BREEDING FOR HIGH FLOWER YIELD AND XANTHOPHYLL CONTENT IN AFRICAN MARIGOLD (*Tagetes erecta* L.)

Thesis submitted in part fulfillment of the requirement for the
Degree of **"Doctor of Philosophy in Horticulture"**
to the Tamil Nadu Agricultural University, Coimbatore.

By

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2002

CERTIFICATE

This is to certify that the thesis entitled "**BREEDING FOR HIGH FLOWER YIELD AND XANTHOPHYLL CONTENT IN AFRICAN MARIGOLD (*Tagetes erecta* L.)**" submitted in part fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (HORTICULTURE)** to **Tamil Nadu Agricultural University**, Coimbatore is a record of **bonafide** research work carried out by **Mr. K.VELMURUGAN** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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ACKNOWLEDGEMENT

ACKNOWLEDGEMENT

My first and foremost thanks to the Lord Almighty for keeping and preserving me all these days and for giving me the best possible chairman.

I wish to place my heartfelt, sincere thanks and deep sense of gratitude to the Chairman of the Advisory Committee **Dr. M.Vijayakumar**, Professor and Head, Department of Floriculture and Landscaping, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, for his inspiring guidance, incessant help, dazzling comments and constant encouragement to bring out the thesis in the present shape.

Valuable comments and suggestions offered by the Advisory Committee Members **Dr. N.Chezhiyan**, Professor and Head, Department of Spices and Plantation Crops, HC & RI, **Dr. A.Gopalan**, Professor and Head, Department of Forage Crops, **Dr. G.Pathmanabhan**, Professor, Department of Plant Physiology are gratefully acknowledged.

My sincere thanks are due to the **Dr. R.S.Azakhia Manavalan**, Dean, Horticultural College and Research Institute, Coimbatore, for his constant encouragement and **Mr. R.Venkatachalam**, Assistant Professor (Hort.) for his constructive criticisms and also for providing needful facilities during the course of endeavour.

I extend my gratitude to **Dr.N.Subbaraman**, Professor (PBG), **Dr.M.Jawaharlal**, Associate Professor (Hort.), **Dr. S.Subramanian**, Associate Professor (Hort.), **Dr. T.Arumugam**, Associate Professor (Hort.) and **A. Ramar**, Assistant Professor (Hort.) for their timely help, suggestions and guidance.

I extend my sincere thanks to my friends **B. Augustine Jerard, P.Gandhikumar, P. Murugesan, S. Muthuramalingam, S. Easwaran,** and **Keisar** for their valuable support, which made this effort much easier and successful.

Words are inadequate to express my grateful gratitude to my beloved **Parents** and my **Brothers** whose support and wishes propelled me to work towards this cherished goal.

Profound thanks are due to my colleagues, staff members and workers in the Horticultural College and Research Institute, TNAU, Coimbatore, who helped in the conduct of study.

I am grateful to **Tamil Nadu Agricultural University**, Coimbatore for giving me an opportunity to conduct this experiment and I duly acknowledge the support rendered through the computer and lab facility to carry out statistical as well as biochemical analysis at HC & RI, TNAU, Coimbatore.

I thank **Tamil Nadu Veterinary and Animal Sciences University**, Chennai for granting me permission to complete my Ph.D. programme successfully.

I also thanks **M/s. Sowmiya Communications**, TNAU Campus, Coimbatore for their neat and punctilious execution of typing.

ABSTRACT

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A Line x Tester analysis was undertaken with a view to estimate the degree of heterosis, combining ability, nature of gene action, association for yield and yield attributing components in twenty four crosses in African marigold involving eleven parental lines *viz.*, Pollachi Local (L_1), Pusa Narangi Gainda (L_2), Nilakkottai yellow (L_3), Yellow Treasure (T_1), Bangalore Local (T_2), Pusa Basanthi Gainda (T_3), Cracker Jack Mix (T_4), Orange Treasure (T_5), Madurai Local (T_6), MDU-1 (T_7) and Rajapalayam local (T_8).

Heterosis over the best parent available was observed for most of the yield influencing characters *viz.*, number of branches per plant, number of flowers per plant, individual flower weight, colour intensity, xanthophyll content and flower yield. A range of 4.73 to 51.11 per cent best parent heterosis was observed in economic characters like plant height, number of flowers per plant, individual flower weight, flower diameter, colour intensity, xanthophyll content and flower yield per plant. Combining ability analysis revealed that non-additive (dominant gene action) gene effects were higher than that of additive type of gene effect for all the characters studied.

Evaluation of parents based on *per se* performance and *gca* effects revealed that the superiority of L_2, T_1, T_2, T_4 and T_8 over the other parents for yield and most of the yield contributing components. The parents T_2, T_5 and T_6 performed best for qualitative character namely xanthophyll content.

The crosses L_2T_3, L_2T_6 and L_3T_2 had high mean performance in F_2 generation for yield and yield contributing components. The cross combinations namely L_1T_4 and L_1T_5 had high mean performance for xanthophyll content.

The estimates of heritability and genetic advance as percentage of mean were high for number of branches per plant ($h^2 = 75.55$, GA = 47.04), flower yield ($h^2 = 89.37$, GA = 22.97), flower diameter ($h^2 = 97.01$, GA = 22.64) and xanthophyll content ($h^2 = 94.68$, GA = 22.66), thereby these characters can be improved by selection.

Association analysis revealed that duration of flowering and plant height had recorded positive and significant correlation with flower yield and none of the characters were found negative correlation with yield. Path analysis revealed that the characters *viz*., plant height, individual flower weight, days to flower initiation, number of branches per plant and flower diameter had direct positive effect on yield. In F_2 generation all the characters except flower diameter and xanthophyll content had positive direct effect on flower yield. From path analysis it could be inferred that selection could be combined for flower yield with plant height, no. of branches and flower weight.

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ABBREVIATIONS

BR	–	Number of branches per plant
CI	–	Colour intensity
DF	–	Duration of flowering
DFI	–	Days to flower initiation
FD	–	Flower diameter
FY	–	Flower yield
gca	–	General combining ability
GA	–	Genetic advance
h^2	–	Heritability
IFW	–	Individual flower weight
NF	–	Number of flowers per plant
PH	–	Plant height
PS	–	Plant spread
sca	–	Specific combining ability
viz.,	–	namely
XC–I	–	Xanthophyll content stage I
XC–II	–	Xanthophyll content stage II

INTRODUCTION

Chapter I

INTRODUCTION

African marigold (*Tagetes erecta* L.) coming under the family Asteraceae is grown around the big cities as a commercial crop both in North and South India. In Tamil Nadu, different flower crops are grown under 8384 ha. and marigold alone accounts to 1494 ha (Chadha and Bhattacharjee, 1995). African marigold is not only grown as a flowering annual and landscape plant but also as a source of pigment for poultry feed (Medina and Beiller, 1993). The pigment is added to intensify the yellow colour of egg yolks and broiler skin. At present, in India, AVT group of companies undertaking marigold on contract farming through 6500 farmers in Vidharbha region for the extraction of xanthophyll pigment from marigold flowers (Suresh Agarwal, 2001).

African Marigold has not been thoroughly studied regarding breeding behaviour and genetic architecture of most of the good performing varieties for their successful exploitation in production of promising F_1 hybrids suitable for Xanthophyll content and development of flower industry. It is generally tall (about 90 cm) with large double flowers and vary in their colour shades from lemon yellow to orange and golden yellow. An understanding of the genetics of the quantitative characters such as yield and components of yield is a prerequisite for making a break through in heterosis breeding programmes.

In addition, careful selection of inbreds is necessary as not all hybrids exhibits economically exploitable heterosis. This is accomplished by the combining ability analyses. An estimate of general combining ability effects is a more reliable test for their performance in hybrid combinations, because lines selected on the basis of high combining ability tend to give high specific combining ability effects also.

In any yield improvement programme, suitable selection criteria have to be formulated. Information on character associations and the way each component character effects the yield is needed for formulating such criteria. Work on crop improvement programme towards this end is yet to be initiated and existing genetic variation has not been fully exploited to produce a recombinant with desirable attributes with high flower yield and Xanthophyll content.

With this background, an attempt has been made to study the genetic mechanisms of inheritance of various characters in African marigold to identify appropriate breeding techniques for transfer of useful traits to an acceptable line. Recently many biometrical techniques have been evolved to understand the complex situations in the inheritance of the yield and the environmental influence on its expression, of which Line x Tester analysis is a significant tool for the breeder. This technique has been employed in this investigation with the following objectives:

i) To assess the breeding potentialities of a selected genotypes for various economic characters.

ii) To find out the extent of heterosis and to isolate high heterotic crosses with specific combining ability effects for commercial exploitation of hybrid vigour.

iii) To select parents and hybrids with high general combining ability effects with reference to local conditions and consumers preference for specific type of flower colour.

iv) To estimate the genetic parameters for various characters in both F_1 and F_2 generations and to assess the magnitude of variability exhibited to understand the heritable components of the variation.

v) To identify the desirable cross and the progeny

vi) To assess the association of different components with the yield and to fix up selection criteria for yield improvement and

vii) To formulate breeding strategies for the improvement of this crop.

REVIEW OF LITERATURE

Chapter II

REVIEW OF LITERATURE

Plant breeding programmes aim at improving the existing types or creating a new type, which should be better than the commercial cultivars, for such improvement programme in crop plants variability forms the main base. If there is adequate variability available naturally it is exploited, otherwise it can be induced by employing several plant breeding techniques of which hybridization continues to be the primary tool for plant breeders. Application of biometrics in plant breeding broadened the scope and perfected the precision of the techniques employed in crop improvement. While devising suitable breeding method for enhancing the yield levels through heterosis breeding knowledge on the genetic architecture of parents is an essential requirement. Among the variety of biometrical procedures available Line x tester analysis proposed by Kempthrone (1957) received considerable attention to assess the genetic differences in parents on quantitative characters. It is supposed to be the most convenient method since, the large number of genotypes can be used as lines could be tested for their combining ability even against a minimum of two or three testers. This L x T analysis indicates the relative capacity of female and male parents to produce a desirable recombinant.

Line x Tester mating system has been successfully employed in vegetable crops like tomato (Kaul and Nandpuri 1972, Nand Puri *et al.* 1974a, Anbu 1978, Dixit *et al.* 1980) African Marigold (Kumar, 1986) and in other crops to identify superior hybrid combinations.

Heterosis

Heterosis is a biological phenomenon. In recent years, it has been put to considerable practical use in enhancing productivity of crop plants. The two earlier views regarding the genetic basis of heterosis as described by Mather (1955) are hybrid vigour in a direct property of heterozygosity and (2) It is due to superior gene content possible in a hybrid where both the parents contributed to them.

Heterosis infers to the increase (or) decrease of F_1 value over the mean parental value. The increase of F_1 over the better parent and/or the best commercial variety is more relevant. Positive expression of hybrid vigour occurs in the F_1 progenies of certain crosses that heterosis was the genetic expression of the beneficial effects of hybridization. The practical utilization of heterosis varies according to the crop plants and the objectives of breeding. The economic characters like high yield, earliness and uniformity in flowering are essential for direct utilization of hybrid vigour.

Literature pertaining to heterosis in various flower crops is reviewed here.

In Marigold, the existence of heterosis was reported by Singh and swarup (1971) for the characters plant height, days for first flowering, duration of flowering flower size, flower weight and number of flowers. The higher percentage of heterosis over better parent was observed in the cross Alaska x Cupid orange mum for early flowering, Katrainlocal x Cupid Orange Mum for total number of flowers and Alaska x Hanawi for flower weight. Highest flower yield was recorded in Hawaii x Cupid Orange Mum. Also medium tall F_1 hybrids with very large (15.2 cm across) uniform flowers were observed by Jalil *et al.* (1974) in Marigold.

Swarup and Ragava (1973) in Hollyhock reported that two varieties, namely Hungarian Rosea annua white introduced from USA and supreme mixed introduced from the UK were found to be the most promising parents for the production of F_1 hybrids. The variety Hangarian Rosea Annua white is dwarf and late in flowering having the flowers with a tofteo centre. It was used as a female parent in the hybridization with the male parent supreme mixed which is tall and early flowering having semi-double flower.

In balsam (*Impatiens* sp.) the heterosis was observed by Swarup *et al.* (1975) in the characters number of branches, total number of flowers per plant, flower size and plant height.

In Zinnia,.Boyle and Stimart (1982), attempted interspecific hybridization and reciprocal crosses between 13 cultivars of *Zinnia elegans* (2n = 12) and *Zinnia augustifolia* (2n = 11 (or) 12). They found that reciprocal differences in seed setting ability. In all the crosses of *Z. augustifolia* and *Z. elegans* seed setting of 47.2 per cent was recorded and in six reciprocal crosses seed setting of 4.6 per cent alone was noted.

Pathak *et al.* (1983) in sunflower observed high heterosis in several crosses. The relative heterosis and heterbeltiosis (174.9 per cent and 147.99 per cent) were recorded in PIL 1602 x PIL 2270. Six hybrids gave higher heterobeltiosis and 12 crosses showed superiority over check.

Reddy (1985) carried out a diallele cross involving 7 parents in African Marigold and obtained 8.91 to 75.30 per cent heterosis over better parent in metric traits of plant height, number of branches per plant, days to 50 per cent flowering, flower diameter, flower weight, number of flowers per plant and flower yield per plant.

The highest standard heterosis of 193 per cent for flower yield in the cross involving Giant double African Orange x Cracker Jack mix was reported by Kumar, (1986) in African Marigold.

A range of 47.20 per cent heterosis for yield and 5 to 55 per cent for other traits in sunflower were observed by Singh *et al.* (1986). Chaudhary and Anand (1986) carried out a Line x Tester design in sunflower and recorded heterosis over the better parent for flower diameter (64.65 per cent), number of leaves (18.47 per cent) and days to flowering (-7.69 per cent).

Barad *et al.* (1993) studied 15 F_1 hybrids of African Marigold in a diallele set involving six parents and they observed that the minimum and maximum heterobeltiosis were 86.21 and 176.29 per cent for number of ray florets per flower and number of branches respectively. The cross Giant double African Orange x Cracker Jack was found to be best.

Raghava and Negi (2001) reported that considerable heterosis in China Aster was recorded for all the characters except days to flower. The mean values of the hybrids were higher than those of parents for all characters except days to flower where higher values indicated late flowering. The minimum and maximum heterosis observed were 0.37 and 126.96 per cent for flower size. In all the characters, the best performing F_1 hybrid was significantly better than the top parent. The best performing

F1 hybrids were different from the best heterotic hybrids in all the characters except in characters days to flower, flowering duration where incidentally both were the same. In the order of merit, Shell Pink x Azure Blue, AST20 x Azure blue and AST 20 x AST-16 combinations were found to be the best, which can be recommended for commercial exploitation of heterosis.

Singh and Swarup (1993) studied heterosis in petunia (*Petunia hybrida*) both in multiflora and grandiflora types in a 8 x 8 set of diallele crosses. Considerable heterosis was recorded for all the characters. The average heterosis was negative for days to first flower opening and days to full bloom stage, where negative value indicated early flowering. The heterosis ranged from 0.13 to 195.89 per cent over their respective better parent. In all the characters except plant height and days to first flower opening, the best performing F1 hybrids were better than the top parent in respect of individual characters. The best heterotic F1 hybrids were different than the best performing F1 hybrids in all the characters except in days to full blooming stage.

Gomathy (1994) reported that in African Marigold heterosis over the best parents was observed only for the characters days to flowering, days taken for completion of flowering, number of flowers per plant, individual flower weight and yield per plant. The heterosis was negative for most of the other characters. The standard heterosis was maximum in number of flowers/plant followed by days to flowering.

Raghava *et al.* (1999) reported that in African Marigold four F_1 hybrids have been developed by using the 'Femina' type genic male sterility. The hybrids are ms-7 x

Pusa Narangi Gainda (Orange, carnation type), ms-8 x Pusa Narangi gainda (Orange, Carnation type), ms-5 x Sel-7 (Yellow, chrysanthemum type) and ms-7 x Sel-7 (Orange, Chrysanthemum type). The first two hybrids were good for loose flower production, while the later two were suitable for garden decoration purposes. Hybrids ms-7 x Pusa Narangi Gainda and ms-8 x Pusa Narangi Gainda produced nearly 20 per cent higher flower yield over Pusa Narangi gainda. The hybrid ms-8 x Pusa Narangi Gainda has been named as Pusa Sankar-1.

Combining ability and gene action

The concept of combining ability in terms of genetic variation was put forward by Sprague and Tatum (1942). They attributed general combining ability (*gca*) to additive effect of gene and specific combining ability (*sca*) to dominant deviations and epistatic interactions. Rojas and Sprague (1952) examined the combining ability over years and found that specific combining ability not only involved dominance and epistasis but also genotype x environment interactions. Griffing (1956) expressed that *gca* involved both additive effects as well as additive x additive interactions.

Kempthrone (1957) defined *gca* and *sca* in terms of covariance of half sibs (HS) and full sibs (FS) in random mating population, where 2 *gca* is cov. HS. and 2 *sca* is cov. FS-2cov. H.S. For estimating combining ability, top cross, polycross, diallel, partial diallel, triallel crosses and Line x Tester analysis have been used.

The literatures pertaining to combining ability and gene action are reviewed below.

Singh and Swarup (1971) in Marigold studied the 7 x 7 diallele cross hybrids, and reported that high *gca* effects in parental lines spungold, sunset giant and Hawaii for different characters. They also stated that the mean squares for *gca* were greater than those for *sca* in all characters except in total number of flowers. The hybrids which showed best *sca* effects involved any of the best parental lines namely Spun gold, Spun Giant and Hawaii. These three parents high *gca* effects for one or more of the characters contributing to yield. It is obvious that there would be possibilities to improve the characters by selection.

Singh and Swarup (1973) observed the inheritance of three important characters, days for first flowering, flower weight and number of flowers in Marigold. Trangressive segregation for various characters was observed in the F_2 generation. The double flower character in Marigold is controlled by a single dominant gene (Towner, 1961; and Singh and Swarup, 1971). According to Punnet (1924) and Towner (1961), the tubular and flat type florets are monogenetically governed and tubular type is a recessive character. The anthocyanin pigments of flower in Marigold was controlled by a single dominant gene with modifying (or) inhibitory factors (Heslot, 1967). The type of flowers and flower colour are governed by two genes each in African Marigold. Monogenic dominance for purple, orange and yellow colour flowers (Mosjids, 1982) and two genes with complementary epistatic action for red and lemon colour flowers (Fick, 1976) have been reported in sunflower.

Singh and Swarup (1973a) studied the inheritance pattern in African Marigold involving in a 7 x 7 diallel crosses. They observed that dominance and epistasis, especially dominance x dominance played a major role in the inheritance of days to first flowering and flower weight. Additive gene effects and epistasis dominance x dominance were found to be more predominant in number of flowers. Transgressive segregation for various characters was observed in F_2 generation.

Miller *et al.* (1980) in a triple test cross design in sunflower observed that additive variance being not important for yield, although epistasis was a minor factor in the overall genetic variation for all traits. The estimate for mean degree of dominance for yield indicated predominance of partial dominance. The improvement of this crop could be continued by developing high yielding synthates (or) open pollinated cultivars.

Subramanian (1980) observed high *gca* effects for diameter of capitulum and yield per plant in the inbred line which combined high per se in sunflower. He found non-additive gene action for diameter and capitulum, girth of stem, days to first flowering. Dominance variances were higher than additive variances for number of leaves and days for first flowering.

Gupta and Khanna (1982) reported complementary or douplicate type of epistasis for yield and component characters in two crosses of sunflower. Complementary or duplicate type of epistasis is not important in the expression of heterosis. All types of gene actions ie additive, dominance and epistatic have been observed in the material. So, recurrent selection was recommended as suitable breeding methodology to upgrade this crop. Line x tester analysis in sunflower indicated that non-additive gene action predominated all characters. Three hybrids showed significant *sca* effects (Sheriff *et al.* 1985).

Ranga Rao (1983) reported that significant general and specific combining ability variances were present for all variables examined in safflower. However, additive genetic variance was predominant for flowering time and branch number, while non-additive variance was predominant for plant height and flowering time. None of the parental lines proved best for their relative combining ability. He suggested utilization of population breeding approach and development of hybrids for attaining rapid and sustained genetic improvement in the yield potential of safflower.

Shankara and Seetharam (1983) found that non-additive gene action was more predominant for stem girth, yield per plant, volume and weight of capitulum where as additive gene action was predominant for days to 50 per cent flowering, plant height and capitulum diameter in sunflower.

Reddy (1985) carried out a 7 x 7 diallele cross in African Marigold. They observed high *gca* effects for all the characters except days to 50 per cent flowering which was early in Gold coin yellow coin. The estimates of *gca* variances and components due to them were high in all the characters except flower diameter. The crosses Giant double African orange with Coimbatore local and African Double yellow x Spun gold had high *gca* effects and were heterotic for yield and hence could be used for exploitation of heterosis by recombination breeding. The hybrids African Double yellow x Orange boy and Orange boy x Coimbatore local recorded high *sca* effects for flower diameter and flower yield and lend scope for recurrent selection. Reciprocal differences were also significant in few crosses for all characters except number of branches per plant and days to 50 per cent flowering.

In a Line x Tester analysis in African Marigold, Kumar (1986) reported that all the characters were predominantly governed by dominant gene action. He obtained a greater *SCA* variance compared to the *GCA* variance. The maximum *gca* and per se performance for plant height, flower diameter and single flower weight were exhibited in MDU-1 and for yield of flowers per plant in local type. The tester local type expressed higher *sca* and per se performance for plant height number of branches and days to first flowering and Giant Double African Mix showed same response to flower stalk length, number of flowers and yield of flowers per plant.

Deshmukh *et al.* (1991) in a line x tester analysis in safflower proved that selection of parents in a crossing programme should be on the basis of *gca* effects.

Govindaraju *et al.* (1991) in a cross involving 20 inbred lines and three open pollinated testers of sunflower indicated the involvement of non-additive gene effects in the inheritance of all the characters.

Wali *et al.* (1995) in a study with eighteen hybrids based on male sterile lines and three pollinators noticed that the lines and testers varied significantly for their *gca* only for days to fifty per cent flowering and plant height. Among the female parents CMS-234 A and CMS-822 A were the best general combiners for early flowering and plant height. CMS-302 for plant height and CMS 821 A for prolonged flowering, head diameter and plant height. The best general combiner was RH-A-265 among the male parents for all the traits except days to flowering none of the hybrids showed significance.

Singh and Singh (2000) reported that the line x tester analysis of five CMS lines crossed with 15 inbreds, tested over two environments revealed the preponderance of non–additive gene action for plant height, number of leaves and days to flowering in sunflower.

Raghava and Negi (2001) reported that the inheritance of flower doubleness (DD) was observed to be monogenically dominant over singleness (dd). Pompon flower type with one row of ray florets and tubular disc florets was dominant over floppy type. Three independent genes Tn, D and C were found to govern these three different flower types. Another genotype having pompon flower type with four rows of ray florets and tubular disc florets was dominant over pompon with one row of ray florets and tubular disc florets. When this pompon type was crossed with chrysanthemum and fluffy types, it was found that the tubular disc florets were incompletely dominant over normal disc florets. Thus, in this pompon type there is a dominant allele 'C' of the gene 'C' which does not allow the conversion of ray florets into tubular disc florets. Tn alone (or) D or C alone fail to produce tubular disc florets.

Heritability and genetic advance

Heritability estimates indicate the effectiveness with which, selection of a genotype may be based on the phenotypic performance but does not necessarily mean a high genetic gain for a particular trait. So the heritability along with genetic advance should be considered more than heritability alone while making a selection (Johnson *et al.*, 1955).

Ashok Kotecha (1979) reported that F_2 variability was largely genetic for all the traits in safflower. The broad sense heritability estimates were high for all the traits studied. In the F_2, continuous distributions were observed, suggesting multiple factor inheritance for all traits. In one cross, narrow sense heritabilities for plant height and time to flowering were 79 and 11 per cent respectively and corresponding expected genetic advance were calculated as 17 and 0.7 per cent.

Ramesh *et al.* (1980) observed the highest heritability estimate for days to flowering and moderate heritability estimate combined with high expected genetic advance for yield per plant in safflower.

In sunflower, Venkateswarulu *et al.* (1980) reported high heritability estimates for plant height (67.6 per cent) and days to flowering (68.8 per cent) and low estimates for head diameter (21.9 per cent).

Ranga Rao (1982) reported that narrow sense estimates were high to very high for most of the attributes in safflower.

In African Marigold, Reddy (1985) reported that heritability and genetic advance were found to range from 48.6 to 65.8 per cent and 1.21 to 198.46 respectively for these components.

Kannan and Seemanthini Ramdas (1990) reported that in Gerbera the heritability was very high in all the characters except flower diameter and flower stalk. It was the highest in respect of number of leaves per plant, (98.37%). The genetic advance estimated was also in line with the heritabiltiy in all the characters. The genetic advance was the highest for number of leaves per plant (29.62%) followed by number of flowers per plant (18.13%), while for the remaining characters it ranged from 0.315% (flower diameter) to 12.22% (number of suckers per plant).

Janakiram and Rao (1992) reported that in African Marigold, heritbaility estimates ranged from 48.55 for flower yield per plant to 92.20 for plant height. Characters like days to flower, plant height, average flower weight and number of flowers per plant exhibited high value of heritability while number of main branches, average flower size had medium heritability values. The estimates of genetic advance ranged from 12.12 for days to flower to 61.64 for number of flowers per plant. Average flower weight had high heritability with moderate genetic advance as percentage of mean.

Janakiram and Rao (1994) reported in china aster the heritability estimates ranged from 86.76 for number of main branches to 99.39 for total yield per plant. All the nine characters exhibited high values of heritability. The estimated genetic advance ranged from 34.64 for days to flower to 188.89 for number of flowers per plant.

Patil and Rane (1995) reported that, in China aster highest heritability was observed for plant height (75.2 per cent) and ray floret rows (75.2 per cent).

Wernett *et al.* (1996) reported that, in gerbera a progeny of 5 x 5 diallel cross yielded estimates of narrow sense heritability ($h^2 = 0.28$) for vase life based on a 1.96 measurements per plant. Additive gene action was postulated to control this character.

Mahanta *et al.* (1998) reported that, in Gerbera the GCV values were in proximation to each other for almost all the characters. The characters like days to visibility of flower bud, days to flower bud opening and days to full bloom exhibited greater genetic variability and high heritability coupled with high genetic advance.

