

X_2= Number of leaves plant^{-1}

X_3= Number of main branches plant^{-1}

X_4= Number of lateral branches plant^{-1}

X_5= Leaf area index

X_6= Main stem diameter (cm)

X_7= Number of flowers plant^{-1}

X_8= Flower weight (g)

X_9= Flower diameter (cm)

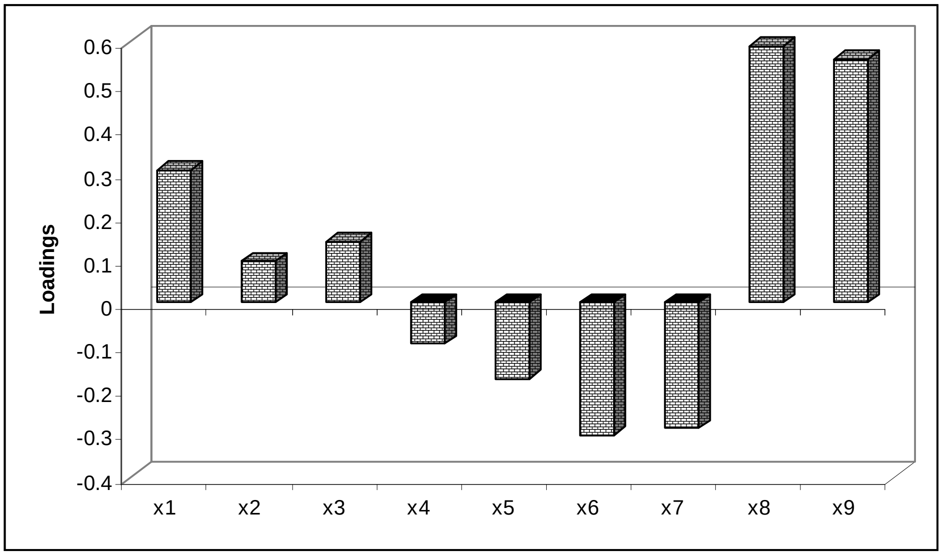


Fig 11: Loadings of second principal component. This plot shows that second principal component is a contrast of X_4, X_5,X_6,X_7 versus the characters X_1,X_2,X_3,X_8,X_8

X_1= Flower yield (g) plant^{-1}

X_2= Number of leaves plant^{-1}

X_3= Number of main branches plant^{-1}

X_4= Number of lateral branches plant^{-1}

X_5= Leaf area index

X_6= Main stem diameter (cm)

X_7= Number of flowers plant^{-1}

X_8= Flower weight (g)

X_9= Flower diameter (cm)

Table-13: Identification of five best genotypes on the basis of absolute principal components analysis (pca) scores under the temperate climatic conditions of Kashmir

Genotypes	Rank	Pca score	Characters								
			x_1	x_2	x_3	X_4	x_5	x_6	x_7	x_8	x_9
Ast-25	1	-7.56	166.19	130.38	11.48	19.89	2.38	2.10	37.05	4.61	7.52
Ast-24	2	-5.74	141.36	120.54	11.34	18.25	2.29	2.07	35.73	4.42	7.14
Ast-18	3	-4.72	149.30	112.3.5	11.12	17.32	2.20	1.98	34.01	4.39	7.03
Ast-9	4	-0.83	87.77	100.41	8.19	18.18	1.97	1.90	32.28	2.72	4.61
Ast-10	5	-0.77	106.65	103.57	7.03	12.39	2.04	1.88	32.03	3.33	4.95

x_1: flower yield (g) plant^{-1}; x_2: number of leaves plant^{-1}; x_3: number of main branches plant^{-1}; x_4: number of lateral branches plant^{-1}; x_5: leaf area index; x_6:main stem diameter (cm); x_7:number of flowers plant^{-1}; x_8: flower weight (g); x_9: flower diameter (cm)

Chapter-5

DISCUSSION

The success of any breeding programme depends on the presence of sufficient genetic variability to pursue effective selection. It is important to assess the relative magnitude of variability in order to use such information together with other selection parameters for the improvement of plant type through selection of effective breeding methods (Rao,1952,Johnson *et al.,* 1955, Hanson *et al,* 1956, Williams, 1964; Briggs and Knowle's, 1967). Genetic variability (GCV) helps to choose a particular genotype, whereas, heritability (h^2) along with genetic advance (per cent of mean) are more useful in predicting the resultant effect of selection of best genotypes.

Knowledge on the extent of genetic variation and diversity for various ecnomic traits viz; number of flowers plant^{-1}, stalk length, etc and wilt resistant traits in traditional China aster genotypes and subsequent identification of land races/genotypes as potential donors in China aster for improvement programmes is therefore, essential (Janakiram and Rao, 1996; Negi and Raghava, 1995; Janakiram, 1994; Rao *et al.,* 1997; Negi and Raghava 1990; Wit, 1937; Vaarama and Sulkinoja, 1958). These workers further emphasized the importance of such gene pools in the development of China aster cultivars possessing better economic traits like number of flowers plant^{-1}; length of flower stalk; flower yield plant^{-1} and other quality traits.

