HETEROSIS AND COMBINING ABILITY STUDIES IN MAIZE (*Zea mays* L.)

A thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI-413 722, DIST. – AHMEDNAGAR,
MAHARASHTRA STATE, INDIA

By

TODKAR LEENA PRAKASH
(Reg. No. 01169)

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL BOTANY
(CYTOGENETICS AND PLANT BREEDING)

DEPARTMENT OF AGRICULTURAL BOTANY
MAHATMA PHULE KRISHI VIDYAPEETH
COLLEGE OF AGRICULTURE, PUNE
MAHARASHTRA, INDIA

2003

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AFFECTIONATELY DEDICATED

TO MY BELOVED

HUSBAND ***'SATISH'*** *AND DAUGHTER*

SHWETA

... LEENA

CANDIDATE'S DECLARATION

I hereby declare that this thesis entitled " Heterosis and combining ability in Maize (*Zea mays* L.)" or part there of has not been submitted by me or any other person to any other University or Institute for Degree or Diploma.

Place : Pune- 411 005
Dated :27/ 6/ 2003

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CERTIFICATE

This is to certify that the thesis entitled "Heterosis and combining ability studies in Maize (*Zea mays* L.)" submitted to the faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar for the award of degree of **MASTER OF SCIENCE (Agriculture)** in **Agricultural Botany (Cytogenetics and Plant Breeding),** embodies the results of a piece of *bona fide* research work carried out by **Miss Todkar Leena Prakash** , under my guidance and supervision, and that no part of the thesis has been submitted for any other Degree or Diploma.

The assistance and the help received during the course of this investigation have been acknowledged.

Place: Pune
Dated:२7/०८ 2003

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CERTIFICATE

This is to certify that the thesis entitled " Heterosis and combining ability studies in Maize (*Zea mays* L.)" in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture)** in **Agricultural Botany (Cytogenetics and Plant Breeding),** embodies the results of a piece of *bona fide* research work carried out by **Miss. Todkar Leena Prakash** , under the guidance and supervision of **Dr. P. A. Navale,** Associate Professor of Agril. Botany, College of Agriculture, Pune -5 and that no part of the thesis has been submitted for any other Degree or Diploma.

Pune- 411 005.
Date : 30 / 6 / 2003

Dr. R. V. Wuike

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Place: Pune

Date:

(Ms. Todkar Leena P.)

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ABSTRACT

HETEROSIS AND COMBINING ABILITY STUDIES IN MAIZE

(*Zea mays* L.)

by

LEENA PRAKASH TODKAR

A candidate for the degree of

Master of Science (Agriculture)

in

CYTOGENETICS AND PLANT BREEDING

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Research Guide : Dr. P.A. Navale

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Major field : Cytogenetics and Plant Breeding

The investigation on "Heterosis and combining ability studies in maize (*Zea mays* L.)" was carried out with an aim to study the heterosis, combining ability, gene action, heritability and correlation between yield and yield contributing characters. Four lines and ten testers were intermated during *kharif*, 2002 and the resulting 40 hybrids were evaluated along with parents and two Standard Check at Botany Farm, College of Agriculture, Pune, in Randomized Block Design with three replications during rabi, 2002.

Mean sum of squares due to lines were significant for the all the characters except number of cobs per plant and ear length while sum of squares due to testers w ere highly significant for days to 50 per cent silking, plant height and 100 grain weight. However, for L x T interaction the mean sum of

squares were highly significant for all the characters except for days to 50 per cent silking, plant height and number of cob per plant.

The combination CM 117 x GPM 328 recorded the highest and significant heterosis over better parent (78.00%) for grain yield per plant. It also recorded the best *Per se* performance. The characters plant height followed by 100-grain weight, days to 50 per cent silking and ear girth showed maximum frequency of significant heterobeltiotic crosses whereas, maximum frequency of standard heterosis was observed for shelling percentage.

The combinations, CM 117 x GPM 328 (plant height, ear girth, 100 grain weight and grain yield per plant), GPM 222 x CML 139 (days to 50 per cent silking), CA00106 x GPM 276 (ear length), GPM 201 x GPM 257 (number of grains per ear), exhibited highly significant and high heterobeltiotic effects for respective characters.

Among the females GPM 201 (plant height, number of cobs per plant, ear girth, number of grain rows per ear, 100 grain weight and grain yield per plant), GPM 222 (days to 50 per cent silking, ear length, grain yield per plant), CM 117(number of grains per ear and shelling percentage) and among male parents GPM 302 (plant height, number of cobs per plant, number of grains per ear and grain yield per plant), CML 139 (days to 50 per cent silking) and LM-6 (100 grain weight, grain yield per plant), GPM 328 (ear length), GPM 257 (ear girth), GPM 276 (shelling per cent) were identified as best general combiners for the respective characters.

The combination CA 000106 x XOB 2276 followed by CM 117 x GPM 276 exhibited significant sca effect for grain yield per plant. Similarly the combination CA 00106 x GPM 257 (days to 50 per cent silking), CA 00106 x LM-6 (plant height), GPM 201 x GPM 257 and GPM 201 x CML 139 (number of cobs per plant), CA 00106 x GPM 276 (ear length), CA 00106 x GPM 328 (ear girth), GPM 201 x XOB 2228 (number of grain rows per ear), GPM 201 x GPM 257 (number of grains per ear), GPM 222 x LM 6 (shelling percentage), CA 00106 x XOB 2276 (100 grain weight) exhibited highly significant and maximum sca effects for the respective characters.

The sca variances were higher than gca for all the characters under study except days to 50 per cent silking indicating the role of nonadditive gene action in the expression these characters whereas, additive gene action for days to 50 per cent silking. The heritability estimates were of high magnitude in respect of, days to 50 per cent silking (73.90%), 100 grain weight (73.89%), grain yield per plant (73.63%) and ear length (69.10%). The grain yield per plant was positively associated with days to 50 per cent siking, ear length, number of grains per ear, number of cobs per plant, number grain rows per ear and 100 grain weight.

Based on the present studies it may be concluded that the hybrids CA 00106 x XOB2276, GPM 201 x GPM 257, CM 117 x GPM 276 and GPM 222 x LM-6 could be used to exploit heterosis and therefore, recommended for multilocation evaluation. The female parent GPM 201 and male parent GPM 302 were identified as the best combiners and could be used in various breeding programmes for improvement in maize.

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INTRODUCTION

1. INTRODUCTION

Maize (*Zea mays* L.) is popularly known as corn. It is a well known cereal crop of global importance. It belongs to the family Gramineae (Poaceae), Tribe-Maydeae. *Zea mays* is the only species in genus, Zea. It is deploid species with 2n=20. Tripasacum (Gama grass) 2n=18 and Teosinte *(Euchleana spp.)* 2n=36 are the two close relatives.

Corn is queen of cereals as it has C_4 photosynthetic pathway, which is more efficient than C_3 under high temperature and dry land conditions, therefore, it is the most productive in terms of food nutrients produced by unit land area, per unit of water transpired and per unit of time.

Central America (Mexico) is the origin of maize. The exact origin is not known so far. It is the native of America from where it was introduced in South East Asia by Portuguese traders in about 16th century.

Maize is one of the most important well-known coarse grain cereal crops of the world. It is the world's 2nd leading cereal crop after wheat. It contributes about 20 per cent of total world cereal production. America ranks first in production of maize, which is equivalent to the value of wheat, oat, rice, ragi and sorghum production in America.

It's easy adaptability in varied agroclimatic conditions and a high yielding potential are the prime reasons for its large-scale expansion.

Today maize has become all season crop in India and being cultivated all over India particularly in the states of Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Punjab, Andra Pradesh, Himachal Pradesh, West Bengal, Karnataka and Jammu and Kashmir. These states jointly contribute 95 per cent of national maize production. In India it is grown on area of 6.55 million hectares with annual production of about 11.84 millon tones with average yield of 18.06 quintals/hectare. In Maharashtra the area under maize is increasing very fast. In Maharashtra the area under maize is 3,26,100 hectare with annual production of about 5,86,900 tonnes with average yield of 18 quintals per hectare in year 2000-2001 (Anonymous, 2001). It is grown as sole as well as an intercrop in sugarcane, paddy and turmeric during *kharif* and rabi season. In Maharashtra maize is largely grown in Solapur, Satara, Pune, Sangli, Kolhapur, Ahamednagar, Nasik and Dhule districts.

Maize is important staple food grain crop as it contains fairly good amount of carbohydrates (starch), proteins, fats and minerals, which are important in human diet. It is one of the best source of starch due to its high starch content of 66.2 per cent along with 11 per cent of protein, 3.6 per cent of fat, 2.7 per cent crude fiber, iron 0.11 mg/100g grains, 1.5 per cent mineral matter, calcium 20 mg/100g and vitamin (thiamine 0.05 mg, riboflavin 0.08 mg, ascorbic acid 11 mg/100g). Maize is only cereal crop, which contains maximum 4 to 7 per cent oil. It is also now emerging as source of edible oil due to high unsaturated fatty acid content. This oil is emerging good to the heart patient.

Principle types of maize are dent, flint, pod, pop, soft or flour, sweet and waxy corn. The floury and opaque are nutritional quality types contains high tryptophan and lysine.

Maize has great worldwide significance as human food, animal feed and as a source of large number of industrial products. Maize is the only cereal, which can be used as food at various stages of development of plant. It is used as baby corn as soon as the plant flowers. Green ears of maize are used on large scale for roasting and boiling and consumed as a food at dough stage.

Maize is an important cereal fodder crop, on account of its high albuminoid and fat contents, it is valuable cattle feed in terms of green fodder as it is highly succulent, palatable and digestible. Chemical composition of green fodder consist of protein (5%), crude protein (31.9%), oil (4.1%), mineral (6.0%) and carbohydrates (52.8%).

Maize is critically vital and versatile energy source in compound animal feed, particularly poultry feed. Besides metabolic energy, maize is rich in xanthophyll (vit-A) content. No other substitute to maize has this content. One kg of maize gives us 3400 k.cal metabolic energy, 90 g protein, 40 g oil and 2.4 g amino acids.

Maize is gaining importance now a day as a food crop in India. Besides its importance as a food grain crop, it has a significant commercial importance in India Economy. It has number of industrial uses. Maize is used as raw material for developing industries like manufacture of starch, alcohol, glucose, paper adhesives, synthetic rubber, resins, acetic acid and lactic acid etc, the demand for which is increasing day by day. Maize starch is used in pharmaceutical, food, textile, chemical, paper, foundry, and fermentation industries. Maize liquid glucose is used in pharmaceuticals, confectionery and soft drinks.

Maize grains are used for making various alcoholic beverages. The fibre in stalks have been used for making paper and yarn. The pith is used for making explosives as light packing material and formerly for upholstery and the inner husk for cigarette papers.

Zein protein in maize being used in artificial fibre with good tensile strength and wool like properties.

Maize an allogamous crop belongs to genus *Zea* Maize is the largest of the cereals, a tall erect, annual grass attaining a height from 2 to 3 meter high (maximum 7 meters) produces single leaf at each node. Stem is round to oval green divided into nodes and internodes. Jointed stem is solid and contains good amount of sugar when young. Leaves are alternative, distichous, simple linear lanceolate. Each leaf consists of sheath surrounding stem and an expanded leaf blade connected to the sheath by a blade joint. The number of leaves may vary from 4 to 48.

Maize is monoecious plant in which male and female flowers are present on the same plant but at different positions. Due to its protoandrous nature of flowering maize is highly cross pollinated.

The male inflorescence is terminal panicle called tassel and the female inflorescence is pistillate an axillary spadix called ear or cob. The panicle has central axis with several rows of paired spikelets and a few lateral branches with only two rows of paired spikelets. One of the each pair of spikelet has a pedicel while other is sessile. Each spikelet consists of 2 flowers in subtended at the base by pair of glumes. The glumes are almost equal in size densely covered with minute hairs, the outer or lower one, more or less, overlapping the other. Each flower has two opposite bracts the lemma and palea. The two lodicules are present at the base of the lemma. Three stamens, filament long with two lobed versatile anthers.

The female inflorescence known as 'cob' or 'ear' arises about midway at a node on the main stalk. It is considered as modified lateral branch originating from axillary bud on main stem. The internodes of this lateral branch are telescoped to form a stout axis from the lower node of this axis modified leaves in the form of overlapping sheaths cover the inflorescence. These are called as 'bract'/ 'spathe' or 'husk'. On the ear shoot pistillate spikelets are born in pairs in longitudinal rows. Each spikelet has two flowers one fertile and one sterile. This results in an even number of rows of kernels on the ear. The hair like structure emerging from the top of husk are called as silk, functions both as stigma and style as it is receptive to fresh pollen grains through out the entire length.

Under natural condition maize is cross pollinated as about 95 per cent of the pistillate flowers on a cob receive pollen from near by other plants and about 5 per cent of the kernels are as a results of self pollination. Maize is protandrous in which pollen shedding normally begins 1 to 3 days before the emergence of silk and continues 3 to 4 days after silks are ready to be pollinated. It has been estimated that a single tassel may produce as many as 25,000,000 pollen grains. Pollengrains remains viable for 12 to 18 hours.

Exploitation of hybrid vigour in maize has been recognized as practical tool in providing the breeders a mean of increasing yield. For developing promising varieties through hybridization, the choice of parents is matter of great concern to the plant breeder. A high yielding genotype may or may not transmit its superiority to its progenies. Therefore, the success of breeding programme is determined by useful gene combination in the form of high combining types.

New cultivars of maize have been developed by some workers. However, they possess one or the other demerits. The improvement in maize needs attention for the characters like days to flowering, number of cobs per plant, ear length, ear girth, high yield and disease and pest resistance.

Understanding the nature of gene action governing the expression of various traits could be helpful in predicting the effectiveness of selection. The efficient pqrtioning of genetic variances into its components namely additive, dominance and their interactions will help in formulating an effective and sound breeding programme. The cases where hybrid seed cost is of greater importance, the use of additive gene effects of parents could be used to retrain the vigour or to exploit hybrid vigour. The breeding material should perform consistently and for that adaptability of the material is an important factor.

Considering the importance of the crop, there is need to generate more information on heterosis, combining ability, nature of gene action, heritability, correlation and adaptability of varieties. With these views the present investigation is planned with the following objectives;

1) To study the magnitude of heterosis in respect of yield and its component characters.
2) To study the general and specific combining ability of the parents and crosses respectively for different characters.
3) To identify best general combiners and best cross combinations for yield and various attributes.
4) To study the nature of gene action for yield and yield contributing traits.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Several studies have been conducted in maize for yield improvement, earliness and other desirable quantitative and qualitative characters. Hybrid development programmes are aimed at increasing the maize yield globally. Studies on hybrid vigour, combining ability and correlations are important in deciding the breeding methodology for the crop under experimentation. The published information, improvement of maize is reviewed and broadly categorized under following sub headings in this chapter.

1) Heterosis
2) Combining ability
3) Heritability and gene action
4) Correlation.

2.1 Heterosis

The phenomenon of heterosis is of wide spread occurrence in the field of biological sciences. It has been exploited both in plants and animals and is being utilized on commercial scale. It has immense practical utility in the varietal improvement.

Heterosis refers to the superiority of F_1 (hybrids) in one or more characters over its parents in other words increase or decrease in fitness or vigour of F_1 over the parental value.

Hybrid vigour in plant was first reported by Kolreuter (1876) who realized that the hybrid vigour results not mearly from crossing but from the union of unlike germplasm.

Ganguli *et al.* (1989) studied 33 hybrids with parents in Line x Tester design. Positive heterosis over better parent was observed for grain yield, ear length, ear girth and negative heterosis for days to silking and plant height. Best crosses were Tuxpeno PBC 17 x CM 600 for yield, Tuxpeno PBC 17 x Laxmi for plant height and ear length and (Changez x JBS) x CM 600 for days to silking.

Tomov *et al.* (1990) while studying 21 hybrids from a diallel set of crosses reported the highest heterosis for ear length and plant height; heterosis was also detected for protein and oil content in the grain.

Aulicino and Magoja (1991) observed high heterosis for most of the characters. Babitskii (1991) revealed that heterosis in the hybrids was associated with greater number of functioning genes present in the lines.

Kocova (1992) reported three hybrids with marked heterosis for yield, two hybrids with less marked heterosis and six hybrids with moderate heterosis for yield.

Vasal *et al.* (1992) while studying combining ability and heterotic pattern among CIMMYT's maize germplasm observed the highest yield in subtropical environments by Population 48 x Pool 27. Better parent heterosis was observed in Population 46 x Pool 130 to the tune of 13 per cent.

Alvarez *et al.* (1993) noted high heterosis value (34%) for grain yield (6.9 t/ha) and also clear heterosis for plant and ear height (7 and 15%, respectively). High heterosis values were also obtained for ear girth, grains per ear and grain weight, while days to silking and number of kernel rows gave negative values.

Stastny (1993) reported superiority of BC 2142 x BC 910 for grain yield and its component traits over standard hybrid. It showed possibility of developing superior heterotic group.

Feng *et al.* (1994) reported that two cultivars produced yield of 11 and 12 t/ha, respectively, which was 8 to 11 per cent higher than that of better parent and control.

In Line x Tester analysis Gupta *et al.* (1994) reported that sixteen of the hybrids gave better yield than the best standard check Shweta.

In breeding of inter synthetic hybrids to exploit heterosis in maize, Vasal *et al.* (1994) reported that inter synthetic yielded 7050 to 7650 kg/ha and these were at par with single cross standard for grain yield, days to silking and plant height. All inter synthetic hybrids were significantly higher yielders than the better parent synthetic as well as the best synthetic. The average better parent heterosis was 19 per cent.

Nagda *et al.* (1995) studied 20 maize hybrids resulting from a 10 lines and two testers crossing programme together with commercial standard check Arun for grain yield where 14 crosses showed significant negative heterosis for days to silking.

Information on heterosis for ten yield related traits in ten maize genotypes was derived by Rao *et al.* (1996). The result showed that yield from the crosses AB male bulk x Composite V2 and Hemant x CIMMYT Pool 23 were significantly higher than controls namely Vijay Composite and Deccan 103.

Sinha and Mishra (1997) showed that the cross Navin x Population 26 gave the highest grain yield and was the most heterotic combination.

A line x tester analysis studies conducted by Sain Dass *et al.* (1998) revealed that only eight crosses showed standard heterosis for grain yield, over standard check-Pratap, while, 23 crosses showed standard heterosis over the best check KH 510. Heterotic responses obtained over better parent were more realistic.

Konak *et al.* (1999) while estimation of combining ability effects, heterosis and heterobeltiosis in Line x Tester analysis reported that the crosses N-74 x IDRN Cornell, H-96 x ALKED-222, N-74 x W-552, A- 69 x W-552, DN-B x IDRN Cornell and H-96 x IDRN Cornell were promising combinations in terms of yield.

Choudhary *et al.* (2000) used nine best crosses (selection intensity 20%) to establish heterotic group for grain yield which can be used for future improvement.

Saleh *et al.* (2002) showed high estimate of heterosis for grain yield, ear weight, grains per ear and grain weight per ear and moderate heterosis for plant height, ear length, shelling percentage, ear girth, number of grain rows per ear and 100 grain weight whereas, negative heterosis was observed for days to silking.Joshi *et al.* (2002) in Line x Tester analysis revealed that, among the selected hybrids two parent (TP) conventional single cross hybrids exhibited the highest magnitude of significant positive economic heterosis for grain yield per plant and was followed by in descending order by the multiparent (MP) conventional three way cross and non conventional two parent (TP) top cross hybrid.

2.2 Combining ability:

The aim of the plant breeder is to identify the parents that will combine well and produce productive progenies. In crop improvement programme the success in identifying the parents, which are nicking well mainly depends on the gene action that controls the trait under improvement. Understanding of genetic architecture of the parents is very much useful in securing overall information on the various genetic systems involved in short time. Combining ability analysis useful in testing the independence of genotypic effect from environmental effects and estimates of general (gca) and specific combining ability (sca), additive and dominance type of gene action along with different non allelic interactions.

The combining ability provides information regarding the genetic architecture of traits, which helps in formulating the criteria for selection of better parents in terms of the performance of their hybrids. Further it also gives useful information about the nature and magnitude of gene action involve in the expression of quantitative traits.

The concept of combining ability in terms of genetic variation was first given by Sprague and Tatum (1942) using single crosses in maize. They defined the terms 'general combining ability' as an average performance of a line in a several hybrid combinations and the term 'specific combining ability' was used to designate those effects in certain combinations which significantly departed from what would be expected on the basis of the average performance of the lines involved. Allard (1960) also defined specific combining ability as the deviation from the performance predicted on the basis of general combining ability. According to Griffing (1956a) the gca is related to both additive effects as well as additive x additive interactions whereas specific combining ability is related to the dominance variance and all three types i.e. additive x additive, additive x dominance and dominance x dominance interactions.

Top cross test can be used for testing general combining ability and preliminary evaluation of inbreds. But single cross tests are necessary for locating best specific combination. Line x tester and diallel are single cross designs used for testing both gca and sca.

Ramamurthy (1980) studied 56 crosses in different maturity groups. In early maturity group crosses 4 x 7, 4 x 8, 5 x 7 and 5 x 8 showed significant SCA effects for earliness and in medium maturity group crosses 1 x 4 and 4 x 5 were earlier than their respective parents. Crosses 2 x 5 and 3 x 5 were the highest yielding in late maturity group.

Eleuterio *et al.* (1988) studied combining ability and heterosis in intervarietal maize hybrids. Five populations and ten crosses between them were evaluated. The high GCA effects were recorded in CM 536 and CM 530 (36.1 and 66.5, respectively) for grain yield per plant. The crosses CM 504 x

CM 530, CM 504 x CM 513 and CM 504 x CM 536 showed high SCA effects for grain yield.

Prasad *et al.* (1988) in eight parent complete diallel for 10 characters reported that CM 500 was good general combiner for most of the characters (grain yield per plant, days to silking, number of grain rows per ear, ear length and ear girth) followed by CM 105 and CM 110 with desirable GCA effect for three characters each. The crosses CM 500 x CM 400, CM 111 x CM 400 were good specific cross combinations showing desirable SCA effects for two characters.

Mateeva (1988) estimated combining ability for grain yield in ten lines and their 45 hybrids in half diallel set. High GCA was seen in AG-52, AG-64-1-1 and AG-153R and the best hybrids were AG-64-1-1 x AG-52, AG-37 x AG 51 and AG-310 x AG-13.

Shamrav and Shalygina (1988) in combining ability studies identified the lines, viz. UCH-4, UCH-262, AL-99, F-19, P-210, K-l, 14-1, ZDL-373, 167 NS and 255 KH as lines with high GCA for yield where as the crosses SM-7 x Glyn – 367, Ky304 x UCH-4 and A-19 x KS-1 were the best combinations possessing high SCA effects.

Jha and Sinha (1989) observed significant and positive GCA and SCA variances for all the traits. The Suwan 2 (w) and Phil DMR Composite 4 showed significant GCA for grain yield per plant at early and late sowing respectively. However, the crosses G25 x FRK 58 – CI 66 and M+2 (W) x G 25 gave significant and positive SCA effects for grain yield.

