

**DEVELOPMENT OF HIGH YIELDING SINGLE CROSS
HYBRIDS FROM NEWLY DEVELOPED INBRED LINES
OF MAIZE (*Zea mays* L.)**

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CONTENTS

Sl. No.	Chapter Particulars
	CERTIFICATE
	ACKNOWLEDGEMENT
	LIST OF TABLES
	LIST OF FIGURES
	LIST OF PLATES
	LIST OF APPENDICES
1.	INTRODUCTION
2.	REVIEW OF LITERATURE
	2.1 Method of diallel cross analysis
	2.2 Evaluation of lines by hybrid and mean inbred performance
	2.3 Combining ability and gene action
	2.4 Heterosis
	2.5 Relationship between heterosis and combining ability
	2.6 Character-wise review
	2.7 Genetic analysis for quality parameters
3.	MATERIAL AND METHODS
	3.1 Experimental Material
	3.2 Field plot technique used
	3.3 Recording of observations
	3.4 Statistical Analyses
	3.4 Estimation of Heterosis
	3.5 Combining ability analysis
4.	EXPERIMENTAL RESULTS
	4.1 Analysis of variance (ANOVA) in respect of 13 characters in a set of 14 × 14 half diallel crosses in maize
	4.2 Heterosis over mid parent, better parent and check
	4.3 ANOVA for combining ability
	4.4 Combining ability effects

Contd....

Sl. No.	Chapter Particulars
5.	DISCUSSION
	5.1 Analysis of variance
	5.2 Heterosis
	5.3 Combining ability
	5.4 Genetic analysis for quality parameters
	5.5 Mean performance of hybrids for yield and its componental characters
	5.6 Selection of useful/promising lines and hybrids for future use
6.	SUMMARY AND CONCLUSIONS
	REFERENCES
	APPENDICES

LIST OF TABLES

Table No.	Title
1.	Character-wise review of literature pertaining to combining ability
2.	Character-wise review of literature pertaining to heterosis
3.	Salient features of the Parents
4.	Analysis of variance for 15 traits in 14 x 14 half diallel crosses in maize
5.	Per cent relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) for maturity characters in maize
6.	Per cent relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) for plant characters in maize
7.	Per cent relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) for ear characters in maize
8.	Per cent relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) for yield characters in maize
9.	Per cent relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) for quality characters in maize
10.	Analysis of variance for combining ability in maize
11.	General Combining effects for 14 parents in maize
12.	Specific combining ability effects of hybrids for 15 quantitative characters in maize
13.	Estimates of heterosis over mid parent, better parent, and standard checks for 15 characters in 91 experimental maize hybrids
14.	Top three desirable hybrids with <i>Per se</i> performance and heterosis for 15 character in maize
15.	Top parents for gca effects with respect to yield and its component traits
16a.	Identified top three crosses based on mean performance and their sca effects, gca status of parents for 15 traits in maize
16b.	Top three crosses exhibiting maximum sca effects, their mean performance with respect to 15 characters in maize
17.	Number of parents and crosses which showed significant gca and sca effects to the positive and negative directions and ranges
18.	Number of crosses showing significant heterosis level with respect to directions and ranges
19.	Scoring of parents based on their gca effects for 15 characters in maize

Contd.....

Table No.	Title
20.	Performance of top ten superior experimental hybrids over checks with respect to <i>per se</i> value of 15 characters in maize
21.	Performance of promising hybrids identified for grain yield and their sca effects in maize
22.	Performance of top five experimental hybrids identified protein content and their sca effects in maize
23.	Performance of top five experimental hybrids identified starch content and their sca effects in maize

LIST OF FIGURES

Figure No.	Title
1.	Scoring of parents based on their gca effects
2.	Top ten experimental hybrids having desirable sca effects for different characters
3.	Per cent heterosis of top ten hybrids of maize over MP, BP and SH with respect to yield (q/ha)
4.	Per cent heterosis of top ten hybrids of maize over MP, BP and SH with respect to protein content (%)
5.	Per cent heterosis of top ten hybrids of maize over MP, BP and SH with respect to starch content (%)

LIST OF PLATES

Plate No.	Title
1.	General view of the crossing block and experimental hybrids evaluation trial
2a.	First high yielding F ₁ hybrids
2b.	Second high yielding F ₁ hybrids
2c.	Third high yielding F ₁ hybrids
2d.	Fourth high yielding F ₁ hybrids
2e.	Fifth high yielding F ₁ hybrids

LIST OF APPENDICES

Appendix No.	Title
1.	Monthly meteorological data for the experimental year 2010-2011 at Meteorological Observatory, Main Agricultural Research Station, College of Agriculture, University of Agricultural Sciences, Dharwad
2.	Mean performance of parents, hybrids and Checks with respect to yield and its component characters

1. INTRODUCTION

Maize (*Zea mays* L.; $2n=20$) is the second most important cereal of the world after wheat. By origin, maize is native to South America and it is a tropical crop and has adapted magnificently to temperate environments with much higher productivity. It is grown from latitude 58° N to 40° S, from sea level to higher than 3000 m altitudes and in areas receiving yearly rainfall of 250 mm to 5000 mm (Downswell *et al.*, 1996). Most of the area under this crop is however in the warmer parts of temperate regions and in humid-subtropical climate. Highest production is in area having the warmest month isotherms from 21° to 27° C and a frost free season of 120 to 180 days duration.

Maize is an important cereal crop belonging to tribe *Maydeae* of the grass family, *Poaceae*. Tribe *Maydeae* comprises eight genera, five of which are Oriental (*Coix*, *Schlerachne*, *Polytoxa*, *Chinonachne* and *Trilobachene*) and are relatively unimportant. They are native to an area extending from India to Burma through East Indies and into Australia. The three American genera are *Zea*, *Tripsacum* and *Euchalaena*. *Euchalaena* (teosinte), which appears to be the closest wild relative of maize, occurs in Mexico and Guatemala. The annual form has 10 pairs of chromosomes like maize and is the most common type. Perennial teosinte has 20 pairs of chromosomes and is found in a restricted area in Mexico. The annual form is used as a forage plant.

Maize is an important staple food in many countries of the world and the acreage and production of maize in the world have been increased continuously. The US has the largest harvested area of corn and contribution one fifth of the world corn harvested area. China, Mexico, India, Brazil and Indonesia are other countries which contribute significantly to world harvested area. These six countries have around 60 per cent of world corn production. In India it occupies an area of 8.11 million hectares with production 19.76 million tonnes and productivity 24.35 quintals per hectare. Karnataka is one of the major maize producing states in the country with an area of 11.13 lakh hectares, production 32.64 lakhs tonnes and productivity 29.24 quintals per ha (Anon., 2011).

Maize is the third most important food grain in India after wheat and rice. In India, about 28 per cent of maize produced is used for food purpose, about 11 per cent as livestock feed, 48 per cent as poultry feed, 12 per cent in wet milling industry (for example starch and oil production) and 1 per cent as seed (AICRP on Maize, 2007). Maize provides nutrients of human and animals, and serves as a basic raw material for the production of starch, oil and protein, alcoholic, beverages, food sweeteners and more recently fuel. It is also a versatile crop, allowing it to grow across a range of agroecological zones. Every part of the maize plant has economic value; grain, leaves, stalk, tassel and cob can all be used to produce a large variety of food and non food products.

Among the cereals grown in India, it is gaining significant importance on account of its growing demand for diversified uses. At the same time, substantial investment in maize research has generated improved production technologies that have provided farmers with the means to respond to changes in demand. As a result of rising yield compared with expansion in area has led to strong growth in maize production during 1990's, which in turn helped to achieve as high as almost 11 million tonnes of maize production by 1997-98. However, this increase could not be sustained as a result of its decreasing productivity in progressive years.

In general, it has greater worldwide significance as human food, animal feed and a source of large number of industrial products. The potential of heterosis is just beginning to be exploited in developing countries through expansion of hybrid seeds. It has the highest potential of per day carbohydrate productivity. Renowned Noble Laureate, Dr. Norman E. Borlaug, the father of green revolution believes that "after the last two decades saw the revolution in rice and wheat, the next few decades will be known as maize era".

The invention of heterosis phenomenon, the development of hybrid breeding technology and successful commercial exploitation of heterosis in maize are considered to be significant achievements and land marks in the history of biological sciences during the present century.

A number of genotypes e.g., single crosses, three way crosses, double crosses, varietal hybrids, multiple hybrids, composites, synthetics, pools, populations etc are feasible to maize growing farmers for commercial cultivation by virtue of the crop being a highly cross pollinated species.

In heterosis breeding programme, the selection of parents/inbreds based on their morphological diversity with good combining ability is very important in producing superior hybrids. The analysis of general combining ability and specific combining ability helps in identifying potential parents/inbreds for the production of superior hybrids.

The concept of general combining ability (GCA) and specific combining ability (SCA) was introduced by Sprague and Tatum (1942) and its mathematical modeling was set about by Griffing (1956a) in his classical paper in conjunction with the diallel crosses. The value of any population depends on its potential *per se* and its combining ability in crosses (Vacaro *et al.*, 2002). The usefulness of these concepts for the characterization of an inbred in crosses have been increasingly popular among the maize breeders since the last few decades.

Maize hybrids are cultivated on only a limited area in the developing countries in spite of their higher yield potential (Vasal *et al.*, 1993). Paterniani (1990) discussed several characteristics of temperate and tropical maize production and suggested that the problems facing maize cultivation in the tropics are more numerous and are of greater magnitude and more challenging than in temperate areas. A series of combining ability studies have been made by many workers from the International Maize and Wheat Improvement Center (CIMMYT) to establish heterotic patterns among several maize populations and gene pools, and to maximize their yield for hybrid development (Beck *et al.*, 1990, 1991; Crossa *et al.*, 1990; Vasal *et al.*, 1992). Likewise, the variances of general and specific combining ability are related to the type of gene action involved. Variance for GCA includes additive portion while that of SCA includes non-additive portion of total variance arising largely from dominance and epistatic deviations (Rojas and Sprague, 1952).

Diallel crosses have been widely used in genetic research to investigate the inheritance of important traits among a set of genotypes. These were devised, specifically, to investigate the combining ability of the parental lines for the purpose of identification of superior parents for use in hybrid development programmes. Analysis of diallel data is usually conducted according to the methods of Griffing (1956b) which partition the total variation of diallel data into GCA of the parents and SCA of the crosses (Yan and Hunt, 2002). A diallel is simple to manipulate in maize and supplies important information about the studied populations for various genetic parameters (Vacaro *et al.*, 2002). The analysis is also useful for the evaluation of populations *per se*.

Keeping these things in views, following objective of this study is to evaluate the performance of 14 newly developed elite maize inbred lines derived from segregating populations highly potential single cross hybrids. These promising lines are never appeared to be tested before for their breeding potential *per se* in specific combinations (SCA) and their overall performance in crosses (GCA). These lines would be valuable source of germplasm to enhance hybrid grain yield. Hence, the present study was undertaken with the following objectives.