China aster possesses a tremendous capacity to tolerate climatic stresses and has been subjected to human selection mostly for numerous ornamental qualities and in such a process, other components of economic traits also appear to have accumulated considerable variations through correlated response to selection. Robinson (1966) recommended that germplasm pools be created to provide a reserviour of gene complexes and to form the base for the profitable selection studies. Such germplasm resources offer an array of materials for incorporation in the breeding programmes, with the possibility of extending economic traits to form a wider genetic base. Since most of the characters are considered quantitatively inherited and are subjected to different degree of non-heritable variability therefore, good knowledge about the gene action is essential for making any improvement. The magnitude of genetic component of heritable variation is most important for the estimation of genetic constitution of breeding materials which subsequently leads to higher selection response. The current test genotypes are best known for their high quality parameters, though they have an inherent low to medium yielding capacity. Judging from the importance of bio-diversity for these China aster genotypes, it is important to document them for use in the future breeding programmes involving exotic and current test genotypes. The present study was accordingly chosen to estimate the genetic variation for economic traits, durability of cut flower and quality parameters present in the current test genotypes. Potent variability in genotypes is the result of prolonged natural and artificial selection, which is heritable and accumulation of the significant magnitude of variability for economic traits leads to the genetic variation, which is important for creation of new genetic variability through hybridization and re-organization of new gene constellation. An effective China aster varietal improvement programme must have sound objectives based on the needs of farmers and consumers (Raghava and Negi 2001; Raghava and Negi, 1944; Negi *et al.,* 1983).

5.1 Genetic variability, heritability and expected genetic gain

In the present study, 30 genotypes of China aster were tested under temperate climatic conditions of the Kashmir valley, for the presence of genetic variability estimation of genetic parameters and selection of best genotypes.

The present study on the vegetative and floral traits revealed that significant genetic variability existed in these current test genotypes. Analysis of variance for the quantitative characters revealed, presence of significant genetic variation for all the characters.

Whereas, mean plant height ranged from 36.12 cm (Ast-3) to 64.52 cm (Ast-19) with a mean of 50.54 cm; other traits like number of flowers plant^{-1} ranged from 22.14 (Ast-28) to 37.05 (Ast-25) with a mean of 28.77; number of main branches plant^{-1} ranged from 5.98 (Ast-14) to 12.30 (Ast-10) with a mean of 8.36; number of lateral branches plant^{-1} ranged from 9.98 (Ast-19) to 1989 (Ast-25) with a range of 14.26; flower weight ranged from 2.10 (g) (Ast-8) to 4.61 (g) (Ast-25) with a mean of 3.86 (g), flower diameter ranged from 3.87 cm (Ast-8) to 7.52 cm (Ast-25) with a mean of 5.80 cm, vase life of cut flower ranged from 8.01 days (Ast-14) to 11.87 days (Ast-8) with a mean of 9.34 days; days taken to first flower bud opening ranged from 54.00 (Ast-5) to 79.15 (Ast-14) with a mean of 61.57; number of leaves plant^{-1} ranged from 96.05 (Ast-4) to 130.38 (Ast-25) with a mean of 101.71; the length of flower stalk ranged from 12.82 cm (Ast-5) to 25.59 cm (Ast-19) with a mean of 19.91 cm and flower yield (g) plant^{-1} ranged from 63.88 g (Ast-8) to 166.19 g (Ast-25) with a mean of 110.12 (g).

Evaluation of the 30 germplasm genotypes revealed that early flowering genotypes were Ast-5, Ast-9, Ast-8, Ast-10, Ast-4, Ast-3 and Ast-2. Similarly, the maximum days taken to first flower bud opening were observed in Ast-14 and Ast-13. However, maximum number of flowers plant^{-1}; flower weight; flower diameter; flower yield plant^{-1}; stalk diameter; number of leaves plant^{-1}; number of lateral branches plant^{-1}; leaf area index and main stem diameter were observed in Ast-25. While, maximum duration of flowering and vase life of cut flower was observed in Ast-8. Similarly, length of flower stalk, plant height and number of main branches plant^{-1} were maximum in Ast-19.