Kapustin (1989) assessed 66 crosses for their combining ability, where Line-2241-2 produced the crosses with high SCA.

Debnath and Sarkar (1990) reported Syn.C, Syn.B and CM 110 as good general combiners for grain yield, ear length and grain rows.

In 7x7 diallel Ivanov (1991) reported that the lines Sh 14402 and C 1040 showed highly significant GCA and appear promising for high yield with the line 358-626 having the highest proportion of dominant genes about 75 per cent associated with the highest grain yeild.

Perez *et al.* (1991) in the diallel set of crosses reported that AG 103, L 670 and Tucma 85 showed the highest GCA for the yield while the highest SCA effects were shown by the hybrids XL670 x G5 $S10_3$ AG103 x Tropico 327, 4F37 x BGO 12 and BGO12 x XLG70. The five crosses that gave the highest yield had at least one parent with high GCA and involved parents with high x high, high x low / low x high combining ability.

Zhang and Wang (1991) observed clear influence of GCA of the two parents on SCA of the particular cross for all the traits studied and accordingly recommended that equal attention should be paid for selecting the parents with high GCA effects for getting high SCA effects of the crosses.

Highly significant GCA effects for grain yield was also reported by Vasal *et al.* (1992), Vasal *et al.* (1994).

Mohamed (1993) reported that GCA effects were higher than SCA effects for kernel yield per plant, number of ears per plant and number of kernels per ear whilst SCA effect were the most important for ear length, ear diameter and 100 kernal weight.

Sharma and Bhalla (1993) suggested that among the parents H 98, CM 25 and V55B were the best general combiners for grain yield and the hybrids V50B x CM 225 were the best general combiners for grain yield and the hybrids V50B x CM205, V20B x V50B, V57B x A654 and V20B x V57B were performing the best for the same trait.

Wang *et al.* (1994) reported that GCA was more important than SCA effects for grain quality traits.

Gama *et al.* (1995) observed that variation due to GCA accounted for the 68 per cent of the variation due to crosses. Significant positive GCA effects were noted for line 6 and 7 and significant positive SCA effects were observed for the crosses line 4 x line 11, line 5 x line 9 and line 5 x line 11. However, line 6 x line 7 seemed promising as potential parents for three way or double cross hybrids.

Ivanov and Tomov (1995) reported that the highest GCA for ear length was shown by the lines OH 4302 and I 6502, which appeared promising for production of the synthetics with long ear. Hybrids involving the line OT 31402 had high SCA and could be used in heterosis breeding directly. The lines OH 4302 and OT 29602 had high GCA for number of grain rows per ear.

Kalita *et al.* (1995) suggested that parents with high GCA estimates did not always give rise to high SCA.

Lee-Wankoo *et al.* (1995) observed that inbreds used in studies differed significantly for plant height, ear height, ear length, ear girth, 100 grain weight, row number and number of grains per ear. Hybrids involving line Bosung showed the longest ear length and the greatest grain weight Dangjin was a good general combiner for reduced plant height and ear length, and Bosung for increased ear length and 100 grain weight and decreased row number. The hybrid which showed the highest specific combining ability for ear length and 100 grain weight was Jewan x Chilbo.

Sain Dass *et al.* (1996) reported that the lines K-725, K-729, K-613 and K-720 were the most desirable donars for seed weight and yield whereas the crosses K-729 x K-644 (5) and K-725 x K-622 (7) were the highest yielding. Studies on SCA effects also indicated that most of the superior crosses were between parents having high x low, high x high, high x medium combining ability indicating the involvement of at least one good combiner.

Sain Dass *et al.* (1998) while studying the genetics of morphophysiological traits responsible for high yield in maize from 10 lines x 5 testers analysis suggested that there was no association between *per se* performance and SCA effect.

Singh and Singh (1998) in line x tester (15 x 2) analysis in maize reported that for the characters, ear length and number of kernel rows per ear, SCA was more important. The SCA was important for other characters like grain yield per plant, ear diameter, 100 seeds weight, days to 50 per cent silking and plant height. D741-45 inbred line was good general combiner for grain yield. The cross combination Sona x A2 had significant SCA effects for grain yield.

Choukan (1999) studied 45 hybrids in diallel analysis without reciprocals and reported significant GCA effects for all the traits and significant SCA effects only for grain yield, plant height and number of grain rows per ear.

Konak *et al.* (1999) in 6 x 4 line x tester analysis noted high SCA values for grain yield, 1000 grain weight, ear length and earliness. However, GCA values were higher and significant for plant height and number of rows per ear. The N-74, H-96, A-619 W-552 and IDRN Cornell were better general combiners for plant height and ear length. The cross combination N-74 x IDRN Cornell, H-96 x ALKED-222 N-74 x W-SS2, A-619 x W-SS2, DN-13 x IDRN Cornell and H-96 x IDRN Cornell recorded highly significant SCA effects and considered as promising combinations in terms of yield.

Kumar *et al.* (1999) obtained information on yield related traits of 24 maize hybrids resulted from 6 lines x 4 testers. The results revealed that GCA variances were less than SCA variances for grain yield and yield components. Among the testers, HOL 73 and TW 26 were the best general combiners for grain yield and TW 28 among the lines was good combiner for grain yield. Further the cross TQPM 45 x HOL 73 was a good specific combination for grain yield indicating its potential for commercial exploitation.

Choudhari *et al.* (2000) reported that mean squares due to GCA were highly significant for the characters studied except for ear length. Mean squares due to SCA were significant for the traits days to tassel, ear length and grain yield. High estimates of a mean squares due to SCA were observed for ear length and grain yield. The parents P_4 x P_2 showed significant and positive SCA effects for ear length and grain yield per plant, respectively. The results also indicated that in general there was good association between high mean performance and SCA effects of the crosses. The cross P_3 x P_8 showed high SCA effects for ear length and grain yield suggesting that better performing cross usually had at least one parent with high general combining ability.

Desai and Singh (2000) observed significant differences for GCA and SCA effects for ten characters studied. Among the parents lb 1073 and lb 1155 were found to have a negative GCA effects for days to 50 per cent silking and positive GCA effect for plant height, ear length and grain yield. The crosses lb 1073 x lb 1143 and lb1075 x lb1155 showed negative SCA effects for days to 50 per cent silking and positive for plant height, ear length and grain yield.

Gupta and Nagda (2000) in diallel cross, revealed that variances due to varieties were significant for all the traits studied. Parents CM 501, Harsha and Navjot showed good varietal effects for earliness while Navjot and Laposta were good for grain yield, 100 grain weight, cob girth and cob length. However, crosses Pool 16 x CM 501, Pool 16 x Laposta, Pool 16 x Harsha and Loposta x Tuxpeno C8 were identified as promising for possible uses in developing broad base genetic population.

Habutamu (2000) reported that Al-204, Al-151 and Al-28 were good general combiners for grain yield and kernel weight and Al-178, Al-128 and

Al-71 were good combiners for plant height. However, the hybrids Al-175 x A1-204, Al-178 x Al-204, A-128 x A1204, Al-151 x A1-204 and A128 x Al-175 were found to be good specific combinations for all the characters studied. Inbred line A1-204 had high heritable potential for grain yield.

In combining ability analysis for characters of 10 main genotypes based upon *per se* performance and GCA effects,Geetha (2000) stated that UMI-760, Prabhat-1, JM 3181-1 and a cross UMI 805 x UMI 760 were good performers for most of the characters and were suitable for recombination breeding.

Kadlubiec *et al.* (2000) in 10 x 5, line x tester analysis observed significant variability in all hybrids. The GCA variances were greater than SCA for majority of traits investigated.

Sain Dass *et al.* (2000) in line x tester analysis reported that there was no similarity in ranking between *per se* performance and its corresponding GCA and SCA effects of the crosses. The lines L1, L2 and L3 and tester T1 were the best general combiners for high yield and disease resistance. However, L2 x T1 and L3 x T1 were the most desirable combinations having both high *per se* performance and high SCA effects for the traits under study.

Dubey *et al.* (2001) in line x tester mating design revealed that both GCA and SCA variences were important for days to 50 per cent silking, grain yield per plant and 100 grain weight. The inbred line SS_3 – 35-2-1-1-1-1 was a good general combiner for grain yield per plant, 100 grain weight and days to 50 per cent silk and lines X 2 W-3997-2-1-7 and X W-1627-1-1 were good combiner for grain yield per plant only.

Kalla *et al.* (2001) revealed that inbreds DKI-144 and DKI-137-A were good general combiners for grain yield per plant and the cross combinations DKI-129 x DKI-162, DKI 129 x DKI-137-A and DKI-162 x DKI-160 recorded significant positive SCA effects for yield and yield contributing characters.

Konak *et al.* (2001) made crosses between five lines as female parents and three testers as male parents to select good combiners and promising hybrids. The results suggested that the parents A-632 and Po 870 were good combiners having high GCA effect however, the crosses B-52 x FR-43, B-79 x Po 870 and A 632 x FR-43 were the good performers having higher SCA effects. Both A-632 x A-634 and A-632 x Po 870 were the highest yielding combinations.

Kara (2001) in (6 x 3) line x tester analysis reported significant GCA effects for all attributes and SCA effects were significant for ear diameter, ear length and grain yield. With respect to ear length and grain yield, SCA effects were more pronounced when compared to GCA effects.

Matho and Ganguly (2001) reported highly significant mean sum of squares for all the characters. The parents CML 56, CML79 and CML 85 were good combiners for grain yield and CML 85, CML 135, CML 80 and CML 79 were good combiners for earliness. Likewise for 100 grain weight and shelling percentage CML 85 and CML 79 were the best performers. The crosses showed positive and highly significant SCA effects for grain yield per plant.

2.3 Heritability and Gene action

Ramamurthy (1980) while studying diallel analysis of yield and maturity observed the predominance of additive gene action for days to 50 per cent silking and days to husk drying. Non-additive gene action was important for grain yield per plant.

Sanghi *et al.* (1982) reported predominance of additive gene effects for grain yield, ear length, ear girth and number of grain rows.

Singh *et al.* (1989) while studying character association in maize obtained high heritability estimates for 1000 grain weight.

Debnath and Sarkar (1990) reported the predominance of non-additive gene action in the inheritance of grain yield, ear diameter and 1000-kernel weight. However, both additive and non-additive gene action was equally important for ear length, kernel rows per ear and kernels per row. He further reported the occurrence of GCA x environment or SCA x environment interactions for expression of traits.

Dordevic (1990) studied effect of epitasis on grain yield in maize and reported that epistasis was apparent and had a negative effect on grain yield in the cross combinations V158 x K139 and Va35 x B14.

Biparental progenies were evaluated in NCD-I by Reddy and Agarwal (1990) and reported that additive genetic variance was more important than dominance variance for grain yield and its component characters. Dominance variance was more important for test weight.

Ivanov (1991) in 7 x 7 diallel reported that over dominant gene action was predominant for grain yield per plant and showed association between 75 per cent dominant genes with highest grain yield.

Pal and Pradhan (1994) evaluated 15 hybrids for combining ability and found greater influence of additive component of gene action in expression of maturity, ear diameter and 100 grain weight and the importance of non additive gene action in controlling grain yield, grains per row, grain rows per ear and ear length.

Wang *et al.* (1994) reported that additive gene effects predominated over nonadditive ones for most of the yield and yield component traits under study.

Gama *et al.* (1995) observed that additive genetic effects were most important than nonadditive effects for grain yield. Vancetovic and Drinic (1999) also indicated predominance of additive genetic effects in controlling yield though the nonadditive effects were significant.

In a six parameter model of generation mean analysis involving ten diverse genotypes, Satyanarayana (1995) observed that dominance with additive x additive type of gene effects played a predominant role in the inheritance of flowering. In majority of the crosses studied, a duplicate type of epistatic gene action was important.

Giridharan *et al.* (1996) observed that yield was controlled by additive and nonadditive gene action in diallel crosses and dominant gene action was observed in triallel and quadriallel crosses, suggesting that grain yield could be improved by heterosis breeding.

Sain Dass *et al.* (1996) in combining ability studies revealed that both additive and nonadditive genetic variances were important in expression of seed weight and yield. Similar conclusion was drawn by Desai and Singh (2000) in L x T analysis for the characters days to 50 per cent silking, plant height, ear length and grain yield.

Sain Dass *et al.* (1998) derived information on combining ability and genetic variance on six yield and cob traits from a 10 lines x 5 testers. Combining ability variances indicated the importance of nonadditive gene action in the inheritance of these traits.

Through diallel analysis Choukan (1999) observed that both additive and nonadditive gene actions were important in genetical control of grain yield per plant, plant height, number of grain rows per ear and substantial additive gene action was also present for controlling days to 50 per cent flowering, ear length and 100 grain weight.

Vozda and Kudecova (1998) observed considerable variation in GCA and SCA and he attributed it to environmental factors. He concluded that for breeding purpose, material should be studied in several environments.

Konak *et al.* (1999) using data from the crosses of 6 x 4, line x tester analysis noted the presence of additive gene action for control of plant height and number of grain rows per ear. However, the characters grain yield per plant, earliness, 1000 grain weight and ear length were influenced by non additive gene action.

Kumar *et al.* (1999) in line x tester analysis revealed a preponderance of non additive gene action for grain yield and yield components.

Pradhan and Rai (1999) in line x tester (30 x 4) analysis indicated that additive gene effects exhibited predominant role in expression of all the characters except kernel rows per ear and kernels per row where nonadditive gene effects were more important.

Choudhari *et al.* (2000) reported preponderance of non additive gene effects in the inheritance of ear length and grain yield per plant.

Geetha and Jayaraman (2000) made crosses between ten maize genotypes. Results showed than additive gene action was operating for plant height, number of rows per cob, cob weight, days to 50 per cent silking and 100 grain weight. Also significant additive and dominant components H1 and H2 were observed for plant height, number of grain rows per ear, cob weight and grain yield. Dominance component was greater in magnitude than additive for the above characters while additive was greater than dominance for the days to 50 per cent silking.

Habutamu (2000) observed that the ratio between GCA:SCA was less than unity, for grain yield and 1000 kernel weight indicating that nonadditive gene action was important for these traits. Whereas GCA: SCA ratio was greater than unity for ear length, days to maturity and plant height indicating additive gene action for inheritance of these traits.

Kadlubiec *et al.* (2000) observed importance of non additive gene action for majority of traits investigated.

Mani *et al.* (2000) observed predominance of additive gene action for ears per plant, ear girth, number of grain rows per ear, 100 grain weight and grain yield. However the highest heritability was observed for grain yield and number of ears per plant.

In line x tester analysis Sain Dass *et al.* (2000) revealed that nonadditive genetic variances were more important in expression of high grain yield and disease resistance.

Dubey *et al.* (2001) in line x tester analysis reported that the ratio of 6^2 SCA/ 6^2 GCA was greater than unity for grain yield per plant, 100 grain weight and days to 50 per cent silking indicating the preponderance of nonadditive gene action for expression of these traits.

Kalla *et al.* (2001) reported that both additive and nonadditive gene actions were operating for 1000 grain weight, kernel row per ear, grains per ear, ear length and ear girth. However, nonadditive gene action was predominant for ear length and 1000 grain weight and significant for grain yield per plant. Both additive and dominant components were significant.

Konak *et al.* (2001) made crosses between five lines as female parents and three testers as male parents to select the suitable parents and promising hybrids. The characters ear length and number of grain rows were influenced by nonadditive gene action. However, additive gene action was important for yield, kernel weight, plant height, ear girth and days to silking.

Kara (2001) from the 6 x 3, line x tester analysis of combining ability indicated predominance of nonadditive gene action in inheritance of ear length, ear diameter and grain yield.

Matho and Ganguly (2001) observed gene action through genetic components of diallel analysis and showed that both additive and non additive components were significant in expression of ear length, ear girth, days to 50 per cent silking, shelling percentage ,100 grain weight and grain yield per plant.

Muhammad and Muhammad (2002) observed highly significant differences among the S1 for all traits viz., days to 50 per cent tasseling, number of days taken to silking, 100 grain weight and grain yield plant except for number ears per plant where it was nonsignificant. Heritability estimates were of moderate high magnitude for all the traits except for number of ears per plant.

Saleh *et al.* (2002) recorded low to moderate heritability for grain yield and showed substantial amount of genetic variation in this population where as low and negligible heritability was observed for days to 50 per cent silking and number of cobs per plant and 100 grain weight indicating that these traits were very much influenced by environmental factors.

2.4 Correlation

Xu (1986) studied influence of major characters of maize on the productivity of individual plant of 40 maize hybrids and observed highly significant multiple correlation between yield per plant and six major characters (plant height, ear length, ear thickness, row number per ear, grain number per ear and 1000 grain weight). The correlation coefficient between yield/ plant and other characters were positive and highly significant except for row number per ear. It was also observed that increase in row number would decrease yield per plant.

Singh *et al.* (1987) studied correlations and path coefficient analysis of yield and component characters in maize and reported that yield was positively and significantly correlated with 1000 grain weight, number of grains per ear and grain yield per plant.

Sharma and Kumar (1987) studied association between grain yield and some quantitative characters in pop corn and revealed that grain yield per plant was positively associated with plant height number of internodes, leaf area, tassel height, cob width, grain number per row and grain rows per cob.

Tyagi *et al.* (1988) in correlation and path analysis through diallel cross of 8 inbred lines indicated that ear length, plant height, 100 grain weight, ear girth and number of ears per plant significantly affected grain yield. Plant height was positively related with grain yield. Days to 50 per cent silking revealed that early maturing plants gave relatively low yield.

Farhatullah G. K. (1990) revealed that ear length had the greatest effect on yield.

Ramesha *et al.* (1990) studied correlation, combining ability and heterosis for plant height husk number and length of ear and seven other quantitative characters in hybrids. The two traits (number of grain rows per year and husk number) showed strong negative correlation with yield and yield components.

Muhammad and Muhammad (2001) observed that grain yield per plant showed significant and positive correlation with plant height and number of grain rows per ear in maize.

Umakanth and Khan (2001) revealed that grain yield was positively and significantly correlated with ear length, ear girth, plant height and 100 seed weight.

Vasic *et al.* (2001) found that grain yield exhibited highly significant and positive correlations with ear girth, kernel per ear, number of ears per plant and ear length. The magnitude of correlation was significantly high between grain yield and ear girth.

MATERIAL AND METHODS

3. MATERIAL AND METHODS

The present investigation on "Heterosis and combining ability studies in maize (*Zea mays* L.)", was undertaken during *kharif*, 2002 at Botany Section Farm, College of Agriculture, Pune. The details of the material used, methodology adopted in conducting the experiment and recording pre and post-harvest observations and the statistical procedures followed during the course of investigation are presented below.

3.1 Materials

The experimental material for the present investigation consisted of 4 lines (female parents) and 10 testers (male parents) obtained from AICRP on maize, Kolhapur. The list of parents along with source and salient features of parents are described in Table 3.1

3.2 Methods

3.2.1 Production of hybrid

The seeds of 14 genotypes i.e 4 lines and 10 testers used as parents were sown during *kharif* 2002 to constitute a crossing block. The crosses were made to obtain hybrid seed. Due to protandrous flowering, pollens comes out of anthers first and then stigma becomes receptive for crossing. First of all selected tassels of female parents (Lines) and male parents (Testers) were bagged before the dehiscence of anthers. The selected cobs from female and male lines were also bagged before silking to avoide contamination of foreign pollens. The pollens of desired male parents were collected in bag by gentle shaking of

Table 3.1 Salient features of parents involved in 4 x10 mlt of maize

Identity	Parents	Source	Salient features
L_1	CM117	AICRP, Kolhapur	Early flowering, dwarf , small, flint, yellow grain .
L_2	CAO0106	AICRP, Kolhapur	Mid late, medium height, medium dent, yellow grain.
L_3	GPM201	AICRP, Kolhapur	Late, tall , medium, flint, dark yellow grain.
L_4	GPM222	AICRP, Kolhapur	Early, tall, medium, flint yellow grain.
T_1	GPM328	AICRP, Kolhapur	Late, tall, bold, dent dark yellow grain.
T_2	GPM276	AICRP, Kolhapur	Late, tall, medium, flint, dark yellow grain.
T_3	GPM254	AICRP, Kolhapur	Late, tall, small, flint, dark yellow grain.
T_4	GPM245	AICRP, Kolhapur	Late, tall, medium, dent, reddish yellow grain.
T_5	GPM302	AICRP, Kolhapur	Late, medium height ,medium, flint, dark yellow grain.
T_6	GPM257	AICRP, Kolhapur	Late, tall, bold, dent, dark yellow grain.
T_7	XOB2276	AICRP, Kolhapur	Mid late, tall, medium ,flint, reddish, yellow grain.
T_8	LM6	AICRP, Kolhapur	Mid late, medium, small, flint, reddish yellow grain.
T_9	XOB2228	AICRP, Kolhapur	Mid late, tall, medium, flint, yellow grain.
T_{10}	CML139	AICRP, Kolhapur	Mid late, tall, medium, dent, yellow grain.

tasseles, then the collected pollens were used to pollinate receptive stigma of female parents and then labeled properly. Each female was crossed with each male. The male and female parents were also selfed. The crossed and selfed seeds of each genotype were harvested separately, cleaned and used for sowing in rabi 2002.

3.2.2 Experimental design

To study heterosis and combining ability the field testing/ evaluation of hybrid and parents was done during rabi 2002. All 40 hybrids along with 14 parents and 2 standard checks Varuna 205 and MLMH 956 were planted in randomized block design with 3 replications. Each entry was represented by single row of 4.5 meter length spaced 75 cm apart. The distance between two plants was 20 cm.

3.2.2.1 Preparation of land

An uniform piece of land was selected for laying out the experiment. The land was brought to the fine tilth by ploughing and harrowing.

3.2.2.2 Sowing and cultural practices

All the crosses (40) along with parents (4+10) and standard check (2) were planted on November 26, 2002. The gap filling and thinning was done 15 days after sowing and only one healthy plant was kept at each hill. As the maize is heavy feeder crop, before sowing 75 kg of N, 50 kg P_2O_5 and 50 kg K_2O per ha. was incorporated in the soil. The sowing was carried out by dibbling following 75 X 20 cm^2 spacing between and within rows. Top dressing with ammonium sulphate was done @ 75 kg/ha, 30 days after planting. The usual cultural practices *viz.*, weeding, irrigation, plant protection measures, etc. were given as and when required during growth period of the crop so as to maintain healthy stand of the crop.

3.3 Observations recorded

Five competitive plants were labeled before flowering in each treatment and in each replication to record observations on various characters. The various observations were recorded at various growth stages in following manner.

3.3.1 Days to 50 per cent silking

The number of days taken from the date of sowing to the appearance of silk in 50 per cent of plants was recorded as days to 50 per cent silking.

3.3.2 Plant height (cm)

The height of plant at maturity was measured from ground level to the tip of plant in centimeter.

3.3.3 Number of cobs per plant

The total number of cobs produced by each plant was counted at the time of harvest and recorded as the number of cobs per plant.

3.3.4 Ear length (cm)

Length of five cobs/ears drawn at random was measured in centimeters and average ear length was worked out. The average of five randomly selected plants per treatment were considered.