Anuradha and Gowda (1999) reported that in gerbera genotypic coefficient of variability was higher than phenotypic coefficient of variability for all the characters studied. Heritability ranged from 29.1 per cent for number of leaves to 94.4 per cent for weight of ray florets. High heritability coupled with high genetic advance was observed for weight of ray florets, disc diameter fresh weight of inflorescence indicating the importance of additive gene effects.

Gupta *et al.* (1999) studied the inheritance pattern of flower types in African Marigold. Two male sterile lines, MS_7 and MS_8 were crossed with apetalous male fertile line. Selection-21 and the F_1's were selfed to get F_2 population to study segregation of petalous and apetalous flowers. In F_2 generation, segregation of male fertile and male sterile plants in 3:1 ratio indicated that apetalous sterile trait was governed by single recessive gene.

Singh (1999) observed in African Marigold that, the co-efficient of variation was minimum for duration of flowering (PCV = 15.20, GCV = 14.89) and maximum for flower yield per plot (PCV = 64.67, GCV = 63.84) in French Marigold, but in African Marigold it was minimum for plant height after 60 days of transplanting (PCV = 8.14, GCV = 7.74). Heritability estimates for all the characters were generally very high. High heritability along with high genetic advance were observed for flower yield per plot (h^2 = 97.52, G.A = 129.85), yield per hectare (h^2 = 98.96, G.A - 8.8) in French Marigold whereas, in African Marigold high values were observed for weight of dry flower (h^2= 99.60 G.A = 108.50), flower yield per plot (h^2 = 99.74, G.A = 88.97) and flower yield per hectare (h^2= 97.34, G.A = 87.46).

Nand Kishore and Raghava (2001) reported that in African Marigold the estimates of heritability in broad sense varied from 89.52 per cent for flower weight to 96.10 per cent for shelf life of cutflowers. In general, high heritability estimates were recorded for all the characters studied. In the present study high genetic advance as percentage of mean was observed for flower weight per plant (54.15). All the characters have shown high heritability values, also ranging form 91.53 to 95.00, such conditions arise due to action of additive genes.

Association of characters

The knowledge on nature of association of various characters as quantitative means can furnish a clue to the mode of influence on a complex trait like yield. Correlations between different plant characteristics in a crop during a given season are also helpful in understanding the behaviour of varieties and may be of value in selection for the desired characters in a breeding programme. The association of component characters with yield could be assessed either through partial or multiple regression analysis through path co-efficient analysis. Literature pertaining to this aspect in related crops have been reviewed here.

In African Marigold Reddy (1985) analysed the association of characters and revealed that plant height, number of primary branches per plant, flower weight, pedicel length, flower colour intensity, number of flowers per plant and vase life had positive direct effects and established significant association with yield in F_1 while break down of association in flower colour intensity and vase life with yield due to breakdown of linkages with inter related components was observed.

Dhaduk *et al.* (1985) and Singh *et al.* (1985) reported that the genotypic correlation co-efficients were generally higher than phenotypic correlation co-efficients for yield component characters in sunflower.

Misra and Saini (1990) reported in Gladiolus that positively significant correlations for number of florets per spike with height of plant, number of leaves per shoot, number of florets remain opens at time,durability of spike, number of capsules per shoot, indicated that the single plant selection would be more effective for its improvement since these characters had positive direct effects also. Number of shoots per planted corm was the only character which showed negative correlation with days to flowering. The strongest positive correlation was observed between number of shoots per planted corm and number of daughter corms produced.

Positive and significant correlation was found between number of flowers per plant and number of branches per plant in chrysanthemum (Chattopadhyay, 1991).

Tanimu and Ado (1991) reported that most important direct positive contribution to yield was made by capitulum diameter and main indirect negative contribution by stem diameter. The results suggested that yield could be improved by selection for capitulum diameter and number of leaves in sunflower.

In African marigold Jankiram and Rao (1993) reported that in general, the genotypic correlation co-efficients were higher than the phenotypic correlation co-efficients. Days taken to flower has positive significant correlation with the eight characters studied where as it had significant negative correlation with days taken to flower, plant height, plant spread and number of lateral branches per plant. Positive significant association between characters can be attributed either to pleotropic effect of a single gene or due to the location of two independent genes controlling these traits in close proximity.

In China Aster, Janakiram and Rao (1994) reported that in general genotypic correlation co-efficients were higher than phenotypic correlation. Days to flowering had positive significant correlation with number of main branches 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 per plant.

Aswath *et al.* (1998) reported that positive correlation between stalk length and days to bud initiation but a negative correlation between flower diameter and days to bud initiation.

Damke *et al.* (1998) studied the association among flowering characters and plant growth characters in rose cultivar Super Star and showed that the total number of flowers recorded high positive correlation with number of shoots per plant and basal diameter of original shoots.

Correlation analysis was carried out among 10 diverse genotypes in African Marigold and 10 genotypes of French Marigold for 13 characters related to growth and flowering. Analysis of variance in case of African group revealed height of plant exhibiting positively significant response at genotypic and phenotypic level with spread of plant and number of lateral branches. Spread of plant also showed positively significant correlation with size and yield of flowers per plant. In French group, plant height showed positively significant correlation with number of lateral branches, days to visibility of buds, first picking and last picking of the flowers. Spread of the plant showed positive correlation with number and yield of flowers per plant. Days to visibility of bud with first picking and last picking of the flowers and first picking of flowers with last picking of flowers showed significant correlation was reported by Banu Pratap *et al.* (1999).

John *et al.* (1999) observed in Gladiolus that, spike length exhibited significant positive correlation with plant height, florets per spike and floret size and strong negative correlation with days to sprout, days to basal floret opening and 10 cormel weight at both phenotypic and genotypic levels.

Sirohi and Behera (1999) observed that positive and significant phenotypic association of yield with flowers per plant. Plant spread and number of branches per plant indicated that selection based on these characters would be more effective for chrysanthemum improvement. The number of flowers per plant had high direct effect on yield through number of branches per plant.

Path co-efficient analysis

Direct selection of yield per se had a limited success in the selection programme. This is because, the yield is a sum total effects of the expression of various yield components. So, the information on the cause and effect of the various components on yield is very important for successful pedigree breeding in yield improvement.

Path analysis in China aster revealed that plant height and plant spread were the major factors influencing stalk length directly. Number of flowers per plant and flower size were also important as their total indirect effect on stalk length was high. Plant height had more total indirect effect on flower size. Stalk length and plant height exhibited high total indirect effect on number of flowers per plant (Manjunath, 1982).

In chrysanthemum Chaugule (1985) reported that the number of flowers per plant followed by plant height had the highest direct positive effect on weight of flowers at genotypic level. Shelf life of flowers had the lowest direct negative effect. Duration of flowering, lasting quality of flower and plant spread though had positive direct effect on weight of flower per plant, their corresponding indirect effects through number of flowers per plant was comparatively higher. The effects of all other characters were direct in negative direction. On the contrary, higher indirect effect was observed in case of the number of branches per plant followed by plant spread and plant height through number of flowers per plant. At the phenotypic level weight of flowers was indirectly influenced by the number of flowers per plant and diameter of flowers. Number of main branches per plant had larger indirect effect followed by plant spread, plant height and days to flowering through number of flowers per plant.

Mainkovick (1992) provided information on direct and indirect effects of the examined characteristics on seed yield per plant in sunflower. The highest direct positive effect on seed yield per plant was exhibited by head diameter, volume weight and kernal content had a direct negative effect on seed yield per plant.

In Chrysanthemum Sirohi and Behera (1999) reported that highly significant and positive phenotypic association of yield was observed with number of flowers per plant (0.650), plant spread (0.547) and number of branches per plant (0.372). The association of flower diameter and number of flowers per plant was significantly higher. The negative phenotypic correlation (-0.345) was observed between flower diameter and disc diameter. Path analysis studied revealed the positive correlation of plant spread (0.547) and number of branches per plant (0.372) with total yield. This is mainly due to its direct effect via number of flowers per plant. The positive association of number of flowers with yield was contributed by its direct effect (0.817).

MATERIALS AND METHODS

Chapter III

MATERIALS AND METHODS

3.1. Materials

The present investigation on African Marigold was carried out at the Department of Floriculture and landscaping, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during 1998 - 2001. The experimental materials chosen for this investigation consisted of eleven parents with diverses origin and variability maintianed at Department of Floriculture and Landscaping. The method followed was Line x Tester analysis. The source and description of the materials is given in the Table 1 and 2 respectively.

3.2. Methods

3.2.1. Selfing

African Marigold (*Tagetes erecta* L.) is self fertile (Writt's, 1980). Two forms of florets exist in "Capitulum", outer female ray florets (flat or ligulate petals) and inner bisexual disc florets (tube petals). Ray florets are zygomorphic, which are entomophilous and are cross pollinated. Out breeding is further enhanced by protandry of flowers. However, large flowered cultivars are seldom visited by insect pollinators because there is a mechanical barrier for pollination due to the enormous length of florets and the small size of pistil. There is considerable amount of natural crossing in Marigold which necessitate selfing or isolation in order to maintain purity.

Selfing was done by covering the flower heads yet to open the following day with butter paper covers tightly clipped with rubber bands. The covers were retained till the seeds were fully ripened.

Table 1. Materials used for the study

Sl. No.	Variety/genotypes	Colour	Source	Code No.
1.	Pollachi Local	Orange	Dept. of Hortl. & Landscaping, TNAU, Coimbatore	L_1
2.	Pusa Narangi Gainda	Orange	IARI, New Delhi	L_2
3.	Nilakkottai Yellow	Yellow	Dept. of Hort. AC & RI, MDU	L_3
4.	Yellow Treasure	Yellow	Dept. of Hort. AC & RI, MDU	T_1
5.	Bangalore Local	Orange	Dept. of Hortl. & Landscaping, TNAU, Coimbatore	T_2
6.	Pusa Basanthi Gainda	Yellow	IARI, New Delhi	T_3
7.	Cracker Jack Mix	Orange	Dept. of Hort. AC & RI, Madurai	T_4
8.	Orange Treasure	Orange	Dept. of Hort. AC & RI, Madurai	T_5
9.	Madurai Local	Yellow	Dept. of Hort. AC & RI, Madurai	T_6
10.	MDU-1	Orange	Dept. of Hort. AC & RI, Madurai	T_7
11	Rajapalayam Local	Orange	Dept. of Hort. AC & RI, Madurai	T_8

L = Lines, T = Testers

Table 2. **Descriptions/Characteristics of the materials used for the study**

Parents/ Characters	PH	BR	PS	DFI	DF	NF	IFW	FD	CI	XC-I	XC-II	FY
L_1	60.60	15.27	47.70	55.33	40.33	50.00	6.8	7.2	780	5.4	5..2	540
L_2	66.0	20.33	44.93	61.67	57.33	53.33	7.0	8.2	815	5.7	5.7	650
L_3	57.67	14.33	51.67	61.00	47.00	50.00	7.2	6.2	666	4.8	4.7	490
T_1	55.6	17.87	39.47	58.67	58.67	50.00	7.0	5.7	735	4.8	4.8	430
T_2	63.87	12.00	42.47	63.33	52.67	35.00	6.9	5.0	793	5.7	5.2	320
T_3	65.00	18.00	42.87	62.67	50.00	50.00	6.0	6.2	690	4.9	4.9	350
T_4	55.27	14.53	54.07	62.00	51.00	47.00	7.0	4.4	715	4.1	4.2	380
T_5	45.60	12.00	43.33	68.67	48.00	39.67	5.7	6.2	805	5.5	5.6	310
T_6	52.40	16.40	47.23	62.33	51.00	49.00	5.3	6.0	801	5.1	5.2	290
T_7	55.27	17.93	46.23	58.00	48.00	44.00	6.0	5.0	668	4.2	4.5	230
T_8	66.00	17.00	42.33	59.00	47.33	47.00	7.0	6.2	690	4.76	4.8	450

L = Lines T = Testers

3.2.2. Crossing Technique

In African Marigold, two types of florets are observed. One is ray floret which is female only and another is disc florets which is bisexual ie., both male and female. Generally ray florets are present as outer whorls which open first and followed by central disc florets. The method suggested by Towner (1961) was adopted for crossing. A day before anthesis between 3 and 6 p.m. the flower heads of female parents were covered with butter paper covers with a size of 10 cm x 8 cm. Next day, in the morning at 6 A.M. the upper involucral bracts of the flower heads in the female parent were cutoff sufficiently to expose the young florets. The upper 0.1 to 0.2 cm petal portion of the ray florets were also scissored to expose the inner bifid stigmatic end. Emasculation was accomplished by scissoring off all disc florets of the capitulum to the base carefully without any damage to the ray florets. Pollen is collected from the fully opened flowers of male parent. By tapping the fully opened flower heads pollen is collected in a petriplate in the previous day or on the same day. Pollination of the female parents was done between 7 and 8 A.M. by dusting the pollen collected from the male parent. Flower heads were then covered immediately and labelling was done mentioning parents involved. The mature capitula were harvested, seeds extracted and dried. A separate brush was used for pollinating different types. Anthesis was observed from 6 A.M. to 11 A.M. under Coimbatore conditions.

3.3. Field plot technique

3.3.1. Studies of F_1 generation

The 11 parents and 24 hybrids of Line x Tester crosses were raised in a randomized block design with three replications. The seeds were sown in a well prepared nursery bed in lines at 10 cm spacing. Thirty days old seedlings were transplanted at a spacing of 60 x 30 cm in ridges. Standard horticultural practices recommended for African Marigold were adopted uniformly to all the plots. The plot size was 4 x 3 m. A plot consisted of 30 plants in each treatment (parent and hybrids). Therefore a total number of 90 plants were maintained totally for each hybrid and parents during January 2000 to May 2000.

3.3.2. Study of F_2 generation

The selfed F_1 seeds were utilized for the study. F_2's of all the hybrids (Line x Tester crosses) and parents were studied during June 2000 to October 2000. A total number of 1050 plants were maintained for all the hybrids and parents (35 types) ie. 30 plants for each type in a plot and replicated thrice in a randomized block design. The observations were recorded on ten plants per treatment.

3.4. Observations

All the parents and their crosses were evaluated for the following twelve characters. Ten plants were selected from each hybrid and parents under each replication for recording the following observations.

3.4.1. Plant height

The height of the plant was measured from the cotyledonary node to the tip of main stem at the time of final harvest and expressed in centimeters.

3.4.2. Number of branches per plant

The primary branches arise from the main stem alone were counted at the time of final harvest and expressed as number per plant.

3.4.3. Plant spread

The plant spread was measured in both East-West and North-south directions and the mean is expressed in centimeters.

3.4.4. Days to flower initiation

The period taken from sowing to anthesis of the first flower in 50 per cent of the population was reckoned days to flowering.

3.4.5. Duration of flowering

The days taken between first flower opening and the last harvest was recorded and expressed in days.

3.4.6. Flower diameter

Ten flowers were chosen and the maximum diameter of the selected fully opened flowers were measured for each treatment and mean flower diameter was computed and expressed in centimeters.

3.4.7. Number of flowers per plant

The number of flowers harvested in each harvest was computed and the total number of flowers are expressed in numbers per plant.

3.4.8. Individual flower weight

Ten flowers from each plant were weighed for each treatment and mean of individual flower weight was computed and expressed in grams.

3.4.9. Flower colour

The colour of ten flowers was compared with the horticultural colour chart and recorded. The numerical weightage assigned to the colour spectrum of Marigold ranged from sulphur yellow (1) to Marigold orange (2) as full hues suffixing these letters to the 'hundreds' number namely 800, 700, 600 and 500 as rating values for darker shades, shaded, tints and lighter tints respectively as the case may be for each treatment. The mean flower colour intensity was computed and expressed in numerical figures.

3.4.10. Flower yield per plant

The flowers picked in each harvest were weighed and added to compute the yield in gram per plant.

3.4.11. Xanthophyll content

A quantity of 1 gm of fresh petals was ground with sand in a mortor and 20 ml of freshly prepared saturated solution of KOH in 95 per cent ethanol was added. This was refluxed for 30 minutes on a hot plate. After cooling, 50 ml of solvent ether was added shaken well and the clear upper layer was transferred to separating funnel leaving sediment in the flask itself. The transferace was repeated with 20 ml portions of ether. The residue in the flask was then treated with 25 ml of 95 per cent ethanol. The extraction continued with small quantities of solvent ether until the extract was colourless. The extract was passed through 100 ml of distilled water in a separating funnel and the aqueous green coloured solution was with drawn and shaken gently with 50 ml. of ether. The ether extracts were combined and washed with distilled water till free of chlorophyll and alkali.

The ether was evaporated by heating on a steam bath. Before drying, the extract was transferred to dessicator and tracer of ether evaporated in vacuo. The residue was dissolved in 30 ml. of petroleum ether. This was transferred to a separating funnel and the Xanthophyll was extracted with five volumes of 85 per cent methanol. The extraction was continued with 90 per cent methanol until the extract was colourless. The solution of carotene was washed with water to remove alcohol. this filtered into a 50 ml. volumetric flask through a dry filter paper containing a small quantity of anhydrous sodium sulphate to get free of water. The filtered solution was made upto 50 ml. with petroleum ether.

The methanol solutions were combined and evaporated to dryness vacuo and dissolved in 85 per cent methanol to make the volume to 50 ml. The yellow coloured solutions were measured at 450 nm. This was compared against the values of the standard solution of 0.2 per cent potassium dichromate diluted to different concentrations. The values of carotene and Xanthophyll were expressed in mg/gm of fresh foliage. (Pathmanaban *et al.,* 1996). The xanthophyll content in flower petals was estimated at half bud opened stage, and in fully opened flowers which are expressed separately as stage I and II.

3.5. Statistical methods

3.5.1. Unit analysis

The statistical parameters like mean, standard deviation, co-efficient of variation and standard error were worked out as per the standard methods of Panse and Sukhatme (1961).

3.5.2. Variability analysis

A. Analysis of variance

The mean values of ten plants in each type and replication were subjected to statistical analysis of variance (Panse and Sukhatme, 1961) and the analysis of variance table was constructed as follows.

Source	**Df**	**Ms**	**Expectation of mean squares**
Replications	(r - 1)		
Genotypes	(g - 1)	M_1	$\sigma^2_e + \sigma^2_g$
Experimental Error	(r- 1) (g - 1)	M_2	σ^2_e
Total	(rg - 1)		

where,

r = number of replications

g = number of genotypes

M_1 = Mean square of genotypes

M_2 = Mean square of error

The Significance was tested by referring to the 'F' table given by Snedecor (1961).

b) Phenotypic and Genotypic variance.

Phenotypic and genotypic variances were calculated as follows.

$$\text{Genotypic variance } (\sigma^2 g) = \frac{M_1 - M_2}{r}$$

where,

M_1 - mean square due to genotypes

M_2 - error mean square

r - number of replications

Phenotypic variance (σ^2p) = $\sigma^2g + \sigma^2e$

where,

σ^2e = Environmental variance

c. **Phenotypic (PCV) and Genotypic co-efficient of variation**

For each character PCV and GCV were computed based on methods given by Burton (1952).

$$\text{PCV} = \frac{(\text{Phenotypic variance})^{1/2}}{\text{Grand mean}} \times 100$$

$$\text{GCV} = \frac{(\text{Genotypic variance})^{1/2}}{\text{Grand mean}} \times 100$$

d. **Heritability - h^2**

$$h^2 \text{ (broad sense)} = \frac{\sigma^2g}{\sigma^2p} \times 100$$

where,

σ^2g = Genotypic variance

σ^2p = Phenotypic variance

e. **Genetic Advance (GA)**

Genetic advance for each character was worked out using the method outlined by Johnson *et al.* (1955).

$$\text{GA} = \frac{\sigma^2g}{\sigma^2p} \times k$$

where,

σ^2g = Genotypic variance

σ^2p = Phenotypic standard deviation

k = Selection differential, the value of which is 2.06 at 5 per cent selection intensity.

GA was expressed as percentage of mean by using the formula proposed by Johnson *et al.*, (1955).

$$\text{GA expressed as \% of mean} = \frac{\text{GA}}{\text{Grandmean}} \times 100$$

3.6. Combining ability analysis

3.6.1. Line x Tester Analysis

The observations recorded for the hybrids and parents were subjected to Line x Tester analysis and the general combining ability of the parents and specific combining ability of the hybrids were carried out by the method out lined by Kempthrone (1957). The mean squares due to different sources of variation in each treatment and their expectations were estimated as indicated in the following ANOVA table.

Source	Degree of freedom	Mean squares	Genetic expectations
Replication	(r-1)		
Testers	(t-1)	M_1	σ^2e + r (cov.(FS) - 2 cov. (HS) + rl (Cov. (HS)
Lines	(l-1)	M_2	σ^2e + r (cov.(FS) - 2 cov. (HS) + rt (Cov. (HS)
Line x Tester	(l-1) (t-1)	M_3	σ^2e + r (cov.(FS) - 2 cov. (HS)
Error	(r-1) (lt-1)	M_4	σ^2e
Total	(r/t-1)		

where

r = number of replications

l = number of female (lines) parents

t = number of male (tester) parents

a) Variance

The variance (mean square) due to GCA and SCA and expressed in terms of co-variance of full sibs (Cov. FS) and half sibs (cov. HS) respectively.

$$\text{Cov. HS} = \frac{(M_1 - M_3) + (M_2 - M_3)}{r\,(l + t)}$$

$$\text{Cov. FS} = \frac{(M_1 - M_4) + (M_2 - M_4) + (M_3 - M_4)}{3\,r} - \frac{r\,(l + t)\ \text{Cov. HS}}{3\,r}$$

Then, variance due to general combining ability σ^2 GCA and variance due to specific combining ability.

σ^2 GCA = Cov. HS

σ^2 SCA = Cov. FS-2 Cov. HS.

b) Estimation of GCA and SCA effects

The model used to estimate the *gca* and *sca* effects of ijk observations was,

$Xij = \mu + gi + gi + Sij + eijk$

where,

μ = Population mean

gi = *gca* effects of i^{th} line

gi = *gca* effects j^{th} tester

S_{ij} = *sca* effect of ij^{th} hybrid.

eijk = error associated with ijk^{th} observation

i = number of lines

j = number of testers

k = number of replications

The individual effects were estimated as indicted below.

i) $$gi = \frac{Xi..}{rt} - \frac{X...}{rlt}$$

ii) $$gj = \frac{X.j.}{rl} - \frac{X...}{rlt}$$

iii) $$Sij = \frac{X.i.j.}{r} - \frac{Xi...}{rt} - \frac{X.j.}{rl} + \frac{X...}{rlt}$$

where

X . . . = Total of all hybrid combinations

Xi .. = Total i^{th} line over 't' tester and 'r' replications

X.j. = Total of j^{th} tester over 'l' lines and 'r' replications.

Xij. = Total of the hybrid between i^{th} line and j^{th} tester over 'r' replications.

The standard error pertaining to *gca* effects of lines and testers and *sca* effects of different hybrids combinations were calculated as indicated below.

$$SE\ (g_i)\ lines = \sqrt{\frac{Ems}{rt}}$$

$$SE\ (g_i)\ \text{testers} = \sqrt{\frac{Ems}{rl}}$$

$$SE\ (S_{ij})\ \text{hybrids} = \sqrt{\frac{Ems}{r}}$$

3.6. 2. Estimation of Heterosis

The magnitude of heterosis was worked out based on

i) Mid parental value

$$di = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

ii) based on better and best parent value

$$dii = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

$$diii = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

where

$\overline{F_1}$ = Mean value of F_1 hybrid

$\overline{MP}$ = Mean of mid-parental value (the average value of two parents involved in each cross)

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

$\overline{BP}$ = Mean of best parent value

The significance was tested by 't' test formula suggested by wynne *et al.* (1970).

$$t = \frac{\overline{Fij} - \overline{MPij}}{\sqrt{3/8\ \sigma^2 e.}}$$

where

$\overline{Fij}$ = Mean of the ijth cross
$\overline{MPij}$ = Mid parental value of ijth cross
$\sigma^2 e$ = Estimate of the error variance

3.6.3. Correlation studies

Correlation co-efficients (r) of characters with yield components and intercorrelations among various components in F_1 and F_2 were calculated using the formula,

$$r = \frac{SP\ x\ Y}{(Sx^2.Sy^2)^{1/2}}$$

where,

x = Independent variable
Y = Dependent variable
SP x y = sum of products of X and Y
Sx^2 = Sum of squares of X
Sy^2 = Sum of squares of y

3.6.4. Path analysis

The path co-efficient analysis was brought out as adopted by Dewey and Lu (1959).

EXPERIMENTAL RESULTS

Chapter IV

EXPERIMENTAL RESULTS

Eleven parents consisted three lines and eight testers were crossed in a Line x tester fashion and the resultant twenty four F_1 hybrids were evaluated for combining ability and heterosis to have and effective selection of parents and hybrids and to understand their breeding value and to assess the relative magnitude of fixable (additive) and non-fixable gene action and to plan for useful breeding programme.

The experimental results on

1) Mean performance of parents and hybrids
2) Combining ability effects and gene action
3) Heterosis effects of hybrids
    a) Relative heterosis
    b) Heterobeltiosis and
    c) Best parent heterosis are presented below.

4.1. Analysis of variance

The variance due to genotypes for the thirteen characters studied are presented in Table 3.Analysis of variances showed highly significant differences among the genotypes for all the characters studied. Analysis of variance for the combining ability for the thirteen characters are presented in Table 4. The variance due to parents showed highly significant for twelve characters except number of branches per plant. The variance due to hybrids/crosses showed highly significant differences for twelve characters except the character plant spread.