1. To study the combining ability for grain yield, its components traits and quality components.
2. To estimate GCA and SCA effects of newly developed inbred lines and single cross hybrids, respectively.
3. To estimate the extent of heterosis in respect to grain yield, its componental traits and quality components.
4. To identify superior single cross hybrids for grain yield and its quality traits.

5. REVIEW OF LITERATURE

The research carried out in the past on gene action, heterosis, correlation and path analysis in respect of qualitative and quantitative characters relevant to the present study in maize is reviewed below.

Study of the behaviour of qualitative and quantitative traits in maize are important because many such traits like maturity characters, plant height, ear length, ear width, number of kernel rows per ear, number of kernels per row, shelling percentage, test weight, grain and yield per plant are under polygenic control.

Literature pertaining to the present investigation on heterosis and combining ability in maize has been reviewed and presented in chronological order under the following headings.

- 2.1 Method of diallel cross analysis
- 2.2 Evaluation of lines by hybrid and mean inbred performance
- 2.3 Combining ability and gene action
- 2.4 Heterosis
- 2.5 Relationship between heterosis and combining ability
- 2.6 Character-wise review
- 2.7 Estimation of hybrids and inbreds for protein and starch

2.1 Method of diallel cross analysis

Diallel crossing is one of the most important mating designs permitting the estimation of combining ability effects as well as partitioning the total genetic variance into additive and dominance components. The diallel mating system can fit into two models, one such model developed for a single diallel gene but extended to many genes with certain restrictions (Jinks and Hayman, 1953). This method is often referred to as component analysis. The genetic basis of analysis is described by many biometricians (Jinks and Hayman, 1953; Jinks, 1954 and Hayman, 1954a and 1958). The components of variance analysis of the data from diallel analysis (Hayman, 1954a) provides actual genetic parameters to decide the predominance of dominance over additive type of gene action and vice-versa; in addition, along with the graphic analysis of the diallel set (Hayman, 1954b), it provides accessory information like the degree of dominance, number of dominant genes in comparison with recessive genes, distribution of positive and negative alleles and dominant and recessive genes *etc.* The gca and sca effects help to locate the parents with a high gca and crosses with high sca to suggest them for use in the appropriate breeding methods.

Arunachalam (1976) commended that Hayman's approach invites criticisms because of stringent, unrealistic and impracticable assumptions to be fulfilled.

The more generalized model of combining ability analysis of diallel cross was given by Griffing (1956a and 1956b).

It consists of;

Method I: Parents, one set of F_1 s and reciprocal F_1 s with combinations are included.

Method II: Parents and one set of F_1 s (reciprocals excluded) with $N(n+1)/2$ combinations

Method III: One set F_1 s and reciprocals (no parents) with $n(n-1)$ combinations

Method IV: One set of direct F_1 s only with $n(n-1)/2$ combinations

He used the term modified diallel for the last two methods where parents are not included. He provided two models for each of the four methods.

Model I (fixed effect model) – Wherein, parental materials are selected and results obtained are applicable to the materials investigated. It estimates combining ability effects.

Model II (random effect model) – Wherein, the parental materials are sampled at random from the population about which the inferences are to be drawn. It estimates different genetic components of the population variance.

2.2 Evaluation of lines by hybrid and mean inbred performance

The final evaluation of inbred lines can be determined by hybrid and mean inbred performance. In the earlier years of the corn breeding programmes, usually inbred lines were not evaluated in hybrid combinations until they had been inbred for several generations. A very large number of hybrids can be produced from a relatively few inbred lines. The lines can be saved or discarded on the basis of the mean performance of the crosses or based on mean performance of the inbred lines.

Jones (1922) reported on the relative performance of top crosses. Davis (1927) used top crosses to estimate the combining ability of S₂ lines. Lindstrom (1931) suggested the commercial use of top crosses. He found that certain inbred lines were very preponderant for ear type, disease resistance, stability and uniformity in maturity.

Jenkins and Brunson (1932) noticed significant correlation between yields of intercrossed inbred lines and the same lines as top crosses. They reasoned that the most valuable lines for use in double crosses, multiple crosses or synthetic varieties are those, which on an average produce the best hybrids when tested with wide range of germplasm. They concluded from their study that crosses with standard open pollinated varieties provide efficient method for the preliminary testing of inbred lines for later use in other types of hybrid combinations. The use of top crosses provides an efficient method for the preliminary evaluation of inbred lines. They are especially useful for determining general combining ability for a large number of lines. The procedure permits the testing of a large number of inbred lines at one time and eliminates the need for preliminary evaluation of inbred lines in top crosses.

A simple inexpensive performance test was designed by Jugenheimer (1949) for the preliminary screening of large number of entries. Each three way cross was planted in replicated, single-hill plots. Its performance was compared to that of the single cross tester grown adjacent to it. The better lines obtained by the preliminary tests might be grown in larger populations for additional selection within families if seemed desirable. The remaining material may also be evaluated in standard yield tests to determine the superior inbred lines and hybrids.

Russell (1968) believed that older methods of evaluating inbred lines may need modification. The current yield levels are much higher and source materials diversified. Inbred lines for use in double cross hybrids were usually evaluated for general combining ability or additive effects. Because of the change to single cross and three way cross hybrids, testing procedures having maximum efficiency require greater emphasis on non-additive effects. The relative importance of additive and non-additive type of gene action is changing in breeding programmes.

Russell (1968) also pointed out that visual selection among and within inbred line progeny permits the breeder to evaluate many more progenies than is possible in replicated yield trials and at a much lower cost. He suggested that visual selection could be carried out for about three generations of progeny evaluation. It may be more logical to test immediately for specific combining ability when visual selection is completed. Established research programmes have a few key lines used in commercial hybrids.

Raghuram Reddy *et al.* (1987) compared yield performance of single cross, double cross and three way cross hybrids in maize crop. Yield levels of single cross maize hybrids were more followed by three way and double cross hybrids.

Jha and Khehra (1992) in their study on evaluation of maize inbred lines derived from two heterotic populations by using factorial mating analysis with eighty crosses of maize produced by crossing five females with sixteen pollen parents in two different locations for combining ability noticed that specific combining ability (sca) and sca x environmental components were of higher magnitude than general combining ability (gca) and gca x environmental components for grain yield indicating greater contribution of non additive gene action and its pronounced interactions with the environments.

Hallauer *et al.* (1994) evaluated B97 and B98 inbred lines by hybrid performance. As they found both B97 and B98 were good inbred lines, they concluded that both can be used as either male or female in the production of hybrid seed.

Venkatesh *et al.* (2001) conducted early generation identification and utilization of potential inbred lines in modified single cross hybrids of maize and suggested that the essential pre-requisite for commercial production of single cross maize hybrids is the development of vigorous high yielding inbred parents.

2.3 Combining ability and gene action

Sprague and Tatum (1942) formulated the concepts of combining abilities. General combining ability is the average performance of a strain in series of cross combinations, estimated from the performance of F_1 s from the crosses, whereas specific combining ability is used to designate those cases in which certain combinations do relatively better or worse than would be expected on the basis of average performance of lines involved.

Griffing (1956a) has shown relationship between various heritable variance components and GCA and SCA variances. Thus, GCA variance is due to additive variance and additive x additive interaction variance. While, SCA variance is due to dominance variance, additive x additive variance, additive x dominance variance and dominance x dominance variance components. Estimates of the variances due to GCA and SCA provide an appropriate diagnosis of the predominant role of additive or non-additive variances of gene action.

Ratio of additive to non-additive gene action is to be considered in order to decide the predominance of the kind of genetic variation for a given character. If the ratio of additive to non-additive gene action is more than unity indicates the major role of additive variance in controlling the expression of a character, whereas, less unity indicates the importance of non-additive variance (Gardner, 1963).

Tandan *et al.* (1970) opined that the combining ability analysis was found to be better than graphical analysis in predicting the prepotency of cultures especially in the later generations, when the expression of dominance effect was reduced. According to Dhillon and Singh (1976), general combining ability was more important than specific combining ability for the inheritance of days to 50 per cent silking, grain moisture, plant height, ear height, ear length, ear circumference and kernel row number but not for grain yield.

Martin and Hallauer (1976) studied diallel analysis for ear length, ear circumference, 100-grain weight, number of grain rows and yield and concluded that epistasis was more frequent for all characters except for 100-grain weight. Epistasis was most common for ear circumference and number of grain rows and least common for yield. Bhalla and Khehra (1977) found significant general combining ability for yield per plant, ear length and plant height.

Ramamurthy (1980) reported the predominance of additive gene effects for plant height, 100-grain weight, while non-additive effects were important for ear height and grain yield per plant. Murthy *et al.* (1981) observed predominance of additive gene action for days to silking and non-additive gene action for grain yield per plant. Ali and Topera (1986) noticed the additive gene action was more important than non-additive gene action for days to silking and plant height, whereas non-additive gene action was more important for ear circumference, number of grain rows per ear, grains per ear and grain yield

Combining ability analysis was carried out in an 8×8 maize diallel for days to silking, plant height, cob placement, kernel row per cob, kernels per row, cob length, cob girth, 1000 grain weight, grain yield per plant were reported in cross CM 500 x CM 400 was showed significant desirable sca effects for 7 out characters followed by CM 111 x CM 400, which is good specific combiner for 6 characters (Prasad *et al.*, 1988).

Muthiah (1989) reported that the proportion of GCA variance was higher than the SCA variance showing preponderance of additive genetic effects for all the characters studied. According to Debnath and Sarkar (1990) non-additive gene action was preponderant in the inheritance of grain yield, ear circumference, whereas equal importance of both additive and non-additive effects were observed for ear length, kernel rows per ear and kernels per row.

Zargar and Singh (1990) suggested that additive components of variance with dominance played a major role in the inheritance of grain yield, plant height, ear height, ear length, kernel rows per ear and 100-kernel weight exhibited importance of variance with dominance in a partial to negligible range. Alika (1994) observed highly significant variation due to *gca* for ear length, ear circumference, ear weight and 100-kernel weight and *sca* for ear circumference.

According to Packiaraj (1995) GCA variance was greater in magnitude than SCA for shelling percentage, number of leaves, leaf breadth, 100-grain weight, days to 50 per cent silking, number of grains per row and plant height. SCA variance was high for ear weight, grain weight per plant and number of grain rows per ear indicating that dominance and epistatic interaction played a major role in the expression of these traits.

Dass *et al.* (1997) reported that non-additive gene action played major role in the inheritance of grain yield and majority of ear traits. But, Geetha (1997) observed that additive gene effects controlled the inheritance of grain yield per plant and also added that proportion of GCA variance was higher than the SCA variance having preponderance of additive genetic effects for characters such as plant height, number of grain rows per cob, number of grains per row, ear weight, days to 50 per cent silking, 100-grain weight and starch content.

According to Altinbas and Tosum (1998) GCA and SCA variances for grain yield per plant and other yield components indicated that screening the parental lines and crosses based on combining ability effects for 100-grain weight and ear length should be effective.