3.3.5 Ear girth (cm)

The maximum thickness of the cob/ear was measured in centimeters and average ear girth of five cobs drawn at random were considered.

3.3.6 Number of grain rows per ear

Total number of grain rows on each cob/ear of observational plant were counted and recorded.

3.3.7 Number of grains per ear

Number of grains per ear was counted from each of the five randomly selected cobs of observational plants after shelling of cob and their average value was estimated.

3.3.8 Shelling percentage (%)

The ratio of total grain weight per cob to the total weight of earhead in percentage was worked out as shelling percentage.

$$\text{Shelling percentage} = \frac{\text{Ave. grain wt. per ear}}{\text{Ave. total wt. of earhead}} \times 100$$

3.3.9 Test weight (g)

Weight of a random sample of hundred grains was recorded in gram.

3.3.10 Grain yield per plant (g)

Grain yield per plant was measured in gram by taking the total grain weight per plant after drying.

3.4 Statistical analysis

The mean values of five randomly selected observational plants for ten different traits were used for statistical analysis. The following various statistical measures were worked out for presentation of the data on different quantitative attributes.

3.4.1 Estimation of heterosis

Heterosis per cent was estimated over better parent and standard check by following Rai (1979) for all the characters under study.

a. Heterosis over better parent (BP) (Heterobeltiosis) $= \bar{F}_1 - \overline{BP} / \overline{BP} \times 100$

b. Heterosis over standard check (SC) (Useful heterosis) $= \bar{F}_1 - \overline{SC} / \overline{SC} \times 100$

Where,

$\bar{F}_1$ = Mean of F_1 hybrid

$\overline{BP}$ = Average better parental value

$\overline{SC}$ = Average performance of standard hybrid check

The significance of heterosis was tested by using the following formula.

$$\text{S.E. (diff) (BP)} = \sqrt{2Me / r}$$

$$\text{S.E. (diff.) (SC)} = \sqrt{2Me / r}$$

Critical difference

C.D. = S.E. x 't' value (at 5% level of significance)

where,

S.E. = Standard error

C.D. = Critical difference

Me = Error mean sum of squares

r = Number of replications

3.4.2 Randomised Block Design Analysis

In order to test the treatment differences among the crosses and parents the data for all characters were analysed by using randomised block design following Panse and Sukhatme (1967).

Table 3.2 Analysis of variance for randomised block design

Source of variation	DF	SS	MSS	Calculated 'F' value
Replication	(r – 1)	RSS	RSS./(r-1) = Mr	Mr / Me
Treatment	(n – 1)	TrSS	TrSS./(n-1) = Mt	Mt /Me
Error	(r-1)(n-1)	ESS	ESS/(n-1)(r-1) = Me	---
Total	(r.n - 1)	TSS		

Where,

DF = Degree of freedom
SS = Sum of squares
MSS = Mean sum of squares
RSS = Replications sum of squares
TrSS = Treatment sum of squares
ESS = Error sum of squares
r = Number of replications
n = Number of treatments
Me = Error mean sum of squares

Standard error (S. E.), critical difference (C. D.) and coefficient of variance (C. V.) were calculated as follows :

$$S.E. (\pm) = \sqrt{Me / r}$$

$$C. D. = \sqrt{S.E.} \times 2 \times \text{'t' value (at error degrees of freedom)}$$

$$C. V. (\%) = \frac{б}{\overline{X}} \times 100$$

Where,

t = table 't' value at error degrees of freedom at 5% level of significance

б = standard deviation

$\overline{X}$ = mean

3.4.3 Combining Ability Analysis

In order to test the combining ability effects of parents (GCA) and crosses (SCA) and to understand the nature of gene action the combining ability analysis was worked out by following line x tester design as suggested by Kempthorne (1957).

$$X_{ijk} = \mu + g_i + g_j + s_{ij} + r_k + e_{ijk}$$

where,

g_i = Effect of i^{th} female.

g_j = Effect of j^{th} male

s_{ij} = Effect of cross between i^{th} female and j^{th} male

r_k = Effect of k^{th} replication

e_{ijk} = Error effect

x_{ijk} = The cross between i^{th} female with j^{th} male in k^{th} replication

Table 3.3 Anova for line x tester design

Sr. No.	Source of variation	DF	SS	MSS	Expected mean squares
1.	Replication	(r - 1)	$\frac{\Sigma x^2..k}{fm} - \frac{x^2...}{fmr}$	---	---
2.	Hybrids	(fm - 1)	$\frac{\Sigma\Sigma x^2(ij.).}{fm} - \frac{x^2...}{fmr}$	---	---
3.	Females	(f -1)	$\frac{\Sigma x^2 i..}{mr} - \frac{x^2...}{fmr}$	M_1	σ^2 + r[cov.(F.S.) - 2cov.(H.S.)] + [mr cov.(H.S.)]
4.	Males	(m - 1)	$\frac{\Sigma x^2.j.}{fr} - \frac{x^2...}{fmr}$	M_2	σ^2 + r[cov.(F.S.) - 2cov.(H.S.)] + [Fr cov.(H.S.)]
5.	Females x males	(f - 1) (m - 1)	$\frac{\Sigma\Sigma x^2(ij.).}{r} - \frac{\Sigma x^2 i..}{mr} - \frac{\Sigma x^2.j.}{fr} + \frac{x^2...}{mfr}$	M_3	σ^2 + r[cov.(F.S.) - 2cov.(H.S.)]
6.	Error	(r - 1) (fm - 1)	By differences	M_4	$\sigma^2 e$
	Total	(fmr -1)	$\Sigma\Sigma\Sigma x^2_{ijk} - \frac{x^2...}{fmr}$	---	---

i = Number of female parents i.e. 1, 2, ..., f

j = Number of male parents i.e. 1, 2, ..., m

k = Number of replications i.e. 1, 2, ..., r

In order to ascertain the heterosis, parents were also included separately in the same set and the analysis of the data was done in the form of modified line x tester design as suggested by Arunachalam (1974)

The sum of squares due to different factors were partioned, as shown in analysis of variance Table (3.3).

where,

f = Number of females

m = Number of males

r = Number of replications

$x_{\cdot\cdot\cdot}$ = Sum of $(ij)^{th}$ hybrid combination

$x_{\cdot\cdot k}$ = Sum of k^{th} replication

$x_{(ij)\cdot}$ = Sum of $(ij)^{th}$ hybrid combination over all the replications

$x_{i\cdot\cdot}$ = Total of i^{th} female over all males and replications

$x_{\cdot j\cdot}$ = Sum of j^{th} male parent over all female and replications

x_{ijk} = $(ij)^{th}$ observation in k^{th} replication

M_1 = Mean sum of squares of females

M_2 = Mean sum of squares of males

M_3 = Mean sum of squares of female x male interaction

M_4 = Error mean sum of squares

cov.(H.S.) = covariance of half sib

cov.(F.S.) = covariance of full sib

6^2 = Environmental variance

$$\text{cov.(H.S.) (females)} = (M_1 - M_3) / r \times m$$

$$\text{cov.(H.S.) (males)} = (M_2 - M_3) / r \times f$$

$$\text{Cov. (F.S.) (average)} = \frac{1}{r(2fm - f - m)} \quad \frac{(f-1)(M_1) + (m-1)(M_2)}{f + m - 2} - M_3$$

$$\text{Cov.(F.S.)} = \frac{(M_1-M_4)+(M_2-M_4)+(M_3-M_4)}{3r} + \frac{6\,r\,\text{Cov.(H.S.)} - r\,(f+m) + \text{Cov .(H.S.)}}{3r}$$

The mean sum of squares due to females and males were tested against female x male interaction, while female x male interaction were tested against error variance. However, when females and males were non-significant then tested against error variance.

3.4.4 Estimation of general and specific combining ability effects

(i) $\mu = \dfrac{x\,...}{fmr}$

(ii) $g_i = \dfrac{\sum x_i\,..}{mr} - \dfrac{x\,...}{fmr}$

(iii) $g_j = \dfrac{\sum x\,.j\,.}{fr} - \dfrac{x\,...}{fmr}$

(iv) $s_{ij} = \dfrac{\sum\sum x_{ij}\,..}{r} - \dfrac{\sum x_i\,..}{mr} - \dfrac{\sum x\,.j\,.}{fr} + \dfrac{x\,...}{fmr}$

Where,

$x...$ = Grand total of all $(ij)^{th}$ hybrid combinations
g_i = Estimation of general combining ability effects for i^{th} female parent
g_j = Estimation of general combining ability effects for j^{th} male parent
s_{ij} = Estimation of specific combining ability effect for $(i \times j)^{th}$ cross
f = Number of female parents
m = Number of male parents
r = Number of replications
$\sum x_i..$ = Sum of i^{th} female parent over all male and replications
$\sum x.j.$ = Sum of j^{th} male parent over all female and replications
$\sum x_{ij}..$ = Total of $(ij)^{th}$ combination over all replications

3.4.5 Estimation of Standard Error (S.E.) for combining ability effects

(i) S.E. (gca for females) = $\sqrt{M_4 / mr}$

(ii) S.E. (gca for males) = $\sqrt{M_4 / fr}$

(iii) S.E. (sca effects) = $\sqrt{M_4 / r}$

where,

M_4 = Error mean sum of squares
r = Number of replications

3.4.6 Estimation of combining ability variance

From the expectation of the mean squares, covariance of half sibs [Cov. (H. S.)] and covariance of full sibs [Cov. (F. S)] were obtained. Following are the formulae for the gca and sca variances.

(i) σ^2 gca = cov. (H. S.)

(ii) σ^2 sca = [cov. (F. S.) – 2 cov. (H. S.)

Where,

σ^2 gca = Variance due to general combining ability

σ^2 sca = Variance due to specific combining ability

3.4.7 Gene action

Variance due to general combining ability (σ^2 gca) and due to specific combining ability (σ^2 sca) where worked out after estimating the cov. (H. S.) and cov. (F. S.) as per Griffings (1956b).

σ^2 gca = cov. (H. S.)

$= [1\ F/4]^2\,\sigma^2 A$ (F=0)

σ^2 sca = [cov. (F. S.) 2 Cov. (H. S.)]

$= [1\ F/2]^2\,\sigma^2 D$ (F=0)

Where,

F = Inbreeding coefficient

$\sigma^2 A$ = Additive genetic variance

$\sigma^2 D$ = Dominance genetic variance

3.4.8 Heritability percentage (narrow sense)

$$h^2\ (ns) = \frac{\sigma^2 A}{\sigma^2 A + \sigma^2 D + \sigma^2 e} \times 100$$

3.4.9 Per cent contribution of females, males and females x males to hybrid sum of squares is given by -

(i) Proportional contribution of females $= \dfrac{\text{Female S.S.}}{\text{Hybrid S.S.}} \times 100$

(ii) Proportional contribution of males $= \dfrac{\text{Male S.S.}}{\text{Hybrid S.S.}} \times 100$

(iii) Proportional contribution of females x males $= \dfrac{\text{Female S.S. x Male S.S.}}{\text{Hybrid S.S.}} \times 100$

3. 4. 10 Correlation

In order to understand association between different characters simple phenotypic correlation coefficients were calculated by following Singh and Chaudhary (1985).

$$r_{x1.x2} = \frac{\text{cov. } x_1 x_2}{\sqrt{\text{Variance } x_1 \cdot \text{Variance } x_2}}$$

Where,

$r_{x1.x2}$ = Correlation coefficient between variables x_1 and x_2

cov. x_1x_2 = Covariance between x_1 and x_2

var. x_1 = Variance of the variable x_1

var. x_2 = Variance of the variable x_2

Significance of correlation coefficient was determined by comparing with table 'r' value (Gomez and Gomez, 1984) at n-2 d.f.

EXPERIMENTAL RESULTS

4. EXPERIMENTAL RESULTS

In the present investigation four diverse lines and ten testers were intermated during *kharif,* 2002. The resulting hybrids and their parents were evaluated in replicated during Rabi 2002, along with the standard checks. Observations on the ten different characters were recorded during crop growth period. Data obtained was analysed by following modified Line X Tester analysis and the results obtained are described below.

4.1 Mean performance of parents and hybrids

Mean performance of parents and hybrids is represented in Table 4.1

4.1.1 Days to 50 per cent silking

Variation for days to 50 per cent silking ranged between 67.00 and 76.67 days among the hybrids. Among the female parents GPM 222 was the earliest to silk taking 69 days followed by Cm 117 (71 days) while GPM 201 took maximum of 75 days indicating its late flowering behaviour.

As regards the male parents, CML 139 was the earliest to flower which flowered in 69 days followed by XOB 2276 (71 days), while GPM 245 (78.67), GPM 257 (78.00) and LM-6 (78.00) were late in days to 50 per cent silking.

Days to 50 per cent silking in hybrids ranged between 67.00 and 76.67 days. Among the hybrids GPM 222 x CML 139 (57.00 days) was the earliest to flower followed by GPM 222 x GPM 276 (67.33 days) and GPM 222 x GPM 245 (67.67 days). The late flowering was recorded in GPM 201 x GPM 328 (76.67 days). It is interesting to note that the hybrids in which GPM 222 was

Table 4.1 Mean performance of parents and hybrids for ten characters in 4 x10 mlt of Maize

Parents/ Hybrids	Days to 50% silking	Plant height (cm)	No. of cobs/ plant	Ear length (cm)	Ear girth (cm)	No. of grain rows/ear	No. of grains per ear	Shelling percent (%)	100 seed weight (g)	Grain yield/plant (g)
Lines										
CM 117	71.00	137.55	1.00	13.13	11.20	14.13	396.00	69.63	12.03	53.93
CA 00106	73.00	162.73	1.00	13.50	13.30	14.20	373.00	77.17	21.20	78.67
GPM 201	75.00	198.73	1.00	14.50	12.40	14.53	324.40	71.83	22.70	77.03
GPM 222	69.00	170.73	1.00	15.20	14.20	14.27	397.50	75.10	26.33	95.42
Mean (L)	72.17	167.43	1.00	14.10	13.00	14.28	372.60	73.43	20.56	76.27
Testers										
GPM 328	76.60	197.63	1.00	17.57	13.50	14.40	434.00	69.13	17.40	87.05
GPM 276	74.00	191.67	1.00	13.00	13.60	13.40	321.35	66.80	22.50	93.60
GPM 254	74.30	190.00	1.00	13.43	13.00	14.00	324.80	72.00	19.65	81.10
GPM 245	78.67	159.33	1.00	9.53	10.54	15.20	301.0	70.40	16.37	35.70
GPM 302	75.33	216.80	1.00	15.27	14.13	13.47	330.82	68.77	23.77	93.20
GPM 257	78.00	228.00	1.13	16.23	15.00	13.30	392.70	71.20	23.40	117.10
XOB 2276	71.00	214.00	1.00	15.13	14.00	15.40	468.40	75.54	24.63	97.53
LM 6	78.00	159.83	1.00	11.27	11.00	11.03	182.84	71.50	20.50	39.90
XOB 2228	72.33	182.47	1.00	13.37	13.00	14.40	339.03	74.10	21.63	57.15
CML 139	69.00	194.67	1.00	14.23	13.00	13.33	336.40	77.17	22.78	86.10
Mean (T)	74.73	192.44	1.01	13.90	13.00	13.80	343.13	71.66	21.26	78.83

Table 4.1 contd…

Parents/ hybrids	Days to 50% silking	Plant height (cm)	No. of cobs/ plant	Ear length (cm)	Ear girth (cm)	No. of grain rows/ear	No. of grains per ear	Shelling percent (%)	100 seed weight (g)	Grain yield/plant (g)
Hybrids										
CM 117 x GPM 328	74.67	215.00	1.00	15.03	14.07	14.83	444.75	76.59	23.62	96.47
CM 117 x GPM 276	68.33	210.27	1.00	14.85	13.93	13.93	433.60	79.20	26.47	107.43
CM 117 x GPM 254	72.33	207.90	1.00	14.70	13.17	14.27	454.99	76.90	19.63	92.90
CM 117 x GPM 245	70.67	196.43	1.00	12.87	12.60	14.80	409.53	75.07	15.03	83.03
CM 117 x GPM 302	69.00	215.97	1.00	15.92	13.82	14.07	482.13	76.33	23.43	96.97
CM 117 x GPM 257	70.67	214.33	1.00	15.10	14.20	14.40	384.73	74.83	18.93	85.47
CM117 x XOB 2276	72.33	218.33	1.00	14.63	13.77	14.17	396.70	74.83	20.77	76.57
CM117 x LM-6	71.33	198.43	1.00	14.07	13.47	14.40	456.61	75.23	23.93	83.57
CM117 x XOB 2228	75.33	208.60	1.00	15.90	14.10	14.67	480.17	73.23	22.17	104.70
CM117 x CML 139	68.00	202.33	1.00	15.87	13.63	13.40	482.99	79.17	22.83	93.03
Mean	71.27	208.76	1.00	14.89	13.67	14.29	442.62	76.14	21.68	92.05
CA 00106 x GPM 328	74.00	219.00	1.00	16.03	15.77	15.40	458.67	74.12	25.95	110.03
CA 00106 x GPM 276	71.00	196.00	1.00	17.73	13.97	15.67	429.53	73.93	22.93	83.10
CA 00106 x GPM 254	72.33	227.53	1.00	15.93	13.13	15.33	430.80	73.00	23.50	106.03
CA 00106 x GPM 245	71.33	195.37	1.00	12.77	13.93	15.57	416.50	75.50	18.67	74.40
CA 00106 x GPM 302	71.00	215.90	1.00	13.70	13.93	14.67	403.05	75.05	28.47	105.53
CA 00106 x GPM 257	68.67	218.27	1.00	14.37	14.69	15.13	417.47	75.71	23.87	104.87
CA 00106 x XOB 2276	69.00	220.33	1.00	14.73	14.70	15.13	472.06	77.00	28.17	114.20
CA 00106 x LM-6	69.67	227.23	1.00	15.90	14.63	14.40	395.60	73.73	26.15	99.27

Table 4.1 continued

Parents/ hybrids	**Days to 50% silking**	**Plant height (cm)**	**No. of cobs/ plant**	**Ear length (cm)**	**Ear girth (cm)**	**No. of grain rows/ear**	**No. of grains per ear**	**Shelling percent (%)**	**100 seed weight (g)**	**Grain yield/plant (g)**
CA 00106 x XOB 2228	70.33	228.33	1.00	14.23	14.20	14.60	403.96	71.57	22.82	104.37
CA 00106 x CML 139	68.33	217.83	1.00	14.07	14.60	15.40	417.27	73.03	23.27	92.07
Mean	70.57	216.58	1.00	14.95	14.32	15.13	424.50	74.27	24.38	99.39
GPM 201 x GPM 328	76.67	224.33	1.00	16.07	14.50	15.67	490.40	72.77	22.03	105.90
GPM 201 x GPM 276	70.67	218.97	1.00	14.37	13.77	13.73	343.80	75.13	26.92	100.10
GPM 201 x GPM 254	73.00	237.87	1.00	15.90	15.10	14.37	384.13	73.27	30.47	109.33
GPM 201 x GPM 245	71.67	217.00	1.00	13.80	14.07	14.80	364.33	75.60	22.28	90.10
GPM 201 x GPM 302	73.00	233.00	1.07	15.33	15.43	15.67	444.73	71.17	29.05	120.30
GPM 201 x GPM 257	73.00	227.67	1.07	16.30	16.30	15.93	537.06	70.47	28.83	126.37
GPM 201 x XOB 2276	69.00	219.00	1.00	15.70	14.82	15.83	412.44	70.82	23.70	93.03
GPM 201 x LM-6	72.67	208.97	1.00	18.10	14.70	15.47	452.02	73.25	30.30	123.40
GPM 201 x XOB 2228	73.33	226.50	1.00	15.90	14.87	16.67	525.92	72.32	22.80	110.93
GPM 201 x CML 139	69.00	225.80	1.07	16.13	14.80	15.73	452.73	70.67	26.53	104.10
Mean	72.20	223.91	1.02	15.76	14.84	15.39	440.76	72.55	26.29	108.36
GPM 222 x GPM 328	72.00	225.07	1.00	17.80	13.50	13.53	434.40	76.20	25.72	118.10
GPM 222 x GPM 276	67.33	222.93	1.00	15.57	13.37	14.07	448.90	74.43	29.77	103.83
GPM 222 x GPM 254	75.00	221.33	1.00	17.40	15.37	15.07	506.80	70.87	25.10	122.10
GPM 222 x GPM 245	67.67	215.13	1.00	14.67	14.97	14.33	432.90	73.63	24.70	103.70
GPM 222 x GPM 302	68.33	230.87	1.07	18.20	14.97	14.67	530.13	73.03	24.43	123.77
GPM 222 x GPM 257	72.33	223.87	1.00	16.33	14.43	13.07	412.73	72.13	25.20	105.07
GPM 222 x XOB 2276	68.67	212.33	1.00	13.60	13.89	14.40	427.25	73.20	22.93	104.53
GPM 222 x LM-6	69.67	204.60	1.00	15.13	14.47	13.20	373.13	79.93	27.48	129.90

Table Contd..

Parents/ hybrids	**Days to 50% silking**	**Plant height (cm)**	**No. of cobs/ plant**	**Ear length (cm)**	**Ear girth (cm)**	**No. of grain rows/ear**	**No. of grains per ear**	**Shelling percent (%)**	**100 seed weight (g)**	**Grain yield/plant (g)**
GPM 222 x XOB 2228	71.67	228.67	1.00	15.40	15.00	13.73	407.53	62.00	22.65	85.57
GPM 222 x CML 139	67.00	195.03	1.00	13.97	13.23	13.87	340.19	78.57	26.32	86.71
Mean	69.97	217.98	1.00	15.81	14.32	13.99	431.41	73.40	25.43	108.33
Varuna 205 (SC)	74.67	231.27	1.00	16.27	13.93	14.27	456.01	73.15	25.55	114.17
MLMH 956 (SC)	74.00	228.00	1.00	17.23	15.56	15.47	500.93	68.70	24.96	119.27
Standard check mean	74.33	229.63	1.00	16.75	14.74	14.87	478.47	70.92	25.25	116.72
Population mean	71.87	209.39	1.01	15.05	13.97	14.52	415.56	73.50	23.63	96.55
SE (±)	1.54	6.91	0.02	0.60	0.42	0.49	23.86	1.20	1.19	6.90
CD at 5%	4.32	19.37	5.63	1.66	1.17	1.36	66.85	3.34	3.32	19.32

involved as female, flowered earlier than other hybrids and also they were earlier than the standard check Varuna 205 and MLMH 956 (74.00 days).

4.1.2 Plant height (cm)

The height of the plant for different parents ranged from 137.53 cm (CM 117) to 228 cm (GPM 257). In females GPM 201 (198.73 cm) was the tallest and CM 117 (137.53cm) was the dwarfest and in males GPM 257 (228.00 cm) was the tallest and GPM 245 (149.33 cm) was the dwarfest.

The plant height in hybrids varied from 195.03 cm (GPM 222 x CML 139) to 237.87 cm (GPM 201 x GPM 254). The hybrids in which GPM 254 and GPM 302 were involved as male parents were taller than other combinations such as GPM 201 x GPM 254 (237.87 cm), CA 00106 x GPM 254 (227.53 cm), GPM 222 x GPM 254 (221.33cm) and GPM 201 x GPM 302 (233.00cm), GPM 222 x GPM 302 (230.87 cm).