Table 3. Analysis of variance for parents and hybrids

Source	Df	PH	BR	PS	DF1	DF	NF	IFW	FD	CI	FY	XC-1	XC-II
Total	104	65.23	24.31	30.24	21.60	20.72	63.98	1.25	0.97	3132.14	15856.0	0.31	0.25
Replication	2	95.64	62.82	12.70	2.85	4.64	22.55	0.84	0.11	366.43	27127.4	0.004	0.20
Genotypes	34	96.67*	38.85**	53.86**	60.54**	55.57**	151.38**	3.04**	2.60**	9179.69**	34055.9**	0.91*	0.69**
Error	68	8.62	2.61	2.94	2.68	3.77	7.49	0.37	0.18	189.71	930.52	0.02	0.04

** Significant at 1% level

Table 4. Analysis of variance for combining ability

Source	Df	PH	BR	PS	DF1	DF	NF	IFW	FD	CI	FY	XC-1	XC-II
Total	104	65.23	24.31	30.24	21.60	20.72	63.98	1.25	0.97	3132.14	15856.04	0.31	0.25
Replication	2	95.64	62.82	12.70	2.86	4.64	22.55	0.84	0.11	366.43	27127.44	0.005	0.20
Genotypes	34	96.67**	38.85**	53.86**	60.54**	55.57**	151.38**	3.04**	2.60**	9179.69**	34055.90**	0.91**	0.69*
Crosses	23	83.24*	47.51**	55.80	49.88**	53.49**	174.06**	2.00**	1.49**	9029.57**	15190.20**	0.93**	0.75*
Parents	10	126.51*	20.58	53.80**	31.10**	63.47**	85.96**	1.26**	3.38**	10267.4**	43166.15*	0.91**	0.61*
Parents vs Crosses	1	107.06	22.24	1025	1025	24.55*	284.04**	44.74**	20.46**	1755.07**	376864.35**	0.40**	0.15*
Lines	2	281.17**	209.20**	137.80	137.80	164.63*	93.43	2.40	0.13**	14663.5	85.76	3.87**	3.11*
Testers	7	83.33	24.27	50.49	50.49	44.76	333.61**	2.23	4.52	14437.7*	33679.71	1.12*	0.70*
Lines x Testers	14	54.92	36.03*	46.73	46.73	41.97**	105.80**	1.83**	0.16**	5520.68**	8103.22**	0.41**	0.44
Error	68	8.62	2..61	2.94	2.68	3.77	7.49	0.37	0.18	189.71	930.52	0.02	0.04

* Significant at 5% level
** Significant at 1% level

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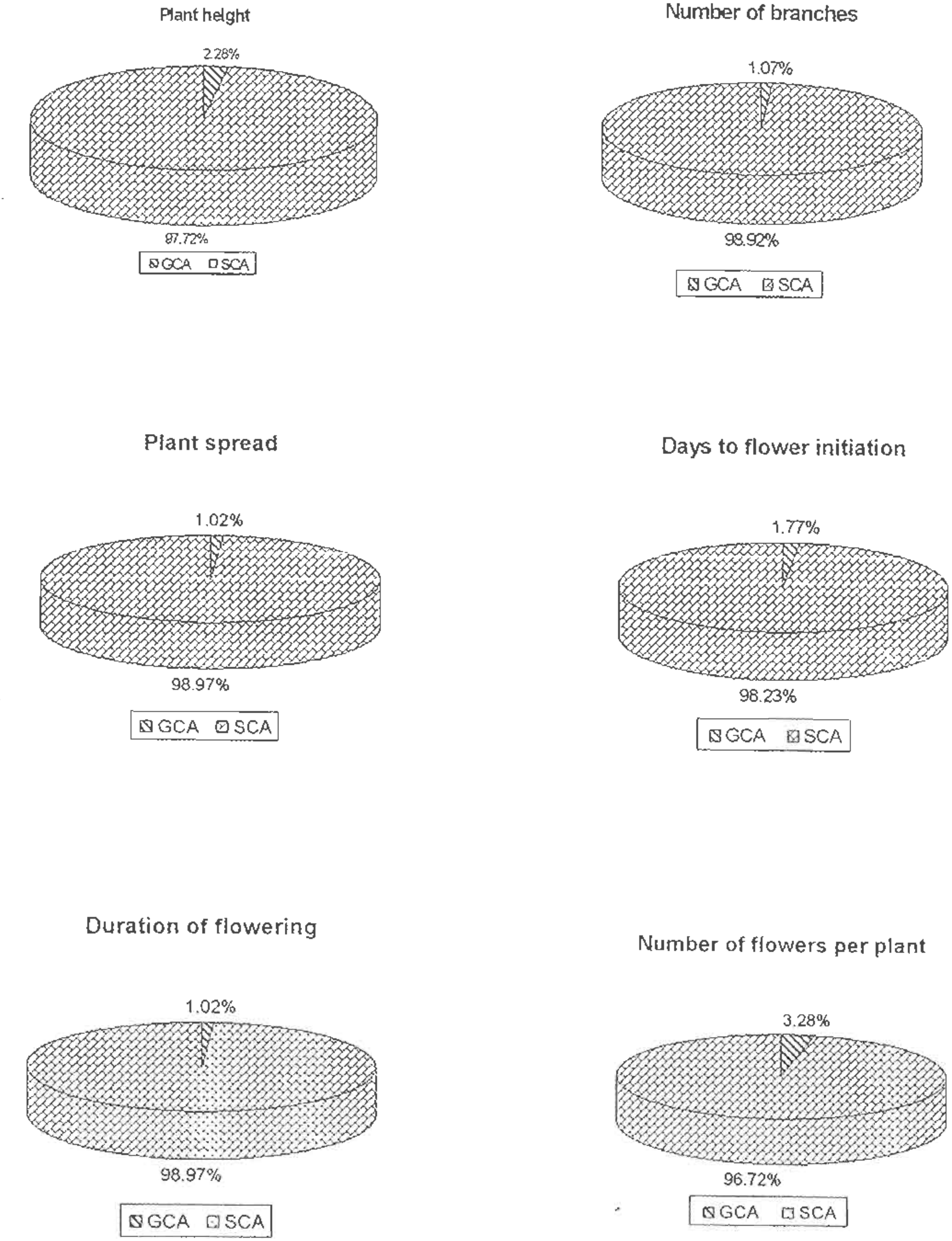
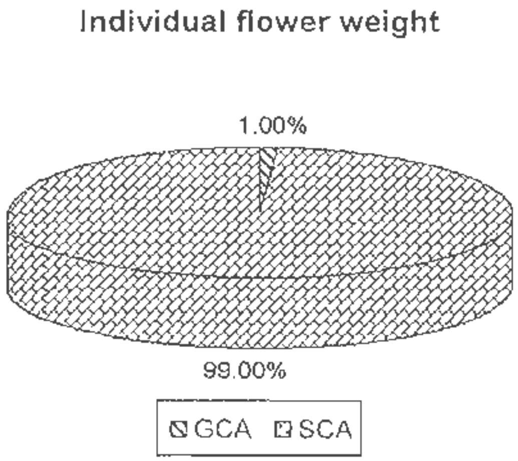
Table 5. Magnitude of combining ability variance

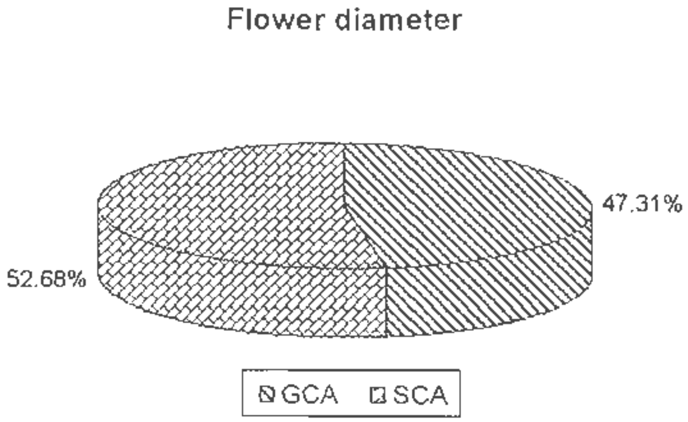
Sl.No.	Characters	σ^2 GCA	σ^2 SCA	GCA/SCA
1.	Plant height (cm)	0.6521	28.0066	0.0232
2.	Number of branches	0.2644	23.674	0.011
3.	Plant spread (cm)	0.2084	19.0292	0.0109
4.	Days to flower initiation	0.5982	33.2041	0.0180
5.	Duration of flowering	0.2651	25.7017	0.0103
6.	Number of flowers per plant	1.5715	46.2773	0.0339
7.	Individual flower weight (g)	0.0039	0.5794	0.0067
8.	Flower diameter (cm)	0.166	0.1491	0.1444
9.	Colour intensity	80.7852	3487.4248	0.0231
10.	Flower yield per plant (g)	571.11	5348.57	0.1067
11.	Xanthophyll content - Stage I (mg g^{-1})	0.0119	0.5488	0.2168
12.	Xanthophyll content - Stage II (mg g^{-1})	0.0072	0.4326	0.0166

Fig. 1. Magnitude of *gca* and *sca* variance

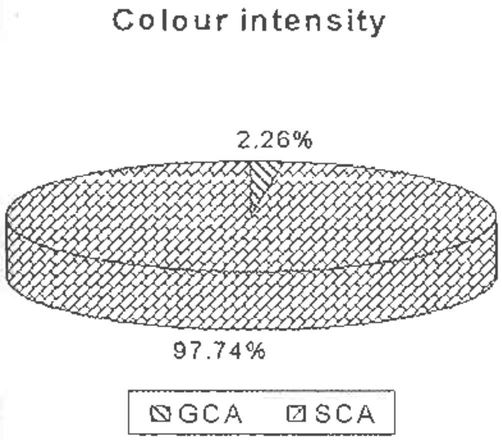




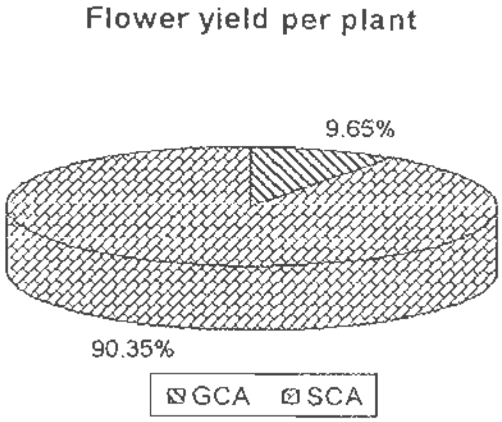
Individual flower weight



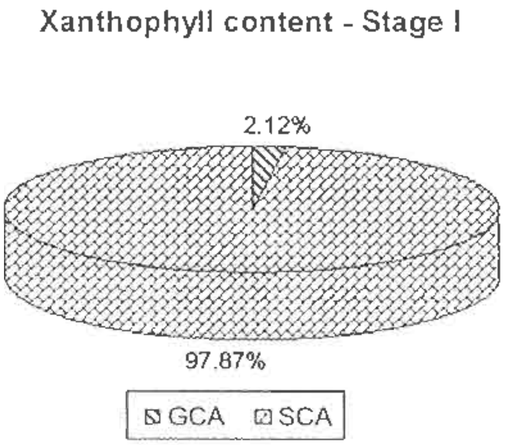
Flower diameter



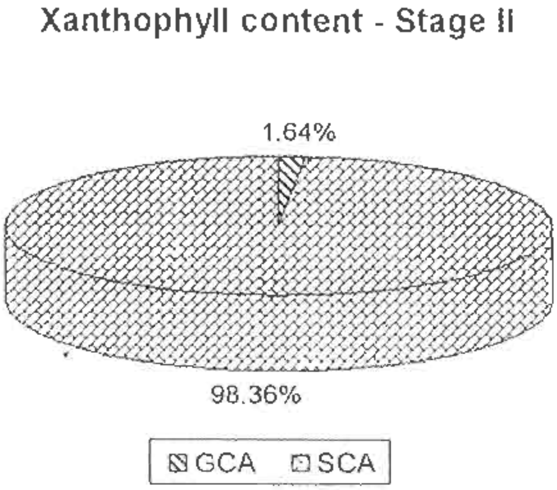
Colour intensity



Flower yield per plant



Xanthophyll content - Stage I



Xanthophyll content - Stage II

Table 5 depicts the variances due to general and specific combining ability effects, which showed that variances due to specific combining ability were predominant for all the thirteen characters studied. The ratio of variances due to general and specific combining ability were below 1.

The data on mean performance of the parents and hybrids, combining ability effects and the degree of mid parent heterosis, better parent and best parent heterosis are presented below.

4.2. Combining ability and heterosis studies

4.2.1. Plant height

The mean performance of lines ranged between 57.67 (L_3) and 66 cm (L_2) and the mean performance of testers ranged between 45.60 (T_5) and 65 cm (T_3). The over all mean of lines were 61.42 cm and the testers were 57.37 cm. The mean performance of hybrids ranged between 51.83 (L_1T_5) cm and 70.17 (L_2T_2) cm. The over all mean of hybrids were 63.40 cm. Seven hybrids exhibited higher values than the mean of hybrids and 17 registered lower values for plant height (Table 6).

The *gca* effects of lines varied from -1.2181 (L_1) to 3.8653 (L_2) and the *gca* effects of testers varied from -64806 (T_5) to 3.2972 (T_6), L_2 recorded positive significant *gca*, whereas L_1 and L_3 recorded negative *gca*. T_5 recorded negative significant *gca* effects. The testers T_1, T_2, T_3 and T_6 recorded significant positive *gca*. The *sca* effects of hybrids ranged from 5.093 (L_1T_3) to 5. 863 (L_1T_1). The hybrid L_1T_1 recorded highest positive (5.863) significant *gca* followed by L_3T_3 (5.836) and L_1T_6 (5.540). 8 hybrids recorded positive significant *gca* effects (Table 7).

Table 6. Mean performance of parents and hybrids for plant height

Lines/Testers	L_1	L_2	L_3	Testers
T_1	67.70	65.47	56.00	55.60
T_2	56.40	70.17	59.60	63.87
T_3	53.50	61.93	62.00	65.00
T_4	61.47	62.87	58.00	55.27
T_5	51.83	57.33	53.33	45.60
T_6	68.27	65.90	57.67	52.40
T_7	60.80	68.43	55.67	55.27
T_8	56.67	64.00	62.00	66.00
Lines	60.60	66.00	57.67	
Mean of Lines	61.42	SEd = 2.03	$CD_{(p=0.05)} = 4.06$	
Mean of Testers	57.37	SEd = 3.28	$CD_{(p=0.05)} = 6.55$	
Mean of Hybrids	63.40	SEd = 5.69	$CD_{(p=0.05)} = 11.36$	

Table 7. Estimates of combining ability effects for plant height

Lines/Testers	L_1	L_2	L_3	GCA of Testers
T_1	5.863**	-1.454	-4.454**	2.4083*
T_2	-4.349**	4.335**	0.014	2.3194*
T_3	5.093**	-0.743	5.836**	-2.8361**
T_4	1.774	-1.710	-0.064	0.0639
T_5	-1.115	-0.699	1.814*	-6.4806**
T_6	5.540**	-1.910	-3.631**	3.2972**
T_7	0.385	2.935**	-3.319**	0.9861
T_8	-3.004**	-0.754	3.758**	0.2417
GCA of Lines	-1.2181*	3.8653**	-2.6472**	
SE of Lines	0.5993			
SE of Testers	0.9785			
SE of Hybrids	1.6951			

* Significant at 5% level
** Significant at 1% level

Table 8. Estimates of heterosis effects of hybrids for plant height

Hybrids	Relative Heterosis (%) di	heterobeltiosis (%) dii	Best Parent Heterosis (%) diii
L_1T_1	11.72	16.52*	2.58
L_1T_2	-11.92	-9.37	-14.55*
L_1T_3	-19.23**	-16.40*	-20.46**
L_1T_4	1.10	5.75	-7.17
L_1T_5	-14.47**	-2.39	-21.47**
L_1T_6	12.65	20.83**	3.43
L_1T_7	0.33	4.95	-7.88
L_1T_8	-14.14*	-10.48	-14.14**
L_2T_1	-0.81	7.66	-0.81
L_2T_2	6.31	-5.45	6.31
L_2T_3	-6.12	8.06	-6.16
L_2T_4	-4.75	3.68	-4.75
L_2T_5	-13.13*	2.75	-13.13
L_2T_6	-0.15	11.32	-0.15
L_2T_7	3.69	12.86	3.69
L_2T_8	-3.03	-3.03	-3.03
L_3T_1	-2.78	-1.06	-15.15*
L_3T_2	-7.09	-2.31	-10.10
L_3T_3	-4.62	1.14	-6.06
L_3T_4	0.69	2.78	-12.12
L_3T_5	-7.47	3.36	-19.19*
L_3T_6	0.12	4.85	-12.62
L_3T_7	-3.36	-1.36	-15.66
L_3T_8	-6.06	0.32	-6.06

* Significant at 5% level
** Significant at 1% level

Among the 24 crosses four hybrids registered for negative significant heterosis with regard to relative heterosis at maximum of -19.23 per cent. Five hybrids registered non significant positive heterosis. Two hybrids registered significant positive heterosis *viz*., L_1T_1 (16.52 per cent) and L_1T_6 (20.83 per cent) with regard to heterobeltiosis. Six hybrids registered significant negative heterosis ranged between -21.47 (L_1T_5) and -14.55 (L_1T_2) per cent with respect to standard heterosis. Four hybrids registered for non-significant standard heterosis which ranged between 2.58 (L_1T_1) and 6.31 (L_2T_2) per cent (Table 8).

4.2.2. Number of branches

The mean performance of lines ranged between 14.33 (L_3) and 20.33 (L_2) and the testers ranged between 12.00 (T_2 and T_5) and 18.00 (T_3) and the over all mean of testeres were 15.72. Five testers were registered higher values than the overall mean of testers. The hybrids ranged between 12.00 (L_3T_3 and L_3T_4) and 27.20 (L_2T_3) for number of branches. The overall mean of hybrids were 18.40. A total number of 6 hybrids registered higher values than the over all mean of hybrids (Table 9).

The *gca* effects of lines varied from -3.2111 (L_3) to 2.5972 (L_2) both of which were registered highly significant values. The *gca* effects of testers were ranged between -2.3833 (T_1) and 1.9500 (T_7). The testers T_3, T_4, T_5 and T_7 recorded positive significant *gca* effects. The *sca* effects of hybrids were ranged between -3.7250 (L_1T_3) and 6.5583 (L_2T_3) six hybrid *viz*. L_1T_4, L_1T_6, L_2T_2, L_2T_3, L_3T_1 and L_3T_8 registered for significant *sca* values (Table 10).

Among the 24 hybrids two hybrids registered for positive significant relative heterosis of 55.02 (L_1T_4) per cent and 33.7 (L_2T_3) per cent the hybrids L_3T_3 (-33.33)

Table 9. Mean performance of parents and hybrids for Number of branches per plant

Lines/Testers	L_1	L_2	L_3	Testers
T_1	12.60	16.47	14.67	17.87
T_2	17.07	22.93	13.67	12.00
T_3	14.93	27.20	12.00	18.00
T_4	23.67	12.90	12.00	14.53
T_5	16.53	17.40	12.67	12.00
T_6	21.47	17.20	13.33	16.40
T_7	20.00	20.40	16.33	17.93
T_8	14.33	15.67	15.33	17.00
Lines	15.27	20.33	14.33	
Mean of Lines	16.64	SEd = 1.152	$CD_{(p=0.05)}$ = 2.297	
Mean of Testers	15.72	SEd = 1.86	$CD_{(p=0.05)}$ = 3.752	
Mean of Hybrids	18.40	SEd = 3.25	$CD_{(p=0.05)}$ = 6.498	

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Table 10. Estimates of combining ability effects for Number of branches per plant

Lines/Testers	L_1	L_2	L_3	GCA of Testers
T_1	-2.5917**	-0.7083	3.3000**	-2.3833**
T_2	-1.4361	2.4472**	-1.0111	0.9278
T_3	-3.7250**	6.5583**	-2.8333**	1.0833*
T_4	4.7639**	-1.6861	-3.0778**	1.3278*
T_5	0.3861	-0.7306	0.3444	1.4278**
T_6	3.5194**	-2.7306**	-0.7889	0.3722
T_7	0.4750	-1.1083	0.6333	1.9500**
T_8	-1.3917	-2.0417*	3.4333**	-1.8500**
GCA of Lines	0.6139	2.5972**	-3.2111**	
SE of Lines	0.3300			
SE of Testers	0.5389			
SE of Hybrids	0.9333			

* Significant at 5% level
** Significant at 1% level

Table 11. Estimates of heterosis effects of hybrids for Number of branches

Hybrids	Relative Heterosis (%) di	heterobeltiosis (%) dii	Best Parent Heterosis (%) diii
L_1T_1	-29.48*	-23.94	-31.77*
L_1T_2	11.790	25.183	-5.185
L_1T_3	-17.04	-10.22	-17.03
L_1T_4	55.02**	58.84**	31.48*
L_1T_5	8.30	21.271	-8.148
L_1T_6	30.89	35.58	19.259
L_1T_7	11.52	20.48	11.11
L_1T_8	-15.69	-11.16	-20.371
L_2T_1	-19.016	-13.787	-8.519
L_2T_2	12.787	41.85**	27.41*
L_2T_3	33.70**	41.91**	51.11**
L_2T_4	-5.574	10.13	6.67
L_2T_5	-1.426	7.629	-3.333
L_2T_6	-15.41	-6.35	-4.446
L_2T_7	0.328	6.620	13.33
L_2T_8	-22.951	-16.071	-12.963
L_3T_1	-22.951	-8.90	-18.519
L_3T_2	-4.651	3.797	-24.074
L_3T_3	-33.33*	-25.77	-33.33*
L_3T_4	-17.43	-16.86	-33.33*
L_3T_5	-11.628	-3.797	-29.63*
L_3T_6	-18.70	-13.23	-25.93
L_3T_7	-8.92	1.24	-9.26
L_3T_8	-9.80	-2.13	-14.82

* Significant at 5% level

** Significant at 1% level

and L_1T_1 (-29.48) registered significant negative relative heterosis. The mid parental heterosis ranged from -25.77 (L_3T_3) to 58.84 (L_1T_4) per cent relative heterosis. 3 hybrids registered positive significant heterosis which ranged between 41.85 (L_2T_2) and 58.84 (L_1T_4) per cent for heterobeltiosis. The hybrids L_2T_2 (27.41 per cent) and L_2T_3 (51.11 per cent) and L_1T_4 (31.48 per cent) registered significant positive heterosis over the best parent (Table 11).

4.2.3. Plant spread

The mean performance of lines ranged between 44.94 cm. (L_2) and 51.67 (L_3) cm and all mean of lines were 48.1 cm. L_3 registered higher mean value than the over all mean of lines. The mean performance of testers were ranged between 39.47 (T_1) cm and 54.07 (T_4) cm. The over all mean of testers were 44.75 cm and three testes registered higher value than the over all mean of testers. The mean performance of hybrids were ranged from 40.67 (L_3T_3 and L_2T_8) cm to 56.77 (L_2T_3) cm. The over all mean of hybrids were 46.27 cm and ten hybrids registered higher value than the over all mean of hybrids (Table 12).

The *gca* effects of lines ranged between -2.577 (L_3) and 0.418 (L_1) and L_2 recorded significant positive *gca* effects. The *gca* effects of testers were ranged between -2.386 (T_7) and 4.325 (T_4). Among the testers T_3 and T_4 registered positive significant *gca* effects. The *sca* effects of hybrids were ranged between -5.604 (L_2T_8) and 6.218 (L_2T_3). Among the hybrids, L_2T_3 (6.218) registered for positive significant *sca* and L_2T_8 (-5.604) registered for negative significant *sca* effect. Seven hybrids registered positive significant *sca* effects (Table 13).

Table 12. Mean performance of parents and hybrids for plant spread (cm)

Lines/Testers	L_1	L_2	L_3	Testers
T_1	47.67	47.67	43.00	39.47
T_2	44.37	51.20	41.67	42.47
T_3	47.73	56.77	40.67	42.87
T_4	48.83	53.00	50.00	54.07
T_5	48.30	52.43	41.00	43.33
T_6	44.07	42.47	46.00	47.23
T_7	44.00	43.00	44.33	46.23
T_8	48.67	40.67	43.00	42.33
Lines	47.70	44.93	51.67	
Mean of Lines	48.10	SEd = 1.257	$CD_{(p=0.05)} = 2.51$	
Mean of Testers	44.75	SEd = 2.049	$CD_{(p=0.05)} = 4.09$	
Mean of Hybrids	46.27	SEd = 3.55	$CD_{(p=0.05)} = 7.09$	

Table 13. Estimates of combining ability effects for plant spread

Lines/Testers	**L_1**	**L_2**	**L_3**	**GCA of Testers**
T_1	1.138	-0.604	-0.533	-0.175
T_2	-1.796	3.926**	-1.500	-0.541
T_3	-1.074	6.218**	-5.144**	2.102**
T_4	-2.196*	0.229	1.967*	4.325**
T_5	0.638	3.029**	-3.667**	0.958
T_6	-0.529	-3.871**	4.400**	-2.108**
T_7	-0.318	-2.693**	3.011**	-2.386**
T_8	4.138**	-5.604**	1.467	-2.175**
GCA of Lines	0.418	2.1597**	-2.577**	
SE of Lines	0.3503			
SE of Testers	0.5720			
SE of Hybrids	0.9907			

* Significant at 5% level
** Significant at 1% level

Table 14. Estimates of heterosis effects of hybrids for Plant spread

Hybrids	Relative Heterosis (%) di	heterobeltiosis (%) dii	Best Parent Heterosis (%) diii
L_1T_1	-0.07	9.37	-11.81
L_1T_2	-6.99	-1.59	-17.94**
L_1T_3	0.07	5.41	-11.71*
L_1T_4	-9.68	-4.03	-9.68
L_1T_5	1.26	6.11	-10.67*
L_1T_6	-7.62	-7.16	-16.50**
L_1T_7	-7.76	-6.32	-18.62**
L_1T_8	2.03	8.11	-9.99
L_2T_1	5.77	12.78*	-11.84
L_2T_2	13.61**	16.98**	-5.30
L_2T_3	25.96**	29.11**	4.99
L_2T_4	-1.97	6.93	-1.97
L_2T_5	16.35**	18.63**	-3.02
L_2T_6	-10.09	-7.98	-21.46**
L_2T_7	-6.20	-5.00	-19.79**
L_2T_8	-9.76	-6.94	-24.78**
L_3T_1	-15.69**	-4.94	-20.47**
L_3T_2	-18.30**	-10.84	-22.94**
L_3T_3	-20.26**	-13.35*	-24.78**
L_3T_4	-7.52	-4.82	-7.52
L_3T_5	-19.61**	-13.07*	-24.17**
L_3T_6	-9.80	-6.35	-14.92**
L_3T_7	-13.07*	-8.81	-18.008**
L_3T_8	-15.69**	-7.85	-20.47**

* Significant at 5% level
** Significant at 1% level

Among the 24 hybrids, three were registered positive significant relative heterosis which ranged between 13.61 (L_2T_2) per cent and 25.96 (L_2T_3) per cent. Six hybrids were registered for significant negative relative heterosis which ranged between -20.26 (L_3T_3) per cent and -13.07 (L_3T_7) per cent. Four hybrids registered significant positive heterobeltiosis and two hybrids registered significant negative heterobeltiosis which ranged between -13.35 (L_3T_3) and 29.11 (L_2T_3) per cent heterobeltiosis. None of the hybrids registered significant positive standard heterosis and 15 hybrids registered significant negative standard heterosis (Table 14).