Dutu (1998) observed that plant height was controlled by additive and non-additive gene actions and cytoplasmic inheritance. Whereas, number of leaves per plant was controlled by additive gene only. Joshi *et al.* (1998) revealed that there was preponderance of non-additive gene action in the expression of yield per plant, protein content and starch content, while for oil content and 100-grain weight there was preponderance of additive gene action. Lou Xiang *et al.* (1998) concluded that most plant and ear characters were improved with additive and dominance effects of the female parents. According to Singh and Singh (1998) GCA variance was more important for ear length, number of kernel rows per ear, but SCA variance was important for other characters like grain yield per plant, ear circumference, number of kernels per ear row, 100-kernel weight, days to 50 per cent silking, plant height and ear height.

Mikhailov and Chernov (1999) reported that partial dominance of the positive allele is the main type of allelic interaction in the loci controlling kernel row number. Paul and Debnath (1999) obtained significant *gca* and *sca* effects for all characters studied *viz.*, days to silking, plant height and ear height. Tallei and Kochaksaraei (1999) observed significant *gca* effects for plant height, ear height, kernel length and yield per plant.

Geetha and Jayaraman (2000b) reported that additive and dominance components were significant for plant height, number of kernel rows per cob, number of kernels per row, ear weight, 100-grain weight and grain yield. Gupta and Nagda (2000) observed variances due to variety heterosis and its components were significant for all the characters studied.

Kadlubiec *et al.* (2000) obtained higher GCA values than those of SCA for majority of traits which suggests the importance of additive gene action. Non-additive gene action effects were responsible for the inheritance of lodging resistance only. Rameeh *et al.* (2000) observed greater ratios of GCA to SCA mean squares for all traits, except for number of seed rows per ear, indicating the importance of non-additive gene effects in their genetic control.

Rosa *et al.* (2000) obtained highest SCA values in 13 x 13 diallel crosses *viz.*, AS-910 x AS-4450 and PP-9538 x AS-948. Suneetha *et al.* (2000) noticed significant variances for GCA and SCA for days to 50 per cent tasseling, plant height and neutral detergent fiber content. Zelleka (2000) had derived an information from data on grain yield, plant height, ear length, days to maturity and 1000-grain weight from a diallel mating that both *gca* and *sca* effects were significant for all traits.

Choudhary *et al.* (2000) estimated the combining ability of early generation inbred lines derived from two maize populations and showed that better performing crosses usually had at least one parent with high general combining ability but for ear length inter population crosses were usually superior to intra-population crosses.

Desai and Singh (2001) reported significant difference in gca and sca effects for the traits viz., days to 50 per cent tasseling, days to 50 per cent silking, anthesis silking interval, plant height, ear height, number of leaves per plant. Kara (2001) observed significant gca effects for all the traits and significant sca effects for ear circumference, ear height and grain yield per unit area. Konak *et al.* (2001) obtained non-additive gene effects for ear length and number of kernel rows on ear and additive gene effect for yield, 1000-kernel weight, plant height, ear height and days to silking. Mandal *et al.* (2001) noticed significant GCA and SCA variances for most of the traits studied. Mahto and Ganguli (2001) observed that both additive and non-additive genetic components were important for 100-grain weight and shelling percentage in CML 85 and CML 79. The crosses showed positive and highly significant specific combining ability effect for grain yield.

Vidal Martinez *et al.* (2001) obtained better *per se* combining ability for pollen yield of Corn Belt genotypes and good combining ability for grain yield and their components for exotic genotypes. Dominance gene effects were the most important contributors to the inheritance of pollen yield, grain yield and their components.

Dubey *et al.* (2001) estimated that inbred line pop 30-128-215-1 was good general combiner for grain yield per plant, 1000 grain weight and days to 50 per cent silking.

Combining ability study were conducted on grain yield and yield contributing characters in a 8 x 8 half diallel in maize, both additive and non additive gene actions were found important for 1000 grain weight, kernel row per ear, grain per ear, ear girth and ear length with non additive gene action being predominantly important for grain yield per plant. Inbreds DKI-144 and DKI-137-A were observed to be good general combiners for grain yield per plant. Estimates of sca effects having significant positive sca effects for yield and most yield contributing characters (Kallu *et al.* 2001).

Vacaro *et al.* (2002) reported that mean sum of square for gca effects was greater than that for sca effects for the traits like plant height, point of insertion of the first ear, number of ears per plant, number of grains per ear, root and stalk lodging and grain yield indicating the predominance of additive effects. Kanta *et al.* (2002) observed preponderance of additive gene effects for all traits.

Dodiya and Joshi (2003) conducted line x tester analysis by using 20 lines and 3 testers in maize (*Zea mays* L.) along with their F₁ hybrids was carried out in three environments to assess combining ability and heterosis with respect to quality and yield attributes and they observed that combining ability analysis showed the predominant role of non-additive type of genetic component in the inheritance of all the characters.

Aurelio Mendes Aguiar (2003) observed that GCA were significant for all traits and SCA were non significant only for ear placement. For grain yield, both additive (GCA) and non-additive (SCA) effects were important, while for the remaining traits additive effects were more important.

Li-Jizhu *et al.* (2004) reported highest heterosis for ear grain weight and lowest for ear row number. All characters studied were controlled by additive gene action. Ear length had significant additive and dominance effects, whereas, ear row number and ear grain weight had dominant and epistatic effects, respectively.

Hossain *et al.* (2004) conducted the combining ability analysis in flood tolerant maize inbred lines and their hybrid under waterlogged situation and the experimental results showed that combining ability study revealed that none of the parents had significant desirable effects of gca for all the characters.

Surya Prakash and Ganguli (2004) revealed that gene action appeared to be non-additive for all traits except for days to 50 per cent tasseling, ear height and number of kernel rows per ear, which are characterized by additive gene action.

El-Moula *et al.* (2004) indicated that magnitude of delta 2-GCA was greater for days to 50 per cent silking, plant and ear heights, while delta 2SCA was greater for number of ears per 100 plant and grain yield. Interaction of delta 2SCA x L was higher than that of delta 2GCA x L for all traits indicating that the non-additive type of gene action was more affected by environmental conditions than the additive type.

Malik *et al.* (2004) reported that temperate material gave high gca effects for striking characters contributing towards high grain yield *i.e.*, plant and ear height, leaf area, ears per plant, ear weight and kernels per row.

Katna *et al.* (2005) in their study of combining ability for yield and its related traits in maize involving 12 x 12 half diallel set and three checks at two climatically diverse locations, noticed that both general and specific combining ability effects were significant for all the traits at both the locations.

Glover *et al.* (2005) evaluated 10 populations of maize, created from Chinese and U.S inbreds evaluated by Griffing's diallel analysis for combining ability of grain yield, stalk lodging, ear height, flowering time. For grain yield general combining ability was largest for the population Mo17 Syn (H14) C5 and for Grain yield specific combining basis of combining ability was largest in the cross Chinese Mix 2 x Mo17 Syn (H14) C5. Chinese Mix 2 x Mo17 Syn (H14) C5 had more stalk lodging than the B73 x Mo17 and Pioneer Brand 3394 checks.

Welcker *et al.* (2005) reported that heterosis and combining ability for maize adaptation to tropical acid soils in five different environments and observed significant genotype x soil condition interactions for grain yield. Mid parent heterosis for yield was significantly higher in acid soils (32%) than non acid soils (20%) and suggested that the development of variety crosses between acid soil-tolerant populations could be used to increase maize yields in acid soil cropping pattern.

Subramanian and Subbaraman (2006) was conducted the experiments to study genetics of yield and its components in diallel cross (excluding reciprocals) of maize involving 11 inbreds, and observed that analysis of variance components indicated the importance of over dominance and epistasis in the inheritance of plant height, leaf length, number of kernels per row and seed yield per plant. Dominance effect was found to influence the inheritance of ear length.

Abelardo *et al.* (2006) estimated that the general combining ability and specific combining ability help plant breeder to devise breeding and selection strategies. The objectives of their study was to apply two mode principle component analysis (PCA) to environment-centered and normalized female (F) or male (M) x environment (E) and these interactions study were able to identify the best tester for either broader specific adaptation.

Combining ability analysis was conducted in early maturing maize (*Zea mays* L.) inbred lines for quality and yield attributes. The ratio of non additive/additive gene effect revealed that there was preponderance of non additive gene action in the expression of all the traits under study. Inbred lines L9 and L10 were good general combiner for all the three quality traits, while inbred line L9 was also good general combiner for grain yield, oil content, starch content and protein content (Amit Dadheech and Joshi, 2007).

Oja *et al.* (2007) estimated that hybrid means were significantly higher than the parental means for all traits except shelling percentage. GCA and SCA mean squares were not significantly different for the yield components. GCA mean squares were however, highly significant for grain yield.

Combining ability analysis for grain yield and its contributing characters in maize were carried out in 5 x 5 diallel cross. The highest percentage of heterosis for grain per ear over mid parent and better parent were observed by the cross P2 x P3. Crosses P1 x P3 and P1 x P5 showed significant negative heterosis for days to maturity. Significant general and specific combining ability variances were observed for all the characters except ear height. Almost equal role of additive and non-additive gene actions was observed for days to maturity. Additive genetic variance was preponderant for grains per ear and 1000-grain weight and non-additive gene action was involved in plant height, ear height, days to silking, and days to maturity. The inbred lines P2 and P5 were found to be best general combiner for 1000-grain weight (Alam *et al.*, 2008).

Ear length (EL), ear diameter (ED), number of kernel rows per ear (RE), kernel number per row (KR), and thousand-kernel weight (TKW) are the most important yield components (YCTs) of grain yield in maize (*Zea mays* L.) and the results showed the GCA effects of ED and RE were generally better for the CIMMYT lines than for local lines (Fan *et al.*, 2008).

Bello *et al.* (2009) studied on general combining ability (gca) and year (y) effects were significant for all the parameters except plant height, while specific combining ability (sca) and gca x year effects were significant only for grain yield. However, Tze Comp4 Dmr Srbc2, Tze Comp4 C2 and Acr 94 Tze Comp5 which are good general combiners for maize grain yield, also showed positive significant gca x year effects for flowering traits. Significant sca x year interaction effects were recorded for maize grain yield and days to flowering, with Hei 97 Tze Comp3 C4 combining very well with 3 parents.

Gene action studies were conducted on grain yield and yield contributing traits in a line x tester in maize and the line x tester interactions revealed sufficient variability for all the traits, except days to 50 per cent silking and pollen shedding, kernel rows per ear and test weight in the material under investigated. The estimates of SCA variance were higher in magnitude from the corresponding GCA variance for all characters during individual years as well as pooled over years, however the dominance components were higher in magnitude and more predominant for all the traits, thus signifying the importance of non additive gene action (dominance deviation) in controlling the inheritance of these traits (Kumar Jagdish *et al.*, 2010).

Ali Akeel Wannows *et al.* (2010) produced 15 hybrids using half diallel fashion in 2008 were evaluated for grain yield and its components. The obtained results indicated that all estimates of additive (VA) and dominance (VD) variance were significant for all characteristics with exception of additive variance for specific leaf weight, dominance variance for leaf area index, plant and ear height, ear length, and number of kernel per row.