As such the hybrids in which CM 117 was involved as female parent were relatively dwarfer than the other combinations such as CM 117 x GPM 245 (196.43cm), CM 117 x LM-6 (198.48 cm), CM 117 x CML139 (202.33 cm), CM 117 x GPM 254 (207.90 cm) and CM 117 x XOB 2228 (208.60 cm). Among the two checks ,Varuna 205 was taller (231.27 cm) and only the two hybrids exceeded its height.

4.1.3 Number of cobs/ears per plant

Number of cobs per plant is desirable because it is directly contributes to yield per plant. It was observed that there were not much differences in parents and hybrids for this character. The mean performance of all other female, male and hybrids showed that all the parents as well as hybrids had single ear per plant. (Table 4.1)

4.1.4 Ear length (cm)

The length of ears ranged from 13.13 cm (CM 117) to 15.20 cm (GPM 222) in female parents. The female parents, GPM 222 (15.00cm) and GPM 201 (14.50cm) produced longer earheads. The earhead length among male parents ranged between 9.53 cm (GPM 245) and 17.57 cm (GPM 328). The male parents GPM 302, GPM 257, XOB 2276 produced more than 15 cm earhead length.

Among the hybrids the earhead length varied between 12.77cm (CA 00106 x GPM 245) and 18.20 cm (GPM 222 x GPM 302). The combination GPM 222 x GPM 302 produced the longest earhead followed by GPM 201 x LM-6 (18.13 cm), GPM 222 x GPM 328 (17.80cm), CA00106 x GPM 276 (17.73cm). The hybrid GPM 222 x GPM 245 (12.77cm) produced shortest earhead .

It was noted that hybrids in which GPM 222 was used as female parent produced long earheads. The standard check MLMH 956 had earhead length 17.23 cm and this was exceeded by only one male parent and 5 hybrids.

4.1.5 Ear girth (cm)

The variation for earhead girth ranged between 11.53 cm (CM 117) and 14.23 cm (GPM 222) in lines, 10.54 cm (GPM 245) and 14.83 cm (GPM 257) in testers and 12.60 cm (GPM 117 x GPM 245) and 16.30 cm (GPM 201 x GPM 254) in hybrids. The line GPM 222 recorded the highest earhead girth of

14.23 cm followed by CA 00106 (13.30 cm). Likewise among the testers GPM 257, GPM 302 and XOB 2276 recorded more than 14 cm ear girth. Whereas the combination GPM 201 x GPM 254 exhibited the highest (16.30 cm) earhead girth followed by CA00106 x GPM 328, GPM 201 x GPM 302, GPM 222 x GPM 254, GPM 201 x GPM 254, GPM 222 x GPM 254, GPM 222 x XOB 2228 which produced more than 15 cm earhead girth.

The lines GPM 201, GPM 222 and CA00106 when used as female produced hybrids with high ear girth (hybrid mean greater than 14.00 cm) which is also higher than standard check Varuna 205 (13.93 cm).

4.1.6 Number of grain rows per ear

In respect of number of grain rows per ear, variation ranged between 11.03 (LM-6) and 15.40 (XOB 2276) among the parental lines. All the lines CM-117, CA00106, GPM 201, GPM 222 and GPM 328, GPM 254, GPM 245, XOB 2228 among the testers produced more than 14 number of grain rows per ear. In case of hybrids GPM 201 x XOB 2228 produced the highest (16.67) number of grain rows per ear. Among the hybrids 22 produced more than 14 grain rows per ear.

The lines CA 00106 and GPM 201 when used as female produced hybrids with more number of grain rows per ear than standard check Varuna 205 and nearly equal number of grain rows per ear with MLMH 956.

4.1.7 Number of grains per ear

The variation for number of grains per ear ranged between 182.84 (LM-6) and 468.37 (XOB 2276) among the male parents and 324.40 (GPM 201) and

397.50 (GPM 222) among the female lines. The female parent GPM 222 (397.50) produced the highest number of grains per ear followed by CM 117 (396.00) and CA 00160 (373.00). While GPM 201 (324.40) produced the lowest number of grains per ear.

The number of grains per ear in male parents ranged from 182.84 (LM-6) to 468.37 (XOB2276). Remaining males had 320 to 393 number of grains per ear.

The range for number of grains per ear among the hybrids was varied from 340.19 to 537.06. The hybrid GPM 201 x GPM 257 (537.06) produced the highest number of grains per ear followed by GPM 222 x GPM 302 (530.13), GPM 201 x XOB 2228 (525.92), GPM 222 x GPM 254 (506.80) and GPM 201 x GPM 328 (490.40). The least number of grains per ear were produced by the cross GPM 222 x CML 139 (340.19) followed by GPM 201 x GPM 276 (343.80), GPM 201 x GPM 245 (364.32) and GPM 222 x LM-6 (373.13). Only 4 hybrids showed higher number of grains per ear than best check MLMH 956 (500.93).

4.1.8 Shelling percentage

Among females, all lines recorded more than 70 per cent shelling percentage, the highest being 77.17 per cent (CA00106) and lowest being 69.73% (CM 117).

Among males, CML139 had the highest shelling percentage of 77.17 per cent followed by XOB 2276 (75.74%) , XOB 2228 (74.10%), GPM 254 (72.00%) and GPM 257, LM-6 (71.00%) while GPM 276 (66.80%) had the lowest shelling percentage followed by GPM 302 (68.77%), GPM 328 (69.13%) and GPM 245 (70.40%).

Shelling percentage among the crosses ranged between 62.00 per cent (GPM 222 x XOB 2228) and 79.93 per cent (GPM 222 x LM-6). The other hybrids *viz.,* CM 117 x GPM 276 (79.20%), CM 117 x CML 139(79.17%), GPM 222 x CML 139 (78.57%),CA00106 x XOB 2276 (77%), CM117 x GPM 254 (76.90%), CM 117 x GPM 328 (76.59%), CM 117 x GPM 302 (76.33%) and GPM 222 x GPM 328 (76.20%) recorded more than 76 per cent of shelling percentage. The hybrids in which CM 117 was used as male produced very high shelling percentage (average 76.14%). The standard check Varuna 205 gave 73.15 per cent shelling percentage and out of 40 crosses 26 hybrids were found superior to standard check for shelling percentage.

4.1.9 100 grain weight (g)

Among female lines GPM 222 recorded the highest 100 grain weight (26.33g) and followed by GPM 201 and CA 00106. The line CM117 produced the lowest 100 grain weight of 12.03g. Likewise, among male parents XOB 2276 produced the highest 100 grain weight followed by GPM 257, CML 139 and GPM 276. The parent GPM 245 among males recorded low 100 grain weight of 16.37g.

Among the hybrids, GPM 201 x GPM 254 produced the highest (30.47g) 100 grain weight followed by GPM 201 x LM 6 (30.30g), GPM 201 x GPM 302 (29.50g) GPM 222 x GPM 276 (29.77g), GPM 201 x GPM 257 (28.83g), CA 00106 x GPM 302 (28.47g) and CA 00106 x XOB 2276

(28.17 g). Sixteen hybrids produced more than 25g of 100 grain weight. The combination CM 117 x GPM 245 produced the lowest (15.03g) 100 grain weight.

All the hybrid involving GPM 201 and GPM 222 as female parents produced more than 25.00 g of 100 grain weight which was greater than both the standard checks Varuna 205 (25.55g) and MLMH 956 (24.96g).

4.1.10 Grain yield per plant (g)

Good amount of variation was observed for grain yield per plant in parents as well as in crosses. Among the lines three lines recorded more than 75g grain yield per plant, the highest being in GPM 222 (95.42g) and the lowest being in CM 117 (53.93 g).

Among males GPM 257 had the highest grain yield of 117.08 g per plant followed by XOB 2276 (97.53g), GPM 276 (93.57g), GPM 302 (93.20g) and GPM 328 (87.05g), While GPM 245 (35.70g) had the lowest grain yield followed by LM 6 (39.90g).

The grain yield per plant among the crosses ranged between 74.40g (CA00106 x GPM 245) and 129.90 gm (GPM 222 x LM 6). The other hybrids *viz.*, GPM 201 x GPM 254 (126.37g), GPM 222 x GPM 302 (123.77g), GPM 201 x LM 6 (123.40g), GPM 222 x GPM 254 (122.10g), GPM 222 x GPM 328 (118g), CA00106 x XOB 2276 (114.20g), GPM 201 x XOB 2228 (110.93g) and CA00106 x GPM 328 (110.03g) recorded more than 110 g grain yield per plant.

The hybrids in which GPM 201 and GPM 222 were used as female parents produced very high grain yield (average 108g). The standard check MLMH-956 produced 119.27 g grain yield per plant and six hybrids were superior to standard check while Varuna 205 produced 114.7 g grain yield per plant and 8 hybrids were superior to Varuna 205 for grain yield per plant.

4.2 Analysis of variance

The analysis of variance is presented in Table 4.2. The mean sum of squares due to treatments for all characters were highly significant. The mean sum of squares due to parents (P), crosses (C) and parent vs. crosses interaction (P vs. C) The mean sum of squares due to parents were highly significant for all the character. In contrast, mean sum of squares due to crosses and parent vs. crosses were also highly significant for all the characters except number of cobs per plant. For line x tester interaction the mean sum of squares were highly significant for all the characters except for days to 50 per cent silking, plant height and number of cobs per plant. However, mean sum of squares due to lines were nonsignificant for number of cobs per plant and ear length while the sum of squares due to testers were highly significant for days to 50 per cent silking, Plant height and 100 grain weight.

4.3 Heterosis

Heterosis expressed as percentage increase or decrease over better parent (BP) and standard check (SC) were calculated for the characters under study and are presented in Table (4.3).

Table 4.2: **Analysis of variance for ten characters in 4 x 10 mlt of Maize**

Sr. No	Source of Variation	D.F.	Days to 50% silking	Plant height (cm)	No. of cobs per plant	Ear length (cm)	Ear girth (cm)	No. of grain rows per ear	No. of grains per ear	Shelling per cent (%)	100 grain weight (g)	Grain yield per plant (g)
1	Replication	2	27.97*	502.75*	-0.00	4.05*	1.55	0.10	3554.00	7.00	10.85	457.06*
2	Treatments	55	25.03*	1360.92*	0.00*	8.09*	3.54*	2.64*	12436.55*	31.05*	40.10*	1171.59*
3	Parents	13	30.41*	2094.36*	0.00*	12.11*	4.80*	3.33*	14038.65*	31.00*	41.68*	1638.16*
4	P vs.C	1	280.00*	30896*	0.00	60.83*	54.20*	18.32*	215736*	114.87*	356.61*	17763.63*
5	Crosses	39	17.00*	363.15*	0.00	5.32*	1.81*	2.06*	6618.67*	28.69*	33.08*	584.81*
6	Lines	3	27.67*	1166.33*	0.00	7.50	6.77*	13.21*	2143.33	70.88*	120.20*	1890.17*
7	Testers	9	43.17*	537.11*	0.00	6.48	1.63	0.52	4791.56	36.36	48.57*	701.49
8	L x T	27	7.08	215.93	0.00	4.36*	1.32*	1.34	7724.96*	21.44*	18.24*	400.88*
9	Error	110	7.13	143.36	0.00	1.50	0.52	0.71	1708.13	4.26	4.23	142.64

* = significant at 5 per cent level of probability

Looking to the importance of better parent and standard check in exploiting hybrid vigour, more emphasis was give on heterobeltiosis and standard heterosis.

4.3.1 Days to 50 per cent silking

Earliness in silking is desirable and hence cross combinations having negative heterosis for days to 50 per cent silking are of great value.

Heterosis for this character ranged from - 14.10 (GPM 222 x CML 139) to 5.16 (CM 117 x GPM 328) and -10.27 (GPM 222 x CML 139) to 2.68 (GPM 201 x GPM 328) per cent over better parent and standard check, respectively.

Out of 40 crosses studied only 8 were significantly superior over better parent for days to 50 per cent silking, whereas none of the crosses were significantly superior over standard check.

The cross combinations CM 117 x GPM 302, CM 117 x CML 139, CA00106 x CML 139, GPM 201 x CML 139, GPM 222 x GPM 302, GPM 222 x LM-6, and GPM 222 x CML 139 exhibited more than 10 per cent heterosis over better parent.

The crosses of female lines CA 00106 and GPM 222 were significantly earlier than others.

4.3.2 Plant height

Among the 40 crosses, eleven exhibited significant positive heterosis for plant height over better parent. The range of variation for heterobeltiosis for plant height varied between -14.46 (GPM 222 x CML 139) and 56.33 (CM

Table 4.3 : Heterosis (%) over better parent and standard check for ten different characters in 4 x 10 mlt of Maize.

Sr. No	Hybrids	Days to 50 per cent silking		Plant height (cm)		No. of cobs per plant	
		BP	SC	BP	SC	BP	SC
1	CM 117 x GPM 328	5.16	0.00	56.33*	-7.03	0.00	0.00
2	CM 117 x GPM 276	-6.82	-8.48	29.21*	-9.08	0.00	0.00
3	CM 117 x GPM 254	-3.56	-3.12	4.61	-10.10	0.00	0.00
4	CM 117 x GPM 245	-0.47	-5.36	15.05	-15.06	0.00	0.00
5	CM 117 x GPM 302	-10.00*	-7.59	9.28	-6.62	0.00	0.00
6	CM 117 x GPM 257	-4.51	-5.36	11.83	-7.32	0.00	0.00
7	CM 117 x XOB 2276	-2.69	-3.12	14.91	-5.60	0.00	0.00
8	CM 117 x LM 6	-9.32	-4.46	32.88*	-14.20	0.00	0.00
9	CM 117 x XOB 2228	0.00	0.89	-3.78	-9.80	0.00	0.00
10	CM 117 x CML 139	-12.82*	-8.93	-11.26	-12.51	-11.77*	0.00
11	CA 00106 x GPM 328	0.91	-0.89	34.58*	-5.30	0.00	0.00
12	CA 00106 x GPM 276	-3.18	-4.91	20.44	-15.25	0.00	0.00
13	CA 00106 x GPM 254	-3.56	-3.12	14.50	-1.61	0.00	0.00
14	CA 00106 x GPM 245	-2.73	-4.46	14.43	-15.52	0.00	0.00
15	CA 00106 x GPM 302	-7.40	-4.91	9.24	-6.65	0.00	0.00
16	CA 00106 x GPM 257	-7.21	-8.04	13.88	-5.62	0.00	0.00
17	CA 00106 x XOB 2276	-7.17	-7.59	15.97	-4.73	0.00	0.00
18	CA 00106 x LM 6	-11.44*	-6.70	39.64*	-1.74	0.00	0.00
19	CA 00106 x XOB 2228	-6.64	-5.80	5.32	-1.27	0.00	0.00
20	CA 00106 x CML 139	-12.39*	-8.48	-4.46	-5.81	-11.77*	0.00
21	GPM 201 x GPM 328	2.22	2.68	12.88	-3.00	0.00	0.00
22	GPM 201 x GPM 276	-5.78	-5.36	10.18	-5.32	0.00	0.00
23	GPM 201 x GPM 254	-2.67	-2.23	19.69*	2.85	0.00	0.00
24	GPM 201 x GPM 245	-4.44	-4.02	9.19	-6.17	0.00	0.00
25	GPM 201 x GPM 302	-4.78	-2.23	17.24*	0.75	6.67	6.67

26	GPM 201 x GPM 257	-2.67	-2.23	14.56	-1.56	6.67	6.67
27	GPM 201 x XOB 2276	-8.00	-7.59	10.20	-5.30	0.00	0.00
28	GPM 201 x LM 6	-7.63	-2.68	5.15	-9.64	0.00	0.00
29	GPM 201 x XOB 2228	-2.66	-1.79	4.47	-2.06	0.00	0.00
30	GPM 201 x CML 139	-11.54*	-7.59	-0.96	-2.36	-5.89	6.67
31	GPM 222 x GPM 328	1.44	-3.57	31.82*	-2.68	0.00	0.00
32	GPM 222 x GPM 276	-8.18	-9.82	30.57*	-3.60	0.00	0.00
33	GPM 222x GPM 254	0.00	0.45	13.37	-4.29	0.00	0.00
34	GPM 222 x GPM 245	-2.40	-9.37	26.00*	-7.00	0.00	0.00
35	GPM 222 x GPM 302	-10.87*	-8.48	16.82	-0.17	6.67	6.67
36	GPM 222 x GPM 257	-2.25	-3.12	16.80	-3.2	0.00	0.00
37	GPM 222 x XOB 2276	-7.62	-8.04	11.75	-8.18	0.00	0.00
38	GPM 222 x LM 6	-11.44*	-6.70	19.84*	-11.53	0.00	0.00
39	GPM 222 x XOB 2228	-4.87	-4.02	5.47	-1.12	0.00	0.00
40	GPM 222 x CML 139	-14.10*	-10.27	-14.46	-15.67	-11.77*	0.00
	SE (±)	3.78	3.78	16.93	16.93	0.05	0.05
	CD at 5 %	7.48	7.48	33.54	33.54	0.09	0.09

Sr. No	Hybrids	Ear length (cm)		Ear girth (cm)		No. of grain rows per ear	
		BP	SC	BP	SC	BP	SC
1	CM 117 x GPM 328	14.53	-7.58	21.96*	0.96	4.95	3.97
2	CM 117 x GPM 276	10.00	-8.71	4.76	-0.00	-1.88	-2.34
3	CM 117 x GPM 254	1.38	-9.63	6.18	-5.50	-1.84	0.00
4	CM 117 x GPM 245	-15.35	-20.90*	-11.47	-9.57	3.74	3.74
5	CM 117 x GPM 302	-9.37	-2.13	2.37	-0.81	-2.31	-1.40
6	CM 117 x GPM 257	15.03	-7.17	4.41	1.91	1.89	0.93
7	CM 117 x xOB 2276	8.93	-10.04	5.90	-1.20	0.24	-0.70
8	CM 117 x LM 6	7.16	-13.52*	16.76	-3.35	-5.26	0.94
9	CM 117 x xOB 2228	4.15	-2.25	-0.24	1.20	3.77	2.80
10	CM 117 x CML 139	-2.26	-2.46	-8.09	-2.15	-5.19	-6.07
11	CA 00106 x GPM 328	18.77	-1.43	18.55*	13.16	8.45	7.94
12	CA 00106 x GPM 276	31.36*	9.02	5.01	0.24	10.33	9.81
13	CA 00106 x GPM 254	9.89	-2.05	2.00	-2.63	5.50	7.48
14	CA 00106 x GPM 245	-16.01	-21.52*	-7.73	-5.74	9.11	9.11
15	CA 00106 x GPM 302	-22.01*	-15.78*	3.16	-0.05	1.85	2.80
16	CA 00106 x GPM 257	6.42	-11.68*	8.02	5.43	6.57	6.07
17	CA 00106 x xOB 2276	9.14	-9.43	10.53	5.50	6.57	6.07
18	CA 00106 x LM 6	17.78	-2.25	10.03	5.02	-5.26	0.93
19	CA 00106 x xOB 2228	-6.77	-12.50*	0.47	1.91	2.81	2.34
20	CA 00106 x CML 139	-13.35	-13.53*	-1.57	4.78	8.45	7.94
21	GPM 201 x GPM 328	10.81	-1.23	16.94*	4.10	7.80	-9.81
22	GPM 201 x GPM 276	-0.92	-11.68	3.51	-1.20	-5.50	-3.74
23	GPM 201 x GPM 254	9.66	-2.25	21.77*	8.37	-1.15	0.70
24	GPM 201 x GPM 245	-9.21	-15.16	-1.17	0.96	1.84	3.74
25	GPM 201 x GPM 302	-12.71	-5.74	14.32	10.77	7.80	9.81
26	GPM 201 x GPM 257	12.41	0.20	19.85*	16.99	9.63	11.68

27	GPM 201 x xOB 2276	8.28	-3.48	13.97	6.34	8.94	10.98
28	GPM 201 x LM 6	25.06*	11.48	18.55*	5.50	1.75	8.41
29	GPM 201 x xOB 2228	4.15	-2.25	5.19	6.70	14.68	16.82
30	GPM 201 x CML 139	-0.62	-0.82	-0.23	6.22	8.26	10.28
31	GPM 222 x GPM 328	17.11	-9.43	-5.15	-3.11	-5.14	-5.14
32	GPM 222 x GPM 276	2.41	-4.30	-6.10	-4.07	-1.40	-1.40
33	GPM 222x GPM 254	14.47	6.97	7.96	10.29	3.67	5.61
34	GPM 222 x GPM 245	-3.51	-9.84	5.15	7.42	0.47	0.47
35	GPM 222 x GPM 302	3.61	11.88	5.15	7.42	1.85	2.80
36	GPM 222 x GPM 257	7.46	0.41	1.40	3.60	-8.41	-8.41*
37	GPM 222 x xOB 2276	-10.53	-16.39*	-2.40	-0.29	0.93	0.94
38	GPM 222 x LM 6	-4.44	-6.97	1.64	3.83	-13.16	-7.48*
39	GPM 222 x xOB 2228	-0.87	-5.33	5.40	7.66	-3.74	-3.74
40	GPM 222 x CML 139	-13.96	-14.14*	-10.79	-5.02	-2.80	-2.80
	SE (±)	1.45	1.45	1.02	1.02	1.19	1.19
	CD at 5 %	2.87	2.87	2.03	2.03	2.36	2.36