The analysis of variance indicated highly significant differences among genotypes under study for all the characters. However, the analysis of variance by itself is not enough and conclusive to explain all the inherent genotypic variation in the collection, so it is revealed by determining the total genetic variability inherent in the genotypes, got after getting due partitioning of the phenotypic variance (Charles and Smith, 1939; Grafuis 1964). However, coefficient of variation (both phenotypic and genotypic) was high for number of main branches plant^{-1} and length of flower stalk. However, in case of number of lateral branches plant^{-1} only phenotypic coefficient of variation was high (>18 per cent). Similarly, phenotypic and genotypic coefficient of variation for days taken to appearance of first flower bud, days taken to first flower bud opening and number of leaves plant^{-1} were observed to be low (<10 per cent) but for the other traits, the phenotypic and genotypic coefficient of variation were moderate (10-18 per cent). Several workers have reported, higher and low to moderate magnitude of genetic variability, genotypic and phenotypic coefficient of variation, heritability and genetic gain in China aster and other related floral crops for various metric traits. Moderate magnitude of genotypic variability and genotypic coefficient of variation have been reported for number of main branches plant^{-1} in China aster (Janakiram and Rao, 1994; Negi *et al.*, 1983). But Jhon *et al.* (1994) reported higher coefficient of variation for number of branches plant^{-1} and flower weight. Similarly moderate genotypic coefficient of variation for plant height was reported by Kumar and Patil (2003); Janakiram and Rao (1994) and Negi *et al.* (1983) in China aster, whereas, Singh *et al.* (1977) and Patnaik and Mohanty (2002) reported high genetic variability and genotypic coefficient of variation for plant height in sunflower and African marigold . However, moderate genotypic coefficient of variation for number of leaves plant^{-1} have been reported by Kumar and Patil (2003); for days taken to appearance of first flower bud and days taken to first flower bud opening in China aster. Low estimates of genotypic coefficient of variation than phenotypic coefficient of variation have been reported by (Kumar and Patil, 2003; Janakiram and Rao, 1994; Negi *et al.* 1983) in China aster. Similar results have been reported in several other related floral crops by various workers viz; Sirohi and Behera (2000) in chrysanthemum; Kishore and Raghava (2001) in African marigold and Nair and Shiva (2003) in gerbera. Similarly, low estimates of genotypic coefficient of variation for number of leaves plant^{-1}and moderate estimates of genotypic coefficient of variation for leaf area plant^{-1} have been reported by Kumar and Patil (2003) in China aster, whereas Nair and Shiva (2003) reported medium genotypic coefficient of variation for number of leaves plant^{-1} in gerbera. However, high estimates of genotypic coefficient of variation was reported by Janakiram and Rao (1994) for the said trait. Similarly, moderate estimates of genotypic coefficient of variation have been reported in China aster by Kumar and Patil (2003) and Negi *et al.* (1983) for flower diameter, flower weight and length of flower stalk, whereas Singh and Sen (2000) and Patnaik and Mohanty (2002) reported medium to high genotypic variability for flower weight in African marigold. Moderate to high estimates of genotypic coefficient of variation have been reported for number of lateral branches plant^{-1} (Kumar and Patil, 2003; Janakiram and Rao, 1994) in China aster. Similarly, moderate estimates of genotypic coefficient of variation have been reported by Kumar and Patil (2003) for duration of flowering and vase life of cut flower in China aster, whereas John *et al.* (1994) reported low estimates of GCV for duration of flowering in *Zinnia elegans*. Moderate estimates of genotypic coefficient of variation have been reported for flower yield plant^{-1} (Kumar and Patil, 2003) whereas Janakiram and Rao (1994) reported it high for said trait in China aster, but Raghava *et al.* (1992) reported higher GCV for flower yield plant^{-1} in chrysanthemum.

Similarly, heritability estimates were high (>60 per cent) for all the traits viz., plant height; number of leaves plant-^{1}; leaf area index; number of lateral branches plant^{-1}; main stem diameter; days taken to first flower bud opening; days taken to appearance of first flower bud; number of flowers plant^{-1}; flower diameter; flower weight; length of flower stalk; vase life of cut flower; stalk diameter; duration of flowering; flower yield plant^{-1} and number of main branches plant^{-1}. In China aster, high heritability estimates for days taken to appearance of first flower bud, days taken to first flower bud opening, plant height, number of lateral branches plant^{-1}, flower diameter and number of flowers plant^{-1} have been reported by Janakiram and Rao (1994); Kumar and Patil (2003) and Aswath and Parthasarathy (1993), whereas Negi *et al.* (1983) reported it moderate for number of lateral branches plant^{-1}, number of flowers plant^{-1}, days taken to flower and number of main branches plant^{-1}. For length of flower stalk and vase life of cut flower, high heritability estimates were reported by Kumar and Patil (2003), Negi *et al.* (1983) and Aswath and Parthasarathy (1993), whereas high heritability estimates for number of leaves plant^{-1} and main stem diameter were respectively reported by Kumar and Patil (2003) and Aswath and Parthasarathy (1993). Negi *et al.* (1983) reported high estimates of heritability for plant height, flower diameter and flower weight, whereas, for duration of flowering, it was reported high by Kumar and Patil (2003). But Patil and Rane (1995) reported higher estimates of narrow sense of heritability for plant height and ray floret rows flower^{-1}. Several workers reported moderate to higher estimates of heritability (broad sense) for various metric traits in other floral crops viz; Pathak (1997) found it high for stalk diameter and medium for seed yield plant^{-1}; Barigidad *et al.* (1992) reported it high for number of branches plant^{-1} and number of flowers plant$^{-1.}$ In chrysanthemum, Nair Shiva (2003) reported higher estimates of heritability for cut flower yield, leaf area, number of leaves plant^{-1}, vase life and stalk length in gerbera.