Shanthi *et al.* (2010) revealed significant mean square due to general and specific combining ability effects indicating that both additive and non additive gene actions involved in inheritance of grain yield.

Combining ability studies were carried out for yield and yield components in 28 single cross maize hybrids produced by crossing eight parents in a diallel fashion excluding reciprocals, the hybrids along with parents and check were evaluated during *rabi*, 2007-08 and the results of combining ability analysis revealed significant mean squares due to general and specific combining ability indicating that both additive and non additive gene actions were important in the inheritance of the characters studied. Variances due to SCA were larger than GCA for all the characters indicating the predominance of non- additive gene action in expression of various traits. Among the parents BML-15 and CM-119 the best general combiners for grain yield and most of the yield contributing characters. Among hybrids, BML-15 x CM-209, CM-132 x CM-209, CM-209 x CM-119, CM- 210 x CM-119 and CM-132 x CM-119 were the best specific combiners for grain yield. Most of the crosses which recorded high sca effects involved at least one parent with desirable gca effect for that trait (Seshu *et al.*, 2010).

Combining ability studies using 10 x 10 diallel set (excluding reciprocal) were carried out for grain yield and quality parameters and inferred that out of 45 hybrids *viz.*, P4 x P7, P5 x P10, P2 x P6, P3 x P5, and P1 x P5 were found to be good specific combiners for grain yield along with protein and tryptophan content. Among the 10 parents P3 and P1 were found to be best parents for grain yield (Shanthi *et al.*, 2011).

Fifteen parents involving Line x tester mating design to was carried out to identify superior parental lines and crosses on the basis of their combining ability. GCA effects were highly significant for all traits. Non additive effects were found important for all characters. The inbred lines L4, L5, T2 and T5 were good combiner for yield and quality traits. The hybrids L10 x T2, L5 x T5, L4 x T2 and L9 x T4 were identified to be significantly superior in term of yield and quality traits (Mohan Lal *et al.*, 2011).

Sandeep Kumar *et al.* (2012) indicated that most traits were under the genetic control of non-additive (over dominance) type of gene action, therefore the material can easily be exploited for heterotic effect.

2.4 Heterosis

Today it is accepted that the characters of plants, animals and human beings are the result of the action, reaction and interaction of countless numbers of genes. What is inherited however, is not the character but the manner of reaction under conditions of environment.

At this time, variability is being expressed as genetic plus environmental variance, one may say that genetic variance is the expression of variability due to genotypic course. It is that part of the total variance that remaining after eliminating environmental variance, as estimated from studying the variance of homozygous lines and F₁ crosses between them.

Heterosis breeding has received more attention than other branches of plant breeding in several crop plants and maize is one such cross fertilized crop which has paid rich dividend since an array of hybrids have been realized over decades. Heterosis is the deviation of F₁ from the reference for the particular character.

Shull (1908) coined the term heterosis to provide a term to describe the phenomenon but it did not include a description of genetic mechanism involved in its expression. Bruce (1910) and Keeble and Pellow (1910) put-forth the dominance hypothesis, which suggested that increase in vigour after crossing resulted from the combination of various dominance alleles by each parent. Shull (1911) and East and Hayes (1912) objected the dominance theory and proposed over dominance hypothesis indicating heterosis as the result of heterozygosis. Jones (1918) stated that heterosis was due to complementary action of linked dominant growth favourable genes brought from both parents.

Ashby (1930 and 1932) suggested that heterosis resulted from the maintenance of the initial advantage in embryo size and not from an acceleration of metabolic process. East (1936) concluded that seed size or the size of any part of the seed can not be the cause of heterosis. Hull (1945, 1946 and 1948) reported the evidence of over dominance in the expression of heterosis.

The degree of geographical separation and the degree of ancestral relationship can be used as an indication of genetic diversity. The greater genetic diversity of the parents is associated with greater heterosis in the F₁ (Moll *et al.*, 1962, Paterniani and Lonquist, 1964; Wellhausen, 1965; Heidrich Sobrinho and Cordeiro, 1975 and Vasal *et al.*, 1992). Moll *et al.* (1967) reported that heterosis increased with increased divergence within certain limits and extremely divergent crosses in maize resulted in decrease in heterosis.

Griffing and Zsiros (1971) viewed heterosis as not entirely the result of genetic stimuli but rather as a result of the interaction between genetic and environmental stimuli and implicated that the environment was a significant factor in the manifestation of heterosis. Kravencheko *et al.* (1971) reported heterosis for ear length, plant height, 100-grain weight, number of kernel rows and yield.

Mukherjee *et al.* (1974) obtained significant heterotic effect for ear width and grain rows per ear. Appadurai and Nagarajan (1975) observed increased yield in 20 combinations exceeding 100 per cent over their respective parents, 33 showed heterosis for plant height, 44 for earliness, 18 for grain rows per ear, 40 for kernel number per row and 45 for grain weight per ear. Dhillon and Singh (1976) obtained heterosis for grain yield over mid parental and better parental values was shown by 31 and 13 hybrids, respectively. Petrenko (1980) observed high positive heterosis for yield and yield components *viz.*, plant height, ear height and length of growth period.

Debnath (1984) obtained heterosis over mid parental value and better parent for grain yield components in 36 F₁ hybrids from a diallel cross among nine elite diverse inbreds. The heterosis for grain yield ranged from 21.07 to 123.58 per cent over the mid parental value and from -2.96 to 95.07 per cent over the better parent. Heterosis was high for grains per row and ear length. According to Prasad and Singh (1986), the magnitude of heterosis for grain yield per plant and six of its components were greater when the parents were moderately diverse than when they were highly diverse. Shakoor (1988) observed positive heterosis for number of leaves (13.4 - 20.0%) and leaf area per plant (-0.01 - 54.8%) over better parent. Muthiah (1989) obtained significant positive heterosis for grain yield per plant and other 15 yield related characters in several cross combinations from 9 x 9 diallel analysis.

Ganguli *et al.* (1989) observed positive heterosis over better parent for grain yield, ear height, plant height, days to maturity and days to silking. Bhatnagar *et al.* (1993) observed high heterotic effects for early silking and grain yield per plant in early maize inbred lines. High heterotic effects for grain yield per plant and time to silk was reported by Vasal *et al.* (1993) based on the combining ability analysis of maize germplasm lines.

Gupta *et al.* (1994) studied 23 double cross hybrids and reported that 16 out of 23 double cross hybrids showed high degree of heterosis for grain yield than the best standard variety "Shweta".

Saha and Mukherjee (1993) observed significant positive heterosis for grains per ear and the crosses with highest heterosis for 100-grain weight and grain yield per plant and negative heterosis for percentage grain conversion. Kumar (1995) observed high degree of heterosis for grain yield per plant and earliness in eight hybrids. Lamkey (1995) indicated that hybrids obtained from the crosses between 24 high yielding and 24 low yielding inbred lines differed significantly for group means and heterosis for yield and days to silking.

Verma and Singh (1996) reported that dominance x dominance gene interactions were important for improving heterosis for yield. Yurankov *et al.* (1996) obtained considerable instability in heterosis for ear width, ear length and number of grains per row. Heterosis was slight or absent for number of rows per ear.

Geetha (1997) obtained positive heterosis over mid parent in 24 hybrids and significant standard heterosis in 19 hybrids. Nagesh Kumar *et al.* (1999) observed heterosis for grain yield ranged from 26.31 to 37.30 per cent over better parent.

Netaji *et al.* (2000) obtained significant and positive heterosis and heterobeltiosis for grain and moreover the expression of heterobeltiosis was most evident for grain yield per plot followed by test weight, ear length, plant height and number of grain rows per ear. Rosa *et al.* (2000) noticed the highest values of heterosis over the mid-parental value in the hybrid PP-9539 x AN-453 (11.35%) and PP-9603 x PP-9539 (11.13%).

Geetha (2001) obtained maximum heterosis for grain yield per plant, ear weight and number of grains per ear. They also reported that significant positive heterosis in grain yield was found to be associated with the heterosis for plant height, number of grains per row, 100-grain weight and number of rows per ear. Kara (2001) observed positive heterosis for all characters studied except for days to tasseling with the average hybrid yield being 79.89 per cent above that of the parents.

Shahwani *et al.* (2001) noticed positive and significant heterosis in 17 hybrids, while 11 hybrids showed heterobeltiosis for ears per plant. Vidal Martinez *et al.* (2001) observed negative heterotic values in pollen yield components and reported heterotic values of 300 per cent for pollen yield in Corn Belt genotypes and upto 200 per cent for grain yield in exotic genotypes. Saleh *et al.* (2002) reported high estimates of heterosis for grain yield, ear weight, grain weight per ear, moderate estimates for plant and ear height, shelling percentage, ear width, number of kernel rows per ear, number of kernels per ear row and grain weight.

Parcial *et al.* (2001) observed significant differences between hybrids and parents, and the control did not differ from parents and hybrid average for yield and the results obtained for plant height, ear height and ear diameter did not show heterosis effects, and, for ear length, the average heterosis was 3.10 per cent. Specific combining ability was not important and the hybrids showed an average yield of about 7 per cent higher than their parents. Some varieties and hybrids presented a grain yield higher than the control, which was an hybrid (G-85) recommended for Southeast and Midwest Brazilian regions.

Choudhary and Chaudhari (2002) reported that significant heterosis for ear length than for any other character, although the proportion of crosses exhibiting positive desirable heterosis were limited. Seven crosses showed significant heterosis for kernel per row.

Dickert and Tracy (2002) reported that among early open pollinated sweet corn cultivars, heterosis for silk date was significant, but the difference between parents was very small, 0.5 day and no hybrids were earlier than the earliest parent, and average mid parent heterosis was 6.8 per cent, but mid parent heterosis was significant and relatively high for 100-kernel weight, ear length, ear height, plant height and 10-ear weight.

Srivastava and Singh (2003) studied heterosis and combining ability for yield and maturity by using exotic and indigenous inbred lines of maize. Eighty single crosses along with parental lines were evaluated in three environments *viz.*, Uttaranchal, Uttarpradesh and Punjab, during *khari* 2000. The mean square due to interaction of lines and lines x testers with environments were significant for all characters, while testers with environments was significant for days to 50 per cent silking.

Betran *et al.* (2003) conducted experiment on genetic diversity and heterosis in tropical maize under stress environment. They observed that SCA had the strongest correlation with genetic diversity. Environment significantly affected the correlation between F_1 , SCA, MPH and HPH, with lower values of gd revealed in most stress condition.

Kabdal *et al.* (2003) in their studies on combining ability and heterosis analysis for grain yield and its components in maize by using 7 inbred lines derived from half-diallel mating, along with 4 control cultivars were determined in a field experiment conducted in Pantnagar, during the *kharif* season of 1999. The general combining ability for all the characters examined was higher than the specific combining ability except for ear height.

Unay *et al.* (2003) reported that the mid parent heterosis values ranged from 46.10 per cent (H.96 x DNB) to 573.12 per cent (ALKD 222 x A 632) whereas the useful heterosis values varied between 46.47 per cent (A 619 x A 632) and 10.78 per cent (N 7A x ALKD 90-1), and only 9 crosses had higher grain yields than that of the check variety.