Sr. No	Hybrids	No. of grains per ear		Shelling per cent		100 grain wt. (g)		Grain yield per plant	
		BP	SC	BP	SC	BP	SC	BP	SC
1	CM 117 x GPM 328	12.32	-2.47	10.00*	4.70*	96.21*	-7.57	78.86*	-15.50
2	CM 117 x GPM 276	9.50	-4.91	2.63	8.28*	24.94	3.59	36.56	-5.90
3	CM 117 x GPM 254	14.90	-0.22	7.05	5.13*	-13.51	-23.16	20.60	-18.63
4	CM 117 x GPM 245	3.04	-10.19	-0.04	2.62*	-42.91	-41.16*	-14.03	-28.15
5	CM 117 x GPM 302	11.11	5.73	9.61*	4.35*	34.67*	-8.28	11.40	-15.07
6	CM 117 x GPM 257	-2.84	-15.63*	7.47	2.31*	-15.85	-25.90*	-8.66	-25.14
7	CM 117 x xOB 2276	0.18	13.01	3.94	2.31*	5.68	-18.72	-5.60	-32.93
8	CM 117 x LM 6	15.1	0.13	6.87	2.85*	46.23*	-6.33	54.94	-26.80
9	CM 117 x xOB 2228	21.26	5.30	5.17	0.12	-6.73	-13.24	12.34	-8.29
10	CM 117 x CML 139	21.98	5.92	11.18*	8.23*	-2.39	-10.63	-20.54	-18.51
11	CA 00106 x GPM 328	15.84	0.58	-3.94	1.33	22.50	1.57	39.86	-3.62
12	CA 00106 x GPM 276	15.30	-5.81	-4.19	1.07	8.26	-10.24	5.63	-27.21
13	CA 00106 x GPM 254	15.64	-5.53	-5.40	-0.20	3.52	-8.02	34.78	-7.12
14	CA 00106 x GPM 245	4.80	-8.65	-2.16	3.22*	-29.11*	-26.94*	-22.03	-34.83
15	CA 00106 x GPM 302	-7.12	-11.61	-2.75	2.60*	34.38*	11.42	21.24	-7.56
16	CA 00106 x GPM 257	12.06	-8.45	-1.88	3.51*	6.07	-6.60	12.07	-8.15
17	CA 00106 x xOB 2276	26.71	3.52	-0.22	5.27*	32.97*	10.24	40.81	0.03
18	CA 00106 x LM 6	6.19	-13.25	-4.45	0.80	23.44	2.35	26.18	-13.05
19	CA 00106 x xOB 2228	8.43	-11.41	-7.26	-2.16	-3.97	-10.67	11.98	-8.58
20	CA 00106 x CML 139	6.26	-8.50	-5.36	-0.15	-0.54	-8.94	-21.36	-19.36
21	GPM 201 x GPM 328	23.85	7.54	1.30	-0.52	-2.94	-13.76	37.47	-7.24
22	GPM 201 x GPM 276	-7.72	-24.61*	-2.64	2.72*	18.58	5.35	27.24	-12.32
23	GPM 201 x GPM 254	18.43	-15.76*	2.00	0.16	34.21*	19.24	-41.93	-4.23
24	GPM 201 x GPM 245	-8.34	-20.11*	0.67	3.35*	-15.38	-12.78	-5.58	-21.10
25	GPM 201 x GPM 302	2.50	-2.47	-0.93	-2.71	27.97*	13.70	38.20	5.37
26	GPM 201 x GPM 257	65.57*	17.77	-1.91	-3.66	27.02*	12.85	35.05	10.69
27	GPM 201 x xOB 2276	27.00	-9.55	-1.64	-3.18	4.40	-7.24	14.71	-18.51
28	GPM 201 x LM 6	39.36*	-0.87	1.98	0.15	33.48*	18.60	60.19*	8.09
29	GPM 201 x xOB 2228	58.97*	15.33	0.68	-1.13	-4.07	-10.76	19.03	-2.83
30	GPM 201 x CML 139	15.29	-0.72	-1.62	-3.40	13.42	3.85	-11.09	-8.82

31	GPM 222 x GPM 328	9.29	-4.74	1.46	-4.17*	-2.34	0.65	23.77	3.44
32	GPM 222 x GPM 276	12.96	-1.54	-3.54	1.76	13.04	16.60	8.82	-9.02
33	GPM 222x GPM 254	27.51	11.14	-5.64	-3.12	-4.68	-1.76	27.96	6.95
34	GPM 222 x GPM 245	8.91	-5.07	-1.95	0.67	-6.20	-3.33	8.68	-9.17
35	GPM 222 x GPM 302	22.17	16.26	-2.75	-0.15	-7.21	-4.37	29.71	8.41
36	GPM 222 x GPM 257	3.84	-9.50	-3.95	-1.38	-4.30	-1.37	10.11	-7.97
37	GPM 222 x xOB 2276	7.50	-6.31	-2.53	0.07	-12.91	-10.24	9.55	-8.44
38	GPM 222 x LM 6	-6.12	-18.17*	6.44	9.28*	4.37	7.57	36.13*	13.78
39	GPM 222 x xOB 2228	2.53	-10.63	-17.44	-15.24*	-13.99	-11.35	-10.33	-25.05
40	GPM 222 x CML 139	-14.41	-25.40*	4.62	7.41*	-0.06	3.00	-25.94	-24.05
	SE (±)	58.45	58.45	2.92	2.92	2.91	2.91	16.90	16.90
	CD at 5 %	115.79	115.79	5.78	5.78	5.76	5.76	33.46	33.46

BP : Heterosis over better parent, SC: Heterosis over standard check.
* Significant at 5 % level of probability.

117 x GPM 328) per cent. The combination CM 117 x GPM 328 produced the highest heterobeltiosis to the tune of 56.33 per cent and was followed by CA00106 x GPM 328, CM 117 x LM 6, GPM 222 x GPM 328 and GPM 222 x GPM 328 and GPM 222 x GPM 276 which produced more than 30 per cent heterosis over better parent.

However, none of the crosses produced significant heterosis over standard check.

4.3.3 Number of cobs per plant

More number of cobs per plant is an important attribute hence positive heterosis for this trait is desirable. Heterobeltiosis for this trait was found ranging between -11.77 (CM 117 x CML 139) and 6.67 (CA 00106 x CML 139) per cent While for standard heterosis ranged between 0.00 to 6.67 per cent. None of the cross combinations exhibited significant positive heterosis over better parent and standard check.

4.3.4 Ear length

The cross CA00106 x GPM 276 produced the highest magnitude of heterobeltiosis to the tune of 31.36 per cent and was followed by GPM 201 x LM 6 (25.06%). In case of standard heterosis none of the cross combination exhibited significant positive heterosis over standard check. The range of heterosis for this trait varied between -22.01 (CA00106 x GPM 302) and 31.36 (CA00106 x GPM 276) per cent over better parent and -21.52 (CA00106 x GPM 245) and 11.88 (GPM x GPM 302) per cent over standard check.

The combinations GPM 222 x GPM 302 (11.88),GPM 201 x LM 6 (11.48) and CA 00106 x GPM 276 (9.02), exhibited non-significant but positive heterosis in desirable direction over standard check.

4.3.5 Ear girth

Heterosis for this trait ranged between -11.47 (CM 117 x GPM 245) and 21.96 (CM 117 X GPM 328) per cent over better parent and -9.57 (CM 117 x GPM 245) and 16.99 (GPM 201 x GPM 257) per cent over standard check.

Only 6 combinations *viz.*, CM 117 x GPM 328, CA 00106 x GPM 328, GPM 328, GPM 201 x GPM 254, GPM 201 X GPM 257 and GPM 201 X LM-6 were significantly superior over better parents for ear girth. However, none of the crosses produced significant heterosis over standard check whereas the crosses GPM 201 x GPM 257 (16.99), CA 00106 x GPM 328 (13.16), GPM 201 x GPM 302 (10.77) and GPM 222 x GPM 254 (10.29) exhibited high magnitude of heterosis over standard check in desirable direction, but were nonsignificant.

The cross combinations involving GPM 201 as female parent and GPM 328 as male parent produced significantly superior heterobeltiosis.

4.3.6 Number of grain rows per ear

The combination GPM 222 x LM 6 recorded minimum heterosis of -13.16 per cent over better parent, whereas the combination GPM 201 x XOB 2228 produced maximum of 14.68 per cent heterosis. The standard heterosis varied between -8.41 (GPM 222 x GPM 257) and 16.82 (GPM 201 x XOB 2228) per cent.

Only one cross combination (GPM 222 x XOB 2276) exhibited positively significant standard heterosis. Whereas, none of the cross combinations produced significant heterosis over better parent.

4.3.7 Number of grains per ear

The heterosis for the number of grains per ear ranged from –14.41 (GPM 222 x CML 139) to 65.57 (GPM 201 x GPM 257) per cent over better parent and -25.40 (GPM 222 x CML 139) to 17.77 (GPM 201 x GPM 257) per cent over standard check.

The cross GPM 201 x GPM 257 produced highly significant and favourable heterosis over better parent to the tune of 65.57 per cent and was followed by GPM 201 x XOB 2228 (59.97) and GPM 201 x LM-6 (39.36). However, none of the crosses produced significant heterosis in favourable direction over standard check.. The cross combinations, GPM 201 x GPM 257 (17.77), GPM 222 x GPM 302 (16.26) and GPM 201 x XOB 2228 (15.83) recorded though nonsignificant but exhibited high magnitude standard heterosis in desirable direction.

4.3.8 Shelling percentage

The heterobeltiosis for shelling percentage ranged from –17.44 (GPM 222 x XOB 2228) to 11.18 (CM 117 x CML 139) per cent, however, for standard heterosis it varied between -15.24 (GPM 222 x XOB 2228) and 9.28 (GPM 222 x LM 6) per cent.

The combination CM 117 x CML 139 produced relatively high magnitude of heterobeltiosis to the tune of 11.18 per cent followed by CM 117 x GPM 302 (9.61%).

Out of 40 crosses studied 19 were significantly superior over standard check for shelling percentage.

All the crosses involving CM 117 as female parent except the cross CM 117 x XOB 2228 and more than 40 per cent crosses of male parent CA 00106 were significantly superior over others. Only the two crosses *viz.*, CM 117 x GPM 302 and CM 117 x CML 139 were highly significant over better parent.

4.3.9 100 grain weight (g)

The heterobeltiosis for 100 grain weight ranged between -42.91 (CM 117 x GPM 245) to 96.21 (CM 117 x GPM 328) per cent.

The range of heterosis for this character over hybrid check was from – 41.16 (CM 117 x GPM 245) to 33.48 (GPM 201 x LM 6) per cent.

The cross combination CM 117 x GPM 328 (96.21%) exhibited the highest per cent of heterosis over better parent followed by CM 117 x LM-6 (46.23%), CM 117 x GPM 302 (34.67) and CA 00106 x XOB 2276 (32.97%). However, none of the crosses produced significant heterosis in favourable direction over standard check.

The high magnitude of standard heterosis was recorded by the crosses, GPM 201 x GPM 254 (19.24), GPM 201 x LM 6 (18.70) and GPM 222 x GPM 276 (16.50) in desirable direction.

4.3.10 Grain yield per plant (g)

The range of heterobeltiosis varied between –25.94 (GPM 222 x CML 139) to 78.86 (CM 117 x GPM 328) per cent, whereas, for the standard heterosis it varied between -34.83 (CA 00106 x GPM 245) to 13.78 (GPM 222 x LM-6) per cent for grain yield per plant.

The combination CM 117 x GPM 328 produced the highest and significant heterobeltiosis (78.86%) for grain yield per plant followed by GPM 201 x LM-6 (60.19%) and GPM 222 x LM-6 (36.13%) whereas, none of the crosses exhibited significant heterosis in favourable direction over standard check.

4.4 Combining ability effects

4.4.1 General combining ability effects

General combing ability effect of different parents for different characters are presented in Table 4.4.

Looking to the data on general combining ability effects it was observed that the parent GPM 201 (for 8 characters) among lines and GPM 302 (for 5 characters) among testers recorded high magnitude of gca effects and were followed by GPM 222 among females and GPM 254 and LM 6 among males.

In the combining ability of yield component characters the parents GPM 222 among the lines and GPM 276 and CML 139 among the testers recorded significantly high gca effect in desirable direction for day to 50 per cent silking. However, the lines and testers showing significant gca effect for

Table 4.4 : Estimates of general combining ability effects for ten characters in 4 x1 0 mlt of Maize

Parents	Days to 50% silking	Plant height (cm)	No. of cobs per plant	Ear length (cm)	Ear girth (cm)	No. of grain rows per ear	No. of grains per ear	Shelling per cent (%)	100 grain weight (g)	Grain yield per plant (g)
GCA- Lines										
CM 117	0.27	-8.05*	-0.01*	-0.46*	-0.61*	-0.41*	7.80	2.05*	-2.76*	-10.08*
CA 00106	-0.43	-0.23	-0.01*	-0.41*	0.03	0.43*	-10.32	0.18	-0.06	-2.61
GPM 201	1.20*	7.10*	0.01*	0.41*	0.55*	0.69*	5.94	-1.54*	1.85*	6.36*
GPM 222	-1.03*	1.17	0.01	0.45*	0.03	-0.71*	-3.41	-0.69	0.98*	6.33*
SE (gi) ±	0.49	2.19	0.01	0.19	0.13	0.15	7.55	0.38	0.37	2.18
SE (gi-gj) ±	0.69	3.09	0.01	0.26	0.19	0.22	10.67	0.53	0.53	3.08
GCA- Testers										
GPM 328	3.33*	4.04	-0.01	0.88*	0.17	0.16	21.23	0.83	-0.12	5.63
GPM 276	-1.67*	-4.77	-0.01	0.27	-0.53*	-0.35	-20.84	1.59*	2.07*	-3.38
GPM 254	2.17*	6.85*	-0.01	0.63*	0.01	0.06	9.36	-0.58	0.23	5.60
GPM 245	-0.67	-10.85*	-0.01	-1.83*	-0.60*	0.17	-28.99*	0.86	-4.27*	-14.44*
GPM 302	-0.67	7.12*	0.03*	0.43	0.25	0.07	30.19*	-0.19	1.90*	9.65*
GPM 257	0.17	4.22	0.01	0.17	0.62*	-0.07	3.18	-0.80	-0.24	3.44
XOB 2276	-1..25	0.69	-0.01	-0.69*	0.01	0.18	-7.70	-0.12	-0.55	-4.91
LM 6	-0.17	-7.00*	-0.01	0.46	0.02	-0.33	-15.48	1.45*	2.52*	7.04*
XOB 2228	1.67*	6.22	-0.01	0.00	0.25	0.22	19.57	-4.31*	-1.84*	-0.60
CML 139	-2.92*	-6..56	0.01	-0.34	-0.22	-0.10	-11.53	1.27*	0.30	-8.02*
SE (gi) ±	0.77	3.46	0.01	0.30	0.21	0.24	11.93	0.60	0.59	3.45
SE (gi-gj) ±	1.09	4.89	0.01	0.42	0.30	0.34	16.87	0.84	0.84	4.88

*, Significant at 5 per cent level of probability.

plant height viz., CM117 among females and GPM 254 and GPM 302 among males showed significantly high gca effects.

Likewise, GPM 201 among lines and GPM 302 among testers for number of cobs per plant; GPM 222 and GPM 201 among lines and GPM 328 and GPM 254 among testers for ear length; GPM 201 among lines and GPM 257 among testers for ear girth; CA 00106 and GPM 201 among lines only for number of grain rows per ear; GPM 302 among the testers only for number of grains per ear; CM 117 among lines and GPM 276, LM-6 and CML 139 among testers for shelling percentage; GPM 201, GPM 222 among lines and GPM 276, GPM 302 and LM 6 among testers for grain yield per plant recorded significant gca effects in desirable direction for respective characters.

4.4.2 Specific combining ability effects.

Specific combining ability effects of different crosses for all the characters are presented in Table 4.5

4.4.2.1 Days to 50 per cent silking

Out of 40 crosses studied none of the crosses produced significant sca effect in desirable direction. The crosses CA 00106 x GPM 257 (-2.07), GPM 201 x XOB 2276 (-1.95), CA 00106 x XOB 2228 (1.90), GPM 222 x GPM 245 (-1.63) and CM 117 x GPM 302 (-1.60) showed sca effect in desirable direction but the effects were nonsignificant.

4.4.2.2 Plant height

Among all fourty crosses studied only the combination CA 00106 x LM 6 recorded the highest and highly significant sca effect (17.65) in desirable

Table-4.5 : Estimates of specific combining ability effects for ten characters in 4 x 10 mlt. of Maize.

Hybrids	Days to 50% silking	Plant height (cm)	No. of cobs per plant	Ear length (cm)	Ear girth (cm)	No. of grain rows per ear	No. of grains per ear	Shelling per cent (%)	100 grain weight (g)	Grain yield per plant (g)
CM 117 x GPM 328	0.07	2.20	0.01	-0.74	0.22	0.38	-20.10	-0.38	2.05	-4.62
CM 117 x GPM 276	-1.27	6.27	0.01	-0.32	0.79	-0.01	11.82	1.47	2.71*	-3.82
CM 117 x GPM 254	-1.10	-7.71	0.01	-0.82	-0.52	-0.08	3.01	1.34	-2.28	2.30
CM 117 x GPM 245	0.07	-1.50	0.01	-0.20	-0.48	0.33	-4.09	-1.93	-2.37*	14.56*
CM 117 x GPM 302	-1.60	0.08	-0.03	0.59	-0.10	-0.29	9.32	0.38	-0.15	-10.41
CM 117 x GPM 257	-0.77	1.35	-0.01	0.03	-0.09	0.17	-61.07*	-0.50	-2.51*	8.01
CM 117 x XOB 2273	2.32	8.88	0.01	0.43	0.08	-0.31	-38.22	-1.18	-0.36	3.18
CM 117 x LM 6	0.23	-3.33	0.01	-1.28*	-0.24	3.44	29.47	-2.36	-0.27	3.76
CM 117 x XOB 2228	2.4	-6.38	0.01	1.00	0.17	0.16	17.97	1.40	2.32	4.14
CM 117 x CML 139	-0.35	0.13	-0.01	1.32*	0.18	-0.79	51.89*	1.76	0.86	-1.11
CA 00106 x GPM 328	0.10	-1.62	0.07	0.21	1.28*	0.11	11.94	-0.97	1.69	8.18
CA 00106 x GPM 276	2.10	-15.83*	0.01	2.51*	0.18	0.89	25.88	-1.92	-3.52*	-12.91
CA 00106 x GPM 254	-0.40	4.10	0.01	0.36	-0.77	0.15	-3.06	-0.69	-1.11	1.05
CA 00106 x GPM 245	1.43	-10.40	0.01	-0.35	-0.59	0.26	21.05	0.37	-1.44	-10.55
CA 00106 x GPM 302	1.10	-7.81	-0.03	-1.68*	-0.64	-0.53	-51.64*	0.98	2.19	-3.50
CA 00106 x GPM 257	-2.07	-2.54	0.01	-0.75	-0.25	0.07	-10.21	2.25	-0.27	2.03
CA 00106 x XOB 2276	-0.32	3.06	0.01	0.47	0.37	-0.18	55.28*	2.86*	4.34 *	19.73*
CA 00106 x LM 6	-0.73	17.65*	0.01	0.50	0.29	-0.40	-13.42	-1.98	0.75	-7.16
CA 00106 x XOB 2228	-1.90	5.74	0.01	-0.72	-0.37	-0.75	-40.11	1.61	0.28	5.60
CA 00106 x CML 139	0.68	7.81	-0.01	-0.54	0.50	0.37	4.30	-2.50*	-1.40	0.70

Hybrids	Days to 50% silking	Plant height (cm)	No. of cobs per plant	Ear length (cm)	Ear girth (cm)	No. of grain rows per ear	No. of grains per ear	Shelling per cent (%)	100 grain weight (g)	Grain yield per plant (g)
GPM 201 x GPM 328	1.13	-3.62	-0.01	-0.58	-0.51	0.12	27.41	-0.61	-4.14*	-8.09
GPM 201 x GPM 276	0.13	-0.18	-0.01	-1.67*	-0.54	-1.30*	-76.12*	1.00	-1.45	-4.88
GPM 201 x GPM 254	-1.37	7.11	-0.01	-0.50	0.25	-1.08*	-65.98*	1.30	3.95*	-4.62
GPM 201 x GPM 245	0.13	3.92	-0.01	-0.14	-0.17	0.76	-47.44	2.19	0.27	-3.82
GPM 201 x GPM 302	1.47	1.97	0.02	-0.87	0.35	0.21	-26.22	-1.18	0.86	2.30
GPM 201 x GPM 257	0.63	-0.47	0.04*	0.36	0.85*	0.61	93.12*	-1.28	2.78*	14.56*
GPM 201 x XOB 2276	-1.95	-5.60	-0.01	0.62	-0.03	0.26	-20.61	-1.60	-2.04	-10.41
GPM 201 x LM 6	0.63	-7.94	-0.01	1.91*	-0.17	0.41	26.74	-0.74	1.49	8.01
GPM 201 x XOB 2228	-0.53	-3.63	-0.01	0.13	-0.22	1.06*	65.59*	4.08*	-1.66	3.18
GPM 201 x CML 139	0.28	8.45	0.04*	0.7	0.19	0.45	23.50	-3.15*	-0.05	3.76
GPM 222 x GPM 328	-1.30	3.04	0.01	1.11	-0.99*	-0.62	-19.24	2.00	0.40	4.14
GPM 222 x GPM 276	-0.97	9.72	0.01	-0.52	-0.42	0.42	38.42	-0.55	2.26	-1.11
GPM 222x GPM 254	2.87	-3.50	0.01	0.96	1.03*	1.02*	66.03*	-1.95	-0.56	8.18
GPM 222 x GPM 245	-1.63	7.98	0.01	0.69	1.24*	0.17	30.49	-0.63	3.54*	9.81
GPM 222 x GPM 302	-0.97	5.76	0.03	1.96*	0.40	0.61	68.53*	-0.57	-2.90*	5.79
GPM 222 x GPM 257	2.20	1.66	-0.02	0.35	-0.51	-0.86	-21.85	-0.47	0.01	-6.71
GPM 222 x XOB 2276	-0.05	-6.34	0.01	-1.52*	-0.43	0.22	3.55	-0.08	-1.94	1.12
GPM 222 x LM 6	-0.13	-6.38	0.01	-1.13	0.12	-0.46	-42.79	5.08*	-0.47	14.53*
GPM 222 x XOB 2228	0.03	4.47	0.01	-0.41	0.43	-0.48	-43.45	-7.09*	-0.94	-22.16*
GPM 222 x CML 139	-0.05	-16.40*	-0.02	-1.50*	-0.87*	-0.03	-79.69*	3.90	0.59	-13.6
SE ± (Sij)	1.54	6.91	0.02	0.59	0.42	0.49	23.86	1.19	1.19	6.90
SE ± (Sij- Ski)	2.18	9.78	0.03	0.84	0.59	0.69	33.74	1.68	1.68	9.75
CD at 5 %	3.05	13.69	0.04	1.17	0.83	0.97	47.27	2.36	2.36	13.66

*,Significant at 5 per cent level of probability

direction indicating its superiority over others. The crosses, GPM 222 x GPM 276 (9.72), CM 117 x XOB 2276 (8.87), GPM 201 x CML 139 (8.45), CA 00106 x CML 139 (7.81) and GPM 201 x GPM 254 (7.11) showed nonsignificant sca effects but in desirable direction.

4.4.2.3 No of cobs per plant

Only two crosses out of 40 studied viz, GPM 201 x GPM 257 (0.04) and GPM 201 x CML 139 (0.04) showed significant sca effect in desirable direction for number of cobs per plant.

4.4.2.4 Ear length

The combination CA 00106 x GPM 276 recorded the highest (2.51) and significant sca effect for ear length, followed by GPM 222 x GPM 302 (1.96), GPM 201 x LM-6 (1.91) and CM 117 x CML 139 (1.32) which gave significant sca effect for this trait.

4.4.2.5 Ear girth

The combination CA 00106 x GPM 328 (1.28) was the best as it exhibited the significant and highly positive sca effect for ear girth, which was followed by GPM 222 x GPM 245 (1.24), GPM 222 x GPM 254 (1.03) and GPM 222 x GPM 257 (0.85) were the other crosses which exhibited significant sca effects.

4.2.6 Number of grain rows per ear

Of the 40 crosses studied only two crosses viz., GPM 201x XOB 2228 (1.06) and GPM 222 x GPM 276 (1.02) exhibited significantly high sca effect.