The expected genetic gain (per cent of mean) was high (>30 per cent) for number of main branches plant^{-1}, length of flower stalk and flower yield plant^{-1}. However, it was low (<20 per cent) for number of leaves plant^{-1}, days taken to appearance of first flower bud and days taken to first flower bud opening, while it was moderate (20-30 per cent) for the remaining characters viz., plant height; leaf area index; number of main branches plant^{-1}; number of lateral branches plant^{-1}; main stem diameter; flower diameter; flower weight; number of flowers plant^{-1}; length of flower stalk; vase life of cut flower; duration of flowering; flower yield plant^{-1} and stalk diameter. In China aster, expected genetic gain was reported high for flower yield plant^{-1} and flower weight by Kumar and Patil (2003) and Janakiram and Rao (1994). For plant height, number of flowers plant^{-1}, number of main branches plant^{-1}, number of lateral branches plant^{-1} and flower diameter, moderate estimates of expected genetic gain have been reported by Negi *et al.* (1983) and Kumar and Patil (2003), whereas Jankiram and Rao (1994) reported it high for these traits. Expected genetic gain was reported high for flower stalk length by Negi *et al.*(1983),whereas Kumar and Patil (2003) reported it moderate for this trait. For days taken to flower the low estimates of expected genetic gain was reported (Janakiram and Rao, 1994; Negi *et al.* 1983), whereas Kumar and Patil (2003) reported it moderate for this trait. Kumar and Patil (2003) reported moderate estimates of genetic gain for number of leaves plant^{-1}, duration of flowering and vase life of cut flowers.

Low to high estimates of expected genetic gain were reported by several workers in other related floral crops viz; Barigidad *et al.* (1992) in chrysanthemum found it high for number of branches plant^{-1} and number of flowers plant^{-1}; Jhon *et al.* (1994) reported higher estimates of expected genetic gain for number of branches plant^{-1}, flower weight and number of flowers plant^{-1} in *Zinnia elegans* and Nair and Shiva (2003) found higher estimates of expected genetic gain for cutflower yield, leaf area and number of leaves plant^{-1} but moderate for stalk length and vase life in gerbera.

Presence of high genotypic and phenotypic coefficient of variation is expected to help in the isolation of desirable genotypes. However, genotypic coefficient of variation alone is not sufficient for determination of magnitude of heritable variation. Burton (1952) suggested that genotypic coefficient of variation together with heritability estimates would give better picture of the expected genetic gain from selection. Higher heritability estimates, along with high genetic gain are usually more useful than either of these parameters taken alone in predicting the resultant effect of selecting the best individuals (Johnson *et al.,* 1955). Falconer (1960) suggested that genotypic and phenotypic error variances are not helpful in determining heritable portion of the variation unless heritability is not estimated.

Low expected genetic advance results more from low genetic variance, genotypic coefficient of variation, rather than due to moderate or low heritability estimates (Singh *et al.*, 1984). Panse (1957) reported that high genetic advance and high heritability are the outcome of additive gene action and vice-versa indicating the presence of more non-additive gene action (Dominance and/ or epistasis). Paramasivan (1988) suggested that high heritability with moderate genetic advance arises from dominance and/ or epistasis effects. Hanson (1963) reported that heritability estimates are influenced by biometrical method used, generation of hybrid, sample size of experimental material and environment when the selection is made on the basis of phenotype.

In the present study, the traits like flower yield plant^{-1} and length of flower stalk, had high heritability and expected genetic gain are supposed to be governed by more additive gene effects. Improvement in these traits could be made through crossing and subsequent selection in the existing germplasm material, as also suggested by earlier workers (Negi *et al.* 1983, Kumar and Patil, 2003). However, high heritability, coupled with moderate genetic gain was found for plant height; number of lateral branches plant^{-1}; leaf area index; main stem diameter; flower weight; flower diameter; vase life of cut flower; duration of flowering and stalk diameter. For these traits, hybridization with more divergent gene pools (exotic) followed by selection is expected to yield good recombinants. But, medium heritability, coupled with high genetic gain, for number of main branches plant^{-1}, is an indication of additive gene effects governing the traits. Thus, it is more reliable for selection (Panse, 1942).

5.2 Character association

Correlation measured by a correlation coefficient is important in plant breeding, because, it measures the degree of association (genetic or non-genetic) between two or more traits. In most of the ornamental crops including China aster, the economic yield (flower yield palnt^{-1} and number of flowers plant^{-1}) is usually the trait of primary interest, though association of other traits like plant height, length of flower stalk, resistance to biotic and abiotic stress, etc are also important. Robinson (1951) and Mode and Robinson (1959) have studied the implication of phenotypic and genotypic correlations in crop improvement programmes. Large number of research workers have studied the utility of correlation among economic traits in ornamental crops. The principal assumption underlying the correlation among traits has been the pleiotropic nature of genes.