A line x tester set was obtained by crossing 10 inbred lines with four testers in maize. Forty F_1 's along with 14 parents and two standard checks were evaluated for eleven characters during *rabi* 2004–05. Out of 40 crosses, 23 crosses over better parent and 11 crosses over standard check were significantly out yielded for grain yield. The crosses DMR 274 x HOL 34, DMR 201 x EI 34 and DMR 156 x EI 34 showed high heterosis over better parent and standard check (DHM 103) for grain yield per plant as well as for 100 seed weight, ear length, chlorophyll content at 50 per cent flowering and plant height. Thus, these crosses possess high heterosis, in future could be exploited commercially for higher yield in maize (Saidaiyah *et al.*, 2008).

Patel *et al.* (2010) investigated that Heterosis over better parent (BP) and standard heterosis over the best check Narmada Moti for grain yield per plant and yield components. The hybrids GWL-2 x GWL-12, GWL-2 x GWL-8, and GWL-8 x GWL- 12 showed significant positive Heterobeltiosis and economic heterosis for grain yield per plant and other yield component traits.

Iqbal *et al.* (2010) studied heterosis for morphological traits in subtropical maize and observed that Mid-parent heterosis ranged from 24.57% -71.28%, 29.30%-37.85%, -6.03% to -9.74% and 0.82% to -9.53% for leaf area, plant height, days to silking and days to maturity, respectively and the study suggested that Pop 9804 x FRW4 as the best hybrid combination for early maturity and high fodder yield. Magnitudes of heterosis, both mid-parent and better parent, were positive and higher for leaf area and plant height traits compared to those for days to flowering and maturity.

Sumalini and Shobha Rani (2010) recorded high *per se* performance for grain yield for KML- 225 x KML-226 followed by KML-223 x KML 224 days to 75 per cent dry husk and KML-181 x KML-75 for ear length, ear girth, number of KML-226. The hybrid, KML-227 x KML-161 was found to be superior in terms of ears per plant and number of kernel rows. and crosses showed significant heterosis for yield contributing characters.

Segrio Dona *et al.* (2011) was observed that the effect of heterosis and its components were highly significant. Considering the grain yield, populations F_2 AG8060, F_2 Fort and F_2 A2555 are promising in hybrid combinations, with high values of parental heterosis. The population F_2 DAS2B710 had the greatest parental heterosis effects. There was heterosis manifestation for grain yield, mainly for hybrid F_2 A2555 x F_2 Fort, and it was confirmed the potential of F_2 population hybrids as an alternative to the commercial maize production with medium to low technological input.

2.5 Relationship between heterosis and combining ability

The information on heterosis and combining ability considered together will be more meaningful. If the heterotic hybrids involve both the parents with high general combining ability effects, then it implies that the parental contribution to heterosis is mainly through additive gene action.

Johnson and Hayes (1940) found that low x low crosses yielded less than low x high or high x high, although the F_1 crosses between low x high yielded as well, on the average, as F_1 crosses between high x high.

Hull (1952) believed that while the mean of the high x high combination may be best, the highest specific combination is more likely to occur in high x low crosses. Leng (1954) reported that if over dominance is present, the highest degree of heterosis should be found in high x low crosses.

Tarutina *et al.* (1980) reported that heterosis was observed for many characters under different environmental conditions. As a rule, hybrid with the highest percentage of heterosis had a line with high gca as one of its parents. Khotyleva *et al.* (1986) in a study of general and specific combining ability for six yield components in F₁-F₂ hybrids from a diallel cross of seven lines and in the backcross to each parent reported that high percentage of heterosis was generally found in those hybrids in which at least one of the parents had high gca and specific combining ability also played major role in determining heterosis.

Vaidya (1986) reported that the crosses showing heterosis over check for yield and yield components had at least one good general combiner in their parentage.

Giridharan *et al.* (1996) in their study on gene action and combining ability in grain yield, found that yield was controlled by additive and non-additive gene action in diallel crosses and dominant gene action in triallel and quadriallel crosses, suggesting that grain yield could be improved by heterosis breeding.

Desai and Singh (2001) revealed significant differences for gca and sca effects for ten characters studied. Among the parents, lb 1073, lb1143 and lb 1155 were found to have negative gca effect for days to 50 per cent tasseling, day to 50 per cent silking and anthesis-silking interval. On the other hand, for plant height, ear height and grain yield per plot, they had positive gca effects. The crosses *viz.*, 18 1073 x lb 1143 and lb 1073 x lb1155 were found to have negative sca effects for days to 50 per cent tasseling, days to 50 per cent silking and anthesis-silking interval. These crosses also exhibited positive sca for plant height, ear height, number of leaves per plant and grain yield per plot.

Reif *et al.* (2005) estimated higher mean heterosis and hybrid performance and a reduced specific combining ability (SCA) variance and a lower ratio of SCA to general combining ability (GCA) variance. Thus early testing becomes more effective and superior hybrids can be identified and selected mainly based on their prediction from GCA effects.

Abdel-Moneam *et al.* (2009) indicated that mean square of genotypes were highly significant for all studied traits, *i.e.* ear diameter, ear length, number of kernels per row, 100 kernel weight, ear yield per plant, grain yield per plant and shelling percentage and both GCA and SCA mean squares were highly significant for all traits.. Based on SCA effects, they concluded that best crosses for ear diameter, 100 kernel weight, ear length, number of kernels per row, ear yield per plant, grain yield per plant and shelling percentage, and also results showed positive significant heterosis value for all traits.

Rim Ahmad Al-Abd Al-Hadi (2010) studied heterosis and combining ability components of 28 single maize crosses obtained by half diallel cross among eight inbred lines, They were (IL. 375-06) P1, (IL.363-06) P2, (IL.260-06) P3, (IL.459-06) P4, (IL.275-06) P5, (IL.792- 06) P6, (IL.256-06) P7 and (IL.362-06) P8, and observed that desirable heterosis percentage relative to mid parents and better parent were 149.73 and 143.97 per cent respectively in hybrid (IL.260-06 x IL.459-06) for grain yield per plant. However many significant positive GCA effects were obtained for all traits, concluded that the inbred lines (IL.375- 06), (IL.275-06), (IL.362-06) and (IL.459-06) seemed to be the best general combiner for grain yield.

Investigation was carried out in maize with 12 parents and 32 hybrids through Line x Tester analysis to study the gene action. The analysis revealed the preponderance of non-additive gene action for seed yield and its components. Among the parents studied the following parents *viz.*, UMI 112, UMI 264, UMI 278, UMI 285 and Co 1 were good general combiners with higher mean values for seed yield and different yield components *viz.*, plant height, ear length, kernel rows and 100 grain weight. Among the 32 hybrids evaluated the hybrids *viz.*, UMI 264 x UMI 285, UMI 278 x UMI 285 and UMI 278 x CO 1, UMI 314 x UMI 285, UMI 328 x UMI x UMI 61 and UMI 334 x UMI 325 were identified as good specific combiners for single plant yield. These hybrids could be utilized in heterosis breeding to exploit hybrid vigour (Jebaraj *et al.*, 2010).

Combining ability and heterosis for grain yield and growth characters was studied in maize through line x tester mating design using nine lines and four testers along with check COH (M) 4. Combining ability analysis showed the predominant role of non-additive gene action for all the characters studied. The lines UMI 199 and UMI 278 and the testers UMI 217 and UMI 314 had recorded high per se and gca for yield and majority of the characters studied. The hybrid UMI 278 x UMI 217 and UMI 334 x UMI 217 had significant and superior per se performances for grain yield per plant, the hybrid UMI 348 x UMI 330 exhibited high sca effect for plant height. Growth influencing characters positively influenced hybrid performance in grain yield. The hybrid UMI 278 x UMI 217 was observed as best and followed by UMI 334 x UMI 217 are potential hybrids for exploitation of yield heterosis (Premlatha and Kalamani 2010).

The review of literature pertaining to combining ability and heterosis in respect of 15 quantitative characters viz., Days to 50 % tasseling, Days to 50% silking, Days to 50% brown husking, Plant height, Ear length, Ear girth, Number of kernel rows per ear, Number of rows per cob, Test weight, Shelling %, Grain yield per plant, Grain yield per hectare, protein and starch have been presented Tables 1 and 2.

2.6 Character-wise review

The review of literature pertaining to combining ability and heterosis in respect of 13 quantitative characters viz., 1) Days to 50 per cent tasseling, 2) Days to 50 per cent silking, 3) Days to 50 per cent brown husk maturity 4) Plant height 5) Ear height 6) Ear length 7) Ear diameter 8) Number of kernel rows per cob 9) Number of kernels per row 10) 100-grain weight 11) Shelling percentage, 12) Grain yield per plant and 13) Grain yield per ha have been presented character-wise here under.

2.6.1 Days to 50 per cent tasseling

Greater importance of GCA variance than SCA (Specific Combining Ability) variance both being significant along with the highly significant heterotic effect for early tasseling was reported by Hassaballa *et al.* (1980) and Sanghi *et al.* (1982). However, Lee (1983) and Guo *et al.* (1986) found predominance of SCA variance. Mathur and Bhatnagar (1995) and Paul and Debnath (1999) have reported predominant role of additive genetic variance in the inheritance of days to 50 per cent tasseling.

Satyanarayana *et al.* (1994) reported the heterobeltiosis for maturity components (for earliness). Significant average heterosis was noticed by Gomes-E-Gamma *et al.* (1995) and Turgut *et al.* (1995) and Perez Velasquez *et al.* (1995) also noticed considerable heterotic effect for this trait.

Desai and Singh (2001) observed that the parents, Ib 1073, Ib1143 and Ib 1155 were found to have negative gca effect for days to 50 per cent tasseling, the crosses viz., 18 1073 x Ib 1143 and Ib 1073 x Ib1155 were found to have negative sca effects for days to 50 per cent tasseling.

2.6.2 Days to 50 per cent silking

Equal importance of both GCA and SCA variance was emphasized by Hassaballa *et al.* (1980) and Khehra *et al.* (1980). While, again equal importance of GCA and SCA variance was emphasized by Lee *et al.* (1986). Paul and Duara (1991) found predominance of non-additive genetic variance. Combining ability studies by Vasal *et al.* (1992), El-Hosary *et al.* (1994b) clearly indicated the predominant role of only GCA variance. Sedhom (1994) observed predominance of SCA variance in the inheritance of days to 50 per cent silking. Altinbos (1995) clearly indicated the predominant role of only GCA variance. However, Dehghanapour *et al.* (1997) reported non-additive genetic variance. Mathur *et al.* (1998), Paul and Debnath (1999) and Tallei and Kochaksaraei (1999) reported predominance of additive genetic variance for this trait.

Akhtar and Singh (1981) observed mid parent heterosis ranging from -3.55 to 11.42. Beck *et al.* (1990) reported low heterosis for this trait. Vasal *et al.* (1992), Satyanarayana *et al.* (1994) and Altinbos (1995) noticed the heterobeltiosis for days to silking (for earliness). Perez-Velasquez *et al.* (1995) found heterotic effect.