4.2.4. Days to flower initiation

The mean performance of lines were ranged between 55.33 (L_1) days and 61.67 (L_2) days. Two lines registered higher values than the over all mean (59.33 days) of the lines. The mean performance of testers ranged between 58 (T_7) days and 68.67 (T_5) days. Among the testers four registered higher values than the over all mean (61.83 days) of testers. The mean performance of hybrids ranged between 50.33 (L_3T_2) days and 62.67 (L_1T_4) days and 11 hybrids registered higher values than the over all men (55.95) of hybrids (Table 15).

The *gca* effects of lines ranged between -3.6528 (L_3) and 2.7639 (L_1) and L_2 registered positive significant *gca* and L_3 registered negative significant *gca* effects. The *gca* effects of testers were ranged between -3.0417 (T_8) and 3.4028 (T_4). Three testers registered positive significant *gca* effects and three testers registered for negative significant *gca* effects.

The *sca* effects of hybrids ranged between -4.2083 (L_1T_8) and 5.8750 (L_3T_8). Among the hybrids 3 were registered for positive significant *sca* and 3 for negative significant *sca* effects (Table 16).

Table 15. Mean performance of parents and hybrids for Days to flower initiation

Lines/ Testers	L_1	L_2	L_3	Testers
T_1	61.00	59.00	52.00	58.67
T_2	60.33	60.00	50.33	63.33
T_3	58.67	61.00	53.33	62.67
T_4	62.67	60.33	55.67	62.00
T_5	58.33	58.00	50.67	68.67
T_6	60.00	51.67	51.33	62.33
T_7	58.67	54.00	51.33	58.00
T_8	51.67	52.33	50.67	59.00
Lines	55.33	61.67	61.00	
Mean of Lines	59.33	SEd = 0.472	$CD_{(p=0.05)} = 0.943$	
Mean of Testers	61.83	SEd = 0.77	$CD_{(p=0.05)} = 1.54$	
Mean of Hybrids	55.95	SEd = 1.33	$CD_{(p=0.05)} = 2.66$	

Table 16. Estimates of combining ability effects for Days to flower initiation

Lines/Testers	L_1	L_2	L_3	GCA of Testers
T_1	0.9027	0.7777	-1.6805	1.1806*
T_2	0.6805	2.2222*	-2.9027**	0.7361
T_3	-1.9861*	2.2222*	0.2361	1.7361**
T_4	0.3472	-0.1111	-0.2361	3.4028**
T_5	-0.0972	1.4444	-1.3472	-0.4861
T_6	2.9027**	-3.5555**	0.6527	-1.8194**
T_7	1.4583	-1.3333	-0.1250	-1.7083**
T_8	-4.2083**	-1.6666	5.8750**	-3.0417**
GCA of Lines	2.7639**	0.8889**	-3.6528**	
SE of Lines	0.3342			
SE of Testers	0.5458			
SE of Hybrids	0.9453			

* Significant at 5% level
** Significant at 1% level

Table 17. Estimates of heterosis effects of hybrids for Days to flower initiation

Hybrids	Relative Heterosis (%) di	heterobeltiosis (%) dii	Best Parent Heterosis (%) diii
L_1T_1	-3.68*	-2.4	-11.17**
L_1T_2	-3.72*	-2.95	-12.14**
L_1T_3	-5.38**	-5.12**	-14.56**
L_1T_4	-8.74**	-3.84*	-8.74**
L_1T_5	-6.42**	-5.91**	-15.04**
L_1T_6	-2.70	0.28	-12.62**
L_1T_7	-4.87**	-2.76	-14.56**
L_1T_8	-16.22**	-12.92	-24.76**
L_2T_1	-6.84**	-5.09**	-14.08**
L_2T_2	-4.26**	-2.97	-12.62**
L_2T_3	-1.61	-0.81	-11.17**
L_2T_4	-12.14**	-6.94**	-12.14**
L_2T_5	-6.95**	-5.95**	-15.53**
L_2T_6	-15.30**	-13.17**	-24.76**
L_2T_7	-11.48**	-10.00**	-21.36**
L_2T_8	-14.21**	-11.30**	-23.79**
L_3T_1	-17.90**	-14.75**	-24.27**
L_3T_2	-19.68**	-17.03**	-26.70**
L_3T_3	-12.90**	-10.50**	-21.36**
L_3T_4	-18.93**	-12.57**	-18.93**
L_3T_5	-18.72**	-16.25**	-26.21**
L_3T_6	-12.50**	-12.00**	-25.24**
L_3T_7	-14.12**	-13.88**	-26.21**
L_3T_8	-5.68**	-4.32	-19.41**

* Significant at 5% level
** Significant at 1% level

Among the 24 crosses, 12 crosses registered negative significant relative heterosis which ranged between -19.68 (L_3T_2) and -3.68 (L_1T_1) per cent. 17 hybrids registered negative significant heterobeltiosis which ranged between -17.03 (L_3T_2) and -3.84 (L_1T_4) per cent. All the hybrids registered significant negative standard heterosis which ranged between -26.70 (L_3T_2) and -8.74 (L_1T_4) (Table 17).

4.2.5. Duration of flowering

The mean performance of lines ranged between 40.33 (L_1) days and 57.33 (L_2) days. The over all mean of lines were 48.22 days. L_2 registered higher mean value than the over all mean of lines. The mean performance of testers ranged between 47.33 (T_8) days and 58.67 (T_1) days. Two testers recorded higher than the over all mean (50.83) days. The mean performance of hybrids ranged between 40.67 (L_3T_8) days and 57.00 (L_2T_1) days. 11 hybrids recorded higher mean values than the over all mean (48.41) of the hybrids (Table 18).

The *gca* effects of lines ranged between -2.8750 (L_3) and 2.2500 (L_2). The Line L_2 registered positive significant *gca* and L_3 recorded negative significant *gca* effect. The *gca* effects of testers ranged between -2.6250 (T_8) and 2.4891 (T_1). Among the testers 4 registered significant positive *gca* effects and 4 registered negative significant *gca* effects. The *sca* effects of hybrids ranged between -4.5833 (L_2T_3) and 4.7500 (L_2T_6). 6 hybrids registered positive significant *sca* effects and 5 hybrids registered negative significant *sca* effects (Table 19).

Among the 24 hybrids, three hybrids recorded positive significant relative heterosis and 13 hybrids recorded negative significant relative heterosis. The relative heterosis ranged between -20.43 (L_3T_1) per cent and 7.95 (L_1T_3) per cent of relative

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Table 18. Mean performance of parents and hybrids for duration of flowering

Lines/Testers	L_1	L_2	L_3	Testers
T_1	52.00	57.00	49.33	58.67
T_2	50.00	53.33	53.67	52.67
T_3	54.33	50.00	52.67	50.00
T_4	52.67	52.67	50.33	51.00
T_5	46.67	49.33	49.33	48.00
T_6	49.33	56.00	41.67	51.00
T_7	53.00	49.00	41.67	48.00
T_8	49.33	53.00	40.67	47.33
Lines	40.33	57.33	47.00	
Mean of Lines	48.22	SEd = 0.559	$CD_{(p=0.05)} = 1.117$	
Mean of Testers	50.83	SEd = 0.914	$CD_{(p=0.05)} = 1.825$	
Mean of Hybrids	48.41	SEd = 1.583	$CD_{(p=0.05)} = 3.16$	

Table 19. Estimates of combining ability effects for duration of flowering

Lines/Testers	L_1	L_2	L_3	GCA of Testers
T_1	-1.4027	1.9722	-0.5694	2.4891**
T_2	-2.9583*	1.2500	4.2083**	2.0417**
T_3	1.3750	-4.5833**	3.2083**	2.0417**
T_4	0.1527	-1.4722	1.3194	1.5972*
T_5	-2.4027	-1.3611	3.7638**	-1.8472*
T_6	0.2916	4.7500**	-4.4583**	-1.2917*
T_7	4.4861**	-1.1388	-3.3472**	-2.4028**
T_8	1.0416	3.0833**	-4.1250**	-2.6250**
GCA of Lines	0.6250	2.2500**	-2.8750**	
SE of Lines	0.3961			
SE of Testers	0.6468			
SE of Hybrids	1.1203			

* Significant at 5% level
** Significant at 1% level

Table 20. Estimates of heterosis effects of hybrids for Duration of flowering

Hybrids	Relative Heterosis (%) di	heterobeltiosis (%) dii	Best Parent Heterosis (%) diii
L_1T_1	-16.13**	-7.42**	-16.13**
L_1T_2	-5.06	-2.91	-19.36**
L_1T_3	7.95**	8.31**	-12.37**
L_1T_4	3.27	3.94	-15.05**
L_1T_5	-7.29**	-5.98*	-24.73**
L_1T_6	-3.27	-2.63	-20.43**
L_1T_7	5.30*	7.80**	-14.52**
L_1T_8	-1.99	1.02	-20.43**
L_2T_1	-8.07**	-4.47*	-8.07**
L_2T_2	-6.98**	-3.03	-13.98**
L_2T_3	-12.79**	-6.83**	-19.36**
L_2T_4	-8.14**	-2.77	-15.05**
L_2T_5	-13.95**	-6.33**	-20.43**
L_2T_6	-2.33	3.39	-9.68**
L_2T_7	-14.54**	-6.96**	-20.97**
L_2T_8	-7.56**	1.27	-14.52**
L_3T_1	-20.43**	-9.48**	-20.43**
L_3T_2	1.90	7.69**	-13.44**
L_3T_3	5.33*	8.59**	-15.05**
L_3T_4	-1.31	2.72	-18.82**
L_3T_5	2.78	3.86	-20.43**
L_3T_6	-18.30**	-14.97**	-32.79**
L_3T_7	-13.19**	-12.28**	-32.79**
L_3T_8	-14.09**	-13.78**	-32.41**

* Significant at 5% level

** Significant at 1% level

heterosis. Four hybrids recorded positive significant heterosis for heterobeltiosis which ranged between 7.69 (L_3T_2) per cent and 8.59 (L_3T_3) per cent. All the 24 hybrids recorded negative significant standard heterosis which ranged between -32.79 (L_3T_7) per cent and -8.07 (L_2T_1) per cent (Table 20).

4.2.6. Number of flowers per plant

The mean performance of lines ranged between 50.00 and 53.33 and the over all mean of lines were 51.11. The mean performance of testers ranged between 35.00 (T2) and 50.00 (T1 and T3) and the over all mean of testers were 45.20. Among the testers T1 (50.00) and T3 (50.00) registered higher values than the over all mean of the testers. The mean performance of hybrids ranged between 34.00 (L_1T_7) and 65.00 (L_1 T_3) and the overall mean of hybrids registered 50.36. 13 hybrids recorded higher values than the over all mean of hybrids and 11 crosses recorded lower values than the overall mean of hybrids (Table 21).

The *gca* effects of lines ranged between -2.1528 (L_2) and 1.722 (L_1). The *gca* effects of testers ranged between -9.6944 (T_7) and 8.9722 (T_3). Four testers *viz.*, T_1 93.3056) T_3 (8.9722), T_6 (2.3056) and T_8 (3.8611) registered positive significant *gca* effects. The *sca* effects of hybrids ranged between -8.389 (L_1T_7) and 10.903 (L_3T_7). 7 hybrids registered positive significant *sca* effects (Table 22).

Among the 24 crosses, positive significant heterosis was recorded for 5 hybrids which ranged between 16.00 (L_1T_1, L_3T_1, L_3T_3) per cent and 30.00 (L_1 T_3) per cent towards relative heterosis. Positive significant heterobeltiosis was recorded in 6 crosses which ranged between 14.78 (L_1T_8) per cent and 30.00 (L_1T_3) per cent. Six hybrids recorded positive significant standard heterosis which ranged between 11.33 (L_1T_8) per cent and 30.00 (L_1T_3) per cent (Table 23).

Table 21. Mean performance of parents and hybrids for Number of flowers per plant

Lines/Testers	L_1	L_2	L_3	Testers
T_1	58.00	45.00	58.00	50.00
T_2	47.00	45.00	43.00	35.00
T_3	65.00	55.00	58.00	50.00
T_4	59.00	46.00	50.33	47.00
T_5	47.00	51.00	38.67	39.67
T_6	51.00	52.00	55.00	49.00
T_7	34.00	36.00	52.00	44.00
T_8	55.67	55.67	51.33	47.00
Lines	50.00	53.33	50.00	-
Mean of Lines	51.11	SEd = 1.338	$CD_{(p=0.05)} = 2.67$	
Mean of Testers	45.20	SEd = 2.184	$CD_{(p=0.05)} = 4.36$	
Mean of Hybrids	50.36	SEd = 3.783	$CD_{(p=0.05)} = 7.55$	

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Table 22. Estimates of combining ability effects for number of flowers per plant

Lines/Testers	**L_1**	**L_2**	**L_3**	**GCA of Testers**
T_1	2.611*	-6.514**	3.903*	3.3056**
T_2	0.278	2.153	-2.451	-5.3611**
T_3	3.944*	-2.181	-1.764	8.9722**
T_4	5.500**	-3.625*	-1.875	1.4167
T_5	-0.278	7.597**	-7.319**	-4.8056**
T_6	-3.389*	1.486	1.903	2.3056*
T_7	-8.389**	-2.514	10.903**	-9.6944**
T_8	-0.278	3.597*	-3.319*	3.8611**
GCA of Lines	1.7222**	-2.1528**	0.4302	
SE of Lines	0.5588			
SE of Testers	0.9125			
SE of Hybrids	1.5800			

* Significant at 5% level
** Significant at 1% level

Table 23. Estimates of heterosis effects of hybrids for Number of flowers per plant

Hybrids	Relative Heterosis (%) di	heterobeltiosis (%) dii	Best Parent Heterosis (%) diii
L_1T_1	16.00**	16.00**	16.00**
L_1T_2	-6.00	10.59	-6.00
L_1T_3	30.00**	30.00**	30.00**
L_1T_4	18.00**	21.65**	18.00**
L_1T_5	-6.00	4.83	-6.00
L_1T_6	2.00	3.03	2.00
L_1T_7	-32.00**	-27.66**	-32.00**
L_1T_8	11.33	14.78**	11.33**
L_2T_1	-15.63**	-12.90*	-10.00
L_2T_2	-15.63**	1.89	-10.00
L_2T_3	3.13	6.45	10.00
L_2T_4	-13.75**	-8.31	-8.00
L_2T_5	-4.36	9.68	2.00
L_2T_6	-2.50	1.63	4.00
L_2T_7	-32.50**	-26.02**	-28.00**
L_2T_8	4.38	10.93	11.33
L_3T_1	16.00**	16.00**	16.00**
L_3T_2	-14.00*	1.18	-14.00
L_3T_3	16.00**	16.00**	16.00**
L_3T_4	0.67	3.78	0.67
L_3T_5	-22.67**	-13.76*	-22.67**
L_3T_6	10.00	11.11	10.00
L_3T_7	4.00	10.64	4.00
L_3T_8	2.67	5.84	2.67

* Significant at 5% level
** Significant at 1% level

4.2.7. Individual flower weight

The mean performance of lines ranged between 6.8 (L_1) and 7.2 (L_2) g and the overall mean of testers recorded to 7.0 g. The mean performance of testers ranged between 5.33 (T_6) g and 7.03 (T_1) g. Four testers registered higher values than the overall mean (6.37 g) of testers. The mean performance of hybrids ranged between 6.50 (L_3 T_8) g and 9.13 (L_1 T_8) g and the overall mean of the hybrids were 7.94 g. Eleven hybrids recorded higher values than the overall mean of hybrids (Table 24).

The *gca* effects of lines varied from –0.2944 (L_3) to 0.3347 (L_2). One parent registered positive significant *gca* effect. The *gca* effects of testers were ranged between –0.5931 (T_7) and 0.9958 (T_4). One parent (T_4) registered positive significant *gca* effect and two parents registered negative significant *gca* effects. Five tester parents recorded non significant *gca* effects.

The *sca* effects of hybrids ranged between –1.4388 (L_3 T_8) and 0.9402 (L_1T_8). Among the crosses, three hybrids recorded positive significant *sca* effects and four hybrids registered negative significant *sca* effects (Table 25)

Among the 24 crosses, 13 crosses observed for positive significant relative heterosis which ranged between 13.33 (L_3T_2) per cent and 30.48 (L_1T_8) per cent. Nineteen crosses were recorded for positive significant heterosis towards heterobeltiosis which ranged between 11.79 (L_3T_7) per cent and 36.57 (L_2T_3) per cent. Thirteen hybrids registered positive significant standard heterosis which ranged between 12.80 (L_3T_2) per cent and 29.89 (L_1T_8) per cent(Table 26)

Table 24. Mean performance of parents and hybrids for individual flower weight (g)

Lines/Testers	L_1	L_2	L_3	Testers
T_1	8.37	7.67	8.43	7.03
T_2	6.93	8.70	7.93	6.9
T_3	7.03	8.90	7.47	6.03
T_4	8.87	9.00	8.97	7.00
T_5	7.40	8.20	7.57	5.67
T_6	7.43	8.03	7.10	5.33
T_7	8.10	6.70	7.27	6.00
T_8	9.13	9.07	6.50	7.00
Lines	6.8	7.2	7.00	
Mean of Lines	7.00	SEd = 0.176	$CD_{(p=0.05)} = 0.3518$	
Mean of Testers	6.37	SEd = 0.287	$CD_{(p=0.05)} = 0.5745$	
Mean of Hybrids	7.94	SEd = 0.498	$CD_{(p=0.05)} = 0.9951$	

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Table 25. Estimates of combining ability effects for individual flower weight

Lines/Testers	L_1	L_2	L_3	GCA of Testers
T_1	0.2513	-0.8236*	0.5722	0.2069
T_2	-0.8819*	0.5097	0.3722	-0.0931
T_3	-0.7263*	0.7652*	0.0388	-0.1486
T_4	-0.0375	-0.2791	0.3166	0.9958**
T_5	-0.2819	0.1430	0.1388	-0.2264
T_6	0.0486	0.1763	-0.1277	-0.4264*
T_7	0.7847*	-0.9902**	0.2055	-0.5931**
T_8	0.9402**	0.4986	-1.4388	0.2847
GCA of Lines	-0.0403	0.3347*	-0.2944*	
SE of Lines	0.1247			
SE of Testers	0.2036			
SE of Hybrids	0.3526			

* Significant at 5% level

** Significant at 1% level

Table 26. Estimates of heterosis effects of hybrids for Individual flower weight

Hybrids	Relative Heterosis (%) di	heterobeltiosis (%) dii	Best Parent Heterosis (%) diii
L_1T_1	18.96**	19.24**	18.96**
L_1T_2	-0.95	-0.24	-1.42
L_1T_3	0.48	7.93	0.00
L_1T_4	26.67**	26.67**	26.06**
L_1T_5	5.71	16.84**	5.21
L_1T_6	6.19	20.54**	5.69
L_1T_7	15.71**	24.62**	15.17**
L_1T_8	30.48**	30.48**	29.89**
L_2T_1	9.01	9.26	9.01
L_2T_2	24.29**	25.18**	23.70**
L_2T_3	27.14**	36.57**	26.54**
L_2T_4	28.57**	28.57**	27.96*
L_2T_5	17.54**	29.47**	16.59**
L_2T_6	14.76**	30.27**	14.22**
L_2T_7	-4.29	3.08	-4.74
L_2T_8	29.52**	29.52**	28.91**
L_3T_1	19.91**	20.19**	19.90**
L_3T_2	13.33*	14.15*	12.80**
L_3T_3	6.67	14.58*	6.16
L_3T_4	28.10**	28.09**	27.49**
L_3T_5	8.10	19.47**	7.58
L_3T_6	1.43	15.14*	0.95
L_3T_7	3.81	11.79*	3.32
L_3T_8	-7.14	-7.14	-7.58

* Significant at 5% level
** Significant at 1% level

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4.2.8 Flower diameter

The mean performance of lines ranged between 6.2 (L_3) cm and 8.2 (L_2) cm. and the overall mean was 7.2 cm. The parent L_2 was higher than the overall mean of the lines. The performance of testers ranged between 4.4 (T_4) cm and 6.2 (T_3, T_5 and T_8) cm and the overall mean of the testers were 5.59 cm. Five tester parents recorded higher values than the overall mean of the testers. The mean performance of hybrids ranged between 6.0 (L_3T_2, L_1T_4, L_1T_8 and L_3T_8) cm and 8.5 (L_2T_3) cm and the overall mean of the hybrids were 6.87 cm. Ten hybrids recorded higher values than the overall mean of the hybrids (Table 27).

The *gca* effects of lines were ranged between –0.4278 (L_3) and 0.6931 (L_2). One female parent registered positive significant *gca* effect and two female parents were registered to negative significant *gca* effects. The *gca* effects of testers were ranged between –0.3986 (T_7) and 0.6681 (T_3). Two testers were recorded positive significant *gca* effects and two testers recorded negative significant *gca* effects and four testers were registered for non significant *gca* effects. The *sca* effects of hybrids ranged between –0.5569 (L_1T_4) and 0.8403 (L_2T_8). Three hybrids recorded positive significant *sca* effects and four hybrids recorded negative significant *sca* effects (Table 28).

Among the 24 hybrids two hybrids viz., L_3T_1 (12.29 per cent) and L_3T_7 (10.69 per cent) recorded significant positive relative heterosis. Six hybrids recorded significant positive heterobeltiosis which ranged between 13.126 (L_2T_1) per cent and 27.50 (L_3T_4) per cent. Only one hybrid (L_1T_8) registered for significant negative (–10.189) heterobeltiosis. Among the crosses, 12 hybrids recorded positive significant standard heterosis which ranged between 9.091 (L_3T_4) per cent and 36.364 (L_2T_3) per cent heterosis (Table 29).

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Table 27. Mean performance of parents and hybrids for flower diameter (cm)

Lines/Testers	L_1	L_2	L_3	Testers
T_1	6.90	7.90	7.00	5.73
T_2	6.50	6.40	6.00	5.00
T_3	7.40	8.50	6.70	6.20
T_4	6.00	7.70	6.80	4.40
T_5	6.50	8.30	6.00	6.20
T_6	7.00	7.40	6.10	6.00
T_7	6.90	6.00	6.90	5.00
T_8	6.00	8.30	6.00	6.20
Lines	7.20	8.20	6.20	
Mean of Lines	7.20	SEd = 0.123	$CD_{(p=0.05)} = 0.2454$	
Mean of Testers	5.59	SEd = 0.200	$CD_{(p=0.05)} = 0.4006$	
Mean of Hybrids	6.87	SEd = 0.347	$CD_{(p=0.05)} = 0.6940$	

Table 28. **Estimates of combining ability effects for flower diameter**

Lines/Testers	**L$_1$**	**L$_2$**	**L$_3$**	**GCA of Testers**
T$_1$	-0.1014	-0.0597	0.1611	0.4014**
T$_2$	0.4653	-0.5931	0.1611	-0.5653**
T$_3$	0.1319	0.2736	-0.4056	0.6681**
T$_4$	-0.5569*	0.1514	0.4056	-0.0431
T$_5$	-0.168	0.6736**	-0.5056*	0.0681
T$_6$	0.4319	-0.1264	-0.3056	-0.0319
T$_7$	0.2986	-0.1264	0.8611**	-0.3986**
T$_8$	-0.5014*	0.8403**	-0.3389	-0.0986
GCA of Lines	-0.2653*	0.6931*	-0.4278*	
SE of Lines	0.0870			
SE of Testers	0.1420			
SE of Hybrids	0.2459			

* Significant at 5% level

** Significant at 1% level

Table 29. **Estimates of heterosis effects of hybrids for Flower diameter**

Hybrids	Relative Heterosis (%) di	heterobeltiosis (%) dii	Best Parent Heterosis (%) diii
L_1T_1	-4.608	6.427	10.695**
L_1T_2	-10.138**	6.267	4.278
L_1T_3	2.304	10.174	18.717**
L_1T_4	-17.051**	2.857	-3.743
L_1T_5	-10.138*	-3.226	4.278
L_1T_6	-3.226	6.061	12.299**
L_1T_7	-10.138*	6.557	4.278
L_1T_8	-17.051**	-10.189**	-3.743
L_2T_1	-0.049	13.126**	26.738**
L_2T_2	-22.267**	-3.275	2.674
L_2T_3	3.239	17.783**	36.364**
L_2T_4	-6.883*	21.053**	22.995**
L_2T_5	0.810	15.012**	33.155**
L_2T_6	-10.121**	4.225	18.717**
L_2T_7	-27.126**	-9.091	-3.743
L_2T_8	0.810	14.747	33.155**
L_3T_1	12.299**	16.992	12.299**
L_3T_2	-3.743	6.825	-3.743
L_3T_3	7.487	7.775	7.487
L_3T_4	9.091	27.500**	9.091*
L_3T_5	-3.743	-3.485	-3.743
L_3T_6	2.139	-0.00	-2.139
L_3T_7	10.695**	23.214**	10.695*
L_3T_8	-3.743	-3.743	-3.743

* Significant at 5% level
** Significant at 1% level

4.2.9. Colour intensity

The mean performance of lines ranged between 666.67 (L_3) and 815.00 (L_2) and the overall mean of lines were 753.89. Two female parents recorded higher values than the overall mean of lines. The mean performance of testers ranged between 668.33 (T_7) and 805.00 (T_5) and the overall mean of testers were 737.28. Three testers recorded for higher values than the overall mean of testers. The range of 553.00 (L_1 T_2) to 880.00 (L_1 T_5) was recorded in the resultant 24 hybrids and the overall mean of the hybrids were 714.12. Ten hybrids recorded higher values than the overall mean of hybrids (Table 30).