However, the presence of linkage has also been observed to affect the correlation. Genetic correlation between characters may be due to either pleiotropy or genetic linkage (Mode and Robinson, 1959). It is possible to break the association due to genetic linkage through genetic manipulations, whereas the association due to pleiotropy is not amendable for separation through breeding due to their physiological evolution. Knowledge of association of various characters among themselves and with economic characters should provide necessary information on indirect selection for improvement of economic characters.

Scientists have investigated the impact of indirect selection of trait and they observed that, this is effective only when the heritability of the trait selected for indirect selection is very high and the additive genetic correlations between the target traits, selected for indirect selection is also very high. Other workers are of the opinion that, indirect selection for a complex trait like economic yield is an expression of fitness and drastic change in any one of the component traits and is accompanied by adjustment on other components; implying the existence of correlated changes of gene frequencies. Therefore, the most effective method for economic improvement is direct selection for economic yield itself. There may be correlated changes among valuable economic characters and economic yield components, but these correlated changes will be inconcert with development of most physiologically efficient genotypes for expression of genotypes.

Relationship could be obtained from simple correlated coefficient, which will aid in determining the direction and number of characters to be considered in improving economic characters. High positive correlation between two characters indicate that selection for the improvement of one character leads to simultaneous improvement in the other character, depending upon the magnitude of association between them. Simultaneous improvement in characters became rather difficult if negative correlation is found to exist between them. These characters are considered to be independent, when weak correlation exists between them and selection for one character may not effect the other. Therefore, much emphasis on genotypic correlation is not being placed as these are easily subjected to large sampling errors and thus are seldom precise (Falconer, 1981).

In the present study, the correlations at the phenotypic level were similar in direction, though lower in magnitude, as expressed to genotypic correlations. Similar trend was reported by Kumar and Patil (2003), Negi *et al.* (1983), Baweja (2000) and Janakiram and Rao (1994) in China aster. Same trend was observed in other related floral crops viz; Raghava *et al.* (1992) in chrysanthemum and Nair and Shiva (2003) in gerbera. In some cases, phenotypic and genotypic correlations were very close indicating less environmental influence. Johnson *et al.* (1955) also highlighted the role of environment in diluting the expression.

However, number of flowers plant^{-1} exhibited significant and positive correlations at genotypic level with plant height, number of leaves plant^{-1}, number of main branches plant^{-1}, number of lateral branches plant^{-1} and flower yield plant^{-1} suggesting that number of flowers plant^{-1} can be improved by exerting selection pressure on any of these characters. Similarly, flower size had positive significant correlation with flower weight but was negatively correlated with number of flowers plant^{-1}. This shows that more number of flowers plant^{-1} reduce flower size. This observtion also indicates that increase in number of main branches plant^{-1} and number of lateral branches plant^{-1} will increase the number of flowers plant^{-1}. Similar results were reported by Negi *et al.* (1983), Kumar and Patil (2003) and Janakiram and Rao (1994) in China aster. However, Baweja (2000) in China aster reported positive and significant association of flower yield with number of flowers plant^{-1}, plant spread and number of branches plant^{-1} but negative association with days to first flower opening.

Significant genotypic correlations of flower yield plant^{-1} was observed in the seven out of 11 polygenic characters whose correlation coefficients were worked out, except with days taken to appearance of first flower bud, days taken to first flower bud opening, length of flower stalk and duration of flowering. Whereas it was positive but insignificant. These findings suggest that, simultaneous improvement of flower yield plant^{-1} can be achieved by exerting selection pressure on any of the characters like plant height, number of leaves plant^{-1}, number of main branches plant^{-1}, number of lateral branches plant^{-1}, number of flowers plant^{-1}, flower weight and flower diameter. These results are according with Janakiram and Rao (1994) in China aster; Shanmugum *et al.* (1972), Sirohi and Behera (1999) and Raghava *et al.* (1992) in chrysanthemum; Narayana and Patil (1998) in sunflower; Hegde and Gopinath (2003) in *Gaillardia pulchella* and Pratap *et al.* (1990) in marigold.

Length of flower stalk showed significant positive correlation (at both genotypic and phenotypic level) with plant height and number of main branches plant^{-1}. These associations were due to the fact that direct effect of number of main branches plant^{-1} and plant height were more on the length of flower stalk. It can be said that by selecting plants based on any of the characters like plant height, number of main branches plant^{-1} and flower diameter, improvement in length of flower stalk can be achieved as they have positive and significant correlations. Similar resultes were obtained by Kumar and Patil (2003) and Negi *et al.* (1983) in China aster.