Setiyono and Subandi (1996) in their study of heterosis found all hybrids showing days to 50 per cent silking earlier than the mid parent values.

Dubey *et al.* (2001) estimated that inbred line pop 30-128-215-1 was good general combiner for days to 50 per cent silking.

Desai and Singh (2001) reported the parents, Ib 1073, Ib1143 and Ib 1155 were found to have negative gca effect for day to 50 per cent silking, the crosses *viz.*, 18 1073 x Ib 1143 and Ib 1073 x Ib1155 were found to have negative sca effects for days to 50 per cent silking.

Iqbal *et al.* (2010) studied heterosis for morphological traits in subtropical maize and observed that Mid-parent heterosis ranged from -6.03 per cent to -9.74 per cent for days to silking and days to maturity. Magnitudes of heterosis, both mid-parent and better parent, were positive and higher for days to flowering and maturity .

2.6.3 Days to 50 per cent brown husk maturity

As per Kalsy and Sharma (1970), variance component due to SCA was much higher than that due to GCA and also reported highly significant negative Heterosis over the mid parent. Murthy *et al.* (1981) noticed that the percentage heterosis value over better parent ranged from -5.76 to 21.94. Variances due to GCA and SCA were highly significant and the magnitude of GCA variance was greater than SCA variance as reported by Murthy *et al.* (1981) and Sanghi *et al.* (1982). According to Satyanarayana *et al.* (1994) and Mathur and Bhatnagar (1995), both components were of equal importance. Crosses P1×P3 and P1×P5 showed significant negative heterosis for days to maturity (Alam *et al.*, 2008).

2.6.4 Plant height

Singh and Singh (1998), Vasal *et al.* (1992) and Zheng-Zuping *et al.* (1995) reported predominant role of GCA variance for this trait, while predominance role of SCA variance was reported by Herbert and Gallis (1986) and El-Hosary *et al.* (1994a).

Equal importance of both additive and non-additive components in the inheritance of plant height was opined by Sharma *et al.* (1982). Shahi and Singh (1986) and Crossa *et al.* (1987) reported predominant role of additive genetic variance in the inheritance of plant height. As per Debnath and Sarkar (1987) both additive and non-additive components were important. Crossa *et al.* (1990) and Vasal *et al.* (1992) reported predominant role of additive genetic variance in the inheritance of plant height again. Importance of SCA variance was reported by El-Hosary *et al.* (1994a).

Zheng-Zuping *et al.* (1995) reported predominant role of GCA variance. Dehghanpour *et al.* (1997) and Petrovic (1998) reported that non-additive component was important for this trait, while equal importance of both additive and non-additive components in the inheritance of plant height was opined by Kumar *et al.* (1998).

Ganguli *et al.* (1989) reported positive heterosis over the better parent. Beck *et al.* (1990), Vasal *et al.* (1992), Reddy and Agarwal (1992), Alvarez *et al.* (1993) reported low heterosis for this trait. Gomes-E-Gama *et al.* (1995) noticed average and non-significant heterosis.

Malik *et al.* (2004) reported that temperate material gave high gca effects for striking characters contributing towards high grain yield *i.e.*, plant height.

Saidaiah *et al.* (2008), crosses DMR 274 x HOL 34, DMR 201 x EI 34 and DMR 156 x EI 34 showed high heterosis over better parent and standard check (DHM 103) for grain yield per plant as well as for plant height.

Iqbal *et al.* (2010) studied heterosis for morphological traits in subtropical maize and observed that Mid-parent heterosis ranged from 29.30%-37.85% for plant height and magnitudes of heterosis, both mid-parent and better parent, were positive and higher for plant height.

Premlatha and Kalamani (2010) reported that, the hybrid UMI 348 × UMI 330 exhibited high sca effect for plant height.

2.6.5 Ear height

Zambezi *et al.* (1986) and Catherine and Pollak (1988), El-Hosary *et al.* (1994b) and Altinbos (1995) reported significance of only GCA variance reported Greater importance of GCA variance than SCA variance with both being significant. However, Sedhom (1994) observed predominance of SCA variance in the inheritance of ear height.

Nawar (1986), Pal *et al.* (1986), Shahi and Singh (1986), Mahajan *et al.* (1991) and Paul and Debnath (1999) reported predominant role of additive component in the inheritance of ear height, while Dehghanapour *et al.* (1997) observed predominant role of non-additive component. However, equal importance of both additive and non-additive genetic variances was stressed by Debnath and Sarkar (1987) and Kumar *et al.* (1998).

Ganguli *et al.* (1989) and Petrovic (1998) reported positive heterosis over the better parent. Altinbos (1995) observed high heterosis over the better parent. But, Beck *et al.* (1990) reported low heterosis for this trait.

Kara (2000) reported significant GCA and SCA effects for ear height, SCA effects were more pronounced when compared to GCA effects, indicating the predominance of non-additive gene action in the inheritance of this traits.

Aurelio Mendes Aguiar (2003) observed that GCA were significant for all traits and SCA were non significant only for ear placement.

Malik *et al.* (2004) reported that temperate material gave high gca effects for striking characters contributing towards high grain yield *i.e.*, ear height and leaf area.

2.6.6 Ear length

Verma and Singh (1980) reported heterosis range of -5.9 to 19.9 per cent over better parent. Debnath (1987) found positive heterosis over better parent and mid parent. Heterotic effect was considerable for this trait (Turgut *et al.*, 1995).

As per Ali and Topera (1986), non-additive component was important for this trait. Shen and Lai (1987) stressed upon both the components of variance, GCA and SCA. A greater role of additive genetic variance was reported by Mahomoud *et al.* (1990). Pre dominance of SCA variance was evident in the results of Mohammad (1993), Pal and Prodhhan (1994), Sedhom (1994) and Sinobas and Monteagudo (1994). Mathur and Bhatnagar (1995) reported predominant role of GCA variance in the inheritance of ear length. Khristova *et al.* (1995) observed importance of non-additive component. For this trait, non-additive component was described to be as important as madditive component by Turgut *et al.* (1995) and Kumar *et al.* (1998). A greater role of additive genetic variance was reported by Mathur *et al.* (1998).

Parcial *et al.* (2001) for ear length recorded the average heterosis was 3.10 percent Choudhary and Chaudhari (2002), reported that significant heterosis for ear length than for any other character.

Subramanian and Subbaraman (2006), dominance effect was found to influence the inheritance of ear length .

2.6.7 Ear diameter

Bhalla and Khehra (1980) observed predominant role of non-additive genetic variance. Sanghi *et al.* (1982) reported the importance of additive genetic variance for this trait. As per Sharma *et al.* (1982) both additive and non-additive components were important. While, Quadri *et al.* (1983) reported predominant role of GCA variance than SCA variance with both being significant, in the inheritance of ear width. Pal *et al.* (1986) observed predominant role of non-additive genetic variance. Mohammad (1993), El-Hosary *et al.* (1994a) and Sinobas and Monteagudo (1994) reported predominant role of SCA variance. Pal and Prodhhan (1994) and Mathur and Bhatnagar (1995) observed predominant role of GCA variance for this trait. As per, Turgut *et al.* (1995) both additive and non-additive components were important. Kumar *et al.* (1998) reported the predominant role of non-additive genetic variance. Mathur *et al.* (1998) observed the importance of additive genetic variance for this trait.

Debnath (1987) observed low mid parent heterosis for ear width. But, considerable heterotic effect for this trait was noticed by Turgut *et al.* (1995).

Abdel-Moneam *et al.* (2009) showed positive significant heterosis value for ear diameter.

2.6.8 Number of kernel rows per cob

Pal and Prodhan (1994), Dehghanpour *et al.* (1997), Kumar *et al.* (1998) reported more importance of non-additive component effects in the inheritance of this trait. While, Petrovic (1998) and Mathur *et al.* (1998) observed a significant GCA and the predominance of additive genetic variance.

Sumalini and Shobha Rani (2010) recorded the hybrid, KML-227 x KML-161 was found to be superior in terms of ears per plant and number of kernel rows.

2.6.9 Number of kernels per row

Marked heterosis was reported by Presolka and Kamara (1991). Dehghanpour *et al.* (1997) reported the more importance of non-additive component effects. Kumar *et al.* (1998) however, reported that both additive and non-additive types of gene actions are important. While, Mathur *et al.* (1998) observed the predominance of additive genetic variance in the inheritance of this trait.

Salillari and Hoxha (1998) in their study of kernel and spike characters in some maize hybrids also found that number of kernels in a row has more strong heterosis effect than others.

Malik *et al.* (2004) reported that temperate material gave high gca effects for striking characters contributing towards high grain yield *i.e.*, plant and ear height and kernels per row.

Choudhary and Chaudhari (2002), reported that Seven crosses showed significant heterosis for kernel per row.

2.6.10 Hundred grain weight

Kimani (1984) reported significant SCA variance. Predominance of additive genetic variance in the inheritance of this trait was emphasized by Shahi and Singh (1985). More or less equal importance of both additive and non-additive genetic variance was observed by Pal *et al.* (1986). Mohammad (1993) stressed importance of non-additive genetic variance Pal and Prodhan (1994), Mathur and Bhatnagar (1995) and Turgut *et al.* (1995) observed significant GCA variance in the inheritance of 100-grain weight. Dehghanapour *et al.* (1997) observed the importance of non-additive genetic variance. On the contrary, Joshi *et al.* (1998) stressed importance of additive genetic variance for this trait.

Mukherjee and Saha (1984) obtained highly significant heterosis over mid parent (4.37 per cent to 30.69%) in inter varietal cross of maize. Considerable heterotic effect for this trait was noticed by Turgut *et al.* (1995). Petrovic (1998) also reported over dominance and heterosis. Salillari and Hoxha (1998) in their study of kernel and spike characters in some maize hybrids they found 100 kernel weight has more strong heterosis effect than others do.

Dubey *et al.* (2001) estimated that inbred line pop 30-128-215-1 was good general combiner for 1000 grain weight.

Saidaiah *et al.* (2008), crosses DMR 274 x HOL 34, DMR 201 x EI 34 and DMR 156 x EI 34 showed high heterosis over better parent and standard check (DHM 103) for grain yield per plant as well as for 100 seed weight.

Jebaraj *et al.* (2010) reported that, among the parents studied the following parents *viz.*, UMI 112, UMI 264, UMI 278, UMI 285 and Co 1 were good general combiners with higher mean values for 100 grain weight.

2.6.11 Shelling percentage

Mathur *et al.* (1998) reported that significant GCA variance for shelling percentage in both normal and stress environments. SCA variance was significant for shelling percentage in the normal environment. A predominance of additive gene effects was observed in the expression of this character.

Abdel-Moneam *et al.* (2009) showed positive significant heterosis value for all traits. The best crosses over both their mid parent for shelling percentage .

2.6.12 Grain yield per plant

Verma and Singh (1980) found heterosis ranging from 1.3 to 98.6 per cent over mid parent, while Murthy *et al.* (1981) reported it to be ranging from –35.3 to 251.8 per cent over better parent. In another study, Mufti and Rao (1995) observed mid-parent heterosis.