The *gca* effects of lines varied from –26.45 (L_3) to 22.50 (L_2) and one female parent recorded significant *gca* positively. Three testers recorded positive significant *gca* values and three testers registered negative significant *gca* effects. The *gca* effects of testers ranged between –49.51 (T_7) and 55.48 (T_5). The *sca* effects of hybrids ranged between –56.31 (L_3 T_5) and 69.93 (L_1 T_5). Seven hybrids recorded positive significant *sca* effects and six hybrids recorded for negative significant *sca* effects (Table 31).

Among the 24 hybrids three hybrids recorded for positive significant relative heterosis and fourteen hybrids recorded negative significant relative heterosis which ranged between –16.67 (L_1 T_7) per cent and 9.32 (L_1 T_5) per cent. Eight hybrids recorded positive significant heterosis and six hybrids recorded for negative significant heterobeltiosis which ranged between –10.67 (L_1 T_1) per cent and 13.71 (L_1 T_4) per cent. With reference to standard heterosis 2 hybrids recorded for positive significant heterosis and 18 hybrids recorded for negative significant heterosis which ranged between –19.26 (L_1 T_7) per cent and 9.32 (L_1 T_5) per cent (Table 32).

Table 30. Mean performance of parents and hybrids for Colour intensity

Lines/Testers	L_1	L_2	L_3	Testers
T_1	676.67	780.00	716.67	735.00
T_2	553.00	810.00	793.33	793.33
T_3	710.00	730.00	700.00	690.00
T_4	850.00	770.00	700.00	690.00
T_5	880.00	815.00	723.33	805.0
T_6	750.00	760.00	753.33	801.67
T_7	650.00	760.00	693.33	668.33
T_8	730.00	760.00	693.33	690.00
Lines	780.00	815.00	666.67	
Mean of Lines	753.89	SEd = 3.975	$CD_{(p=0.05)} = 7.934$	
Mean of Testers	737.28	SEd = 6.493	$CD_{(p=0.05)} = 12.956$	
Mean of Hybrids	714.12	SEd = 11.24	$CD_{(p=0.05)} = 22.44$	

Table 31. Estimates of combining ability effects for colour intensity

Lines/Testers	L_1	L_2	L_3	GCA of Testers
T_1	-51.73**	33.05**	18.68*	-26.18**
T_2	-11.73	-10.27	22.01**	47.15**
T_3	-7.29	-5.83	13.12	-37.29**
T_4	66.04**	-32.50**	-33.54**	29.37**
T_5	69.93**	-13.61	-56.31**	55.48**
T_6	-8.40	-16.94*	25.34**	3.81
T_7	-55.07**	36.38**	18.68*	-49.51**
T_8	-1.73	9.72	-7.98	-22.84**
GCA of Lines	3.95	22.50**	-26.45**	
SE of Lines	2.8115			
SE of Testers	4.5912			
SE of Hybrids	7.9522			

* Significant at 5% level
** Significant at 1% level

Table 32. Estimates of heterosis effects of hybrids for Colour intensity

Hybrids	Relative Heterosis (%) di	heterobeltiosis (%) dii	Best Parent Heterosis (%) diii
L_1T_1	-13.25**	-10.67**	-15.94**
L_1T_2	-0.42	0.42	-1.86
L_1T_3	-8.97**	-3.40**	-11.80**
L_1T_4	8.97**	13.71**	5.59**
L_1T_5	9.32**	11.04**	9.32**
L_1T_6	-6.45**	-5.16**	-6.83**
L_1T_7	-16.67**	-10.24**	-19.26**
L_1T_8	-6.41**	-0.68	-9.32**
L_2T_1	-4.29**	0.65	-3.11**
L_2T_2	-0.61	0.73	0.62
L_2T_3	-10.43**	-2.99**	-9.32**
L_2T_4	-5.52**	0.65	-4.35**
L_2T_5	0.00	0.62	1.24
L_2T_6	-6.75**	-5.98**	-5.59**
L_2T_7	-6.75**	2.47*	-5.59**
L_2T_8	-6.75**	1.00	-5.59**
L_3T_1	-2.49*	2.26	-10.97**
L_3T_2	0.00	8.68**	-1.45
L_3T_3	1.45	3.19*	-13.04**
L_3T_4	0.70	4.22**	-10.56**
L_3T_5	-10.15**	-1.69	-10.15**
L_3T_6	-6.03**	2.61	-6.42**
L_3T_7	3.74**	3.87**	-13.87**
L_3T_8	0.48	2.21	-13.87**

* Significant at 5% level
** Significant at 1% level

4.2.10. Flower yield per plant

The mean performance of lines varied from 490.00 (L_3) g top 650.00 (L_2) g and the overall mean of the lines recorded as 560.00 g. The L_2 female parent recorded higher value than that of the overall mean of the lines. The mean performance of testers ranged between 230.00 g (T_7) and 450.00 (T_8) g and the overall mean of the testers recorded as 345.00 g. Two testers recorded higher values than the overall mean of testers. The mean performance of hybrids varied from 310.00 (L_3 T_7) g to 650.00 (L_3T_2) g and the mean value of the hybrids were recorded as 492.90 g. 12 hybrids recorded higher values than the overall mean of hybrids (Table 33).

The general combining ability (*gca*) effects of lines varied from –19.167 (L_3) to 30.83 (L_2) and one female parent (L_2) recorded positive significant *gca*. The *gca* effects of testers varied from –62.92 (T_5) to 63.75 (T_3) and three testers recorded for positive significant *gca* effects and three testers recorded for negative significant *gca* values. The *sca* values of hybrids varied from –88.33 (L_1T_2) to 169.16 (L_3T_2). Seven hybrids registered positive significant *sca* effects (Table 34).

Among the crosses, two hybrids L_3T_2 (32.65 per cent) and L_3T_3 (14.29 per cent) recorded significant positive relative heterosis. Ten hybrids recorded positive significant heterosis towards better parent heterosis and it ranged between 13.40 (L_1T_1) per cent and 60.49 (L_3T_2) per cent. The hybrid L_3T_7 (–13.89 per cent) registered negative significant heterobeltiosis. Eleven hybrids recorded positive significant heterosis towards standard heterosis which ranged from 11.11 (L_1T_4) per cent to 44.44 (L_3T_2) per cent. Three hybrids recorded for negative significant heterosis and ranged between –11.11 (L_1T_5) per cent and –31.11 (L_3T_7) per cent (Table 35).

Table 33. Mean performance of parents and hybrids for Flower yield per plant (g)

Lines/Testers	L_1	L_2	L_3	Testers
T_1	550.00	520.67	500.00	430.00
T_2	400.00	450.00	650.00	320.00
T_3	510.00	600.00	560.00	350.00
T_4	500.00	480.00	400.00	380.00
T_5	400.00	450.00	440.00	310.00
T_6	490.00	620.00	470.00	290.00
T_7	470.00	560.00	310.00	230.00
T_8	530.00	510.00	460.00	450.00
Lines	540.00	650.00	490.00	
Mean of Lines	560.00	SEd = 11.38	$CD_{(p=0.05)} = 22.71$	
Mean of Testers	345.00	SEd = 18.58	$CD_{(p=0.05)} = 37.09$	
Mean of Hybrids	492.90	SEd = 32.19	$CD_{(p=0.05)} = 64.24$	

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Table 34. Estimates of combining ability effects for flower yield per plant

Lines/Testers	L_1	L_2	L_3	GCA of Testers
T_1	38.33*	-34.167	-4.167	30.416**
T_2	-88.333**	-80.833**	169.16**	7.083
T_3	-35.00*	12.500	22.500	63.75**
T_4	51.66**	-10.833	-40.83*	-32.916**
T_5	-18.333	-10.833	29.167	-62.916**
T_6	-25.00	62.500**	-37.500*	33.75
T_7	35.00*	82.50**	-117.500**	-46.25**
T_8	41.666*	-20.833	-20.833	7.08
GCA of Lines	-11.6667	30.8333**	-19.1667**	
SE of Lines	6.2266			
SE of Testers	10.1682			
SE of Hybrids	17.6117			

* Significant at 5% level
** Significant at 1% level

Table 35. Estimates of heterosis effects of hybrids for Flower yield per plant

Hybrids	Relative Heterosis (%) di	heterobeltiosis (%) dii	Best Parent Heterosis (%) diii
L_1T_1	1.85	13.40**	22.22**
L_1T_2	-25.93**	-6.98	-11.11*
L_1T_3	-5.56	14.61**	13.33*
L_1T_4	-7.41	8.69	11.11*
L_1T_5	-25.93**	-5.88	-11.11*
L_1T_6	-9.26*	18.07**	8.89
L_1T_7	-12.96**	22.08**	4.44
L_1T_8	-1.85	7.07	17.78**
L_2T_1	-20.00**	-3.70	15.56**
L_2T_2	-30.71**	-7.22	0.00
L_2T_3	-7.69*	20.00**	33.33**
L_2T_4	-26.15**	-6.80	-1.45
L_2T_5	-30.71**	-6.25	0.00
L_2T_6	-4.62	31.92**	37.78**
L_2T_7	-13.85**	27.27**	24.44**
L_2T_8	-21.54**	-7.27	13.33*
L_3T_1	2.04	8.69	11.11*
L_3T_2	32.65**	60.49**	44.44**
L_3T_3	14.29**	33.33**	24.44**
L_3T_4	-18.37**	-8.05	-11.11*
L_3T_5	-10.20*	10.00	2.22
L_3T_6	-4.08	20.51**	4.44
L_3T_7	-36.73**	-13.89**	-31.11**
L_3T_8	-6.12	-2.13	2.22

* Significant at 5% level

** Significant at 1% level

4.2.11. Xanthophyll content – stage I (Half bud opened stage)

The mean performance of lines varied from 4.8 (L_3) mg/g to 5.7 (L_2) mg/g. and the overall mean of lines were recorded as 5.30 mg/g. Two lines recorded higher values than the overall mean of lines. The mean performance of testers ranged between 4.10 (T_4) mg/g and 5.7 (T_2) mg/g and the overall mean of the testers were recorded as 4.88 mg/g. Four tester parents recorded higher values than the overall mean of the tester parents. The mean performance of hybrids ranged between 4.4 (L_3T_7) mg/g and 6.2 (L_1T_5) mg/g and the overall mean of the hybrids were recorded as 5.13 mg/g (Table 36).

The *gca* effects of lines varied from –0.4619 (L_3) to 0.2672 (L_2) and two line parents recorded for significant positive *gca* effects. The *gca* effects of testers ranged between –0.4994 (T_8) and 0.4117 (T_5). Four testers of each recorded for both positive and negative significant *gca* effects. The *sca* effects of hybrids were ranged between –0.4614 (L_1T_7) and 0.4608 (L_1T_5). Six hybrids recorded for positive significant *sca* effets and 6 parents recorded for negative significant *gca* effects (Table 37).

Among the 24 crosses, 3 hybrids recorded for positive significant heterosis and 8 hybrids were negative significant heterosis towards relative heterosis. The relative heterosis ranged between –18.13 (L_2T_8) per cent and 12.96 (L_1T_6) per cent. The heterobeltiosis ranged between –10.83 (L_2T_8) per cent and 24.21 (L_1T_4) per cent. Five hybrids recorded for positive significant heterobeltiosis and 3 hybrids registered for negative significant heterobeltiosis. The standard heterosis ranged between –22.81 (L_3T_7) per cent and 8.77 (L_1T_5) per cent. Two hybrids recorded for positive significant standard heterosis and 19 crosses recorded for negative significant standard heterosis (Table 38).

Table 36. Mean performance of parents and hybrids Xanthophyll content stage I (mg/g)

Lines/Testers	**L_1**	**L_2**	**L_3**	**Testers**
T_1	4.73	5.50	4.63	4.83
T_2	5.50	5.83	5.07	5.70
T_3	4.96	5.20	4.67	4.90
T_4	5.90	5.40	4.53	4.10
T_5	6.20	5.80	4.63	5.50
T_6	6.10	5.40	4.93	5.10
T_7	4.50	5.40	4.40	4.20
T_8	4.73	4.67	4.50	4.76
Lines	5.40	5.70	4.80	
Mean of Lines	5.30	SEd = 0.044	$\text{CD}_{(p=0.05)} = 0.089$	
Mean of Testers	4.88	SEd = 0.073	$\text{CD}_{(p=0.05)} = 0.1468$	
Mean of Hybrids	5.13	SEd = 0.127	$\text{CD}_{(p=0.05)} = 0.2544$	

Table 37. Estimates of combining ability effects Xanthophyll content stage I

Lines/Testers	**L_1**	**L_2**	**L_3**	**GCA of Testers**
T_1	-0.4214**	0.2794**	0.1419	-0.1794**
T_2	-0.1614	0.0994	0.0619	0.3339**
T_3	-0.1769	-0.0094	0.1864*	-0.1906**
T_4	0.4275**	-0.1450	-0.2825**	0.1450**
T_5	0.4608**	-0.117	-0.4492**	0.4117**
T_6	0.4275**	-0.3450**	-0.0825	0.3450**
T_7	-0.4614**	0.3661**	0.0953	-0.3661**
T_8	-0.0947	-0.2339**	0.3286**	-0.4994**
GCA of Lines	0.1947**	0.2672**	-0.4619**	
SE of Lines	0.0319			
SE of Testers	0.0521			
SE of Hybrids	0.0902			

* Significant at 5% level
** Significant at 1% level

Table 38. Estimates of heterosis effects of hybrids for Xanthophyll content at stage-I

Hybrids	Relative Heterosis (%) di	heterobeltiosis (%) dii	Best Parent Heterosis (%) diii
L_1T_1	-12.469**	-7.32**	-17.08**
L_1T_2	-3.509*	-0.90	-3.51*
L_1T_3	-8.148**	-3.69	-12.98**
L_1T_4	9.26**	24.21**	3.51
L_1T_5	12.05**	13.42**	8.77**
L_1T_6	12.96**	16.19**	7.02**
L_1T_7	-16.67**	-6.25**	-21.05**
L_1T_8	-12.35**	-6.89**	-16.96**
L_2T_1	-3.51*	4.76*	-3.51*
L_2T_2	2.34	2.34	2.34
L_2T_3	-8.77**	-1.89	-8.77**
L_2T_4	-5.26**	10.20**	5.26**
L_2T_5	1.75	3.26	1.75
L_2T_6	-5.26	0.00	-5.26**
L_2T_7	-5.26	9.09	-5.26**
L_2T_8	-18.13	-10.83	-18.13**
L_3T_1	-3.47	-3.47	-18.71**
L_3T_2	-11.11	-3.49	-11.11**
L_3T_3	-4.76	-3.78	-18.13**
L_3T_4	-5.56	1.87	-20.47**
L_3T_5	-16.27	-10.32	-18.71**
L_3T_6	-3.27	-0.34	-13.45**
L_3T_7	-8.33	-2.22	-22.81**
L_3T_8	-6.25	-5.92	-21.05**

* Significant at 5% level
** Significant at 1% level

4.2.12. Xanthophyll content – stage II (Fully opened flowers)

The mean performance of lines varied from -4.77 (L_3) to 5.7 (L_2) mg/g and the overall mean of lines recorded as 5.24 mg/g. Two parents recorded higher values than the overall mean of lines. The mean performance of testers ranged between 4.3 (T_4) mg/g and 5.63 (T_5) mg/g and the overall mean of the testers recorded as 4.93 mg/g. Three testers registered higher values than the overall mean of testers. The mean performance of hybrids ranged between 4.37 (L_3T_7) mg/gm and 6.13 (L_1T_5) mg/gm and the overall mean of hybrids were recorded as 4.93 mg/gm. Ten hybrids registered for higher values than the overall mean of hybrids (Table 39).

The *gca* effects of lines varied from –0.4083 (L_3) to 0.2725 (L_2) and two parents (L_1 and L_2) recorded positive significant *gca* effects. The *gca* effects of testers ranged between –0.3719 (T_8) and 0.4392 (T_5). Three testers recorded for positive significant *gca* effects and four testers recorded negative significant *gca* effects. The *sca* effects of hybrids ranged between –0.5136 (L_1T_6) and 0.4864 (L_1T_4). Five hybrids recorded positive significant *sca* effects and 6 hybrids recorded for non-significant *sca* effects (Table 40).

Among the 24 crosses, 2 hybrids recorded positive significant heterosis and 15 hybrids recorded negative significant heterosis towards relative heterosis which ranged between –18.71 (L_2T_8) per cent and 12.02 (L_1T_4) per cent. Six hybrids recorded positive significant heterosis and six hybrids recorded negative significant heterosis towards heterobeltiosis, which ranged between –12.44 (L_2T_8) per cent and 24.65 (L_1T_4) per cent. There were 2 hybrids alone recorded for positive significant heterosis towards standard heterosis (Table 41).

Table 39. **Mean performance of parents and hybrids Xanthophyll content stage II (mg/g)**

Lines/Testers	L_1	L_2	L_3	Testers
T_1	4.70	5.47	4.55	4.80
T_2	5.37	5.76	4.97	5.23
T_3	4.97	5.23	4.67	4.90
T_4	5.90	5.43	4.50	4.30
T_5	6.13	5.73	4.73	5.63
T_6	4.50	5.20	4.93	5.20
T_7	5.51	5.47	4.37	4.53
T_8	4.77	4.63	4.77	4.88
Lines	5.27	5.70	-4.77	
Mean of Lines	5.24	SEd = 0.056	$CD_{(p=0.05)} = 0.1135$	
Mean of Testers	4.93	SEd = 0.028	$CD_{(p=0.05)} = 0.0578$	
Mean of Hybrids	4.93	SEd = 0.160	$CD_{(p=0.05)} = 0.3212$	

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Table 40. Estimates of combining ability effects for Xanthophyll content stage II

Lines/Testers	**L_1**	**L_2**	**L_3**	**GCA of Testers**
T_1	-0.3425**	0.2875*	0.0550	-0.1875**
T_2	-0.1358	0.1275	0.0083	0.2725**
T_3	-0.1247	0.0053	0.1194	-0.1386*
T_4	0.4864**	-0.1169	-0.3694**	0.1836**
T_5	0.4641**	-0.0725	-0.3917**	0.4392**
T_6	-0.5136**	0.0497	0.4639**	-0.2614**
T_7	0.2575	0.0808	-0.3383**	0.0912
T_8	-0.0914	-0.3614**	0.4528**	-0.3719**
GCA of Lines	0.1358**	0.2725**	-0.4083**	
SE of Lines	0.0420			
SE of Testers	0.657			
SE of Hybrids	0.1138			

* Significant at 5% level
** Significant at 1% level

Table 41. Estimates of heterosis effects of hybrids for Xanthophyll content stage-II

Hybrids	Relative Heterosis (%) di	Heterobeltiosis (%) dii	Best Parent Heterosis (%) diii
L_1T_1	-10.76**	-6.62**	-16.57**
L_1T_2	1.89	2.22	-4.74*
L_1T_3	-5.69**	-2.61	-11.83**
L_1T_4	12.02**	24.65**	4.73*
L_1T_5	8.87**	12.54**	8.87**
L_1T_6	-14.56**	-14.01**	-20.12**
L_1T_7	4.56	12.38**	-2.25
L_1T_8	-9.49**	-6.08*	-15.38**
L_2T_1	-4.09	4.13	-2.96
L_2T_2	1.17	5.49**	2.37
L_2T_3	-8.18**	-1.57	-7.10**
L_2T_4	-4.68*	9.76**	-3.55
L_2T_5	.58	1.17	1.77
L_2T_6	-8.77**	-4.59*	-7.69**
L_2T_7	-4.09	6.84**	-2.96
L_2T_8	-18.71**	-12.44**	-17.75**
L_3T_1	-5.14*	-4.81	-19.17**
L_3T_2	-5.09*	-0.67	-11.83**
L_3T_3	-5.40*	-3.78	-17.16**
L_3T_4	-5.59*	0.37	-20.12**
L_3T_5	-15.98**	-8.97**	-15.98**
L_3T_6	-5.2*	-1.01	-12.43**
L_3T_7	-8.39**	-6.09	-22.49**
L_3T_8	-2.39	-1.21	-15.36**

* Significant at 5% level

** Significant at 1% level

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4.3. Evaluation of F_2

The mean performance of all the crosses and its variability presented in the Table 42 to 44.

4.3.1. Plant height

The crosses showed differences among themseleves for plant height. It ranged between 48.33 cm (L_1T_5) and 65.33 cm (L_1T_6). The cross L_1T_6 (65.33 cm) recorded highest plant height followed by L_2T_6 (64.67 cm) and L_2T_2 (63.67 cm). The cross L_1T_5 recorded lowest plant height (48.33 cm). Seven crosses recorded higher values than the over all mean of the hybrids. (Table 42). Plant height recorded higher phenotypic variance (30.44) than genotypic variance (21.10) (Table 44).

4.3.2. Number of branches per plant

The crosses showed differences among themselves for number of branches which ranged between 10.00 (L_1T_1, L_3T_1) and (L_2T_3) 24.3. Number of branches per plant recorded higher phenotypic variance (16.99) than the genotypic variance (13.18). The cross L_2T_3 recorded highest number of branches (24.33) followed by L_1T_4, L_2T_2, L_1T_4 (20.67). The crosses L_1T_1 and L_3T_1 recorded lowest (10.00) number of branches per plant. The over all mean of the crosses were 14.00 and four crosses recorded higher values than the over all mean of the hybrids (Table 42 and 44).

4.3.3. Plant spread

Among the crosses differences were observed for the character plant spread. It ranged between 37.00 cm (L_3T_6) and 59.00 (L_2T_4) cm. The over all mean of the crosses were recorded as 45.25 cm. and ten hybrids recorded higher values than the over all mean of the hybrids. This character recorded higher phenotypic variance (32.79) than the genotypic variance (20.98) (Table 42 and 44).

Table 42. Mean performance of crosses in F_2 generation

Hybrids	PH	BR	PS	DFI	DF	NF	IFW	FD	CI	XC-I	XC-II	FY
L_1T_1	56.00	10.00	43.33	60.00	46.67	53.00	8.00	6.33	653.33	4.60	4.60	490.00
L_1T_2	50.67	14.00	45.00	60.00	46.00	42.00	6.53	6.10	550.00	5.40	5.47	363.33
L_1T_3	49.67	10.33	44.67	57.00	46.33	60.33	6.60	7.13	700.00	4.86	4.87	456.67
L_1T_4	51.33	20.67	49.00	60.67	47.33	54.00	7.87	5.80	850.00	5.93	5.73	583.33
L_1T_5	48.33	13.33	44.33	57.67	45.00	43.00	7.00	6.10	860.00	6.03	5.97	356.67
L_1T_6	65.33	20.67	46.67	60.00	47.00	49.00	7.13	6.77	716.67	5.67	4.20	550.00
L_1T_7	53.33	15.33	42.67	57.00	48.00	39.67	7.50	6.27	606.67	4.50	5.10	420.00
L_1T_8	53.00	11.33	44.66	50.00	47.00	52.00	8.37	5.93	710.00	4.67	4.40	473.33
L_2T_1	61.67	12.00	54.33	57.67	50.33	41.00	8.10	7.47	766.67	5.37	5.23	576.67
L_2T_2	63.67	20.67	45.67	61.00	46.33	50.00	8.47	6.23	803.33	5.77	5.90	403.33
L_2T_3	56.00	24.33	45.67	59.33	48.00	55.67	8.47	8.20	730.00	5.27	5.03	660.00
L_2T_4	50.57	14.33	59.00	60.00	47.667	41.00	7.90	7.23	760.00	5.37	5.10	416.67
L_2T_5	54.33	13.00	47.33	57.00	50.00	46.00	7.83	7.90	810.00	5.80	5.23	390.00
L_2T_6	64.67	14.67	51.33	52.33	56.00	55.00	6.17	7.40	723.33	5.67	5.23	676.67
L_2T_7	57.67	12.00	47.33	53.67	49.33	41.00	8.53	5.97	716.67	5.33	6.17	503.33
L_2T_8	56.00	12.00	41.33	53.667	47.00	48.00	7.90	8.00	720.00	4.57	4.70	460.00
L_3T_1	51.67	10.00	40.00	51.00	45.33	48.33	7.20	6.87	696.67	4.47	4.33	443.33
L_3T_2	60.33	12.667	40.33	49.00	53.33	45.67	7.17	6.00	776.67	5.00	4.73	676.67
L_3T_3	53.33	11.67	49.33	53.00	46.67	50.33	6.69	6.33	703.33	4.43	4.70	493.33
L_3T_4	53.33	11.33	39.00	55.67	46.67	43.67	8.37	6.43	803.33	4.40	4.27	323.33
L_3T_5	52.00	11.67	45.33	49.00	44.33	39.67	6.90	5.90	696.67	4.50	4.80	400.00
L_3T_6	50.33	12.00	37.00	51.33	44.33	42.33	6.37	5.90	723.33	4.80	4.80	410.00
L_3T_7	54.33	13.67	43.00	51.33	42.33	48.33	6.67	6.60	676.67	4.40	4.20	286.67
L_3T_8	59.67	14.33	39.67	53.00	48.33	47.00	6.23	5.87	670.00	4.47	4.53	410.00
Mean	55.31	14.00	45.25	55.43	47.56	47.33	7.43	6.61	725.97	5.07	4.93	467.64
SEd	2.49	1.59	2.81	1.12	2.02	1.57	0.25	0.11	15.03	0.11	0.13	16.26
CD	5.02	3.21	5.65	2.25	4.07	3.16	0.50	0.21	30.26	0.22	0.26	32.73

Table 43. **Analysis of variance for crosses in F_2 generation**

Sources	df	pH	BR	PS	DFI	DF	NF	IFW	FD	CI	XC-I	XC-II	FY
Total	71	29.68	16.67	32.39	16.84	12.63	3.92	0.65	0.55	5187.77	0.34	0.27	11370.41
Rep	2	3.40	5.54	18.29	3.02	3.18	1.13	0.10	0.01	573.33	0.01	0.07	476.83
Trt	23	72.64**	43.36**	74.70**	47.96**	24.60	97.19**	1.80**	1.65**	15286.38**	1.01**	0.77**	34265.18**
Error	46	9.34	3.82	11.84	1.88	6.12	3.70	0.09	0.02	339.10	0.02	0.03	396.66

** Significant at 1% level

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Table 44. Genotypic and phenotypic variation in F_2 generation

S.No.	Characters	Mean	GV	PV	SEd	CD (P = 0.05)
1.	Plant height (cm)	55.31	21.10	30.44	2.49	5.02
2.	Number of branches	14.00	13.18	16.99	1.59	3.21
3.	Plant spread (cm)	45.25	20.95	32.79	2.81	5.65
4.	Days to flower initiation	55.43	15.35	17.24	1.12	2.25
5.	Duration of flowering	47.56	6.15	12.28	2.02	4.07
6.	Number of flowers	47.33	31.16	34.86	1.57	3.16
7.	Individual flower weight (g)	7.43	0.57	0.66	0.25	0.50
8.	Flower Diameter (cm)	6.61	0.54	0.56	0.11	0.21
9.	Colour intensity	725.57	4982.42	5321.52	15.03	30.26
10.	Xanthophyll content-stage - I (mg g^{-1})	5.07	0.32	0.34	0.11	0.22
11.	Xanthophyll content - Stage - II (mg g^{-1})	4.93	0.25	0.27	0.13	0.26
13.	Flower yield (g)	467.64	11289.50	11686.16	16.26	32.73

4.3.4. Days to flower initiation

Table 42 depicts the mean performance of twenty four crosses and it showed the differences among the crosses. It ranged between 49.00 (L_3T_2, L_3T_5) and 61.00 (L_2T_2) days. The crosses L_3T_2 and L_3T_5 registered for lowest days for flower initiation and the cross L_2T_2 recorded for highest days (61) for days to flowering. The over all mean of the crosses were recorded as 55.43 days and 13 crosses recorded higher values than the all mean of the hybrids for days to flower initiation. The parents L_2 and L_3 with all the testers crosses recorded for lesser number of days to flower initiation. The phenotypic variance (17.24) was observed higher than the genotypic variance (15.35) for the character (Table 42 and 44).