The other crosses CA 00106 x GPM 276 (0.89), GPM 201 x GPM 257 (0.61), GPM 222 x GPM 302 (0.61) and CM 117 x LM-6 (0.44) showed sea effect in desirable direction.

4.4.2.7 Number of grains per ear

The combination GPM 201 x GPM 257 recorded the highest and highly significant sea effect (93.12) in desirable direction, indicating its superiority over others. The combination GPM 222 x GPM 302 (68.53) followed by GPM 222 x GPM 254 (66.03), GPM 201 x XOB 2228 (65.59), CA 00106 x XOB 2276 (55.28) and CM 117 x CML 139 (51.89) recorded high magnitude of significant sea effect in desirable direction. Among the crosses studied, six crosses exhibited significant sea effect for number of grains per ear.

4.4.2.8 Shelling percentage

The combination GPM 222 x LM 6 (5.08) was the best as it exhibited the highest significant positive sea effect for shelling percentage. The combination GPM 201 x XOB 2228 (4.08), GPM 222 x CML 139 (3.90) and CA 00106 x XOB 2276 (2.86) recorded high magnitude of sea effect in desirable direction.

4.4.2.9 100 grain weight (g)

Among hybrid combinations, significant positive sea effects for 100 grain weight were observed for five combinations. The combination CA 00106 x XOB 2276 (4.34) exhibited highly significant sea effect for 100 grain weight which was followed by GPM 201 x GPM 254 (3.95), GPM 222 x GPM 245 (3.54), GPM 201 x GPM 257 (2.78) and CM 117 x GPM 276 (2.71).

Table- 4.6 Per cent contribution of lines, testers and lines x testers for ten characters in 4 x 10 mlt of Maize.

Sr. no.	Name of character	Contribution of (per cent)		
		Lines	Testers	Lines X Testers
1.	Days to 50% silking	12.52	58.63	28.85
2.	Plant height (cm)	24.71	34.13	41.16
3.	No. of cobs per plant	16.70	30.58	52.72
4.	Ear length (cm)	10.84	32.41	56.75
5.	Ear girth (cm)	28.72	20.77	50.52
6.	No. of grain rows per ear	49.25	5.86	44.89
7.	No. of grains per ear	2.50	16.71	80.80
8.	Shelling per cent (%)	19.00	29.25	51.75
9.	100 grain weight (g)	27.95	33.88	38.17
10.	Yield per plant (g)	24.86	27.68	47.46

4.4.2.10 Grain yield per plant (g)

The extent of sca effect ranged between -22.16 and 19.73 for grain yield per plant . The combination CA 00106 x XOB 2276 recorded the highest sca effect for grain yield per plant followed by CM 117 x GPM 276 (18.90), GPM 201 x GPM 257 (14.56) and GPM 222 x LM 6 (14.53).

4.5 Per cent contribution of females, males and female x males

Per cent contribution of females (lines), males (testers) and female x male (line x tester) to the sum of squares of hybrids are presented in Table 4.6.

Per cent contribution of females to the total variance was the highest for number of grain rows per ear (49.25%) followed by ear girth (28.72%), 100 grain weight (27.95%), grain yield per plant (24.86%) and plant height (24.71%). The contribution of female parents to the total variance was minimum for number of grains per ear (2.5%), ear length (10.84%) and days to 50 per cent silking (12.52%). The contribution of females was higher than the contribution of males and females x males interaction for the character number of grains per ear.

Per cent contribution of male parents to the total variance was the highest for days to 50 per cent silking (58.63%) followed by plant height (34.13%), 100 grain weight (33.88%), ear girth (32.58%) and number of cobs per plant (30.58%), while the contribution was minimum for number of grain rows per ear (5.86%). The contribution due to males compared to females and females x males interaction for the character days to 50 per cent silking was high.

Contribution of females x males interaction was the highest for number of grains per ear (80.80%) followed by ear length (56.75%), number of cobs per plant (52.72%), shelling percentage (51.75%) and ear girth (50.52%). As compared to the parents, females x males interactions contributed more almost for all the characters except days to 50 per cent silking and number of grain rows per ear.

4.6 Components of variance : Gene action and heritability

Gene action was worked out by comparing the values of σ^2gca, σ^2 sca , σ^2A, σ^2 D and A:D ratio. This will indicate the genetic control of the respective character in the process of inheritance. The magnitude of various variances are given in Table 4.7. The gca variance was greater than sca variance for the days to 50 per cent silking, whereas the sca variances were greater than gca variances for all the remaining characters.

Estimate of dominance variance (σ^2D) was higher for all the characters than additive variance (σ^2A) except for days to 50 per cent silking. Similar trend was observed while looking to the A: D ratio. The A : D ratio was greater than unity only for the days to 50 per cent silking.

Estimates of heritability were obtained by comparing genotypic variance to the total phenotypic variance.

The data in respect of heritability percentage revealed that high values of heritability were observed for most of the characters except number of cobs per plant (13.56%), plant height (45.53%) and number of grain rows per ear (47.40%). The high heritability percentage was observed for days to 50 per cent

Table 4..7 : Components of variance for ten different characters in 4 x 10 mlt of Maize.

Component	Days to 50% silking	Plant height (cm)	No. of cobs per plant	Ear length (cm)	Ear girth (cm)	No. of grain rows per ear	No. of grains per ear	Shelling per cent	100 grain weight (g)	Grain yield per plant (g)
σ^2gca	-0.16	2.42	0.00	0.01	0.01	0.01	-18.16	0.12	0.24	3.02
σ^2 sca	-0.02	24.19	-0.00	1.10	0.27	0.21	2005.61	5.73	4.67	86.08
σ^2 A	2.60	38.67	0.00	0.25	0.13	0.20	-290.54	1.90	3.90	48.30
σ^2D	-0.07	96.75	-0.00	4.42	1.07	0.83	8022.45	22.91	18.68	344.33
h^2 (%)	73.90	45.53	13.56	69.10	65.84	47.40	67.78	67.72	73.89	70.63
A:D ratio	-37..14	0.39	0.00	0.06	0.12	0.24	-0.04	0.08	0.21	0.14

silking (73.90%) and 100 grain weight (73.89%) followed by grain yield per plant (70.63%), ear length (69.10%), shelling percentage (67.72), number of grains per ear (67.68%) and ear girth (65.84%). Thus, the heritability ranged between the 13.56 per cent for number of cobs per plant and 73.90 per cent for days to 50 per cent silking and 73.89 per cent for 100 grain weight.

4.7 Correlation

The correlation coefficients for all the characters are presented in Table 4.8. However, only the significant correlations with respect to important characters are described here.

Looking to the table it was observed that the highest correlation (0.83) was observed between the characters ear girth and grain yield per plant. Grain yield per plant showed highly significant and positive association with days to 50 per cent silking (0.78), ear length (0.73), 100 grain weight (0.71), number of grains per ear (0.67) and number of grain rows per ear (0.28).

Likewise days to 50 per cent silking had highly significant and positive association with grain yield per plant (0.78), ear girth (0.78), ear length (0.63). 100 grain weight (0.60), number of grains per ear (0.55), number of grain rows per ear (0.30) and number cobs per plant (0.27) while it had negative association with plant height (-0.17) and shelling percentage (- 0.063).

The second highest association was observed between ear length and ear girth (0.68). Both of these characters showed highly significant and positive association with days to 50 per cent silking (0.63, 0.78), number of cobs per

Table 4.8: Simple correlation coefficient among different characters in 4 x 10 mlt of Maize

	Days to 50% silking	Plant height (cm)	No. of cobs per plant	Ear length (cm)	Ear girth (cm)	No. of grain rows per ear	No. of grains per ear	Shelling per cent	100 grain weight (g)	Grain yield per plant (g)
Days to 50% silking	1.00	-0.17*	0.27*	0.63*	0.78*	0.30*	0.55*	-0.063	0.60*	0.78*
Plant height (cm)		1.00	0.14	-0.07	-0.19	-0.64*	-0.22	-0.45*	-0.28*	-0.21
No. of cobs per plant			1.00	0.25*	0.34*	0.08	0.20	-0.20	0.19	0.33*
Ear length (cm)				1.00	0.68*	0.25*	0.67*	-0.063	0.47*	0.73*
Ear girth (cm)					1.00	0.44*	0.65*	-0.12	0.63*	0.83*
No. of grain rows per ear						1.00	0.61*	-0.09	0.10	0.28*
No. of grains per ear							1.00	0.065*	0.28*	0.67*
Shelling per cent %)								1.00	0.17	0.10
100 grain weight (g)									1.00	0.71*
Yield per plant (g)										1.00

* Significant at 5 per cent level of probability

plant (0.25, 0.34), number of grain rows per ear (0.25, 0.44), number of grains per ear (0.65, 0.61) and grain yield per plant (0.73, 0.83).

The number of cobs per plant had highly significant and positive association with days to silking (0.27), ear length (0.25), ear girth (0.34) and grain yield per plant (0.33). Whereas, 100 grain weight had highly significant and positive association with ear girth (0.63), days to 50 per cent silking (0.60), ear length (0.47) and number of grains per ear (0.28).

DISCUSSION

5. DISCUSSION

Yield increase is accomplished by developing more productive plant types as a result of greater physiological efficiency. This, when further coupled with appropriate agronomic practices and disease resistance serves the needs of the human being in better way. Among the various tools the breeder uses to improve the productivity, the natural phenomenon of heterosis has fascinated him a lot and its use in crop improvement has assumed considerable importance in obtaining higher yields with quality produce in many field crops and vegetables.

One of the major tasks in heterosis breeding programme is the right choice of parents to be used in breeding programme. It is therefore, necessary to select the parents with good general combining ability for yield and its components traits. The combining ability analysis assesses the utility of the crosses and the parents. The knowledge of combining ability is prerequisite for understanding the genetic architecture of the parents which is useful in securing overall information on various genetic systems involved in short time. In order to isolate best specific combinations and for the study of combining ability of inbreds with diverse genetic variability involved in testing programme, the knowledge of combining ability is necessary. Thus a critical examination of the relative magnitude of gca and sca variances and the gca and sca effects of the parents and their crosses, respectively provides valuable information of choice of the parents and planning a suitable breeding methodology. But, a high yielding genotype may or may not transmit its superiority to its progenies.

Therefore, the success of breeding programme is determined by useful gene combination in the form of high combining inbreds.

Understanding the nature of gene action governing the expression of various traits could be effective in predicting the breeding methodology to be adopted. Efficient partitioning of genetic variance in to its components *viz.,* additive, dominance and their inerteraction will help in formulating an effective and sound breeding programme.

Maize (*Zea mays* L.) is one of the most important cereal crops grown for food, feed and fodder purpose through out the country. It's quick growing and short duration nature enables the geneticist and plant breeder to raise the crop through out the year facilitating quicker genetic improvement. Besides, its flower being monoecious and protandrous in nature makes the pollination process easier. Success in crossing is also high besides the large number of the seeds borne in a single earhead. However maize needs attention to improve the yield and yield contributing characters along with pest and disease resistance.

Keeping this in view, the efforts were made in present investigation to study the extent of heterosis, to identify the best combining and high yielding parental lines and also to study gene action, heritability and correlation for improvement in yield and yield contributing characters of crosses developed by intermating four female and ten male lines in modified line x tester form. The results of present investigation are discussed below under suitable headings.

5.1 Heterosis

Heterosis is the measure of deviation of progeny means from parental means. Heterosis may be either positive or negative depending on the magnitude for exploitation of hybrid vigour, a high degree of heterosis for grain yield and its components is a prerequisites. The negative heterosis is important for the characters like earliness and disease resistance.

Parent vs. crosses (P vs.C) interaction mean sum of square provide a measure of heterosis (Arunachalam, 1974). In present investigation parent vs. crosses interaction mean sum of squares were significant for all the traits studied except number of cobs per plant. But such comparison will test the differences between parental and hybrid group means. The significant differences could arise due to a few but highly heterotic crosses (Arunachalam, 1974). Hence analysis of heterosis based on single crosses or between two lines or two populations, which have no common origin has its importance (Falconer, 1985).

5.1.1 Magnitude and direction of heterosis

It was observed from the data (Table 5.1) that, all the characters except number of ears per plant and number of grain rows per ear had significant heterosis over better parent in desirable direction. In respect of heterosis over standard hybrid check only the characters number of grain rows per ear and shelling percentage showed significant heterosis. The extent of heterosis differed for different characters. The combination CM 117 x GPM 328 recorded the highest better parent heterosis (78.86%) followed by GPM 201 x

Table 5.1: Range of heterosis and number of crosses showing significant heterosis in desirable direction of Maize.

Sr. No.	Name of the character	Heterosis (%) over Better parent		Heterosis (%) over Standard check	
		Range	No. of significant crosses	Range	No. of significant crosses
1	Days to 50 per cent silking	-14.10 to 5.16	8 (20%)	-10.27 to 2.68	0 (0.00%)
2	Plant height (cm)	-14.50 to 56.33	11 (27.5%)	-15.67 to 2.85	0 (0.00%)
3	No. of cobs per plant	-11.77 to 6.67	0 (0.00%)	0.00 to 6.67	0 (0.00%)
4	Ear length (cm)	-22.01 to 31.36	2 (5.00%)	-21.52 to 11.89	0 (0.00%)
5	Ear girth (cm)	-11.48 to 21.96	6 (15.00%)	-9.56 to 16.99	0 (0.00%)
6	No. of grain rows per ear	-12.16 to 14.68	0 (0.00%)	-8.41 to 16.82	1 (2.50%)
7	No. of grains per ear	-14.41 to 65.58	3 (7.50%)	-25.40 to 17.78	0 (0.00%)
8	Shelling per cent	-17.44 to 11.18	3 (7.50%)	-15.24 to 9.28	18 (45.00%)
9	100 grain weight (g)	-42.91 to 96.21	9 (22.50%)	-41.16 to 19.24	0 (0.00%)
10	Grain yield per plant (g)	-25.94 to 78.86	3 (7.50%)	-34.83 to 13.78	0 (0.00%)

LM 6 (60.19%), GPM 222 x LM 6 (36.13%) for grain yield per plant indicating their superiority over others and need for their immediate exploitation. The standard heterosis was not observed for any cross. The high magnitude of better parent heterosis for grain yield have been reported by Aulicino and Magoja (1991), Kocova (1992), Vasal *et al.* (1992), Stastny (1993), Feng *et al.* (1994), Vasal *et al.*(1994) and Sain Dass *et al.* (1998).

The genotypes with early silking have special significance in multiple cropping system. For days to 50 per cent silking negative heterosis to the extent of -14.10 per cent and –10.27 per cent over better parent and standard check hybrid MLMH-956 was found. The earlier findings of Ramamurthy (1980), Ganguli *et al.* (1989), Alvarez *et al.* (1993) and Nagda *et al.* (1995) were similar to the present results.

In present investigation the extent of heterobeltiosis for plant height was up to 56.33 per cent, however none of the crosses produced significant heterosis over standard hybrid check. Similar results were reported by Ganguli *et al.* (1989), Alvarez *et al.* (1993) and Saleh *et al.* (2002).

The combination CA 00106 x GPM 276 recorded 31.36 per cent heterosis over better parent and none of the crosses produced significant heterosis over standard hybrid check for ear length. The above results were in agreement with findings of Debnath *et al.* (1987), Ganguli *et al.* (1989), Alvarez *et al.* (1993) and Saleh *et al.* (2002).

For the character ear girth five crosses produced significant and positive heterosis over better parent and none of the crosses produced significant heterosis over standard hybrid check. The extent of heterobeltiosis for ear girth was upto 21.96 per cent. The combinations CM 117 x GPM 328 and GPM 201 x GPM 254 showed 21.96 per cent and 21.77 per cent heterobeltiosis for ear girth. The present result of heterosis for ear girth confirm the findings of Sanghi *et al.* (1982), Ganguli *et al.* (1989), Alvarez *et al.* (1993) and Saleh *et al.* (2002).

In case of number of grain rows per ear, the magnitude of heterobeltiosis was observed only for the cross GPM 222 x XOB 2276 to the extent of 0.94 per cent over standard hybrid check, however none of the crosses produced significant heterosis over better parent. The earlier findings of Sanghi *et al.* (1982), Debnath *et al.* (1987) and Saleh *et al.* (2002) were similar to the present results whereas, contrary to this Alvarez *et al.* (1993) observed negative heterosis for number of grain rows per ear.

The combination GPM 201 x LM 6 recorded 65.57 per cent and 17.77 per cent heterosis over better parent and standard hybrid check, respectively for number of grains per ear. The two other combinations GPM 201 x XOB 2228 and GPM 201 x CML 139 were also significantly heterotic for number of grains per ear. The earlier findings of Sanghi *et al.* (1982), Debnath *et al.* (1987), Alvarez *et al.* (1993) and Saleh *et al.* (2002) were similar to the results in the present studies.

The magnitude of standard heterosis to the extent of 11.18 per cent over better parent whereas 9.28 per cent over standard hybrid check, respectively was observed for the shelling percentage. Among hybrid combinations three crosses were significantly superior over better parents and eighteen crosses over standard hybrid check. The results are in agreement with the results of Debnath *et al.* (1987) and Saleh *et al.* (2002).

The cross combination CM 117 x GPM 328 (96.21%) recorded the highest magnitude of heterobeltiosis for 100 seed weight. Nine crosses were highly superior over better parent however, none of the crosses produced significant heterosis over standard check. The situation of better parent heterosis suggested that CM 117 or GPM 328 could be used in exploiting high 100 seed weight heterosis in maize. These results are in agreement with the results of earlier workers like, Debnath *et al.* (1987), Alvarez *et al.* (1993) and Saleh *et al.* (2002).

It was noticed in present investigation that the hybrids having significant heterosis for grain yield also possess significant heterosis for one or more characters. The crosses namely GPM 201 x LM 6, GPM 222 x LM 6, GPM 201 x GPM 257, GPM 201 x GPM 302 and CA 00106 x GPM 328 with high percentage of better parent heterosis for grain yield also exhibited heterosis for other character like days to 50 per cent silking, plant height, ear length number of grains per ear and 100 grain weight. This indicated that heterosis for grain yield seems to be influenced by heterosis for one or more important components of yield.

The frequency of crosses showing significant better parent heterosis ranged between 5 per cent (ear length) and 27.5 per cent (plant height). The plant height recorded maximum frequency of 27.5 per cent followed by 100 grain weight, days to 50 per cent silking, ear girth, number of grains per ear,

Table 5.2 : The crosses with high *per se* performance and high heterosis for yield and its component charaacters

Sr. No.	Cross	Mean grain yield (g/ plant)	Heterosis for yield (%)	No. of characters with desirable heterosis	Characters having significant heterosis in desirable direction
1	GPM 222 x LM 6	129.90	36.13*	3	Plant height, days to 50 per cent silking, grain yield per plant
2	GPM 201 x GPM 257	126.37	35.05	3	Ear length, number of grains per ear, 100 grain weight
3	GPM 222 x GPM 302	123.77	29.71	1	Days to 50 per cent silking
4	GPM 201 x LM 6	123.40	60.19*	4	Ear length, number of grains per ear, 100 grain weight, grain yield per plant
5	GPM 222 x GPM 254	122.10	27.96	0	-
6	GPM 201 x GPM 302	120.30	38.20	2	Plant height, 100 grain weight
7	GPM 222 x GPM 328	118.10	23.77	1	Ear girth
8	CA 00106 x XOB 2276	114.20	14.71	2	Shelling percentage, 100 grain weight
9	GPM 201 x XOB 2228	110.93	19.03	1	Number of grains per ear
10	CA 00106 x GPM 328	110.03	39.86	2	Plant height, ear girth

shelling percentage and grain yield per plant. However, frequency was low for ear length.

None of the crosses produced significant standard heterosis for the characters under study except for shelling percentage (45.00%) and number of grain rows per ear (2.5%).

The best combinations exhibiting high magnitude of heterosis in desirable direction for yield and important yield contributing characters are given below.

The combinations CM 117 x GPM 328 and GPM 201 x LM 6 (grain yield per plant), CM 117 X GPM 328 and CM 117 x XOB 2276 and CA 00106 x LM 6 plant height), GPM 222 x CML 139 and CM 117 x CML 139 (days to 50% silking), CA00106 x GPM 276 and GPM 201 x LM-6 (ear length), CM 117 x GPM 328 and GPM 201 x GPM 254 (ear girth), GPM 201 x GPM 257 and GPM 201 x XOB 2228 (number of grains per ear), CM 117 x CML 139 and CM 117 x GPM 302 (shelling percentage) were found to be best combinations for respective traits based on the magnitude and direction of the heterobeltiosis exhibited by them. It appears from the data that there are no crosses with significant heterosis over standard check.

5.1.2 Heterosis and *per se* performance of hybrids

The comparative data of *per se* performance and heterosis for grain yield per plant (Table 5.2) indicated that the crosses GPM 201 x LM 6 and GPM 201 x GPM 257 exhibited high percentage of heterosis and high *per se* performance. However, high heterosis in crosses CA 00106 x GPM 328 and

GPM 201 x GPM 302 was not reflected in high *per se* performance. The highest heterosis was observed for the cross GPM 201 x LM 6 but *per se* performance was very low, whereas in the crosses GPM 201 x GPM 257, GPM 222 x GPM 302 and GPM 222 x GPM 254, heterosis was low but *per se* performance was comparatively high, indicating the fact that high *per se* performance does not necessarily produce high heterosis.

5.2 Combining ability

5.2.1 General combining ability effects

The data on gca effects (Table 5.3) indicated that the gca effects varied significantly for different characters and different parents, indicating the variation in the combining ability of the parents involved. The high gca effects in desirable direction for yield and its component traits indicated that such line would combine well with other lines to produce superior progenies for all the traits. In the present investigation among the female parents the line GPM 201 was the best general combiner for grain yield and component traits. It also had significantly desirable gca effect for plant height, ear length, ear girth, number of grain rows per ear, number of grains per ear and 100 seed weight. Among the male parents GPM 302 showed the highest positive and significant gca effects for grain yield in desirable direction followed by LM 6. The parent GPM 302 was the best general combiner having desirable gca effect for all the character excepts shelling percentage.

Another female line GPM 222 was found to be best general combiner for ear length. It also had significant and desirable gca effect for 100 grain

Table 5.3: Significant gca effects in desirable direction for the ten characters in 4 x 10 mlt, of maize

Parents	Days to 50% silking	Plant height (cm)	No. of cobs per plant	Ear length (cm)	Ear girth (cm)	No. of grain rows per ear	No. of grains per ear	Shelling per cent	100 grain weight (g)	Grain yield per plant (g)
CM 117	-	-	-	-	-	-	✓	✓ *	-	-
CA 00106	✓	-	-	-	✓	✓ *	-	✓	-	-
GPM 201	-	✓ *	-	✓ *	✓ *	✓ *	✓	-	✓ *	✓ *
GPM 222	✓ *	✓ *	-	✓ *	✓	-	-	-	✓ *	✓ *
GPM 328	-	✓ *	-	✓ *	✓	✓	✓	✓	-	✓
GPM 276	✓ *	-	-	✓	-	-	-	✓ *	✓ *	-
GPM 254	-	✓ *	-	✓ *	✓	✓	✓	-	✓	✓
GPM 245	✓	-	-	-	-	✓	-	✓	-	-
GPM 302	✓	✓ *	✓ *	✓	✓	✓	✓ *	-	✓ *	✓ *
GPM 257	-	✓	✓	✓	✓ *	-	✓	-	-	✓
XOB 2276	✓	✓	-	-	✓	✓	-	-	-	-
LM 6	✓	-	-	✓	✓	-	-	✓ *	✓ *	✓
XOB 2228	-	✓	-	-	✓	✓	✓	-	-	-
CML 139	✓ *	-	✓	-	-	-	-	✓ *	✓	-

Where -
✓ = Desirable direction
* = Significant at 5 per cent level of probability.

weight and grain yield per plant and hence could be utilized in further breeding programme, where yield could be exploited through ear volume or weight. Similarly CM 117 for shelling percentage and CA 00106 for number of grain rows per ear were the best general combiners for the respective characters (Table 5.3).