5.3 Principal components analysis

In the principal component analysis (pca), the values are first scaled to make their variances equal. A new set of axes is then chosen in multivariate space so that the variances on the first and second axes are as large as possible, but are at right angles to each other. The coefficient of the data points on each new axis is a weighed sum of its coefficient on the originally scaled axis (Bhargava *et al.* 2005). Loadings (eigenvectors) of the first principal component (PC_1) revealed that it had number of leaves plant^{-1}, leaf area index, number of flowers plant^{-1} and main stem diameter as the variables with largest coefficients. This means that the first component distinguished those genotypes that possessed maximum number of leaves plant^{-1}, leaf area index, number of flowers plant^{-1} and main stem diameter. The second component (PC_2) accounted for 29.19 per cent of the total variance and the variable that contributed to PC_2 with the largest coefficient was flower weight, but with a positive sign. The traits associated with reproductive development viz., flower yield plant^{-1}; flower weight and flower diameter contributing positively to PC_2 but number of flowers plant^{-1} contributed negatively to it. However, variable related to vegetative growth viz., main stem diameter contributed negatively to PC_2; and number of main branches plant^{-1} contributed positively to it. Therefore, second principal component (PC_2) reflects the tendency of the genotypes to emphasize both vegetative and reproductive growth. Therefore, selection based on vegetative and reproductive characters viz; number of leaves plant^{-1}, leaf area index, main stem diameter, number of flowers plant^{-1} and flower weight would be more efficient as they account for maximum 82 per cent of the total variability. Several workers viz; Asawa *et al*. (1977); Lakshmanaiah (1978); Ghafoor *et al.*, (2001) and Bhargava *et al.*, (2005) also reported similar results in various other crops and suggested that the genotypes, which emphasize on vegetative growth tend to have larger leaves but fewer number of inflorescences and selection based on these variables would be more efficient as they account for major portion of variability. Absolute principal components analysis scores were worked out and on the basis of their magnitudes five best genotypes identified as most superior for selection viz; Aster-25, Aster-24, Aster-18, Aster-9 and Aster-10.

Chapter-6

SUMMARY AND CONCLUSION

The present study was conducted on 30 genotypes of China aster (*Callistephus chinensis)* with the objectives of finding out the genetic variability for 16 metric traits, working out interrelationship among 12 characters, studying nature of heritability and identifying best genotypes using principal component analysis. For quantitative analysis the data were recorded on plant height, number of leaves plant^{-1}, leaf area index, number of main branches plant^{-1}, number of lateral branches plant^{-1}, main stem diameter, days taken to appearance of first flower bud, days taken to first flower bud opening, number of flowers plant^{-1}, flower weight, flower diameter, duration of flowering, length of flower stalk, vase life of cut flower, stalk diameter and flower yield plant^{-1} for the estimation of different genetic parameters and identification of best genotypes.

The experiment was conducted from April, 2005 to September, 2005 at the experimental farm of Division of Floriculture, Medicinal and Aromatic Plants, of Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir. Experiment was laid out in a randomized block design with three replications.

Wide and significant variations for all the characters were observed among the genotypes studied through analysis of variance. The coefficient of variation (genotypic and phenotypic) was high for number of main branches plant^{-1} and length of flower stalk, low for days taken to first flower bud opening, days taken to appearance of first flower bud and number of leaves plant^{-1} and moderate for the rest of the traits. The difference between phenotypic and genotypic coefficients of variation was narrow for leaf area index and medium for remaining characters.

Heritability estimates (broad sense) for all the characters were found to be high. High heritability coupled with high genetic grain was observed for length of flower stalk, flower yield plant^{-1} and number of main branches plant^{-1} indicating additive gene effects. These characters can be very effectively improved upon by selection. High heritability accompanied by medium genetic gain was found for plant height, leaf area index, main stem diameter, flower weight, flower diameter, duration of flowering, vase life of cut flower, stalk diameter and number of flowers plant^{-1}. Therefore, selection for these characters would be effective. High heritability along with low genetic grain was exhibited by the characters viz., days taken to first flower bud opening, number of leaves plant^{-1} and days taken to appearance of first flower bud, whereas number of lateral branches plant^{-1} exhibited high heritability and moderate genetic gain. Those association which have high or moderate heritability coupled with low genetic gain, indicate the predominance of non-additive gene actions.

The correlations at the phenotypic level were mostly similar in direction, though lower in magnitude as compared to genotypic correlations, revealing that, association at both the phenotypic and genotypic levels were reliable and mostly outcome of genotypic component. Number of flowers plant^{-1} exhibited significant and positive correlations with plant height, number of leaves plant^{-1}, number of main branches plant^{-1}, number of lateral branches plant^{-1}, and flower yield plant^{-1} but it had negative significant correlation with flower diameter and flower weight. Positive and significant correlations were observed between flower yield plant^{-1} and each of seven characters viz; plant height, number of main branches plant^{-1}, number of lateral branches plant^{-1}, number of leaves plant^{-1}, number of flowers plant^{-1}, flower weight and flower diameter. Length of flower stalk exhibited significant positive correlations with plant height and number of main branches plant^{-1}. For maintaining and utilizing germplasm effectively, it is imperative for the breeder to ascertain the extent of diversity present in the material. The results of principal component analysis have established the presence of a large amount of genetic variability among the 30 genotypes for all the traits and on the basis of absolute principal component analysis scores, five best genotypes were identified.