4.3.5. Duration of flowering

There existed significant differences among the crosses and it ranged between 42.33 (L_3T_7) days and 56.00 (L_2T_6) days. The cross L_3T_7 recorded for lowest duration of flowering and L_2T_6 recorded for highest days for duration of flowering. The over all mean for duration of flowering was recorded as 47.56 days. A total of nine hybrids recorded higher values than the over all mean of the hybrids. This character recorded higher phenotypic variance (12.28) than the genotypic variance (6.15) (Table 42 and 44).

4.3.6. Number of flowers per plant

Number of flowers per plant were ranged between 39.67 (L_1T_7, L_3T_5) and 60.33 (L_1T_3) and there exists significant differences among the crosses. The highest number of flower per plant were recorded in the hybrids L_1T_3 and the lowest number of flowers per plant were recorded in the hybrids L_1T_7 and L_3T_5. The over all mean of all hybrids were recorded as 47.33 and 11 hybrids recorded higher value than the over all mean of all hybrids. The phenotypic variance (34.36) was higher than the genotypic variance (31.16) (Table 42 and 44).

4.3.7. Individual flower weight

The crosses showed differences among themselves. It ranged from 6.17 gm to 8.47 gms. The crosses L_2T_2 and L_2T_3 recorded highest flower weight followed by L_1T_8 and L_3T_4 and the lowest flower weight was recorded by the L_2T_6. The overall mean of the hybrids were recorded as 7.43 gm. and 12 hybrids recorded higher values than the overall mean of all hybrids. The phenotypic variance (0.66) was recorded higher than the genotypic variance (0.570) (Table 42 and 44).

4.3.8. Flower Diameter

The crosses showed significant difference among themselves. It ranged from 5.8 cm to 8.2 cm. The highest flower diameter was recorded by the hybrid L_2T_3 followed by L_2T_8 and L_2T_5. The testers crossed with the L_2 parent recorded higher flower diameters. The lowest flower diameter was recorded in the hybrid L_1T_4. The over all mean of the hybrids were recorded as 6.61 cm. A total number of ten hybrids recorded higher values than the over all mean of all the hybrids. The phenotypic variance (0.56) was recorded higher than the genotypic variance (0.54) (Table 42 and 44).

4.3.9. Colour Intensity

There exists significant differences among the crosses. The colour intensity was ranged between 550 (L_1T_2) and 860 (L_1T_5) (hues values of colour chart). The highest colour intensity was recorded by the hybrid L_1T_5, followed by L_1T_4, L_1T_4 (850) L_2T_2 (803) L_2T_5 (810) and L_3T_4) (803.33). The lowest colour intensity was recorded by the hybrid L_1T_2. All the three female parental combination with testers recorded for both higher and lower colour intensity. The overall mean of the hybrids for colour intensity were recorded as 725.97 (hue values of colour chart). Eight hybrids recorded higher colour intensity values than the over all mean of all hybrids. The phenotypic variance (5321.52) was higher than the genotypic variance (4982.42) (Table 42 and 44).

4.3.10. Xanthophyll content stage - I

The mean performance of crosses for Xanthophyll content (Half bud opened stage) ranged between 4.40 mg/gm and 6.03 mg/gm. The highest mean for xanthophyll content was recorded by the cross L_1T_5 followed by L_1T_4 (5.93 mg/gm) and L_1T_6 (5.67 mg/gm). The lowest mean was recorded by the cross L_3T_4 and L_3T_7. The over all mean of all the crosses were recorded as 5.07 mg/gm. Ten crosses recorded higher values than over all mean of the hybrids. The phenotypic variance was higher (0.34) than the genotypic variance (0.32) (Table 42 and 44).

4.3.11. Xanthophyll content - Stage II (Fully opened flowers)

The mean performance of crosses for Xanthophyll content ranged between 4.20 mg/gm and 6.17 mg/gm. The highest value was recorded in the cross L_2T_7 followed by L_1T_5 (5.97 mg/gm), L_1T_2 (5.90 mg/gm) and L_1T_4 (5.73 mg/gm). The lowest Xanthophyll content was registered by the cross L_3T_7. The over all mean of hybrids recorded as 4.93 mg/gm. There were 11 hybrids recorded higher values than the over all mean of the hybrids. The phenotypic variance (0.27) was higher than the genotypic variance (0.25) (Table 42 and 44).

4.3.12. Flower yield per plant

The crosses showed significant differences among themselves. It ranged between 286.67 gm and 676.67 gm per plant. The highest yield was recorded in the crosses L_2T_6 and L_3T_2 (676.67 gm) followed by L_2T_3 (660.00 gm) and L_1T_4 (583.33 gm) and the lowest flower yield was recorded in the hybrid L_3T_7. The over all mean of hybrids recorded as 467.64 gm per plant. A total number of 11 hybrids recorded higher values than the over all mean of the hybrids. The genotypic variance (11289.50) was lesser than the phenotypic variance (1186.16) (Table 42 and 44).

4.4. Association analysis

Simple, genotypic, phenotypic and path co-efficient of variance analysis were computed to find out the strength of association of the component characters with yield and among themselves in F_1 and F_2 generations.

The data on phenotypic and genotypic co-efficient of variation, heritability (broad sense) and genetic advance as per cent over mean of the characters in F_1 and F_2 generations are furnished in Tables 45 and 46, respectively.

The phenotypic co-efficient of variation in F_1 and F_2 generations for all the characters were greater than the genotypic co-efficient of variation. Heritability in a broad sense was also greater in F_1 than F_2 for the characters duration of flowering and vase life, While it was less in F_1 than F_2 for the characters plant height, number of branches per plant, plant spread, days to flower initiation, number of flowers per plant, individual flower weight, flower diameter, colour intensity, Xanthophyll content stage - I, Xatnhophyll content stage - II and flower yield per plant. The genetic advance as per cent over mean was higher in F_1 than F_2 for the characters days to flower initiation, duration of flowering, number of flowers per plant, Individual flower weight and flower diameter (Table 45).

Table 45. Genotypic and phenotypic coefficient of variation h^2 and GA (as % of mean) in F_1 generation

Characters	GCV	PCV	HERT (%)	GA as (%) OF MEAN
PH	6.66	13.42	24.67	6.82
BR	16.60	29.23	32.27	19.43
PS	7.46	12.09	38.03	9.48
DFI	7.88	8.39	88.34	15.26
DF	7.83	8.62	82.65	14.68
NF	14.35	16.32	77.21	25.97
IFW	12.02	14.65	67.29	20.31
FD	13.99	15.39	82.64	26.20
CI	7.28	7.62	91.08	14.14
XC-I	8.00	11.08	52.13	11.90
XC-II	6.74	9.97	45.75	9.39
FY	19.47	24.46	63.38	31.93

Table 46. Genotypic and phenotypic coefficient of variation h^2 and GA (as % of mean) in F_2 generation

Characters	GCV	PCV	HERT (%)	GA as (%) OF MsEAN
PH	8.31	9.98	69.32	14.25
BR	25.93	29.45	77.55	47.04
PS	10.12	12.66	63.89	16.66
DFI	7.07	7.49	89.08	13.75
DF	5.22	7.37	50.15	7.61
NF	11.79	12.47	89.37	22.97
IFW	10.17	10.96	86.06	19.43
FD	11.16	11.33	97.01	22.64
CI	9.72	10.05	93.63	19.38
XC-I	11.30	11.62	94.68	22.66
XC-II	10.14	10.65	90.66	19.88
FY	22.72	23.12	96.61	46.00

In F_1 generation among the thirteen characters studied, the character number of branches per plant had recorded high PCV (29.22) followed by flower yield per plant (24.45), Number of flowers per plant (16.32) and flower diameter (15.39). While days to flower initiation recorded low PCV (8.38). But with respect to GCV, flower yield recorded the higher values (19.47) followed by number of branches per plant (16.60), Number of flowers per plant (14.38) and flower diameter (13.99). While the character colour intensity recorded lowest GCV (6.61). The heritability in a broad sense ranged from 24.67 per cent to 88.34 per cent. The highest per cent of heritability was recorded by the character days to flower initiation (88.34 per cent), followed by flower diameter (82.64 per cent), number of flowers per plant (77.21 per cent) and individual flower weight (70.44 per cent) lowest heritability was recorded by plant height (24.67 per cent). The other characters ranged between 32.27 per cent to 67.60 per cent, number of branches 32.27 per cent, plant spread 38.03 per cent, duration of flowering 55.38 per cent, Colour intensity 32.43 per cent, vase life 67.60 per cent, xanthophyll content - stage I 52.79 per cent, xanthophyll content - stage II 45.75 per cent and flower yield per plant 63.38 per cent heritability were recorded. The genetic advance as per cent of mean ranged between 6.82 per cent and 31.93 per cent. Flower yield recorded highest GA as per cent of mean followed by flower diameter (26.20), number of flowers per plant (25.97) and individual flower weight (21.72). While the lowest GA as per cent of mean was recorded by plant height (6.82) (Table 45).

In F_2 generation PCV ranged from 7.37 to 29.45. The highest PCV was recorded by number of branches per plant (29.45) followed by flower yield (23.12) and number of flowers per plant (12.47), while the lowest PCV was recorded by duration of flowering (7.37). The GCV ranged between 5.22 and 25.93. The highest GCV was recorded by number of branches per plant (25.93) followed by flower yield per plant (22.72) and number of flowers per plant (11.79) while the lowest GCV was recorded by duration of flowering (5.22). The highest heritability was recorded in flower diameter (97.01 per cent) followed by flower yield per plant (96.61 per cent) and xanthophyll content-stage I (94.68 per cent) while the lowest heritability was recorded in duration of flowering (50.15 per cent). The GA as per cent of mean ranged between 7.61 and 47.04. The highest GA as per cent of mean was recorded by number of branches per plant (47.04 per cent) followed by flower yield (46.00 per cent) and number of flowers per plant (22.97 per cent) while the character duration of flowering recorded the lowest GA as per cent of mean (7.61) (Table 46).

4.4.1. Simple correlation

F_1 generation

Flower yield had significant positive correlation with plant height, duration of flowering, number of flowers per plant, individual flower weight and flower diameter. Among these characters individual flower weight had highest positive significant correlation (r=0.519). Correlation with yield followed by flower diameter (r=0.500). The characters days to flower initiation (r=-0.337) and vase life (r=0.330) had a negative significant correlation with flower yield.

Among the characters xanthophyll content - stage I (r=0.558) and xanthophyll content - stage II (r=0.631) had a positive significant correlation with colour intensity and also the characters flower diameter, days to flower initiation and number of branches per plant had significant positive correlation. The character vase life had a significant negative correlation with plant spread and flower diameter. Number of flowers and individual flower weight had a positive significant correlation with flower diameter (Table 47).

Table 47. Simple correlation coefficient in F_1 generation

Characters	PH	BR	PS	DFI	DF	NF	IFW	FD	CI	XC-I	XC-II	FY
PH	1.000	0.416**	-0.044	-0.051	0.272	0.038	0.307	0.264	-0.072	0.268	0.149	0.485**
BR		1.000	0.338*	0.260	0.180	0.016	0.240	0.305	0.202	0.536**	0.546**	0.192
PS			1.000	0.346*	-0.065	0.143	0.340	0.196	0.097	0.220	0.319	0.022
DFI				1.000	0.260	-0.201	-0.294	-0.092	0.229	0.364*	0.366*	-0.337*
DF					1.000	-0.012	0.242	0.241	0.269	0.295	0.290	0.377*
NF						1.000	0.293	0.438**	-0.072	-0.013	-0.022	0.355*
IFW							1.000	0.421**	0.020	0.041	0.091	0.464**
FD								1.000	0.167	0.398*	0.372*	0.500**
CI									1.000	0.656**	0.736**	0.036
XC-I										1.000	0.881**	0.230
XC-II											1.000	0.201
FY												1.000

* Significant at 5% level (r = 0.321)
** Significant at 1% level (r = 0.413)

Table 48. Simple correlation coefficient in F_2 generation

Characters	PH	BR	PS	DFI	DF	NF	IFW	FD	CI	XC-I	XC-II	FY
PH	1.000	0.356	0.155	0.048	0.559**	0.144	0.097	0.184	0.056	0.267	-0.069	0.515*
BR		1.000	0.211	0.542**	0.079	0.253	0.217	0.160	0.215	0.555**	0.349	0.343
PS			1.000	0.407*	0.334	-0.004	0.218	0.334	0.202	0.501**	0.395	0.295
DFI				1.000	-0.017	0.135	0.355	0.228	0.138	0.583**	0.505*	0.004
DF					1.000	0.095	0.013	0.264	0.091	0.345	0.223	0.698**
NF						1.000	-0.029	0.278	0.074	0.068	-0.097	0.410
IFW							1.000	0.205	0.365	0.135	0.135	0.116
FD								1.000	0.110	0.156	-0.029	0.258
CI									1.000	0.508**	0.367	0.150
XC-I										1.000	0.699**	0.303
XC-II											1.000	0.088
FY												1.000

* Significant t 5% level

** Significant at 1% level

F_2 generation

Among the characters studied duration of flowering (r=0.698) and plant height (r=0.515) had recorded significant positive correlation with flower yield. No character recorded significant negative correlation with yield.

Inter correlation within other characters were observed for xanthophyll content - stage I had significant positive correlation with number of branches, plant spread, days to flower initiation and colour intensity while the character plant height had significant positive correlation with duration of flowering. Plant spread and number of branches per plant had positive significant correlation with days to flower initiation. The characters xanthophyll content stage I and days to flower initiation had positive significant correlation with xanthophyll content stage II (Table 48).

4.4.2. Genotypic correlation

F_1 generation

The characters plant height, duration of flowering, individual flower weight and flower diameter had a significant positive genotypic correlation with flower yield.

The characters individual flower weight (r=0.611) had highest positive significant genotypic correlation with flower yield followed by plant height (r=0.600), flower diameter (r=0.531) and duration of flowering (r=0.412).

Among the characters studied, intergenotypic correlation was observed that xanthophyll content - stage II had positive genotypic correlation with plant spread, number of branches per plant, days to flower initiation, duration of flowering, flower

Table 49. Genotypic correlation coefficient in F_1 generation

Characters	PH	BR	PS	DFI	DF	NF	IFW	FD	CI	XC-I	XC-II	FY
PH	1.000	0.881**	-0.119	-0.069	0.431	0.033	0.418*	0.343*	-0.128	0.147*	0.258	0.600**
BR		1.000	0.445**	0.329*	0.272	0.034	0.399*	0.435*	0.282	0.787**	0.948**	0.264
PS			1.000	0.458**	-0.090	0.169	0.398*	0.232	0.122	0.264	0.494**	0.041
DFI				1.000	0.277	-0.214	-0.330	-0.090	0.233	0.404*	0.421**	-0.380*
DF					1.000	-0.018	0.277*	0.259	0.273	0.358	0.344*	0.445*
NF						1.000	0.317*	0.473**	-0.086	-0.021	-0.002	0.403
IFW							1.000	0.408**	0.016	0.041	0.140	0.545**
FD								1.000	0.171	0.461**	0.457**	0.531**
CI									1.000	0.750**	0.879**	0. 030
XC-I										1.000	1.017	0.326
XC-II											1.000	0.289
FY												1.000

* Significant at 5% level (r = 0.321)
** Significant at 1% level (r = 0.413)

Table 50. Genotypic correlation coefficient in F_2 generation

Characters	PH	BR	PS	DFI	DF	NF	IFW	FD	CI	XC-I	XC-II	FY
PH	1.000	0.411*	0.211	0.048	0.663*	0.156	0.104	0.198	0.056	0.299	-0.073	0.550*
BR		1.000	0.261	0.577*	0.070	0.282	0.223	0.164	0.229	0.597**	0.376	0.364
PS			1.000	0.440*	0.456*	0.003	0.259	0.370	0.212	0.540**	0.422*	0.324
DFI				1.000	-0.008	0.135	0.368	0.231	0.141	0.599**	0.515*	0.006
DF					1.000	0.098	0.057	0.306	0.122	0.391	0.302	0.799*
NF						1.000	-0.031	0.282	0.077	0.069	-0.107	0.418*
IFW							1.000	0.215	0.375	0.150	0.141	0.127
FD								1.000	0.112	0.156	-0.0135	0.261
CI									1.000	0.518**	0.378	0.151
XC-I										1.000	0.716**	0.307
XC-II											1.000	0.093
FY												1.000

* Significant t 5% level (r = 0.404)
** Significant at 1% level (r = 0.515)

diameter and colour intensity, while vase life had negative significant genotypic correlation. Vase life had significant negative genotypic correlation with plant spread, individual flower weight, flower diameter and colour intensity. The character individual flower weight had significant positive genotypic correlations with plant height, number of branches per plant, plant spread, duration of flowering and number of flowers per plant (Table 49).

F_2 generation

Flower yield had a significant genotypic correlation with the characters duration of flowering (r=0.799), number of flowers per plant (r=0.418) and plant height (r=0.550). No character was observed for significant negative genotypic correlation with flower yield.

Inter genotypic correlation among the characters studied observed for xanthophyll content-stage I had significant positive genotypic correlation with number of branches per plant (r=0.597), plant spread (r=0.540), days to flower initiation (r=0.599) and colour intensity (0.518), while the character vase life (r=-0.450) had a significant negative genotypic (r=-0.450) had a significant negative genotypic correlation. Vase life had a significant negative genotypic correlation with colour intensity, days to flower initiation and plant spread.(Table 50)

4.4.3. Phenotypic correlation

F1 generation

Flower yield had a positive significant phenotypic correlation with flower diameter (r=0.457), individual flower weight (r=0.395) and plant height (r=0.418).

Table 51. Phenotypic correlation coefficient in F_1 generation

Characters	PH	BR	PS	DFI	DF	NF	IFW	FD	CI	XC-I	XC-II	FY
PH	1.000	0.154	0.001	-0.039	0.153	0.045	0.233	0.215	-0.027	0.168	0.079	0.418**
BR		1.000	0.263	0.204	0.126	-0.001	0.101	0.189	0.130	0.337*	0.240	0.132
PS			1.000	0.233	-0.003	0.119	0.288	0.161	0.074	0.182	0.173	0.004
DFI				1.000	0.230	-0.180	-0.252	-0.094	0.221	0.316	0.307	-0.275
DF					1.000	-0.001	0.190	0.213	0.263	0.216	0.231	0.280
NF						1.000	0.259	0.384*	-0.047	-0.004	-0.046	0.289
IFW							1.000	0.440**	0.028	0.040	0.038	0.358*
FD								1.000	0.162	0.322*	0.276	0.457**
CI									1.000	0.542**	0.575**	0.047
XC-I										1.000	0.750**	0.119
XC-II											1.000	0.108
FY												1.000

* Significant t 5% level (r = 0.321)
** Significant at 1% level (r = 0.413)

Table 52. Phenotypic correlation coefficient in F_2 generation

Characters	PH	BR	PS	DFI	DF	NF	IFW	FD	CI	XC-I	XC-II	FY
PH	1.000	0.276	0.079	0.047	0.441*	0.126	0.087	0.163	0.056	0.217	-0.062	0.462*
BR		1.000	0.141	0.485*	0.092	0.206	0.207	0.155	0.193	0.484*	0.304	0.309
PS			1.000	0.361	0.198	-0.013	0.159	0.282	0.188	0.447*	0.358	0.254
DFI				1.000	-0.029	0.134	0.331	0.224	0.131	0.553**	0.487*	0.001
DF					1.000	0.092	-0.044	0.213	0.052	0.291	0.121	0.578**
NF						1.000	-0.026	0.272	0.069	0.067	-0.079	0.395
IFW							1.000	0.187	0.348	0.108	0.124	0.097
FD								1.000	0.106	0.157	-0.017	0.254
CI									1.000	0.488*	0.346	0.148
XC-I										1.000	0.667**	0.297
XC-II											1.000	0.081
FY												1.000

* Significant t 5% level
** Significant at 1% level

Among the characters studied inter phenotypic correlations observed for xanthophyll content-stage II had positive phenotypic correlation with colour intensity (r=0.418) and xanthophyll content stage I (r=0.747). The character flower diameter had significant positive phenotypic correlation with number of flowers per plant (r=0.384) and individual flower weight (r=0.465) (Table 51).

F_2 generation

Flower yield had a significant positive phenotypic correlation with duration of flowering (r=0.578) and plant height (r=0.462).

Among the characters studied inter correlations observed were, xanthophyll content stage-I had positive significant phenotypic correlation with number of branches per plant (r=0.484), plant spread (r=0.447), days to flower initiation (r=0.553) and colour intensity (r=0.488). All other characters had no significant phenotypic correlation among themselves.(Table 52)

4.4.4. Path analysis

Path co-efficient analysis showing both direct and indirect effect on the component characters on yield at genotypic level in F_1 and F_2 generations are presented in Tables 53 and 54.

F_1 generation

Direct effects

The characters plant height, number of branches per plant, plant spread, duration of flowering, number of flowers per plant, individual flower weight, flower diameter and Xanthophyll content at half bud opened stage had direct positive effect

Table 53. Path analysis in F_1 generation

Character	PH	BR	PS	DFI	DF	NF	IFW	FD	CI	XC–1	XC–II
PH	**0.50106**	-0.75007	-0.06780	0.08258	0.30913	0.00696	0.20401	-0.23486	0.21446	1.57698	-0.24053
BR	-0.44138	**0.85150**	0.25296	-0.39463	0.17353	0.00703	0.19448	-0.29750	-0.47075	2.97677	-0.88482
PS	0.05975	-0.37885	**0.56854**	-0.54818	-0.06495	0.03545	0.19423	-0.15966	-0.20299	0.99909	-0.46119
DFI	0.03454	-0.28049	0.26016	**-1.19797**	0.19919	-0.04470	-0.16077	0.06146	-0.38898	1.52992	-0.39236
DF	0.21574	-0.20580	-0.05143	-0.33236	**0.71796**	-0.00382	0.13511	-0.17686	-0.45531	1.35381	-0.32090
NF	-0.01667	0.02859	0.09632	0.25592	-0.01309	**0.20925**	0.15475	-0.32320	0.14434	-0.07795	0.00178
IFW	-0.20959	-0.33953	0.22642	0.39488	0.19888	0.06639	**0.48773**	-0.27936	-0.02695	0.15590	-0.13034
FD	-0.17205	-0.37035	0.13271	0.10764	0.18564	0.09887	0.19920	**0.68400**	-0.28504	1.74407	-0.42609
CI	0.06438	0.24014	0.06914	-0.27917	0.19584	-0.01809	0.00758	-0.11680	**-1.66920**	2.83660	-0.82024
XC–I	-0.20890	-0.67012	0.15017	-0.48455	0.25697	-0.00431	0.02010	-0.31539	-1.25179	**3.78246**	-0.94874
XC–II	-0.12917	-0.80750	0.28102	-0.50377	0.24693	-0.00040	0.06813	-0.31237	-1.46741	3.84615	**-0.93303**

Residual effect = 0.4163334

on yield. The characters days to flower initiation, colour intensity and Xanthophyll content at fully opened flower bud stage had negative direct effect on flower yield. The character Xanthophyll content stage - I had the highest direct positive effect (3.7824) followed by duration of flowering (0.71796), plant spread (0.56854) and Individual flower weight (0.48773). The lowest direct positive effect was recorded by number of flowers per plant (Table 53).

Indirect effects

The indirect effect of plant height on flower yield through plant spread, days to flower initiation and colour intensity was positive. Whereas, the number of branches on flower yield through all the characters were negative except number of flowers per plant. The indirect effect of plant spread on flower yield were positive through all the characters except plant height and duration of flowering. Likewise, the days to flower initiation on flower yield through plant height, number of flowers per plant, individual flower weight, and flower diameter was positive.

The indirect effect of duration of flowering on flower yield through all the characters were positive except plant spread and number of flowers per plant. While, the number of flowers per plant on flower yield through plant height, number of branches, plant spread, individual flower weight and flower diameter was positive.

The indirect effect of individual flower weight on flower yield through all the characters were positive except days to flower initiation. In contrast, the flower diameter on flower yield through all the characters were negative except days to flower initiation. The indirect effect of colour intensity on flower yield through plant height and number of flowers per plant was positive. Similarly, the Xanthophyll content at half bud opened staged (Stage I) on flower yield through all the characters were positive except number of flowers per plant.

The indirect effect of Xanthophyll content in fully opened flowers on flower yield through all the characters were negative except number of flowers per plant.

F_2 generation

Direct effects

The characters plant height, number of branches, days to flower initiation, duration of flowering, number of flowers per plant, Individual flower weight, flower diameter and colour intensity had direct positive effect on flower yield. All other characters had direct negative effect on flower yield. The character duration of flowering recorded highest direct effect (2.08466) followed by number of branches (1.18426) (Table 54).