The male parents CML 139 and GPM 276 and GPM 222 among female parents possess desirable (negative) gca effect for days to 50 per cent silking. Prasad *et al.* (1988), Desai and Singh (2000), Gupta and Nagda (2000), Dubey *et al.* (2001) and Matho and Ganguli (2001) reported similar results.

For plant height, GPM 201 among female parents and GPM 302 and GPM 254 among male parents were the best general combiners. The earlier findings of Konak *et al.* (1999) and Habutamu (2000) were similar to the present findings.

The GPM 201 among the female parent and GPM 302 among the male parents exhibited significant desirable gca effect for number of ears per plant. Similar results were also reported earlier by Mohamed (1993).

For ear length the female parent GPM 202 was the best general combiner followed by GPM 201, which also had significant positive gca effect for ear girth, whereas among the male parents GPM 328 and GPM 254 for ear length and GPM 257 for ear girth were the best general combiners. Prasad *et al.*. (1988), Debnath and Sarkar (1990), Ivanov and Tomov (1995), Lee Wankoo *et al.* (1995), Singh and Singh (1998) and Konak *et al.* (1999) also reported similar significant gca effects for ear length and ear girth earlier.

The female lines GPM 201 and CA 00106 for number of grain rows per ear and GPM 302 among male parents for number of grains per ear exhibited significant positive gca effects. The earlier findings of Prasad *et al.* (1988), Debnath and Sarkar (1990), Mohamed (1993) and Singh and Singh (1998) were similar to the results of present findings.

GPM 201 among females and LM 6 among males were the best general combiners having desirable positive gca effects for 100 grain weight. Lee Wankoo *et al.* (1995), Gupta and Nagda (2000) and Dubey *et al.* (2001) also reported desirable positive gca effects. It is evident from gca effects that among females, GPM 201 was the best general combiner exhibiting gca effects in desirable direction for all the traits except number of grains per ear and shelling percentage, whereas among males GPM 302 was the best general combiner exhibiting gca effects in desirable direction for five characters (Table 5.3)

5.2.1.1 GCA effects and *per se* performance of parents

The female parents, GPM 201 and GPM 222 and male parents GPM 302 and GPM 276 with high gca effects exhibited high *per se* performance for all the characters studied except number of ears per plants indicating good correspondence between gca effects and *per se* performance for various traits studied.

It was observed that parents with the best general combining ability for grain yield per plant were also the best general combiners for most of the yield contributing characters. This relationship showed that gca for grain yield per plant could be attributed to good gca effects for one or more yield contributing

Table 5.4 : Distribution of significant heterotic crosses into groups on general combining ability.

Crosses		Days to 50% silking	Plant height (cm)	No. of cobs per plant	Ear length (cm)	Ear girth (cm)	No. of grain rows per ear	No. of grains per ear	Shelling per cent (%)	100 grain weight (g)	Grain yield per plant (g)
Heterotic crosses (no.)	BP	8	11	-	2	6	-	3	3	9	3
	SC	-	-	-	-	-	1	-	18	-	-
H x H (%)	BP	62.5	18.18	-	50	33.33	-	-	33.33	33.33	33.33
	SC	-	-	-	-	-	-	-	11.11	-	-
L x L (%)	BP	-	45.45	-	-	-	-	66.67	-	22.22	-
	SC	-	-	-	-	-	-	-	27.78	-	-
H x L/ L x H (%)	BP	38.5	36.36	-	50	66.67	-	33.33	66.67	44.45	66.67
	SC	-	-		-	-	100	-	61.11	-	-

Where,

H x H = Crosses with high x high combiners
L x L = Crosses with low x low combiners
H x L = Crosses with high x low combiners

traits such as plant height, ear length, ear girth, number of grain rows per ear, number of grains per ear and 100 grain weight.

5.2.1.2 GCA effects and heterosis

The crosses producing significantly high heterobeltiotic effects (more than 50%) involved low x high/ high x low type general combiners for days to 50 per cent silking, ear length, ear girth, shelling percentage and grain yield per plant. Likewise significant heterotic crosses over standard hybrid check (more than 50%) for number of grain rows per ear and shelling percentage showed involvement of low x high/ high x low general combiners.

It was also noted that significantly heterotic crosses over standard check involved parents with only low x low general combining ability, suggesting the presence of non-allelic gene interaction for expression of shelling percentage, plant height and 100 grain weight. The crosses recording significant heterosis over better parent and standard check respectively involved high x high, low x low and low x high/ high x low type of general combiners (Table 5.4).

Among the significantly heterobeltiotic crosses the frequency of low x low type crosses was observed in three characters namely plant height, number of grains per ear and 100 grain weight whereas, the frequency of low x high combiners was more in all characters studied showing necessity for involvement of at least one good general combiner for the cross to be heterotic. However for crosses to be heterotic over standard hybrid check, involvement of one good general combiner was necessary as the frequency of low x high/ high x low was greater that low x low type combiners for the characters shelling percentage and number of grain rows per ear. Similar results were reported by Perez *et al.* (1991), Sain Dass *et al.*(1996) and Choudhari *et al.*(2000).

In general the frequency of crosses involving high x high type general combiners for all the traits was moderate to high. The importance of low x low combining parents with high heterosis suggested that both the parents might be compatible to each other for most of the genes resulting in the complementary inter allelic interactions.

Most of the high x high combinations comparatively resulted in poor heterotic expressions, indicating the mutual cancellation of gene effects, which might be resulted in non significant heterotic effects for the characters studied.

5.2.2 Specific combining ability effect

Out of 40 crosses studied only 4 crosses showed highly significant and desirable sca effect for grain yield per plant (Table 5.5). The cross CA 00106 x XOB 2276 was the best combination producing maximum and significant sca effects (19.73). The other combinations namely CM 117 x GPM 276, GPM 201 x GPM 257 and GPM 222 x LM 6 with high significant sca effects exhibited high *per se* performance for grain yield per plant. The result of Choudhari *et al.* (2000), Geetha (2000) and Sain Dass *et al.* (2000) showed that high *per se* performance of hybrids was associated with high sca effects indicating that selection of hybrids based on *per se* performance will be equally effective, whereas Sain Dass *et al.* (1998) showed that there was no association between *per se* performance and sca effects.

Table 5.5 Crosses showing significant and desirable sca effects for ten characters

Hybrids	Days to 50% silking	Plant height (cm)	No. of cobs per plant	Ear length (cm)	Ear girth (cm)	No. of grain rows per ear	No. of grains per ear	Shelling per cent (%)	100 grain weight (g)	Grain yield per plant (g)
CM 117 X GPM 328	-	✓	-	-	✓	✓	-	-	✓	-
CM 117 X GPM 276	✓	✓	-	-	✓	-	✓	✓	✓ *	✓ *
CM 117 X GPM 254	✓	-	-	-	-	-	✓	✓	-	-
CM 117 X GPM 245	-	-	-	-	-	✓	-	-	-	✓
CM 117 X GPM 302	✓	-	-	✓	-	-	✓	✓	-	-
CM 117 X GPM 257	✓	✓	-	-	-	✓	-	-	-	-
CM 117 X XOB 2276	-	✓	-	✓	-	-	-	-	-	-
CM 117 X LM 6	-	-	-	-	-	✓	-	-	-	-
CM 117 X XOB 2228	-	-	-	✓	-	✓	✓	✓	✓	✓
CM 117 X CML 139	✓	-	-	✓ *	-	-	✓ *	✓	✓	✓
CA 00106 X GPM 328	-	-	-	✓	✓ *	✓	✓	-	✓	✓
CA 00106 X GPM 276	-	✓ *	-	✓ *	✓	✓	✓	-	-	-
CA 00106 X GPM 254	✓	-	-	✓	-	✓	-	-	-	✓
CA 00106 X GPM 245	-	✓	-	-	-	✓	✓	✓	-	-
CA 00106 X GPM 302	-	✓	-	-	-	-	-	✓	✓	-
CA 00106 X GPM 257	✓	✓	-	-	-	-	-	✓	-	✓
CA 00106 X XOB 2276	✓	-	-	✓	✓	-	✓ *	✓ *	✓ *	✓ *
CA 00106 X LM 6	✓	-	-	✓	✓	-	-	-	-	-
CA 00106 X XOB 2228	✓	-	-	-	-	-	-	✓	✓	✓
CA 00106 X CML 139	-	-	-	-	✓	✓	✓	-	-	-
GPM 201 X GPM 328	-	✓	-	-	-	✓	✓	-	-	-
GPM 201 X GPM 276	-	✓	-	-	-	-	-	✓	-	-
GPM 201 X GPM 254	✓	✓	-	-	✓	-	-	✓	✓ *	-
GPM 201 X GPM 245	-	✓	-	-	-	-	-	✓	✓	-
GPM 201 X GPM 302	-	✓	-	-	✓	✓	-	-	✓	✓

GPM 201 X GPM 257	-	-	✓ *	✓	✓ *	✓	✓ *	-	✓ *	✓ *
GPM 201 X XOB 2276	✓	-	-	✓	-	✓	-	-	-	-
GPM 201 X LM 6	-	-	-	✓ *	-	✓	✓	-	✓	✓
GPM 201 X XOB 2228	✓	-	-	✓	-	✓ *	✓ *	✓ *	-	✓
GPM 201 X CML 139	✓	✓	✓ *	✓	✓	✓	✓	-	-	✓
GPM 222 X GPM 328	✓	✓	-	✓	-	-	-	✓	✓	✓
GPM 222 X GPM 276	✓	✓	-	-	-	✓	✓	-	✓	-
GPM 222X GPM 254	-	-	-	✓	✓ *	✓ *	✓ *	-	-	✓
GPM 222 X GPM 245	✓	✓	-	✓	✓ *	✓	✓	-	✓ *	✓
GPM 222 X GPM 302	✓	✓	-	✓ *	✓	✓	✓ *	-	-	✓
GPM 222 X GPM 257	-	✓	-	✓	-	-	-	-	✓	-
GPM 222 X XOB 2276	✓	-	-	-	-	✓	✓	-	-	✓
GPM 222 X LM 6	✓	-	-	-	✓	-	-	✓ *	-	✓ *
GPM 222 X XOB 2228	-	✓	-	-	✓	-	-	-	-	-
GPM 222 X CML 139	✓	-	-	-	-	-	-	✓ *	✓	-

✓ Desirable direction

* Significant at 5% level of probability

The cross combination GPM 222 x LM 6 with highly significant sca effect (14.53) also possesses significant *per se* performance (129.90 g/plant) and significant heterosis for grain yield per plant, showing importance of their effective exploitation in production of good hybrids for high yield. The number of crosses having significant sca effect in favourable direction were more for number of grains per ear (6) followed by 100 seed weight (5), ear length ear girth, shelling percentage and grain yield per plant (4 each), number of ears per plant and number of grain rows per ear (2 each), plant height (1). However none of the cross showed significant sca effect in desirable direction for days to 50 per cent siliking. The present findings in general were similar with those reported by Eleuterio *et al.* (1988), Jha and Sinha (1989), Sharma and Bhalla (1993), Sain Dass *et al.* (1996), Konak *et al.* (1999), Geetha (2000), Habutama (2000) and Kara (2001).

The combinations CA 00106 x XOB 2276 and GPM 201 x GPM 257 showed sca effects in desirable direction for four characters whereas the combinations GPM 201 x XOB 2228 and GPM 222 x GPM 254 exhibited significant sca effects in desirable direction for three characters, respectively (Table 4.5). These specific combinations could be exploited for their hybrid vigour in breeding programme.

Likewise, the combinations CA 00106 x XOB 2276 and CM 117 x GPM 276 for grain yield per plant, CA 00106 x LM 6 for plant height, GPM 201 x GPM 257 and GPM 201 x CML 139 for number of ears per plant, CA 00106 x GPM 328 for ear girth, GPM 201 x XOB 2228 for number of grain rows per ear, GPM 201 x GPM 257 for number of grains per ear, GPM 222 x LM 6 for shelling percentage and CA 00106 x XOB 2276 for 100 seed weight exhibited significant and maximum sca effects (Table 5.7).

Among the 40 crosses studied only 4 (10%) exhibited significant sca effects for grain yield. In these crosses, 50 per cent of the crosses involved high x high, and 50 per cent low x low combining parents indicating role of allelic gene interaction for the expression of grain yield. Same was observed for number of grain rows per ear. In case of days to 50 per cent silking, none of the crosses showed significant sca effects. For the plant height and number of ears per plant, 100 per cent crosses involved low x low combining parents.

In-case of ear length ,25 per cent of the crosses involved high x high, 25 per cent low x low and 50 per cent high x low/low x high combining parents indicating the role of allelic as well as nonallelic interactions for the expression.

In case of ear girth and shelling percentage 25 per cent of the crosses involved high x high combining parents 50 per cent low x low and 25 per cent high x low/low x high combining parents indicating presence of higher order interactions for these characters.

Likewise, in case of number of grains per ear the crosses with significant sca effects involved the parents with high x high low x low and high x low/low x high combining ability.

Table 5.6 : Crosses with the highest mean performance, significant sca effects and heterosis along with gca effects of their parents in maize

Sr. No.	Cross	SCA effects	Heterosis (%)		Mean performance (g/plant)			G.C.A. effects	
			B. P.	S.C	P_1	P_2	F_1	P_1	P_2
1	CA 00106 x XOB 2276	19.73*	40.81	0.03	78.67	97.53	114.20	-2.61	-4.91
2	CM 117 x GPM 276	18.90*	36.56	-5.90	53.96	93.60	107.43	-10.08*	-3.38
3	GPM 201 x GPM 257	14.56*	35.05	10.69	77.03	117.10	120.37	6.36*	3.44
4	GPM 222 x LM 6	14.53*	36.13*	13.78	95.42	39.90	129.90	6.33*	7.04*

* Significant at 5 per cent level of probability

Where,

BP = Better parent and SC = Standard Check

P_1 = Female parent, P_2 = Male parent and F_1 = First filial generation

Table 5.7 : The best general combiners and the best specific combinations for ten different characters of maize

Character	GCA effects (significant)		Best specific combination with significant sca effects
	Lines (females)	Testers (Males)	
Days to 50% silking	GPM 222	CML 139	-
Plant height (cm)	GPM 201	GPM 302	CA 00106 x LM 6
No. of cobs per plant	GPM 201	GPM 302	GPM 201 x GPM 257 GPM 201 x CML 139
Ear length (cm)	GPM 222	GPM 328	GPM 222 x GPM 302, CA 00106 x GPM 276 CM 117 x CML 139, GPM 201 x LM 6
Ear girth (cm)	GPM 201	GPM 257	GPM 201 x GPM 257, GPM 202 x GPM 254 CA 00106 x GPM 328, GPM 222 x GPM 245
No. of grain rows per ear	GPM 201	-	GPM 201 x XOB 2228 GPM 222 x GPM 254
No. of grains per ear	-	GPM 302	GPM 222 x GPM 302, CM 117 x CML 139 CA 00106 x XOB 2276, GPM 201 x GPM 257 GPM 201 x XOB 2228, GPM 222 x GPM 254
Shelling per cent (%)	CM 117	LM 6	GPM 222 x LM 6, CA OO106 x XOB 2276 GPM 201 x XOB 2228, GPM 222 x CML 139
100 grain weight (g)	GPM 201	LM 6	GPM 201 x GPM 254, GPM 201 x GPM 257 CM 117 x GPM 256, GPM 222 x GPM 245 CA 00106 x XOB 2276
Yield per plant (g)	GPM 201	GPM 302	GPM 201 x GPM 257, CA OO106 x XOB 2276 CM 117 x GPM 276, GPM 222 x LM 6

Table 5.8 : Distribution of the crosses producing significant sca effects based on combining ability of parents

	Days to 50% silking	Plant height (cm)	No. of cobs per plant	Ear length (cm)	Ear girth (cm)	No. of grain rows per ear	No. of grains per ear	Shelling per cent (%)	100 grain weight (g)	Grain yield per plant (g)
Crosses showing *significant sca* effect	-	1	2	4	4	2	6	4	5	4
H x H (%)	-	-	-	25.00	25.00	50.00	33.33	25.00	20.00	50.00
L x L (%)	-	100.00	100.00	25.00	50.00	50.00	16.67	50.00	-	50.00
L x H / H x L (%)	-	-	-	50.00	25.00	-	50.00	25.00	80.00	-

Where,

H x H = Crosses with high x high combiners
L x L = Crosses with low x low combiners
H x L = Crosses with high x low combiners

For 100 grain weight the 20 per cent of the crosses involved high x high and 80 per cent of the crosses possess high x low/low x high combining parents.

In the present investigation, the crosses with significant sca effects involved the parents with low x low combining ability with more frequency than the crosses with low x high/high x low combining ability for the character under study. However earlier findings of Perez *et al.* (1991) reported that the crosses having high sca effects involve at least one parent with high gca.

Similarly Zang and Wang (1991) recommended that equal attention should be paid for selecting parents with high gca effects for getting high sca effects of the crosses. Same result was reported by Sain Dass *et al.*(2000) indicating superior crosses having high sca effects were between parents having high x high, high x medium and high x low combining ability indicating involvement at least one good general combiner.

In the present studies, high sca effects might be due to complementation of high and low combining loci.

5.3 Heritability and gene action

The conventional procedures are very slow in improving complicated traits like yield. Hybridization can improve these traits on the basis of variability and the heritability of the character under improvement. The breeding procedures therefore, need reorientation of the selection of suitable parents, not only based on their agronomic performance but also their genetic arthitecture. This is more important particularly for the characters like yield and its components, which are complex in their nature of inheritance.

The character expressions are related to the type of gene action and its interaction with the environment. The type of gene action namely, additive, dominance and epistatic as well as their relative magnitude determine the methodology to be adopted for the genetic improvement of traits. For the characters governed by additive type gene action the best breeding methodology will be adoption of different selection procedures. However, for the characters with inter allelic gene action (complementary or duplicate epistatic) exploitation of heterosis or development of composite/ synthetic varieties would be effective. The value of parents, therefore can be determined by the study of gene action, which would provide better guidance to the breeder in breeding methodology.

Thus, the total genetic variance may be partitioned into additive, dominance and epistatic variances (Griffing 1956 a). In the present study 6^2A (additive) and 6^2D (dominance) variances were estimated and heritability was worked out to determine the relative contribution of genetic variances. The magnitudes of specific combining ability variances were greater than general combining ability variances for all the characters except days to 50 per cent silking suggesting predominance of non additive gene action for all the characters and additive gene action for days to 50 per cent silking. Hence straight exploitation of heterosis will be effective. Similar findings were reported by Ramamurthy (1981), Debnathn and Sarkar (1990), Ivanov (1991), Pal and Pradhan (1994), Sain Dass *et al.* (1998), Konak *et al.* (1999), Kumar *et al.* (1999), Choudhari *et al.* (2000), Geeta and Jayaraman (2000), Habutamu (2000), Kadlubuiec *et al.* (2000), Kalla (2001), Sain Dass *et al.* (2000), Dubey *et al.*. (2001) and Kara *et al.* (2001). However, the findings of Sain Dass *et al.* (1996), Choukan (1999), Desai and Singh (2000), Geetha (2000) and Matho and Ganguly (2001) were contradictory and where they reported significance of both gca and sca variances for all the traits studied. Contrary to this, Sanghi *et al.* (1982), Wang *et al.* (1994), Gama *et al.* (1995), Vancentoric and Drinic (1994), Pradan and Rai (1999), Mani *et al.* (2000) and Konak *et al.* (2001) reported predominance of gca variances over sca variance for the various traits studied.

In case of grain yield per plant A:D ratio was less than unity showing predominance of dominance gene action. Geetha and Jayaraman (2000), Habutamu (2000), Dain Dass *et al.* (2000), Kara (2001), Ramamurthy (1980), Debnath and Sarkar (1990) and Pal and Pradhan (1994) reported similar results earlier. However, the findings of Sanghi *et al.* (1982), Reddy and Agarwal (1990), Mani *et al.* (2000) and Dubey *et al.* (2001) were contradictory to the present findings indicating control of additive gene effects for grain yield.

The heritability estimates were of moderate to high magnitudes for days to 50 per cent silking (73.90%), 100 seed weight (73.89%), grain yield per plant (70.63%), ear length (69.10%), number of grains per ear (67.78%), shelling percentage (67.72%) and ear girth (65.84%) indicating major role of genotype in the inheritance of these characters. Singh *et al.* (1989) and Mani *et al.* (2000) reported similar results.

Heritability estimates were of low magnitude only for number of cobs per plant (13.56%) indicating major role of environment in expression of this trait, similar result were reported by Saleh *et al.* (2002) and Muhammad and Muhammad (2000) reported moderate to high estimates of heritability for all characters except number of cobs per plant. However, the findings of Mani *et al.* (2000) was contradictory to the present result recording the highest heritability for number of ears per plant.

5.4 Correlation

Direct selection for yield is often misleading as it is polygenically controlled and also subjected to the effect of fluctuating environment. Efficiency of selection in any breeding programme depends upon the knowledge of association between different characters, which enables simultaneous selection for dependent characters.

In the present investigation, grain yield per plant showed significant positive association with days to 50 per cent silking, number of cobs per plant, ear length, ear girth, number of grain rows per ear, number of grains per ear and 100 grain weight indicating dependency of yield on these character. The earlier findings of Singh (1987), Xu (1986), Sharma and Kumar (1987), Muhammad and Muhammad (2001) and Umakanth and Khan (2001) were similar to the present findings.

In present investigation, grain yield showed significantly high correlation with ear girth and ear length confirming the finding of Vasic *et al.* (2001) and Farhatullah (1990), respectively.

Among the association between component characters plant height was positively associated only with number of cobs per plant whereas it was negatively comelated with remaining all the characters confirming the earlier finding of Tyagi *et al.* (1988) and Ramesha *et al.* (1990).

SUMMARY AND CONCLUSION

6. SUMMARY AND CONCLUSIONS

The present investigation on " Heterosis and combining ability studies in maize (*Zea mays* L.)" was carried out during rabi 2002 at Botany farm, College of Agriculture, Pune 5. The ten genotypes used as male parent namely GPM 328, GPM 276, GPM 245, GPM 254, GPM 302, GPM 257, XOB 2276, LM 6, XOB 2228 and CML 139 and four genotypes *viz.,* CM 117, CA 00106, GPM 201, GPM 222 were used as female lines and were crossed during *kharif,* 2002 to obtain 4 x 10, line x tester. The resulting 40 hybrids were evaluated along with fourteen parents and two checks (Varuna 205 and MLMH 956) in randomized block design with three replications during rabi, 2002. In this investigation an attempt was made to study heterosis, combining ability effects and variances, heritability, gene action and correlation in respect of ten different morphological characters.