Based on these findings the following broad line conclusion could be drawn.

1. Significant genetic variability was present for all the vegetative and floral characters among the current test China aster genotypes.
2. Higher magnitudes of genotypic coefficient of variation was observed for number of main branches plant^{-1}, length of flower stalk, which also revealed high heritability coupled with high expected genetic gain.
3. Economic trait viz., flower yield plant^{-1} exhibited high heritability and expected genetic grain (percent of mean) but moderate genotypic coefficient of variation.
4. Positive and significant correlation at genotypic level existed for flower yield plant^{-1} with plant height, number of leaves plant^{-1}, number of main branches plant^{-1}, number of lateral branches plant^{-1}, number of flowers plant^{-1}, flower diameter and flower weight.
5. On the basis of magnitude principal component analysis scores 05 best genotypes were identified for selection viz; Aster-25, Aster-24, Aster-18, Aster-9 and Aster-10.

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APPENDIX –I

Meteorological data for the crop growth period (April 2005 to September, 2005)

Standard week	Maximum temperature (°C)	Minimum temperature (°C)	Total rainfall (mm)	Relative humidity (%)
14	20.8	6.5	8.2	53
15	16.8	4.0	2.6	60
16	23.5	5.0	0.6	55
17	18.2	7.5	28.0	78
18	22.2	8.2	54.6	69
19	21.2	8.2	10.9	68
20	22.0	8.1	2.1	66
21	19.2	9.1	14.0	77
22	21.6	7.9	11.3	67
23	26.4	10.6	4.8	61
24	26.2	11.2	7.5	62.7
25	31.2	13.2	0.0	56
26	39.1	17.7	0.0	57
27	24.8	15.07	19.1	71
28	27.8	17.05	110.4	76
29	29.9	16.8	3.2	75
30	30.5	19.8	6.2	72
31	31.8	18.4	2.6	69
32	28.6	15.2	3.8	68
33	32.1	17.4	1.4	64
34	30.5	14.2	32.4	66
35	29.7	12.1	2.2	68

Source: Meteorological Observatory, Division of Agronomy, SKUAST-K, Shalimar Srinagar

Appendix-II

Mean performance for various vegetative and floral characters in China Aster *Callisteplus chinensis* (L) genotypes under temperate climatic conditions of Kashmir

Genotypes	**Characters**							
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Ast-1	60.140	98.750	1.650	9.250	14.020	1.540	54.350	59.320
Ast-2	37.240	97.040	1.580	6.380	13.080	1.290	51.450	58.140
Ast-3	36.120	99.860	1.610	6.020	13.050	1.410	50.350	57.840
Ast-4	39.783	96.050	1.590	6.540	13.820	1.320	53.450	59.450
Ast-5	47.056	100.320	1.690	7.640	14.080	1.610	50.683	54.000
Ast-6	48.250	99.430	1.950	7.670	15.150	1.760	55.560	61.930
Ast-7	50.380	102.400	1.796	8.000	15.730	1.660	54.000	59.480
Ast-8	54.250	99.150	1.810	8.130	14.450	1.680	49.390	57.000
Ast-9	57.360	100.410	1.970	8.190	18.180	1.900	50.000	58.830
Ast-10	43.653	103.570	2.040	7.030	12.390	1.880	52.130	58.120
Ast-11	51.620	98.950	1.710	8.090	14.210	1.650	54.900	59.430
Ast-12	50.820	99.050	1.750	8.030	14.490	1.710	55.110	62.560
Ast-13	61.320	104.520	1.630	10.870	13.120	1.440	62.353	69.120
Ast-14	36.200	99.250	1.910	5.980	13.540	1.780	72.340	79.150
Ast-15	49.320	98.480	1.620	7.930	13.450	1.510	56.170	64.730
Ast-16	50.030	100.240	1.640	7.980	13.180	1.520	56.000	63.180
Ast-17	39.400	96.830	1.580	6.350	13.540	1.270	50.190	58.930
Ast-18	57.540	112.350	2.200	11.120	17.320	1.980	51.240	58.850
Ast-19	64.520	97.000	1.560	12.380	9.980	1.250	56.890	63.110
Ast-20	59.650	99.390	1.940	11.020	16.396	1.810	54.450	60.250
Ast-21	55.350	98.880	1.690	8.160	10.450	1.550	53.850	60.220
Ast-22	52.170	99.250	1.620	8.060	10.870	1.520	55.120	63.310
Ast-23	51.930	98.386	1.600	8.080	10.940	1.420	54.110	60.000
Ast-24	60.850	120.540	2.290	11.340	18.250	2.070	53.180	60.390
Ast-25	58.120	130.380	2.380	11.480	19.890	2.100	53.420	60.100
Ast-26	40.250	100.240	1.700	7.010	13.150	1.570	59.593	67.146
Ast-27	47.380	98.680	1.630	7.430	15.890	1.520	56.180	62.680
Ast-28	46.210	96.530	1.550	7.390	16.350	1.236	54.320	61.930
Ast-29	50.020	101.200	1.640	8.043	15.180	1.510	53.450	60.810
Ast-30	59.240	104.000	1.620	9.140	13.580	1.400	59.880	67.000
Mean	**50.539**	**101.705**	**1.764**	**8.357**	**14.257**	**1.595**	**54.803**	**61.566**
C.D at 5%	7.027	4.754	0.076	1.834	2.826	0.084	3.837	4.222

Contd…..