Indirect effects

The indirect effect of plant height on flower yield through Xanthophyll content at fully opened stage was positive. While, the number of branches per plant on flower yield through all the characters studied were positive. While, the plant spread on flower yield through all the characters were negative. The indirect effect of days to flower initiation on flower yield through all the characters were positive except duration of flowering. Whereas, the duration of flowering on flower yield through all the characters was positive except days to flower initiation. The indirect effect of number of flowers per plant on flower yield through all the characters were positive except individual flower weight and Xanthophyll content stage - II. Similarly, the individual flower weight on flower yield through all the characters was positive

Table 54. Path analysis in F_2 generation

Character	PH	BR	PS	DFI	DF	NF	IFW	FD	CI	XC–1	XC–II
PH	**1.30688**	0.48719	-0.02235	0.00520	1.38154	0.00732	0.00491	-0.07316	0.01066	-0.02607	0.08135
BR	-0.53763	**1.18426**	-0.02759	0.06238	0.14586	0.01322	0.01049	-0.06058	0.04383	-0.05197	-0.41814
PS	-0.27632	0.30906	**-0.10571**	0.04754	0.95117	0.00012	0.01218	-0.13683	0.04056	-0.04699	-0.47030
DFI	-0.06287	0.68303	-0.04646	**0.10816**	-0.01597	0.00632	0.01733	-0.08529	0.02706	-0.05220	-0.57306
DF	-0.86609	0.08286	-0.04823	-0.00083	**2.08466**	0.00461	0.00268	-0.11313	0.02335	-0.02308	-0.33642
NF	-0.20437	0.33434	-0.00028	0.01460	0.20525	**0.04682**	-0.00148	-0.10420	0.01474	-0.00599	0.11891
IFW	-0.13628	0.26407	-0.02737	0.03984	0.11858	-0.00147	**0.04705**	-0.07947	0.07181	-0.01307	-0.15690
FD	-0.25871	0.19413	-0.03914	0.02496	0.63819	0.01320	0.01012	**0.36955**	0.02151	-0.01307	0.03950
CI	-0.07272	0.27098	-0.02238	0.01528	0.25415	0.00360	0.01764	-0.04151	**0.19153**	-0.04511	-0.42073
XC–I	-0.39130	0.70685	-0.05705	0.06484	0.81594	0.00322	0.00706	-0.05768	0.09924	**-0.08707**	-0.79704
XC–II	0.09549	0.44476	-0.04465	0.05567	0.62992	-0.00500	0.00663	0.01311	0.07238	-0.06233	**-1.11336**

Residual effect = 0.4169638

except number of flowers per plant. The indirect effect of flower diameter on flower yield through Xanthophyll content at fully opened stage (stage II) was positive. Likewise, the colour intensity on flower yield through all the characters studied were positive. The indirect effect of Xanthophyll content at half bud opened stage (Stage I) on flower yield through all the characters studied was negative. While, the Xanthophyll content at fully opened flower stage (Stage II) on flower yield through plant height, number of flowers per plan and flower diameter was positive.

DISCUSSION

Chapter V

DISCUSSION

Present day plant breeding research is more concerned with monogenic and qualitative characters, as these present fewer problems in the development and application of modern techniques. However, complex characters such as yield, time of flowering, suitability for qualitative characters are too important to remain on the sideline for long. To make them more amenable to improvement by conventional and perhaps also modern biotechnological breeding methods, a detailed analysis of their components is required. Many of the characters plant breeders seek to improve are genetically complex. In the present investigation flower yield and Xanthophyll content are the economically important characters which required a detailed analysis and discussion for further improvement.

In the present investigation the data collected from 11 parents and their hybrids were discussed in the following headings:

1. Evaluation of parents
2. Evaluation of hybrids
3. Combining ability
4. Heterosis and
5. Variability studies

Evaluation of parents

i) Mean performance

Parents

Twenty four hybrids synthesised adopting the L x T mating design 3 lines (L_1 to L_3) and 8 testers (T_1 to T_8) were evaluated for their mean performance. Mean performance is a realised value. Hence, it may be employed as the first criterion for selecting superior parents and hybrids (Hepziba, s. Juliet, 1996). Mean performance was taken as a criterion the discussion furnished below. The line L_2 surpassed the remaining lines in performance for almost all characters studied. The line L_3 had displayed its superiority for plant spread, and days to flower initiation. Colour intensity and Xanthophyll content in stage–I and stage–II, the parent L_1 had shown considerable superiority towards performance. Kalloo *et al.* (1974) infact emphasized the importance of mean expression in selecting the parents.

Among the tester parents T_1 established its high performance for flower yield and yield related floral characteristics. It is a valuable parent for yield improvement programme in African Marigold. The next best parent was T_8. It is a worth parent for improvement of individual flower weight, flower diameter and flower yield. When we consider the question of flower colour these 3 parents namely T_2, T_5 and T_6 have to be included in the future breeding programme for colour improvement. The overall consideration of mean performance suggested that the parent L_2, T_1 and T_8 were the best parents for improvement of quantitative characters while, parents T_2, T_5 and T_6 for colour improvement. The parents evaluated based on *per se* performance and *gca* (general combining ability) effects are indicated in the following table for all the characters studied.

Evaluation of parents based on per se and gca effects

S. No.	Characters	Mean performance		gca effects		Per se and gca effects	
		Lines	**Testers**	**Lines**	**Testers**	**Lines**	**Testers**
1.	Plant height (cm)	L_2	T_1, T_2, T_3, T_8	L_2	T_1, T_2, T_6	L_2	T_1, T_2
2.	No. of Branches per plant	L_2	T_1, T_3, T_7	L_2	T_3, T_4, T_5, T_7	L_2	T_3
3.	Plant spread (cm)	L_3	T_4	L_2	T_4	-	T_4
4.	Days to flower initiation	L_2, L_3	T_5	L_1, L_2	T_1, T_3, T_4	L_2	-
5.	Duration of flowering	L_2	T_1, T_2	L_2	T_1, T_2, T_3, T_4	L_2	T_1, T_2
6.	No. of flowers per plant	L_2	T_1, T_3	L_1	T_1, T_3, T_6, T_8	-	T_1, T_3
7.	Individual flower weight (g)	-	T_1, T_2, T_4, T_8	L_2	T_4	-	T_4
8.	Flower Diameter (cm)	L_2	T_3, T_5, T_6, T_8	L_2	T_1, T_3	L_2	T_3
9.	Colour Intensity	L_1, L_2	T_2, T_5, T_6	L_2	T_2, T_4, T_5	L_2	T_5
10.	Flower yield per plant (g)	L_2	T_1, T_4, T_8	L_2	T_1, T_3	L_2	T_1
11.	Xanthophyll content - I (mg g^{-1})	L_1, L_2	T_2, T_5, T_6	L_1, L_2	T_2, T_4, T_5, T_6	L_1, L_2	T_2, T_5, T_6
12.	Xanthophyll content - II (mg g^{-1})	L_1, L_2	T_2, T_5, T_6	L_1, L_2	T_2, T_4, T_6	L_1, L_2	T_2, T_4, T_6

Evaluation of hybrids

The hybrids namely L_2T_3, L_2T_6, L_2T_7, L_3T_2 and L_3T_3 exhibited high mean flower yield. Among the five hybrids the hybrid L_2T_3 exhibited superiority for more number of floral characters. The next best hybrid was L_2T_7. The high mean parents namely L_2 and T_8 failed to produce the best yielding hybrid suggesting, these two parents involved dominant gene action for flower yield. This also indicated that lack of interaction between dominant genes of the involved parents. The same was the case with testers T_1 and T_4. For flower yield influencing characters such as plant height and number of branches the hybrid L_2T_2 had shown high mean performance for plant height and L_2T_2, L_2T_3 and L_1T_4 produced more number of branches.

The parents namely L_2 and T_3 showed highest performance for plant height and number of branches which are flower yield influencing characters. Most of the high performed hybrids had L_2 and T_3 as their parents. This indicated these two parents are not only important for floral characters but also important for yield influencing characters. Hence, these parents may be exploited in any floral yield improvement programme. Besides these parents T_1, T_7 and T_8 were also important for improving plant height and number of branches.

Combining ability analysis

It is normally not possible to deduce about the genotype of an individual in an F_2 population from its own phenotype because of the combined effects of environment, gene distribution, dominance and epistasis. The difference between the mean performance of the progeny of a given male and the mean of the progeny from all the males is called its general combining ability. It reflects howell its genes combined on average with those of all females in the population.

If there is no dominance or epistasis it should be possible to predict the mean performance of the progeny of a cross between ith male and jth female.

The data collected from parents and hybrids were analysed for their combining ability are discussed characterwise here under.

Plant height

In African Marigold, plant height is an important character as it provides ample space for production of branches. In turn, they provide, space for more number of flowers. This trait was under the influence of dominance gene action for its inheritance since the magnitude of *sca* variance was high. Ranga Rao (1983) and Singh and Singh (2000) reported for non–additive gene action for plant height in safflower and sunflower respectively. Reddy (1985) and Gomathy (1994) reported for additive gene action for plant height in African Marigold. In the present investigation, Among the parents L_2 alone registered positive significant value for *gca*. So, it was considered as best combiner for plant height. In case of tester parents T_1, T_2 and T_6 displayed significant and positive value for *gca* effects suggesting they are all good combiners for plant height. Significant and positive *sca* effects were noticed for 8 hybrid combinations namely L_2T_2, L_2T_7, L_1T_1, L_1T_3, L_1T_6, L_3T_3, L_3T_5 and L_3T_8. Among these hybrids, the hybrid L_2T_2 was resulted from parents of the good combiners. This would serve as a valuable source for developing taller genotypes. Reddy (1985) reported that two good combiners resulted for high heterotic effects in its progeny. Another hybrid L_2T_7 which had one good and one poor combiners as its parent. This hybrid may throw transgressive segregants for plant height. Singh and Swarup (1971) reported that one good and one poor combiners resulted in significant *sca* effects.

The remaining best hybrids for plant height had poor combiners as their parents. Since, these hybrids showed dominant gene action for plant height, selection for desirable genotype may be postponed for later generation. Eventhough L_2T_1, and L_2T_6 were best combiners, L_2T_1 and L_2T_6 failed to produce significant *sca* effects indicating lack of interaction between dominant genes of the parents. Such hybrids may be exploited for developing parental genotypes because the involved gene action for plant height was additive gene action.

In the present investigation the genotypes L_2, T_1, T_2 and T_6 were identified as good combiners for plant height. The high performance form the good combiners L_2 and T_2 was noticed in L_2T_2 combination. Besides this combination, most of the cross combinations exhibited high performance for plant height wherever L_2 as one of the parents. Similar performance was noticed in most of the combinations of T_1 and T_6.

Number of branches

In African Marigold the number of branches per plant is one of the deciding factor of its economic importance. It is linearly associated with the production of number of flowers. This was evident from the results of the mean performance of parents (Table 6 and 21) for eg. Parents L_2, T_3 and T_1. The variance ratio of *gca* : *sca* indicated that the number of branches was controlled mostly by dominant gene action. Reddy (1985) and Gomathy (1994) reported for additive gene action and Putt (1944) and Narkhede (1984) reported non-additive gene action in sunflower.

In the current investigation, the combining ability effects showed that L_2, T_3, T_4, T_5 and T_7 were best combiners for number of branches per plant. The close correspondence between mean performance and *gca* effects in parents L_2, T_3 and T_7

indicated that mean performance itself as an indicator for the *gca* effects in these parents. Reddy (1985) reported that high mean performance resulted for high *gca* effects.

Among the hybrids, six combinations recorded positive and significant *sca* effects. The combination L_2T_3 had good combiners as its parents. In this combination simple breeding technique pedigree type of breeding would result desirable significance with more number of branches. The other best hybrids namely L_1T_4, L_1T_6 and L_2T_2 were resulted from good and poor combiners. Singh and Swarup (1971) reported that good and poor combiners resulted in significant *sca* effects. In these combinations parents with both type of gene action namely additive and non-additive effects involved for the inheritance of number of branches. These hybrids in their seggregating generations may produce transgressive seggregants. Selection among these seggregants may express genotype with more number of branches. In the combinations L_3T_1 and L_3T_8 both the parents were poor combiners. In this case involved gene action was non additive. Hence, for obtaining genotypes with more number of branches the selection has to be resorted in the later generations. The best combiners namely L_2, T_4, T_5 and T_7 failed to produce hybrids with significant *sca* effects indicating the lack of interaction among the parental genes. The combinations L_2T_4, L_2T_5 and L_2T_7 may be exploited to mop up favourable genes for more number of branches in the resulting progenies which may be utilized for the increasing the number of branches. The notable hybrid L_2T_3 having good combiners as parents also exhibited high performance for flower yield. Hence, interest is needed to develop these two parents for further exploitation.

Plant spread

The plant spread decides the number of plants to be accommodated in an unit area. The total number of plants per unit area play a major role in the economic return. Further, the plant spread have a logical relation with photosynthetic efficiency. In the present investigation L_2, T_1 and T_8 exhibited such relationship. In these parents low spread and flower yield had a close association but in other parents this logic does not holdgood. The length of the branches may be the reason for the low yield. In the present set of materials the inheritance of plant spread was under the control of dominant gene action as per the *gca* : *sca* ratio. Among the parents L_2, T_3 and T_4 had positive and significant *gca* effects they are the best combiners for plant spread.

Among the hybrids, 7 have recorded positive and significant *sca* effects. The good combiners L_2 and T_3 produced significant *sca* effects for plant spread in their combination. Although both the parents have low spread the hybrid of their combination expressed high plant spread than its parents indicating the lack of interaction among the genes of parents. The other hybrids L_1T_8, L_2T_2, L_2T_5, L_3T_4, L_3T_6 and L_3T_7 showed high and significant *sca* effects. In these hybrids L_1T_8, L_3T_6 and L_3T_7 exhibited low plant spread in their mean performance. For the low spread in these combinations the testers T_6, T_7 and T_8 might have produced substantial role because, L_1 and L_3 exhibited mean performance for plant spread. The parents L_2, T_6, T_7 and T_8 possessed genes for low plant spread. In any ideal low spread plant type development programme these genotypes may serve as a good parental source. The hybrid combination L_3T_4 would yield transgressive segregants in later generations, because T_4 was a good combiner and L_3 poor combiner. Singh and Swarup (1971) reported that one good and one poor combiners resulted in significant *gca* effects.

Days to flower initiation

In any ornamental flowering plants days to flower initiation is considered as an important economic activity. In the present study, the dominant gene action was predominant in determining the days to flower initiation with reference to the variance ratio of *gca* : *sca*. Reddy (1985) reported for additive gene action of this character. Subramanian (1980) and Singh and Singh (2000) reported for non–additive gene action for this character. Among the parents L_3, T_6, T_7 and T_8 were considered as best general combiners as they had significant and negative values for *gca* effects. A close correspondence was noticed between mean performance and *gca* effects in these parents for days to flower initiation. This indicated that mean performance itself had been taken as an indicator for *gca* effects for days to flower initiation. Deshmukh *et al.* (1991) proved that selection of parents in a crossing programme should be on the basis of *gca* effects.

Among the hybrids L_1T_3, L_1T_8, L_2T_6 and L_3T_2 had recorded significant and *sca* effects. Except hybrid L_1T_3 the remaining hybrids had a close agreement with mean performance and negative *sca* effects indicating the best combiners had favourable alleles for days to flower initiation. This is in consonance with the findings of Kumar (1986). These parents namely L_3, T_6, T_7 and T_8 produced early flowering hybrids. Therefore these parents be considered as a valuable source for developing early hybrids in African Marigold breeding programme. Pedigree selection also resulted valuable early seggregants for days to flower initiation. The hybrid L_3T_8 had good combiners as parents. Therefore, the exploitation of this hybrid through pedigree type of selection would yield early flowering segregants. The other hybrid L_1T_6 would throw an array of seggregants for days to flower initiation. Selection among the seggregants of this hybrids would yield desirable early flowering seggregants. The hybrid of poor combiners namely L_2 and T_2 would throw valuable segregants in the later generations. Hence, selection may be postponed to later generations. In the present study revealed that parents L_3 and T_8 were valuable parents for developing early flowering genotypes.

Duration of flowering

In the farmer's point of view this is the most important character in African marigold cultivation. This trait determines the economic return to the farmer. The importance of dominant gene action was observed in this study in the inheritance of duration of flowering. Ranga rao (1983) in safflower and Kumar (1986) reported for non-additive gene action for duration of flowering in African Marigold. Gomathy (1994) reported additive gene action for this character in African Marigold. The combining ability analysis showed that Line L_2 and testers T_1, T_2, T_3 and T_4 were the best general combiners for duration of flowering.

Best general combiners could not produce hybrids with positive significant *sca* effects indicating the lack of interaction among the dominant gene of the parents. Varshney (1985) reported that a cross with high *per se* performance may show low heterosis, but on the other hand, high heterotic response may also be observed in the crosses with low performance. However hybrids of their combinations may serve as a source for developing parental lines with high frequency of favourable alleles. The hybrids L_1T_7, L_2T_6, L_2T_8, L_3T_2, L_3T_3 and L_3T_5 recorded positive and significant *sca* effects. Among these hybrids L_3T_2, L_3T_3 would serve as a source for transgressive seggregants because, their parents were of one poor and one good combiner. This is in consonance with the findings of Singh and Swarup (1971). Therefore selections in their seggregating generations would evil desirable genotypes with longer duration for flowering. The remaining best hybrids involved non-additive gene action for duration of flowering. Hence, selections in the later generations may pave the way for getting seggregants with longer duration flowering genotypes.

Number of flowers per plant

In African Marigold the ultimate economic product is flower. Naturally any breeder would like to get more number of flowers per plant. Hence, genetics of number of flower production is an important factor with regard to African Marigold improvement. The variance ratio between *gca* : *sca* indicated the number of flowers per plant was under the control of non-additive gene action. This is in consonance with the findings of Kumar (1986) in African Marigold. Reddy (1985) reported for additive gene action for this character. The *gca* effects showed that L_1, T_1, T_3, T_6 and T_8 were best combiners for number of flowers per plant. All the best combiners from testers exhibited a close relationship between mean performance and *gca* effects suggesting in these parents the mean itself is an indicator for *gca* effects. The only one best combiner L_1 did not show any linear association with mean performance suggesting the number of flowers per plant in this parent was under the influence of non-additive gene action.

Six cross combinations recorded with significant and positive *sca* effects for this trait. Only one hybrid combination namely L_1T_3 which resulted from best combiners showed significant *sca* effects. This hybrid had the highest number of flower (Table 21). In African Marigold development of this hybrid would serve as a valuable source. Exploitation of this hybrid may also produce desirable seggregants with more number of flowers. The advocated plant breeding technique for exploitation is pedigree. The remaining best hybrids were L_1T_4, L_2T_5, L_3T_1 and L_3T_7. Among these L_2T_8 and L_3T_1 had one poor and one best combiners as their parents. This is in consonance with the findings of Singh and Swarup (1971). Here the possibility of getting desirable seggregants was more because of the combination of poor and best combiner. The reciprocal recurrent selection technique could be utilized for exploiting both additive and non additive gene action in these hybrids. The remaining 2 hybrids namely L_2T_5 and L_3T_7 were resulted from poor combiners for exploiting dominance gene action in these hybrids. Brijendra Singh and Vishnu Swarup (1973) reported that additive gene effects and epistasis dominance x dominance were found to be more predominant in number of flowers. Hence selection may be exercised in later generations.

Individual flower weight

This trait has a direct bearing on the flower yield. The flowers with high weight in African Marigold are always preferable. in the present investigation it was observed that dominance gene action was more important. Brijendra Singh and Vishnu Swarup (1973) observed that non–additive gene action for this character in African Marigold. Reddy (1985) reported for additive gene action. The parents L_2 and T_4 recorded positive and significant *gca* effects. These two parents were not only best combiners but also high performer for individual flower weight. The individual flower weight in these parents were very high (Table 24). Unfortunately their combination did not produce a hybrid with significant *sca* effect indicating the lack of interaction between dominant genes of the parents. The hybrids L_1T_7, L_1T_8 and L_2T_3 recorded positive significant *sca* effects. The hybrid L_2T_3 may throw transgressive segregation in the later generations. Its mean performance also moderately high. If receiprocal recurrent selection method is adopted among the selected genotypes it would be possible to obtain genotypes with high individual flower weight. The other 2 hybrids had dominant gene action for their individual flower weight. To harnesh non-additive gene action selection could be postponed to later generations in these hybrids.

The further improvement of parents of L_2T_3 would result a best hybrid which could be released as hybrid for cultivation.

Flower diameter

This trait has a significant and a positive relationship with number of flowers as well as flower yield. More over in all respects the increased size of flower is a desirable one. Hence, in African Marigold it is one of the important character to be improved. The inheritance of flower diameter depends on non-additive gene action. In the present investigation it was evident from the variance ratio *gca* : *sca*. Subramanian (1980) reported for non–additive gene action for this character. But Shankara and Seetharam (1983) reported for additive gene action for this character in sunflower. Like most other characters, in this also the L_2 recorded significant and positive *gca* effects. The testers T_1 and T_3 had high value for *gca* effects. All the 3 parents namely L_2, T_1 and T_3 were best combiners for flower diameter. The combinations of these parents did not produce significant *sca* effects. However they had high mean performance. If these hybrids subjected to pedigree line of breeding they would produce best parental lines for higher diameter.

The hybrids namely L_2T_5, L_2T_8 and L_3T_3 recorded significant and positive *sca* effects. The hybrids L_2T_5 and L_2T_8 had one parent as best combiner. There is a chance that these hybrids may throw transgressive seggregants. The recommended plant breeding technique for realizing desirable seggregants may be reciprocal recurrent selection. In the hybrid L_3T_7 the inheritance for flower diameter was under non-additive gene action. Selection exercise in the later generation among the seggregants of this hybrid would yield genotypes with larger flower diameter.

Colour intensity

In marigold colour intensity dominated in market preference. The colour intensity is also an indicator for Xanthophyll content. Today's world mostly attracted towards natural products. The natural pigments and colour from African Marigold would have a greater future. Hence, the improvement of pigments and colour of marigold flower is one of the main objectives in any African marigold improvement programme.

This trait is also under the influence of dominance in gene action. Reddy (1985) reported for additive gene action for this character. Significant and positive *gca* effects of L_2, T_2, T_4, and T_5 classified them as best combiners for this trait. None of the best combiners in their combination produced hybrids with significant *sca* effects. This is in consonance with the earlier findings of Varshney (1985). However, all these hybrids expressed high mean colour intensity. If these hybrids were exploited through simple pedigree line of breeding they may produce genotypes with high colour intensity flowers. Heslot (1967) reported that a single dominant gene with modifying inhibitory factors seemed to be responsible in governing the anthocyanin pigments in Marigold. The hybrids L_1T_4, L_1T_5, L_2T_1, L_2T_7 and L_3T_2 showed significant and positive *sca* effects. In these hybrids one of the parents is best combiner. This is in agreement with the previous findings of Singh and Swarup (1971). If reciprocal recurrent selection method employed among the seggregants of these hybrids there may be a possibility to obtain genotypes whose flowers had high colour intensity. Another set of hybrids namely L_3T_1, L_3T_6, and L_3T_7 had high *sca* effects but, their colour intensity mainly depended on non-additive gene action. To exploit this gene action for getting desirable genotypes selection should be exercised in later generations.

Flower yield

The main aim of any plant breeding in any crop is to get higher yield of the economic product. In African marigold the main economic product is flowers. This complex character depends on many characters for its high mean performance. Hence, the direct improvement of this character is little-bit difficult. This complex character sub divided into components to know the reason for positive or negative performance. In the present investigation the contribution of the sub components will be discussed in subsequent pages.

The flower yield per plant mainly depends for its inheritance on dominant gene action. Shankara and Seetharam (1983) reported for non-additive gene action in sunflower. But Gomathy (1994) reported for additive gene action in African Marigold. The parents L_2, T_1, T_3 and T_6 were the best combiners because they expressed high magnitude and significant *gca* effects. The hybrid L_2T_6 showed positive and significant *sca* effects the parents of this hybrid were the best combiners. Reddy (1985) reported that two good combiners resulted for high heterotic effects in its progeny. This hybrid had also higher yield (Table 33). This hybrid may be considered for direct release for cultivation. This hybrid had not only yield but also had significant quality aspects such as colour intensity and Xanthophyll contents (Tables 30, 36 and 39). Hence, in every respect it is one of the best hybrid to be considered for improvement. The hybrids L_1T_1, L_1T_4, L_1T_7, L_1T_8 and L_3T_2 displayed high and significant *sca* effects. The high magnitude of *sca* effects of the hybrid L_3T_2 reflected its highest mean performance for flower yield (Table 33). This is in consonance with the findings of Varshney (1985). Both the parents of this hybrid are poor combiners. The high heterosis for flower yield was resulted from the interactions of the dominant genes of the parents. The only one hybrid namely L_1T_1 which resulted from one poor and one best combiner showed positive and significant *sca* effect. It had moderate high flower yield for realising best parental lines we have to employ cyclic method of plant breeding. The remaining hybrids namely L_1T_4, L_1T_7 and L_1T_8 which had significant *sca* effects were resulted from poor combiners. Selection in the later stages could yield best parental lines for flower yield.

Xanthophyll content stage - I

Unlike chemical ingredients Xanthophyll did not produce any adverse side effects when added to poultry feed. The environmental conscious people now realized the importance of natural products such as Xanthophyll from flowers. So, the modern industries turned its attention to extract Xanthophyll from natural products. African marigold is one of the natural resources for Xanthophyll. So, breeders naturally attracted to improve Xanthophyll content in this crop. The knowledge about the genetic aspects of Xanthophyll content is an important aspect in any African marigold improvement programme. This trait also mainly controlled by non-additive gene action. The lines L_1, L_2 and testes T_4, T_5 and T_6 were the best combiners for this trait (Table 37). The best combiners except L_2, all the best combiners produced significant *sca* effects in their combinations. These combinations namely L_1T_4, L_1T_5 and L_1T_6 are definitely a valuable source for high Xanthophyll content. The mean performance of these hybrids (Table 36) suggested the importance of these hybrids. For further improvement we may get high Xanthophyll content genotypes through simple breeding techniques. The best combiner L_2 could not produce hybrids with high *sca* effect with its best combining testers indicating lack of interaction among parents. However their mean performance were high in order. So, they would serve as a source for developing parental lines through pedigree breeding.