Murthy *et al.* (1981) observed significant GCA variance in the inheritance of this trait. Sanghi *et al.* (1982) observed the predominance of additive genetic variance in the inheritance of this trait. Yang (1982) noticed the equal importance of both additive and non-additive genetic variance. However, Mohammad (1993) observed the predominance of GCA variance over SCA variance. While El-Hosary *et al.* (1994) reported significant SCA variance in the inheritance of grain yield per plant. Mathur and Bhatnagar (1995) reported the predominance of non-additive gene action. Joshi *et al.* (1998) observed the preponderance of non-additive gene action. Kumar *et al.* (1998) noticed the equal importance of both additive and non-additive genetic variances. Mathur *et al.* (1998) reported the predominance of additive genetic variance in the inheritance of this trait.

Alam *et al.* (2008) observed that highest percentage of heterosis for grain per ear over mid parent and better parent were observed by the cross P2 x P3.

Dubey *et al.* (2001) estimated that inbred line pop 30-128-215-1 was good general combiner for grain yield per plant.

Kallu *et al.* (2001) reported that non additive gene action being predominant important for grain yield per plant and Inbreds DKI-144 and DKI-137-A were observed to be good general combiners for grain yield per plant.

Patel *et al.* (2010), the hybrids GWL-2 x GWL-12, GWL-2 x GWL-8, and GWL-8 x GWL- 12 showed significant positive Heterobeltiosis and economic Heterosis for grain yield per plant and other yield component traits .

Jebaraj *et al.* (2010) reported that among the 32 hybrids evaluated the hybrids *viz.*, UMI 264 x UMI 285, UMI 278 x UMI 285 and UMI 278 x CO 1, UMI 314 x UMI 285, UMI 328 x UMI x UMI 61 and UMI 334 x UMI 325 were identified as good specific combiners for single plant yield.

Premlatha and Kalamani, 2010, the hybrid UMI 278 x UMI 217 and UMI 334 x UMI 217 had significant and superior per se performances for grain yield per plant.

2.6.13 Grain yield per plot

Verma and Singh (1980) reported heterosis of 1.3 to 98.6 per cent over better parent. Debnath (1984) obtained heterosis range of 21.07 to 123.68 and 2.69 to 95.07 per cent over mid parent and better parent, respectively.

According to Zambezi *et al.* (1986) both GCA and SCA variances were important. Predominance of non-additive genetic variance was evident in the reports of Guo *et al.* (1986). Crossa *et al.* (1990) and Paul and Duara (1991) stressed the non-additive genetic variance. Saindass *et al.* (1992) quoted equal importance of both additive and non-additive genetic variance. Vasal *et al.* (1992) observed significant GCA variance. Greater importance of SCA variance than GCA variance was reported by Mohammad (1993). Pal and Prodhon (1994) emphasized on both additive and on-additive genetic variances. Greater importance of SCA variance than GCA variance was reported by Damborsky *et al.* (1994) and Sathyanarayana (1994). Sedhom (1994) stressed the importance of SCA variance for this trait. As per Turgut *et al.* (1995) both GCA and SCA variance were importance. Zheng-Zuping *et al.* (1995) noticed high variance. On the contrary, dominance of non-additive genetic variance was evident in the reports of Joshi *et al.* (1998).

Ganguli *et al.* (1989) reported positive heterosis over the better parent. Jha and Khehra (1992) reported that 16 crosses significantly out yielded the best hybrid control similarly, Mejjia and Lambert (1992) observed the heterosis for grain yield over control. Vasal *et al.* (1992) noticed the heterosis over mid parent. Gomes-E-Gama (1993) observed the average heterosis of 8.4 per cent for top crosses.

Considerable heterotic effect was noticed for grain yield by Turgut *et al.* (1995) and Perez-velasquez *et al.* (1995). Satyanarayana *et al.* (1994) and Perez-Velsquez *et al.* (1995) and Larish and Brewbaker (1999) reported 55 per cent mid parent heterosis for variety crosses and 105 per cent for inbred crosses for grain yield.

Shanthi *et al.* (2010) in this investigation combining ability analysis revealed significant mean square due to general and specific combining ability effects indicating that both additive and non additive gene actions involved in inheritance of grain yield (4)

Seshu *et al.* (2010) recorded that hybrids, BML-15 x CM-209, CM-132 x CM-209, CM-209 x CM-119, CM- 210 x CM-119 and CM-132 x CM-119 were the best specific combiners for grain yield. Shanthi *et al.* (2011) found that among the 10 parents P3 and P1 were found to be best parents for grain yield.

Unay *et al.* (2003) observed that 9 crosses had higher grain yields than that of the check variety. Desai and Singh (2001) reported crosses exhibited positive sca for grain yield per plot.

2.7 Genetic analysis for quality parameters

2.7.1 Protein

Inbred lines L9 and L10 were good general combiner for all the three quality traits, while inbred line L9 was also good general combiner for grain yield, oil content, starch content and protein content (Amit Dadheech and Joshi, 2007).

Pasztor *et al.* (1998) observed that an increase in 1000-kernel weight was accompanied by a rise in the starch and protein content.

Shanthi *et al.* (2011) inferred that out of 45 hybrids *viz.*, P4 x P7, P5 x P10, P2 x P6, P3 x P5, and P1 x P5 were found to be good specific combiners for grain yield along with protein and tryptophan content.

Mohan Lal *et al.* (2011) observed that inbred lines L4, L5, T2 and T5 were good combiner for yield and quality traits. The hybrids L10 x T2, L5 x T5, L4 x T2 and L9 x T4 were identified to be significantly superior in quality traits.

2.7.2 Starch

Krishnaveni (1983) reported that starch content ranged from 41 to 75 per cent in hybrids and the hybrid UMI-47 x MUI-134 contained the highest amount of starch.

Shalygina *et al.* (1990) screened 128 inbred lines of maize for highest starch and sugar content to select best lines to be used in breeding programmes for increased grain quality and reported V- 239A, B-187 and V-461 as promising lines with higher content of starch and sugar.

Mazzoni and Robutti (1990) reported average starch yields for flint (Cargill-157) and dent (Cargill-P17) hybrid as 57.62 and 52.59 per cent, respectively. Alike and Ojomo (1996) demonstrated that additive and non-additive gene actions significantly influenced the variation of starch content and gel spread. Additive gene action was more pronounced, implicating the effectiveness of selection for starch yield through a recurrent selection procedure. Reciprocal effects were equally significant for grain starch content, an indication of the importance of cytoplasmic effects.

Pasztor *et al.* (1998) observed that an increase in 1000-kernel weight was accompanied by a rise in the starch and protein content.

Wang *et al.* (1998) observed heterosis for starch content was higher than protein content, while heterosis for protein content was negative. Daneswar and Dickinson (1999) obtained the starch content ranged from 64.6 to 72.58 per cent on dry weight basis in G-4646 hybrid.

Larissa *et al.* (2004) reported significant kernel composition association in the three starch production genes, sh-1, sh-2 and ht-2, tests for association with either starch pasting characteristics and/or analyze content were significant in sh-1, sh-2 and aa1.

Table 1: Character-wise review of literature pertaining to combining ability

Sl. No	Character	Additive (GCA)	Non- additive (SCA)	Additive and non-additive
1	Days to 50% tasseling	Hassaballa <i>et al.</i> (1980), Sanghi (1983), Mathur and Bhatnagar (1995), Paul and Debnath <i>et al.</i> (1999), Surya Prakash and Ganguli (2004), Bello <i>et al.</i> (2009).	Lee (1983) and Guo <i>et al.</i> (1986).	Desai and Singh (2001), Kabdal <i>et al.</i> (2003), Saad Imran Malik <i>et al.</i> (2005), Uddin <i>et al.</i> (2006).
2	Days to 50% silking	Singh <i>et al.</i> (1983), Vasal <i>et al.</i> (1992), El-Hosary <i>et al.</i> (1994b), Altinbos (1995), Mathur <i>et al.</i> (1998), Paul and Debnath (1999), Talleei and Kochak Saraei (1999), Bello <i>et al.</i> (2009).	Paul and Duara (1991), Sedhom (1994), Dehghanapour <i>et al.</i> (1997), Singh and Singh (1998).	Hassaballa <i>et al.</i> (1980), Lee <i>et al.</i> (1986), Desai and Singh <i>et al.</i> (2001), Kabdal <i>et al.</i> (2003), Uddin <i>et al.</i> (2006), Alam <i>et al.</i> (2008).
3	Days to 50% brown husking	Murty <i>et al.</i> (1981).	Kalsy and Sharma (1970).	Satynarayana <i>et al.</i> (1994), Habtamu Zelleke. (2000), Alam <i>et al.</i> (2008).
4	Plant height	Singh <i>et al.</i> (1983), Shahi and Singh (1986), Crossa <i>et al.</i> (1987, 1990), Vasal <i>et al.</i> (1992), Zheng-Zuping <i>et al.</i> (1995).	Guo <i>et al.</i> (1986), Herbert and Gallis (1986), Pal <i>et al.</i> (1986), El-Hosary <i>et al.</i> (1994a), Singh and Singh (1998).	Sharma <i>et al.</i> (1982), Debnath and Sarkar (1987), Kumar <i>et al.</i> (1998), Habtamu Zelleke. (2000), Desai and Singh. (2001), Kabdal <i>et al.</i> (2003), Malik <i>et al.</i> (2004), Uddin <i>et al.</i> (2006), Alam <i>et al.</i> (2008).

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Sl. No	Character	Additive (GCA)	Non-additive (SCA)	Additive and non-additive
5	Ear height	Nawar (1986), Pal <i>et al.</i> (1986), Shahi and Singh (1986), Mahajan <i>et al.</i> (1991), Surya Prakash and Ganguli (2004).	Dehghanpour <i>et al.</i> (1997), Sedhom (1994), Singh and Singh (1998).	Debnath and Sarkar (1987), Kumar <i>et al.</i> (1998), Desai and Singh (2001), Kabdal <i>et al.</i> (2003), Saad Imran Malik <i>et al.</i> (2005), Uddin <i>et al.</i> (2006), Alam <i>et al.</i> (2008).
6	Ear length	Mohamoud <i>et al.</i> (1990), El-Hosary <i>et al.</i> (1994b), Mathur and Bhatnagar (1995) Mathur <i>et al.</i> (1998), Singh and Singh (1998).	Ali and Topera (1986), Mohammed (1993), Pal and Prodhan (1994), Sedhom (1994), Sinobas and Monteagudo (1994), Khristova <i>et al.</i> (1995).	Singh <i>et al.</i> (1983), Shen and Lai (1987), Turgut <i>et al.</i> (1995), Kumar <i>et al.</i> (1998), Habtamu Zelleke (2000), Kalla <i>et al.</i> (2001), Kabdal <i>et al.</i> (2003), Li-Jizhu <i>et al.</i> (2004) Uddin <i>et al.</i> (2006), Fan <i>et al.</i> (2008), Abdel-Moneam <i>et al.</i> (2009), Amiruzzaman <i>et al.</i> (2010).
7	Ear width	Sanghi <i>et al.</i> (1982), Quadri <i>et al.</i> (1983), Pal and Prodhan (1994), Mathur and Bhatnagar (1995), Mathur <i>et al.</i> (1998)	Pal <i>et al.</i> (1986), Mohammed (1993), El-Hosary <i>et al.</i> (1994a), Sinobas and Monteagudo (1994), Kumar <i>et al.</i> (1998).	Sharma <i>et al.</i> (1982), Turgut <i>et al.</i> (1995), Kabdal <i>et al.</i> (2003), Uddin <i>et al.</i> (2006), Fan <i>et al.</i> (2008), Abdel-Moneam <i>et al.</i> (2009), Amiruzzaman <i>et al.</i> (2010).
8	Number of kernels per row	Mathur <i>et al.</i> (1995), Petrovic (1998),	Pal and Prodhan (1994), Dehghanapour <i>et al.</i> (1997), Kumar <i>et al.</i> (1998), Singh and Singh (1998), Li-Jizhu <i>et al.</i> (2004).	Malik <i>et al.</i> (2004), Uddin <i>et al.</i> (2006), Fan <i>et al.</i> (2008), Abdel-Moneam <i>et al.</i> (2009), Amiruzzaman <i>et al.</i> (2010).