Genotypes	**Characters**							
	X_{9}	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}
Ast-1	10.000	0.180	27.733	3.830	5.413	24.380	39.050	105.050
Ast-2	8.690	0.150	24.260	4.270	6.753	16.380	38.480	104.270
Ast-3	8.930	0.150	26.223	4.210	6.413	14.010	37.550	110.380
Ast-4	8.580	0.146	25.000	4.220	6.603	15.080	34.820	105.500
Ast-5	8.080	0.130	29.920	3.630	5.180	12.820	38.100	108.600
Ast-6	8.330	0.140	31.220	3.590	4.920	18.030	42.120	112.070
Ast-7	8.680	0.150	30.250	3.410	5.070	19.970	41.050	103.150
Ast-8	11.870	0.200	30.420	2.100	3.870	20.450	45.100	63.880
Ast-9	9.520	0.170	32.276	2.720	4.610	21.830	42.140	87.770
Ast-10	9.086	0.160	32.030	3.330	4.950	13.080	39.240	106.650
Ast-11	9.630	0.173	30.236	3.240	5.020	18.140	40.520	97.940
Ast-12	10.020	0.180	30.500	3.510	5.100	17.700	41.250	107.050
Ast-13	10.210	0.193	26.780	4.160	6.150	25.080	38.140	111.400
Ast-14	8.010	0.130	31.200	3.480	4.746	12.880	37.820	109.090
Ast-15	9.480	0.170	26.930	4.020	5.820	20.380	32.140	108.250
Ast-16	9.550	0.170	27.030	4.000	5.643	20.413	31.133	108.120
Ast-17	8.730	0.150	24.300	4.230	6.690	15.350	36.540	102.780
Ast-18	10.030	0.180	34.010	4.390	7.030	21.970	40.130	149.300
Ast-19	10.450	0.206	24.003	4.340	6.810	25.593	34.350	104.160
Ast-20	8.830	0.150	31.890	3.473	4.970	24.300	32.420	106.510
Ast-21	9.050	0.160	28.210	4.150	6.133	21.050	33.400	117.070
Ast-22	8.450	0.140	27.266	4.080	5.953	19.880	30.140	110.160
Ast-23	8.400	0.140	26.610	4.190	6.196	18.110	29.400	111.423
Ast-24	10.720	0.203	35.730	4.420	7.140	25.006	40.520	154.700
Ast-25	11.480	0.220	37.050	4.610	7.520	25.120	41.850	166.190
Ast-26	9.180	0.163	29.680	3.810	5.240	20.850	31.820	113.080
Ast-27	10.210	0.183	27.020	4.010	5.656	21.820	30.450	108.350
Ast-28	9.360	0.166	22.140	4.100	5.990	21.080	29.890	90.770
Ast-29	8.190	0.133	26.910	4.070	5.943	22.740	34.830	109.520
Ast-30	8.480	0.143	26.2000	4.210	6.403	23.810	36.430	110.300
Mean	**9.340**	**0.164**	**28.7677**	**3.860**	**5.798**	**19.910**	**36.694**	**110.116**
C.D at 5%	2.046	0.010	3.420	0.182	0.548	2.792	3.307	7.321

X_1 = Plant height (cm); X_2=No. of leaves plant^{-1},X_3=Leaf area index; X_4=No. of main branches plant^{-1}; X_5=No. of lateral branches plant^{-1}; X_7=Days taken to appearance of first flower bud; X_8=Days taken to first flower bud opening; X_9=Vase life of cutflower (days); X_{10}=Stalk diameter (cm); X_{11}= No. of flowers plant^{-1}; X_{12}=flower weight (g); X_{13}=flower diameter (cm); X_{14}=length of flower stalk (cm); X_{15}=Duration of flowering (days); X_{16}=Flower yield (g) plant^{-1}

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Certificate

This is to certify that all corrections and modifications suggested by the external examiner in the thesis script of **Manzoor Ahmad Wantoo (Regd. No. 2004-A-736-M)** entitled **"Studies on Genetic Variability in China aster *Callistephus chinensis*"** have been taken care of before final binding of the same.

(Major Advisor)
SKUAST-K, Shalimar

Aster-8

A field view of China Aster

Aster-11

Aster-12

Aster-05

Aster-02

Aster-17

Aster-04

Aster-25

Aster-24

Aster-18

Aster-09

Aster-10

Aster-06

Six top ranking genotypes of China aster