The other best hybrids namely L_2T_1, L_2T_7 and L_3T_8 also exhibited high *sca* effects. But these hybrids are under the influence of dominant gene action. Therefore to exploit this dominance gene action advantageously we have to postponed the selection for desirable seggregants to later generations. This trait is more important to extract Xanthophyll content because we can save atleast a weeks time. Since xanthophyll is extracted at half bud opened stage. Nielson and Bloor (1997) reported that the changes in pigment content associated with colour pattern within flowers, and during floral development from a bud to a fully matured open flower.

Xanthophyll content stage - II

For this trait the gene action and *gca* effect except for T_6 are almost similar as in the case of Xanthophyll content stage I. The diminishing nature of Xanhophyll content during another 7 days was observed in hybrid L_1T_6. The parental mean performance did not show any reduction but in combination namely L_1T_6 showed reduction. This may be due to interaction effect at later stage. The other hybrids L_1T_5 and L_1T_7 repeated their same performance in the stage-II also. Considering Stage - I and Stage - II the hybrids L_1T_4 and L_1T_5 would serve as a valuable source to capitalize this source we have to resort pedigree type of breeding to improve parental source for further breeding. The best combiner L_2 did not show any change its combining capacity with T_4, T_5 and T_6.

The hybrid L_2T_1, L_3T_6 and L_3T_8 significant *sca* effects. Incase of L_2T_1 the cyclic type of breeding decide appropriate one for getting genotypes with Xanthophyll content. In the other 2 hybrids the selection at later stages may yield genotypes with high Xanthophyll content.

Heterosis

The extent of heterosis has been measured as heterosis over mid parent, better parent and the best parent. It was observed that heterosis over mid parent (relative heterosis) was consipicuous for all the characters.

Character	Frequency of positive and significant heterotic combinations over		
	Mid parent	Better parent	Best parent
1. Plant height	–	2	–
2. No. of branches	2	3	3
3. Plant spread	3	4	–
4. Days to flower initiation	22	16	24
5. Duration of flowering	3	4	–
6. No. of flowers per plant	5	6	6
7. Individual flower weight	13	19	12
8. Flower diameter	2	5	12
9. Colour intensity	3	7	2
10. Flower yield per plant	12	12	12
11. Xanthophyll content–I	3	5	3
12. Xanthophyll content–II	2	6	2

The heterosis over the better parent could be a better measure of heterosis for breeding purposes (Mather, 1955, Pathak *et al.*, 1983 and Subbaraman, 1984). The maximum flower yield heterosis in the present investigation over better parent was 56.426 per cent by L_3T_2 and 47.907 per cent by L_3T_3. The parents L_3, T_2 and T_3 were diversed geographically however, heterosis has frequently been related to the degree of genetic diversity of parents crossed (Timothy, 1963 and Vanderberg and Matzinger, 1970, Swarup and Raghava, 1973). The cross combinations which exhibited high heterosis were L_1T_1, L_1T_6 (Plant height), L_1T_4, L_2T_2, L_2T_3 (No. of branches), L_2T_1, L_2T_2, L_2T_3, L_2T_5 (Plant spread), L_3T_2, L_3T_5 (Days to flower initiation), L_1T_3, L_1T_7, L_3T_2, L_3T_3 (Duration of flowering), L_1T_1, L_1T_3, L_1T_4, L_1T_8, L_3T_3 (Number of flowers per plant), L_1T_8, L_2T_3, L_2T_5 (Individual flower weight), L_2T_1, L_2T_3, L_2T_4, L_2T_5 (Flower diameter), L_1T_4, L_1T_5, L_3T_2, L_3T_4 (Colour intensity), L_3T_2, L_3T_3, L_2T_3, L_2T_6 (Flower yield), and L_1T_4, L_1T_5, L_2T_4 (Xanthophyll content). In marigold, the existence of heterosis was reported by Singh and Swarup (1971) for the characters plant height, days for first flowering, duration of flowering, flower size,flower weight and number of flowers. Reddy (1985) reported in African marigold heterosis over better parent in metric traits of plant height, number of branches per plant, days to 50 per cent flowering, flower diameter, flower weight, number of flowers per plant, flower yield per plant and colour intensity. Singh and Swarup (1993) reported in Petunia that the average heterosis was negative for days to flower opening and days to full bloom stage, where negative value indicated early flowering.

However, the F_1 superiority need not be always related to diversity. In the present investigation the parents L_3 and T_7 exhibited high heterosis of flower diameter and colour intensity originated from same area. Singh and Ramanujam (1981) and Singh et al. (1981) observed no relation between heterosis and origin.

Heterosis and combining ability

Arunachalam (1976) concluded that the combining ability analysis could be more reliable since it was not restricted to one gene model and it operated with feasible assumptions. The high magnitude of *sca* variances for the all the characters studied established the importance of non-additive gene action (Table 5).

The above fact indicated the possibility of utilizing cyclic selection for almost all the characters. An evaluation of parents and crosses in terms of genetic components like *gca* and *sca* will be very useful in realizing heterosis. The designation of the African marigold parents as high or low based on their significant *gca* effects over a number of component characters was found very effect (Reddy and Arunachalam, 1981).

In the present study, the ranking of parents for flower yield on the basis of *gca* effects was same as that on the basis of their mean performance except for the parent T_6. The potentiality of a strain to be used as a parent in hybridization or in a cross to be used as a commercial hybrid may be judged by comparing the *per se* performance, the parents, the F_1 value and the combining ability effects (Venkateswaralu and Singh, 1982). The parents L_2, T_1 and T_3 exhibited high status while other parents exhibited low status based on mean performance and *gca* scores. The parents L_2 and T_3 were best general combiners for many component characters studied, failed to exhibit positive significant *sca* effects for flower yield (Table 34). This may be because, of its poor *sca* with each other.

Most of the crosses showing significant and positive *sca* effects had either one good and one poor (or) even negative general combiner. Such crosses could produce desirable transgressive segregants if the additive genetic system present in the good combiner and the complementary epistatic effects in the F_1's at in the same direction to maximize the desirable plant attributes (Venkateswaralu and Singh, 1982). Higher estimates of *sca* effects for yield components were usually recorded in crosses namely L_1T_1 (Plant height), L_2T_3 (Number of branches), L_3T_7 (Number of flowers per plant), L_1T_8 (Individual flower weight), L_2T_8 (Flower diameter) and L_3T_2 (Flower yield) which involved parents having diversed characters. Thus, for production of hybrid variety diverse parents showing high *sca* effects should be chosen. The performance of hybrids in a heterosis breeding is generally assessed by three criteria *viz.*, *per se* performance, heterosis and *sca* effects. Based on these criteria the hybrids are indicated in the following table for all the characters studied.

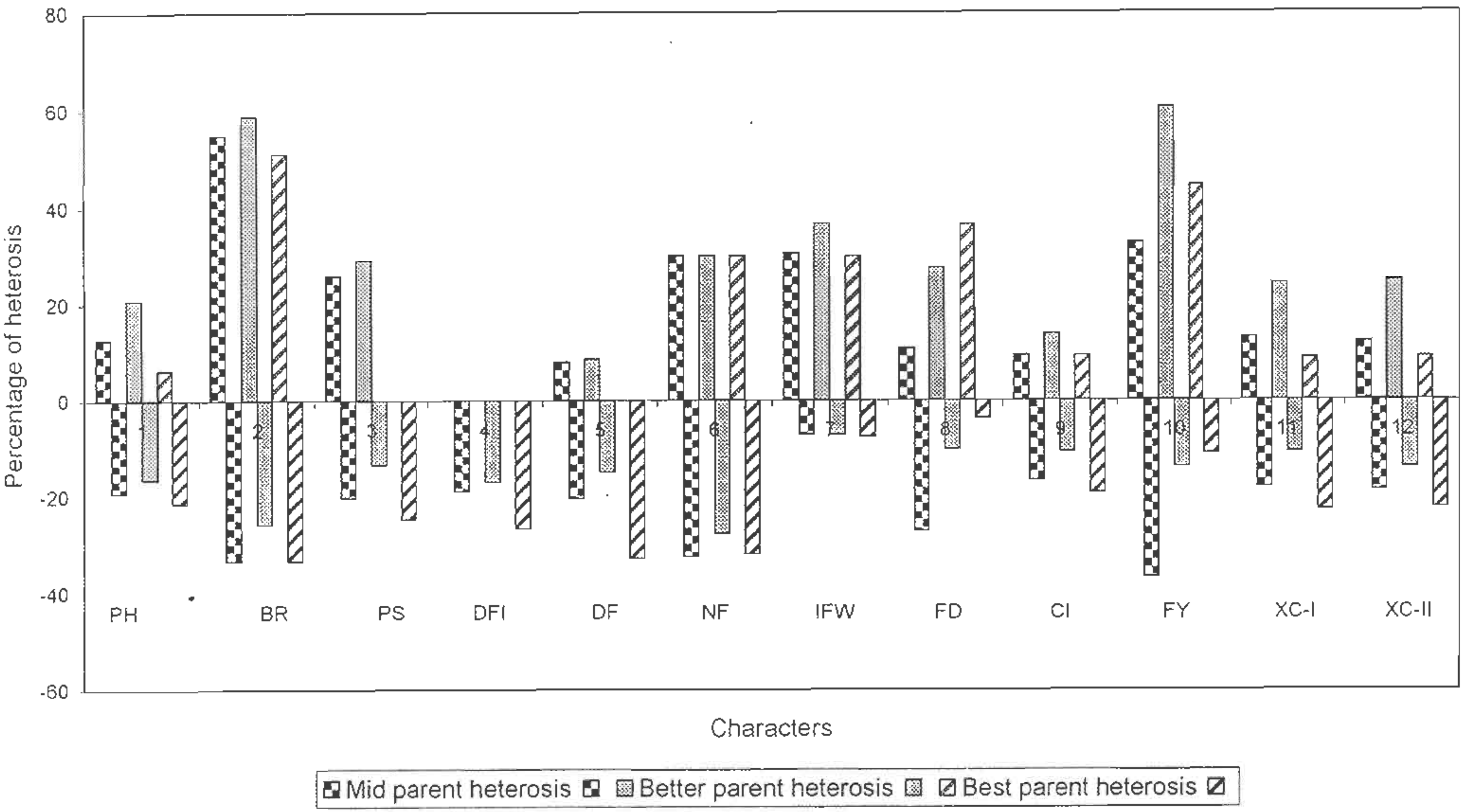
Evaluation of hybrids based on per se, sca and best parent heterosis

S. No.	Characters	per se	Sca	Best parent heterosis	Per se, sca and best parent heterosis
1.	Plant height (cm)	L_2T_2	L_1T_1, L_1T_3, L_1T_6, L_2T_3, L_2T_7, L_3T_3, L_3T_5, L_3T_8	-	-
2.	No. of Branches per plant	L_1T_4, L_2T_2, L_2T_3	L_1T_4, L_1T_6, L_2T_2, L_2T_3, L_3T_1, L_3T_8	L_1T_4, L_2T_2, L_2T_3	L_1T_4, L_2T_2, L_2T_3
3.	Plant spread (cm)	L_2T_2, L_2T_3, L_2T_4, L_2T_5, L_3T_4	L_1T_8, L_2T_2, L_2T_3, L_2T_5, L_3T_4, L_3T_6, L_3T_7	-	
4.	Days to flower initiation	L_1T_1, L_1T_2, L_1T_3, L_1T_4, L_1T_5, L_1T_6, L_1T_7, L_2, T_1, L_2T_2, L_2T_3, L_2T_4	L_1T_6, L_2T_3, L_3T_8	-	-
5.	Duration of flowering	L_1T_1, L_1T_3, L_1T_7, L_2T_1, L_2T_2, L_2T_4, L_2T_6, L_2T_8, L_3T_1,L_3T_3	L_1T_7, L_2T_6, L_2T_8, L_3T_2, L_3T_3, L_3T_5	-	-
6.	No. of flowers per plant	L_1T_1, L_1T_3, L_1T_4, L_3T_1, L_3T_3	L_1T_4, L_2T_5, L_3T_7	L_1T_1, L_1T_3, L_1T_4, L_1T_8, L_3T_1, L_3T_3	L_1T_4
7.	Individual flower weight	L_1T_8, L_2T_2, L_2T_3, L_2T_4, L_2T_8, L_3T_1, L_3T_4,	L_1T_7, L_1T_8, L_2T_3	L_1T_1, L_1T_4, L_1T_7, L_1T_8, L_2T_2, L_2T_3, L_2T_4, L_2T_5, L_2T_6, L_2T_8, L_3T_1, L_3T_2, L_3T_4	L_1T_8, L_2T_3

Contd…

S. No.	Characters	per se	Sca	Best parent heterosis	Per se, sca and best parent heterosis
8.	Flower Diameter (cm)	L_2T_1, L_2T_3, L_2T_4, L_2T_5	L_2T_5, L_2T_8, L_3T_7	L_1T_1, L_1T_3, L_1T_6, L_2T_1, L_2T_3, L_2T_4, L_2T_5, L_2T_6, L_2T_8, L_3T_1, L_3T_4, L_3T_7	L_2T_5
9.	Colour Intensity	L_1T_4, L_1T_5, L_2T_1, L_2T_2, L_2T_4, L_2T_6, L_2T_7, L_2T_8, L_3T_2, L_3T_6	L_1T_4, L_1T_5, L_2T_1, L_2T_7, L_3T_1, L_3T_2, L_3T_6, L_3T_7	L_1T_4, L_1T_5	L_1T_4, L_1T_5
10.	Flower yield/plant (g)	L_1T_1, L_1T_4, L_1T_8, L_2T_3, L_2T_6, L_2T_7, L_3T_2, L_3T_3	L_1T_1, L_1T_7, L_1T_8, L_2T_6, L_2T_7, L_3T_2	L_1T_1, L_1T_3, L_1T_8, L_2T_1, L_2T_3, L_2T_6, L_2T_7, L_2T_8, L_3T_1, L_3T_2	L_1T_1, L_1T_8, L_2T_6, L_2T_7, L_3T_2
11.	Xanthophyll content - I (mg g^{-1})	L_1T_2, L_1T_4, L_1T_6, L_2T_1, L_2T_2, L_2T_4, L_2T_5, L_2T_6, L_2T_7	L_1T_4, L_1T_5, L_1T_6, L_2T_1, L_2T_7, L_3T_8	L_1T_5, L_1T_6	L_1T_6
12.	Xanthophyll content - II (mg g^{-1})	L_1T_4, L_1T_5, L_1T_7, L_1T_8, L_2T_1, L_2T_2, L_2T_3, L_2T_4, L_2T_5, L_2T_7	L_1T_4, L_1T_5, L_2T_1, L_3T_6	L_1T_4, L_1T_5	L_1T_4, L_1T_5

Fig. 2. Range of heterosis for different characters



Association Analysis

Hybridization pursued by choice is a common procedure among the breeding strategies. The genetic potential of a seggregating population can be evaluated by the mean performance of the population itself and in comparison with the parents. In the present study F_2'S of the cross combinations along with their parents were assessed for their mean performance and genetic parameters that have emphasis on the contribution of various component characters to flower yield.

The availability of a rich source of variants lends scope to exercise desirable selections. However the maintenance and the ability of expression of a particular character of the desiderata in succeeding generations are vested in efficient genetic selection. This is achieved by disuniting the observed variability as due to heritable and non-heritable components, aided by the genetic parameters such as genotypic and phenotypic co-efficents of variation and heritability per cent in broad sense.

The present study brought out the existence of high degree of variability in the features like flower yield, number of branches per plant, plant spread, number of flowers, individual flower weight, flower diameter, Xanthophyll content stage - I and Xanthophyll content stage - II in the F_2 generation. The phenotypic variability was more than 23 per cent for flower yield and 29 per cent for number of branches and the remaining characters displayed more than 10 per cent. High variability was observed by Singh *et al.* (1999) for flower yield and low for plant height. Janakiram and Rao (1992) observed high variability for plant height, flower weight, number of branches and flower size. The high phenotypic co-efficient of variability obtained here in for the above also revealed a close correspondence of high genotypic co-efficient of variation, a fact indicative of wide genetic seggregation in the F_2S. Owing to their high genotypic co-efficient of variability, these characters offer scope for selection than the other traits. The attributes like plant height, days to flower initiation, duration of flowering and colour intensity exerted a comparatively low degree of variability as evidenced from the low phenotypic co-efficient of variability. Despite the low PCV values these characters also showed larger proportion of genotypic co-efficient of variability (Table 46). Expression of low degree of variability is in confirmity with the results of Mahanta *et al.* (1998) in gerbera and Singh *et al.* (1999) for plant height in African Marigold.

The estimate of heritability measures the ability of expression of a trait. It is the ratio of genetic variance to the total variance (Allard, 1960). In the present study heritability value computed in broad sense showed high estimates in all the yield components including yield. This is in consonance with the previous findings of Reddy (1985), Kannan (1990), Janaki Ram and Rao (1994), Singh *et al.* (1999), Nand Kishore and Raghava (2001).

The estimate of high heritability does not always signify an increased genetic advance (Reddy, 1985). In order to envisage the relative utility of genetic progress among the yield and its components, genetic advance as per cent of mean was computed. It was observed that the estimates of genetic advance as per cent of mean were high for number of branches per plant, flower yield, number of flowers, flower diameter and Xanthophyll content Stage - I and could be ascribed to additive gene effects. These results are in consistency with findings of Reddy (1985), Kannan and Seemanthini Ramdas (1990) for number of flowers per plant, Janaki Ram and Rao (1992) for number of flowers per plant and flower weight, Mahanta *et al.* (1998) for days to flower initiation, Anuradha and Gowda (1999) for flower diameter, Singh *et al.* (1999) for weight of flower and flower yield, Nandkishore and Raghava (2001) for flower weight. It is significant and of interest to note that the genetic advance expressed as per cent of mean was high for flower yield *per se*. This would indicate a dependable measure of selection. Flower yield as a reliable measure of selection in seggregating population was also reported by Reddy (1985) and Kumar (1986).

Hybridization pursued by choice is a common procedure among the breeding strategies. Studies on the inter relationship of component characters of yield as provided by correlation studies present information about the likely consequences of selection for simultaneous improvement of desirable characters under selection. The situation is further explicable by path analysis, proposed by (Wright, 1921) and as illustrated by Dewey and Lu (1959) which is an efficient biometrical tool throwing light on the contribution (Direct effect) of a character to the flower yield and also its influence (Indirect effect) through other characters.

The high direct effect of plant height in path analysis connoting that the increased plant height was helpful in the formation of number of branches, number of flowers, flower weight and flower diameter, there by leading to the result of significant and positive associations with flower yield. All the three characters namely number of branches per plant, flower weight, flower diameter substantial indirect contribution thorough plant height while number of flowers per plant exhibited high indirect contribution through flower diameter. The low values of residual effect obtained in the present study is attributable to unresolved factors in the path analysis and substantiate that the characters studied were appropriate (Dewey and Lu, 1959). From path analysis it could be inferred that selection could be combined for flower yield with plant height, number of branches, flower weight and flower diameter.

SUMMARY

Chapter VI
SUMMARY

The present study was undertaken to assess the breeding value of African marigold genotypes for use as parents in hybridization programme and to study the genetic architecture of economic characters. A line x tester analysis was undertaken utilizing eleven parents (3 parents as lines and 8 parents as testers) and their 24 hybrids. The hybrids, besides their parents were studied for combining ability, heterosis, correlation and path analysis for 12 important economic characters.

The important findings are presented below:

1. Analysis of variance of parents and hybrids clearly revealed the presence of significant differences among the genotypes tested for all characters studied.
2. The analysis of variance for combining ability showed significant differences among the lines, testers and line x tester interaction for all characters except plant spread and individual flower weight.
3. Based on *per se* performance, parent L_2 (Pusa Narangi Gainda) was found to be the best for all the characters except individual flower weight. L_1 (Pollachi Local) was best for colour intensity and Xanthophyll content and L_3 (Nilakkottai Yellow) was best for days to flower initiation. Among the testers, T_2 (Bangalore Local) performed best for most of the characters. T_1 (Yellow Treasure), T_4 (Cracker Jack Mix) and T_8 (Rajapalayam Local) for flower yield and T_2 (Bangalore Local), T_5 (Orange Treasure), T_6 (Madurai Local) were best performers for Xanthophyll content.

4. The female parent L_2 (Pusa Narangi Gainda) was the best general combiner for all the characters except number of flowers per plant. The parent L_1 was best for Xanthophyll content days to flower initiation and number of flowers per plant.

5. Based on the *per se* performance of hybrids, the cross L_2T_3 (Pusa Narangi Gainda x Pusa Basanthi Gainda) was best for number of branches per plant, plant spread, days to flower initiation, individual flower weight, flower diameter, flower yield per plant and Xanthophyll content - Stage II.

6. Based on sca effects L_2T_3 (Pusa Narangi Gainda x Pusa Basanthi Gainda) was best for plant height, number of branches per plant, plant spread, days to flower initiation and individual flower weight. The cross L_2T_1 (Pusa Narangi Gainda x Yellow Treasure) was best for colour intensity and Xanthophyll content in both the stages. The crosses L_1T_1 (Pollachi Local x Yellow Treasure), L_1T_4 (Pollachi Local x Cracker Jack Mix), L_1T_7 (Pollachi Local x MDU–1), L_1T_8 (Pollachi Local x Rajapalayam Local), L_2T_6 (Pusa Narangi Gainda x Madurai Local) and L_2T_7 (Pusa Narangi Gainda x MDU–1) were found to be best for high flower yield per plant.

7. Based on the best parent heterosis (diii) cross L_2T_3 (Pusa Narangi Gainda x Pusa Basanthi Gainda) was the best for number of branches, individual flower weight, flower diameter and flower yield per plant. The crosses L_1T_1 (Pollachi Local x Yellow Treasure), L_1T_3 (Pollachi Local x Pusa Basanthi Gainda), L_2T_6 (Pusa Narangi Gainda x Madurai Local), L_2T_8 (Pusa Narangi Gainda x Rajapalayam Local) and L_3T_1 (Nilakkottai Yellow x Yellow Treasure) were found to be best for flower diameter and flower yield per plant. The crosses L_1T_4 (Pollachi Local x Cracker Jack Mix) and L_1T_5 (Pollachi Local x Orange Treasure) were best for colour intensity and Xanthophyll content.

8. Based on the per se performance, sca effects and best parent heterosis, the crosses L_1T_1 (Pollachi Local x Yellow Treasure), L_1T_8 (Pollachi Local x Rajapalayam Local), L_2T_6 (Pusa Narangi Gainda x Madurai Local), L_2T_7 (Pusa Narangi Gainda x MDU–1) and L_3T_2 (Nilakkottai Yellow x Bangalore Local) were best for flower yield. The crosses L_1T_4 (Pollachi Local x Cracker Jack Mix) and L_1T_5 (Pollachi Local x Orange Treasure) are best for colour intensity combined with Xanthophyll content.

9. Among the 24 hybrids most of the hybrids were found to suitable for recombination breeding and reciprocal recurrent selection.

10. The magnitude of general combining ability was lesser than the specific combining ability for all the 12 characters studied indicating the role of non-additive gene effects.

11. The crosses L_2T_3 (Pusa Narangi Gainda x Pusa Basanthi Gainda), L_2T_6 (Pusa Narangi Gainda x Madurai Local) and L_3T_2 (Nilakkottai Local x Bangalore Local) had high mean performance besides high variability in F_2 generation for flower yield per plant.

12. Heritability components in broad sense showed high estimates in all the yield contributing components including yield. Heritablity was found to range between 50.15 (duration of flowering) and 96.61 (flower yield) per plant.

13. The estimates of genetic advance as per cent of mean were high for number of branches per plant (47.04), flower yield per plant (22.64), number of flowers per plant (22.97), flower diameter (22.64) and xanthophyll content (22.66).

14. Correlation studies indicated that the characters plant height and duration of flowering had direct positive significant correlation and none of the character found negative correlation with yield.

15. Path analysis revealed that the characters namely, plant height, individual flower weight, days to flower initiation, number of branches and flower diameter had direct positive effect on yield. In F_2 generation all the characters had positive direct effect on flower yield. From path analysis it could be inferred that selection could be combined for flower yield with plant height, number of branches per plant, flower weight and flower diameter.

L_2T_3

(Pusa Narangi Gainda x Pusa Basanthi Gainda)

Plate 1 Best hybrid for high flower yield

L_2T_6

(Pusa Narangi Gainda x Madurai Local)

Plate 2 Best hybrid for high flower yield

L_1T_4

(Pollachi Local x Cracker Jack Mix)

Plate 3 Best hybrid for colour intensity combined with xanthophyll content

L_1T_5

(Pollachi Local x Orange Treasure)

Plate 4 Best hybrid for colour intensity combined with xanthophyll content

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* Originals not seen.

APPENDIX

APPENDIX – I

Parentage of the crosses

L_1T_1 – Pollachi Local x Yellow Treasure
L_1T_2 – Pollachi Local x Bangalore Local
L_1T_3 – Pollachi Local x Pusa Basanthi Gainda
L_1T_4 – Pollachi Local x Cracker Jack Mix
L_1T_5 – Pollachi Local x Orange Treasure
L_1T_6 – Pollachi Local x Madurai Local
L_1T_7 – Pollachi Local x MDU–1
L_1T_8 – Pollachi Local x Rajapalayam Local

L_2T_1 – Pusa Narangi Gainda x Yellow Treasure
L_2T_2 – Pusa Narangi Gainda x Bangalore Local
L_2T_3 – Pusa Narangi Gainda x Pusa Basanthi Gainda
L_2T_4 – Pusa Narangi Gainda x Cracker Jack Mix
L_2T_5 – Pusa Narangi Gainda x Orange Treasure
L_2T_6 – Pusa Narangi Gainda x Madurai Local
L_2T_7 – Pusa Narangi Gainda x MDU–1
L_2T_8 – Pusa Narangi Gainda x Rajapalayam Local

L_3T_1 – Nilakkottai Yellow x Yellow Treasure
L_3T_2 – Nilakkottai Yellow x Bangalore Local
L_3T_3 – Nilakkottai Yellow x Pusa Basanthi Gainda
L_3T_4 – Nilakkottai Yellow x Cracker Jack Mix
L_3T_5 – Nilakkottai Yellow x Orange Treasure
L_3T_6 – Nilakkottai Yellow x Madurai Local
L_3T_7 – Nilakkottai Yellow x MDU–1
L_3T_8 – Nilakkottai Yellow x Rajapalayam Local