Significant mean sum of squares were observed due to parents for day to 50 per cent silking, plant height, number of cobs per plant ,ear length, ear girth, number of grain rows per ear, number of grains per ear, shelling percentage, 100 grain weight and grain yield per plant and due to crosses for all the characters indicating existence of variability in parents and crosses respectively except number of cobs per plant.

The parents vs. crosses interaction mean sum of squares were significant for all the traits studied except number of cobs per plant indicating existence of good amount of heterotic effects for these characters.

Significant heterobeltiotic crosses occurred most frequently for plant height followed by 100 grain weight, days to 50 per cent silking and ear girth whereas the character shelling percentage showed maximum frequency to heterotic crosses over standard hybrid check.

The combination CM 117 x GPM 328 produced the highest and significant heterosis over better parent (78.00%) for grain yield per plant. The *per se* performance of this cross was also the highest indicating association between *per se* performance and heterosis.

The other combinations *viz.,* GPM 201 x LM 6 and GPM 222 x LM 6 also recorded significant heterobeltiosis for grain yield per plant.

Likewise, the CM 117 x GPM 328 for plant height, ear girth, 100 grain weight and grain yield per plant, GPM 222 x CML 139 for days to 50 per cent silking, CA 00106 x GPM 276 for ear length and GPM 201 x GPM 257 for number of grains per ear were the best crosses expressing significant heterobeltiosis and standard heterosis for respective characters.

Significant heterosis over better parent in favourable direction was the highest for 100 grain weight (96.21 %) followed by grain yield per plant (78.86%), number of grains per ear (65.57%), plant height (56.33%), and ear length (31.36%) while the significant heterosis over standard hybrid check in favourable direction was the highest for shelling percentage (9.87%).

Looking to the overall performance of all parents based on general combining ability effects, GPM 201 among the females was the best combiner as it produced significantly desirable gca effects for all the traits except days to

50 per cent silking, number of grains per ear and shelling percentage. Among the males, GPM 302 was the best general combiner exhibiting gca effects in desirable direction for five characters *viz.,* plant height, number of cobs per plant, number of grains per ear, 100 grain weight and grain yield per plant.

Among females, GPM 201 (plant height, number of cobs per plant, ear girth, number of grain rows per ear, 100 grain weight and grain yield per plant), GPM 222 (days to 50 per cent silking, ear length and grain yield per plant) were identified as the best general combiners for respective characters. Whereas, among male parents, GPM 302 (plant height, number of cobs per plant, number of grains per ear and grain yield per plant). CML 139 (days to 50 per cent silking), GPM 328 (ear length), GPM 257 (ear girth), GPM 276 (shelling percentage) and LM 6 (100 seed weight) were identified as best general combiners for respective characters. Good association between gca effects and *per se* performance was recorded for all the traits studied.

The combinations CA 00106 x XOB 2276 and GPM 201 x GPM 257 were identified as the best hybrids, whereas among females GPM 201 and among males GPM 302 were identified as the best general combiners and can be used for immediate exploitation.

The combination CA 00106 x XOB 2276 recorded magnitudinally highest sca effects followed by CM 117 x GPM 276, GPM 201 x GPM 257 and GPM 222 x LM 6 for grain yield per plant. All these four crosses produced high grain yield .The hybrids CA 00106 x XOB 2276 and CM 117 x GPM 276 involved low x low general combiners suggesting interallelic or higher order interaction for the expression of grain yield whereas, GPM 201 x GPM 257 and GPM 222 x LM 6 involved high x high combining parents indicating predominance of additive gene action for grain yield.

Similarly, the combinations CA 00106 x LM 6 (Plant height), GPM 201 x GPM 257 and GPM 201 x CML 139 (number of cobs per plant), CA 00106 x GPM 276 (ear length), CA 00106 x GPM 328 (ear girth), GPM 201 x XOB 2228 (number of grain rows per ear), GPM 201 x GPM 257 (number of grains per ear), GPM 222 x LM 6 (shelling percentage) and CA 00106 x XOB 2276 (100 seed weight) exhibited highly significant and maximum sca effects for the respective characters . The crosses that producing significant sca effects involved parents with high x low combining ability suggesting predominance of interallelic interaction for respective characters. However, most of the crosses exhibiting significant sca effects had at least one parent with good gca.

Based on these observations it can be concluded that the combinations, which produced significant and desired sca effects for most of the characters, have potential for exploiting hybrid vigour in breeding programme. Importance of low x low and low x high/high x low general combining parents in significant specific combinations revealed the importance of dominance and epistatic gene action for expression of most of the traits.

The sca effects and *per se* performance for most of the yield contributing characters namely number of cobs per plant, ear length, ear girth, number of grain rows per ear and number of grains per ear were independent of each other, suggesting that per *se* performance can not be used as indicator while selecting the heterotic crosses.

The hybrids involving the parents with good gca effects in desirable direction recorded high heterosis for yield and yield contributing characters. However, the crosses with high percentage of heterosis did not necessarily produce high yield per plant and it appeared that both the *per se* performance and heterosis percentage were essential in judging the utility of hybrid combination for exploiting hybrid vigour.

Mostly low x high/high x low combinations were involved in the significant heterobeltiotic and heterotic crosses over standard hybrid check revealing the complementary interallelic interactions between low and high general combing loci. The mutual cancellation of gene effects resulted in poor heterobeltiotic response of high x high combinations.

In the present investigation nonadditive gene action was predominant for all the characters except for days to 50 per cent silking, hence indicated the need of exploiting the characters through hybrid breeding. Simple recurrent selection or biparental mating followed by recurrent selection or development of synthetics could serve to bring genetic improvement in the population with reference to the characters studied as long term plan whereas, predominance of additive gene action for days to 50 per cent silking suggested that parents involved in present studies could prove useful in varietal improvements.

Study of correlations showed significant positive association of grain yield with days to 50 per cent silking, number of cobs per plant, ear length, ear girth, number of grain rows per ear, number of grains per ear and 100 grain weight suggesting the dependency of yield on all these component characters and indicated the use of these characters in making simultaneous selections for improvement in maize.

LITERATURE CITED

6. LITERATURE CITED

*Allard, R. W. 1960. Principles of Plant Breeding. John Wiley and Sons Inc. New York. pp. 485.

*Alvarez, A., G. Garay, J. Gimenez, Ruiz, de and J. I. Galarreta. 1993. Heterosis in two synthetic varieties of maize based on morphological and reproductive traits. Investigation - Agraria-Prodiction - Y-Protection - Vegetates. 8(3): 333-340.

Anonymous 2001. The Chief statistician Dept. Of Agril. Commissioner Central Building, Pune-411001.

Arunachalam, V. 1974. The fallacy behind the use of modified Lx T design. Indian J. Genet. 24 (2) : 280-287.

*Aulicino, M. B. and J. L. Magoja. 1991. Variability and heterosis in maize-basal teosinate and maize-Guatemala teosinte hybrids. Maize-Genetics-Co-operation-News letter. 65:43-44.

*Babitskii, A. F. 1991. Variation in leaf length in the case of heterosis in maize. Buletinul-Acactemiei-de-stiinte-a Republicii-Molctova-stiinte-Biologice-Si-Chimica. 6: 15-22.

Choudhary, A. K., L. B. Choudhary and K.C. Sharma, 2000. Combining ability estimates of early generation inbred line derived from two maize populations. Indian J. Genet. 60 (1) : 55-61.

Choukan, R. 1999. General and specific combining ability of ten maize inbred lines for different traits in diallel cross. Seed and Plant. 15 (3) : 280-295.

Debnath, S. C and K. R. Sarkar. 1990. Combining ability analysis of grain yield and some of the other attributes in maize (*Zea mays* L.). Indian J. Genet. 50 (1) : 57-61.

Debnath, S.C., K. R. Sarkar and Dalgit Singh. 1987. Combining ability estimates in maize *(Zea mays* L.) Annl. Agril. Res. 9 (1) : 37-42.

Desai, S. A. and R. D. Singh. 2000. Combining ability studies for some mophophysiological and biochemical traits related to drought tolerance in maize (*Zea mays* L.). Indian J. Genet. 61 (1) : 34-36.

*Dordevic, J. 1990. Effect of epistasis on grain yield in maize (*Zea mays* L.) Genetika (Beograd). 22 (1) : 1-7.

Dubey, R. B., V. N. Joshi, and N. K.Pandiya. 2001. Heterosis and combining ability for quality, yield and maturity traits in conventional and non-conventional hybrids of maize (*Zea mays* L.). Indian J. Genet. 61 (4) : 353-355.

East, E. M. and H. K. Hayes. 1912. Heterozygocity in evolution and in plant breeding. U. S. D. A. Bur. Pl. Ind. Bull. 243.

East, E. M. 1916. Elementary principles of plant breeding. By H. K. Choudhary. 1971. pp. 122.

*Eleuterio, A., E. E. Gama, G. E. Morais and A. R. DE Morais. 1988. Combining ability of heterosis in maize intervarietal hybrids adapted to acidic soil. Pesquisa Agropecuaria Brasileira. 23 (3) : 247-253.

Falconer, D. S. 1985. "Introduction to quantitative genetics" 2nd edition, Longman Inc. New York, pp: 1-340.

Farahtullah. 1990. Correlated responses of maize grain yield with yield contributing traits. Sarhad J. Agric., 6 (5): 455-457.

Feng, C. S., Z. R. Yin, S. W. Zhao and W. Y. Li. 1994. Correlation between photosynthetic rate and yield of densely planted maize. Acta Agriculture-Nudeatal-Sinica. 8 (2) : 80-86.

Gama, E. E. Ge, A. R. Hallaller, R. G. Ferrao and R. G. Barbosa. 1995. Heterosis in maize single crosses derived from yellow Tuxpeno variety in Brazil. Revista-Brasileira-de-Genetica. 18(1) : 81-85.

Ganguli, D. K., M. F. Haque and D. K. Sinha 1989. Heterosis in interpopulation crosses in maize . J. Res. Birsa. Agric. Univ., 1 (1): 59-63.

Geetha, K. 2000. Combining ability for grain yield and component traits in maize. Madras agric. J. 87 (7/9) : 447-449.

Geetha, K. and N. Jayaraman. 2000. Genetic analysis of yield in maize (*Zea mays* L.). Madras agric. J. 87 (10/12) : 638-640.

Giridharan, S., M. N Prasad and S. R. Rangaswamy. 1996. Diallel, triallel and quadriallel and analysis for grain yield in maize. Madras agric. J. 83 (4) : 230-236.

Gomez, K. A. and A. A. Gomez. 1984. Statistical procedures for Agricultural Research, 2nd edition. John Wiely and Sons. Inc.New York. pp. 580.

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

Griffing, B., 1956b. A generalised treatment of the use of Diallel crosses in quantitative inheritance. Heredity. 10 : 31-50.

Gupta, S. C. and A. K. Nagda. 2000. Analysis of variety diallel cross for yield and its component in winter maize. Indian J. Gent. 60 (3) : 301-303.

Gupta, S. C., A. K. Nagda, and G. K. Kulmi. 1994. Economic heterosis in double cross hybrids of maize. Crop Res. Hisar. 8 (3) : 634-636.

Habutamu Zelleke. 2000. Combining ability for grain yield and other agronomic characters in inbred lines of maize (*Zea mays* L.). Pakistan J. Genet. 61 (1): 7-9.

*Ivanov S. and N. Tomov. 1995. Combining ability for yield components in high lysine maize line homorygous for opaque-z gene. Rasteniev" dni Nauki 32: 1-2, 120-123.

Ivanov, S. 1991. Combining ability and some genetical characteristics of high lysine maize lines homozygous for opaque 2 gene I. Grain yield. Genetika i. Selektsiya. 24 (5) : 327-334.

Jha, P. B and G. K. Sinha. 1989. Combining ability for yield and cold tolerance in early maturing maize. Crop Improvement. 16 (2) : 137-140.

Joshi, V. N., R. B. Dubey and S. Marker. 2002. Controlling ability for polygenic traits in early maturing hybrids of maize (*Zea mays* L.). Indian J. Genet. 62 (4) : 312.315.

*Kadlubuiec, W., C. Karwowsika, Z. Kurczyuch, R. Kuriata and S. Walczowska- Kurczych. 2000. Combining ability of maize inbred lines. Genetika. i. Selektsia 216 (2) : 371-378.

Kalita, U. C., R. B. Saikia and P. K Duara. 1995. Studies of combining ability in maize (*Zea mays* L.). J. Agric. Sci. Soc. North East Asia. 8 (2) : 216-219.

Kalla, V., R. Kumar and K. A. Basandrai. 2001. Combining ability analysis and gene action estimates of yield and yield contributing characters in maize (*Zea mays* L.). Crop Res. Hisar. 22 (1) : 102-106.

*Kapustin, A. A. 1989. Evaluating combining ability in inbred lines of sweet corn. Opytno Selekstsionnaya. Stantsiya VIR Krymsk USSR. 123 : 74-78.

*Kara, S. M. 2001. Evaluation of yield and yield components in inbred maize lines. Heterosis and Line x Tester analysis of C. A. Turkish J. Agril. and Forestry. 25 (6) : 383-391.

Kempthorne, O. 1957. 'An introduction to genetic statistics'. John Wiley and Sons Inc. New York. PP. 458-471.

*Kocova, M. 1992. Photochemical activity of isolated chloroplasts in maize (*Zea mays* L.) in relation to the expression of heterosis and complementation. Genetika-a-Slechteni. 28 (1): 37-51.

Kolreuter, J. 1763. Heterosis and hybrid vigour. Cytogenetics and Plant Breeding. Publ. By Sekhra and Sarthy. pp. 351.

*Konak, C., A Unay, H. Bansal, and E. Serter, 2001. Combining ability and heterotic effects in some characters of second crop maize. Turkish J. Field Crops. 6 (2) : 64-70.

*Konak, C., A. Unay, E. Serter and H. Basal 1999. Estimation of combining ability effects, heterosis and heterobeltiosis by L x T method in maize. Turkish J. Field Crops 4 (1) : 1-9.

Kumar, M. V. N., S. S. Kumar and M. Ganesh. 1999. Combining ability studies for yield and oil improvement in maize (*Zea mays* L.) Crop Res. Hisar. 18 (1) : 93-99.

*Lee,Wankoo, Choe-BongHo, Lee-Wk and B. H. Choe. 1995. Characteristics and combining ability of Korean local waxy inbreds and hybrids. Korean J. Crop Sci. 40 (2) : 175-184.

Mani, V. P., N. P Gupta, G. S. Bisant and R. Singh. 2000. Genetic variance and heritability of some ear traits in prolific maize. Crop Res. Hisar. 20 (2) : 217-220.

Mateeva, G. V. 1988. Evaluation of the combining ability of popcorn maize lines N.I. Vavilov Vsesoywinyi. Instititute Rastenievodstva Leningard USSR No. 183: 19-25.

Matho, R. N. and D. K. Ganguly. 2001. Heterosis and combing ability studies in maize (*Zea mays* L.). J. Res. Birsa agric. Univ. 13 (2) : 197-199.

Mohamed, A. A. 1993. Effect of nitrogen fertilization levels on the performance and combining ability of maize hybrids. Annl. agric. Sci. Cairo. 38(2) : 531-549.

Mohammad, Yousuf and Mohammad Saleem. 2002. Estimates of heritability for some quantitative characters in maize. Intern. J. agric. and Biol. 4 (1) : 103-104.

Muhammad Saleem 2001. Correlation analysis of 5, families of maize for grain yield and its component traits. International J. agric. and Biol. 3 (4) : 387-388.

Nagda, A. K., R. B Dubey and N. K. Pandiya 1995. Studies in combining ability in *rabi* maize (*Zea mays* L.). Crop Res. Hisar. 9 (2) : 309-312.

Pal, A. K. and H. S. Pradhan. 1994. Combining ability analysis of grain yield and oil content along with some other attributes in maize. Indian J. Genet. 54 (4) : 376-380.

Panse and Sukhatme, 1967. Statistical methods for Agricultural workers. Indian Council of Agricultural Research. New Delhi. pp. 381.

*Perez, F. R., C. G. Arevalo and D. Gamboa. 1991. Combining ability and heterosis in nine maize hybrids in Tucuman. Revista Industrial-Y-Agricola-de Tucuman. 68 (1/2) : 39-47.

Pradhan, H. S. and R. Rai. 1999. Combining ability for popping quality and grain yield along with other associated attributes in popcorn. Environ. and Ecol. 17 (4) : 827-830.

Prasad, R., S. Singh and R. S. Poroda. 1988. Combining ability analysis in maize diallel. Indian J. Genet. 48 (1) : 19-23.

Rai. B. 1979. Heterosis Breeding. Agro-Biological publication, Delhi. pp. 183.

Ramamurthy, A. 1980. Genetic analysis of some quantitative characters in maize (*Zea mays* L.) Mysore J. agric. Sci. 14 (1) : 126.

Ramesha, M. S., S. J. Patil, , J. V. Goud and S. S. Patil. 1990. Correlation, combining ability and heterosis studies on husk number and shank length in maize. Indian J. Genet. 50 (4) : 338-341.

Rao, G. P., B. Rai, S. V. Singh, and J. P. Shai 1996. Heterosis and combining ability in intervarietal crosses of maize. Madras Agril. J. 83 (5) : 291-295.

Reddy, K. H. P. and B. D. Agarwal 1990. Genetic analysis for grain yield and its component in an improved population of maize. Crop Management. 17 (1) : 9-12.

Sain Dass, Pawan Arora , K. S. Dhanju, S. Dass. and P. Arora 1996. Heterosis for maydis leaf blight disease resistance and grain yield in maize. Indian J. Genet. 58 (3) : 313-317.

Sain Dass, Pawan Arora, K. S. Danju, S. Dass, P. Arora, S. Kumar, and P. Singh, 2000. Gene effects of maydis leaf blight (*Drechslera mayedis*) resistance and grain yield in maize (*Zea mays* L.). Indian J. Genet. 70 (5) : 317-319.

Sain Dass, V. P. Ahuja and M. Singh 1998. Combining ability for yield in maize. Indian J. Genet. 57 (1) : 98-100.

Saleh, G. B., D. Abdullah, and A. R Ankur. 2002. Performance of heterosis of heritability in selected, tropical maize single double and three way cross hybrids. J. agric. Sci. 38 (1) : 21-28.

Sanghi. A. K., K. N. Agarwal and M. I. Quadri. 1982. Gene effects and heterosis for grain yield and ear traits in maize. Indian J. Genet. 42 (3) : 360-363.

Satyanarayana, E. 1995. Genetic analysis of flowering period in *rabi* maize. Himachal J. agric. Res. 21 (1/2) : 11-16.

*Shamrav, G. E. and O. M. Shalygina 1988. Combining ability of inbred maize lines N. I. Vavilov, Vsesoyunzyi Institute Rastenievoctstva Leningard, USSR No. 183. 3-8.

Sharma, J. K. and S. K. Bhalla. 1993. Combining ability for some drough tolerant traits in maize (*Zea mays* L.). Indian J. Genet. 53(1) 79-84.

Sharma, R. K. and S. Kumar. 1987. Association analysis for grain yield and some quantitative traits in popcorn. Crop Improv. 14 (2) 201-204.

Shull, G. H. 1914. Duplicate gene for capsule form in Bursa bursapastoris heterosis, Iowa State College.

Singh, D. N. and I. S. Singh. 1998. Line x tester analysis in maize (*Zea mays* L.) J. Res. Birsa agric Univ. 10 (2) : 177-182.

Singh, K., D. S. R. M. Rao and Harbir Singh. 1987. Correlation and path coefficient analysis of yield and yield components in maize. Haryana agric. Univ. J. Res. 17 (1) : 64-67.

Singh, R. K. and B. D. Chaudhary. 1985. Biometrical methods in Quantitative Genetic analysis. Kalyani Publ. New Delhi.

Singh, S. N., K. N. Singh and H. G. Singh. 1989. Character association in maize. Farm Sci. J. 4 (1-2) : 32-37.

Sinha, A. and S. N. Mishra. 1997. Combining ability analysis in varietal crosses of maize. Indian J. Genet. 57 (2) : 149-152.

Sprague, G. P. and L. A. Tatum. 1942. General v/s Specific combining ability in single crosses of Corn. Agron. J. 34 : 923-932.

*Stastny, K. 1993. Study of combining ability of inbred maize lines originating from native flint types. Poljoprivredna-Znastvena-Smotra. 58 (2) : 101-115.

*Tomov, N . 1990. Expression of heterosis in maize. Rastenieve dni Nauki 27 (1) : 20-26 [Bq ru en 14 ref] Institute Do Tsa eavitsata Knezha Bhlgaria.

Tyagi, A. P., G. P. Pokhariyal and U. M. Odongo. 1988. Correlation and path coefficient analysis for yield components and maturity traits in maize (*Zea mays* L.). Maydica. 33 (2) : 109-119.

Umakanth, A.V and H. A. Khan. 2001. Correlation and path analysis of grain yield and yield component in maize (*Zea mays* L.). J. Res. ANGRU. 29 (2/3) : 87-90.

*Vancetovic J. and G. Drinic 1994. Combining ability for grain yield in eight local and synthetic populations of maize (*Zea mays* L.). Selekeija-I-Semenarstvo. 1(1): 41-43.

Vasal S. K., B. S. Dhillon, G. Srinivasan, S. D. Mc Lean, S. H. Zhang and C. F. Gohzalez. 1994. Breeding intersynthetic hybrids to exploit heterosis in maize. Maydica. 39 (3) : 183-186.

Vasal, S. K., G. Srinivasan, , J. Crossa and D. L. Beck. 1992. Heterosis and combining ability of CIMMYT'S subtropical and temperate early maturity maize germplasm. Crop Sci. 1992, 32 (4) : 884-890.

Vasic, N., M Ivanovic, L. A Peternelli, D. Jockovic, M Stojakovic and J. Bocanski. 2001. Genetic relationship between grain yield and yield component in synthetic maize population and their implications of selection. Acta. Agronomic. Hungarica. 49 (4) : 337-342.

Vozda. J and B. Kubecova. 1998. Evaluation of combining ability in maize genotype using diallele cross in macro environment. Mendeleum Vedecke Pracoviste VSZ. 25 (1) : 33-46.

Wang, L. M., D Q Shi, R D Liu and L. Bai. 1994. Studies on combining ability of high lysine maize. Acta-Agronomica-Sinica. 20(4) : 446-452.

*Xu, Z. B. E. 1986. Influence of major characters of maize on the productivity of individual plant. Ningxia agric. Sci. and Tech. No. 5. 26-27.

Zhang, D. S. and G. R. Wang. 1991. Analysis of combining ability of main photosynthetic and agronomic characters in maize (*Zea mays* L.) J. Shandong Univ. China. 22: 212 -220.

* Originals not seen

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