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Sl. No	Character	Additive (GCA)	Non-additive (SCA)	Additive and non-additive
9	Number of rows per cob	Mathur <i>et al.</i> (1998), Singh and Singh (1998), Surya Prakash and Ganguli (2004),	Packiaraj (1995), Dehghanpour <i>et al.</i> (1997), Malik <i>et al.</i> (2004).	Kumar <i>et al.</i> (1998), Kalla <i>et al.</i> (2001), Kabdal <i>et al.</i> (2003), Uddin <i>et al.</i> (2006), Fan <i>et al.</i> (2008).
10	Test weight	Shahi and Singh (1985), Pal and Prodhan (1994), Mathur and Bhatnagar (1995), Turgut <i>et al.</i> (1995) and Joshi <i>et al.</i> (1998).	Kimani (1984), Mohammed (1993), Dehghanapour <i>et al.</i> (1997), Petrovic (1998), Singh and Singh (1998).	Pal <i>et al.</i> (1986), Habtamu Zelleke. (2000), Kalla <i>et al.</i> (2001), Kabdal <i>et al.</i> (2003), Saad Imran Malik <i>et al.</i> (2005), Uddin <i>et al.</i> (2006), Alam <i>et al.</i> (2008), Fan <i>et al.</i> (2008), Abdel-Moneam <i>et al.</i> (2009), Amiruzzaman <i>et al.</i> (2010),
11	Shelling %	Mathur <i>et al.</i> (1998)		Abdel-Moneam <i>et al.</i> (2009).
12	Grain yield per plant	Murthy <i>et al.</i> (1981), Sanghi <i>et al.</i> (1982), Mohammed (1993), Mathur <i>et al.</i> (1998), Ojo <i>et al.</i> (2007)	El-Hosary <i>et al.</i> (1994a), Mathur and Bhatnagar (1995), Joshi <i>et al.</i> (1998), Kalla <i>et al.</i> (2001).	Yang (1982), Kumar <i>et al.</i> (1998), Kalla <i>et al.</i> (2001), Fan <i>et al.</i> (2008), Abdel-Moneam <i>et al.</i> (2009), Amiruzzaman <i>et al.</i> (2010),
13	Grain yield per ha	Singh <i>et al.</i> (1983), Vasal <i>et al.</i> (1992)	Singh <i>et al.</i> (1983), Guo <i>et al.</i> (1986), Crossa <i>et al.</i> (1990), Paul and Dura (1991), Mustyaysa <i>et al.</i> (1991), Mohammed (1993), Damborsky <i>et al.</i> (1994), Satyanarayana (1994), Sedhom (1994), Zheng-Zuping <i>et al.</i> (1995).	Zambezi <i>et al.</i> (1986), Saindass <i>et al.</i> (1992), Pal and Prodhan (1994), Turgut <i>et al.</i> (1995), Habtamu Zelleke. (2000), Aydin Unay <i>et al.</i> (2003), Uddin <i>et al.</i> (2006), Bello <i>et al.</i> (2009).
14	Protein content			Shanthi <i>et al.</i> (2011)
15	Starch content			Alika and Ojomo (1996)

Table 2: Character-wise review of literature pertaining to heterosis

SI. No	Character	Heterosis	References
1	Days to 50% tasseling	Significant average heterosis High heterosis Significant positive heterobeltosis and economic heterosis Heterobeltosis	Gomes-e-Gamma <i>et al.</i> (1993), Turgut <i>et al.</i> (1995), Perez-Velasquez <i>et al.</i> (1995) Sumalini and Shobha Rani. (2010) Patel <i>et al.</i> (2010) Satyanarayana <i>et al.</i> (1994)
2	Days to 50% silking	Low heterosis Mid parent heterosis ranges from -3.55 to 11.42 Heterotic effect Heterobeltiosis Range of heterobeltosis -0.22 to -8.31% Mid parent heterosis ranged from -6.03% to -9.74% High heterosis Significant positive heterobeltosis and economic heterosis Mid parent heterosis	Beck <i>et al.</i> (1990) Akhtar and Singh (1981) Perez-Velasquez <i>et al.</i> (1995), Setiyono and Subandi (1996) Vasal <i>et al.</i> (1992), Satyanarayana <i>et al.</i> (1994), Altinbos (1995) Uddin <i>et al.</i> (2006), Iqbal <i>et al.</i> (2010) Sumalini and Shobha Rani. (2010) Patel <i>et al.</i> (2010) Iqbal <i>et al.</i> (2010)
3	Days to 50% brown husking	Positive mid parent and better parent heterosis Economic heterosis Significant negative heterosis Mid parent heterosis ranged from 0.82% to -9.53% High heterosis	Iqbal <i>et al.</i> (2010) Patel <i>et al.</i> (2010) Alam <i>et al.</i> (2008) Iqbal <i>et al.</i> (2010) Sumalini and Shobha Rani. (2010)

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Sl. No	Character	Heterosis	References
4	Plant height	<p>Low heterosis</p> <p>Average and non-significant heterosis</p> <p>Positive heterobeltiosis</p> <p>Mid parent heterosis ranged from 29.30%-37.85%</p> <p>Economic heterosis</p> <p>High heterosis over better parent and standard check</p>	<p>Beck <i>et al.</i> (1990), Vasal <i>et al.</i> (1992), Reddy and Agarwal (1992)</p> <p>Gomes-E-Gamma <i>et al.</i> (1993)</p> <p>Ganguli <i>et al.</i> (1989)</p> <p>Iqbal <i>et al.</i> (2010)</p> <p>Patel <i>et al.</i> (2010)</p> <p>Saidaiah <i>et al.</i> (2008)</p>
5	Ear height	<p>High heterosis</p> <p>Economic heterosis</p> <p>Low heterosis</p> <p>Hihh heterosis over the better parent</p>	<p>Sumalini and Shobha Rani. (2010)</p> <p>Patel <i>et al.</i> (2010)</p> <p>Beck <i>et al.</i> (1990)</p> <p>Altinbos. (1995)</p>
6	Ear length	<p>Positive heterobeltiosis and mid parent heterosis</p> <p>Heterobeltiosis ranged from -5.9 to 19.9</p> <p>Over mid parent and better parent heterosis</p> <p>highest mid parent heterosis</p> <p>High heterosis</p> <p>Significant positive heterosis</p> <p>Economic heterosis</p> <p>Significant heterosis</p> <p>Average heterosis 3.10%</p>	<p>Debnath (1987)</p> <p>Verma and Singh (1980)</p> <p>Abdel-Moneam <i>et al.</i> (2009)</p> <p>Kabdal <i>et al.</i> (2003)</p> <p>Sumalini and Shobha Rani. (2010)</p> <p>Amiruzzaman <i>et al.</i> (2010),</p> <p>Patel <i>et al.</i> (2010)</p> <p>Choudhary and Chaudhari. (2002)</p> <p>Parcial <i>et al.</i> (2001)</p>

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Sl. No	Character	Heterosis	References
7	Ear width	Heterotic effect Low mid parent heterosis Over mid parent and better parent heterosis High heterosis	Turgut <i>et al.</i> (1995) Debnath (1987) Abdel-Moneam <i>et al.</i> (2009) Sumalini and Shobha Rani. (2010)
8	Number of kernels per row	Marked heterosis Heterotic effect Over mid parent and better parent heterosis highest estimates of economic heterosis High heterosis Heterobeltosis Significant heterosis	Presolka and Kamara (1991) Salillari and Hoxha (1998) Abdel-Moneam <i>et al.</i> (2009) Premlatha <i>et al.</i> (2010) Sumalini and Shobha Rani. (2010) Patel <i>et al.</i> (2010) Choudhary and Chaudhari. (2002)
9	Number of rows per cob	Highest estimates of economic heterosis High heterosis	Premlatha <i>et al.</i> (2011) Sumalini and Shobha Rani. (2010)
10	Test weight	Significant heterosis over mid parent ranges from -.37% to 30.69% Heterotic effect Over mid parent and better parent heterosis highest estimates of economic heterosis	Mukherjee and Shah (1984) Turgut <i>et al.</i> (1995), Salillari and Hoxha (1998), Petrovic (1998) Abdel-Moneam <i>et al.</i> (2009) Premlatha <i>et al.</i> (2010)

Contd....

Sl. No	Character	Heterosis	References
		High heterosis Positive heterosis Positive heterosis High heterosis over better parent and standard check	Sumalini and Shobha Rani. (2010) Amiruzzaman <i>et al.</i> (2010), Choudhary and Chaudhari. (2002) Saidaiah <i>et al.</i> (2008)
11	Shelling %	Over mid parent and better parent heterosis	Abdel-Moneam <i>et al.</i> (2009)
12	Grain yield per plant	Significant epistatic effect Heterosis ranges from 1.3 to 98.6 per cent over mid parent Heterosis ranges from -35.3 to 251.8 per cent over better parent Mid parent heterosis Over mid parent and better parent heterosis highest estimates of economic heterosis Standard heterosis Significant positive heterobeltosis and economic heterosis High heterosis over better parent and standard check	Li-Jizhu <i>et al.</i> (2004) Verma and Singh (1980) Murthy <i>et al.</i> (1981) Mufti and Rao (1995) Abdel-Moneam <i>et al.</i> (2009) Premlatha <i>et al.</i> (2011) Amiruzzaman <i>et al.</i> (2010), Patel <i>et al.</i> (2010) Saidaiah <i>et al.</i> (2008)
13	Grain yield per ha	Heterosis ranges from 1.3 to 98.6 per cent over better parent Heterosis ranges from 21.07 to 123, 68 per cent and 2.69 to 95.07 per cent over mid parent and better parent respectively Positive heterosis over better parent	Verma and Singh (1980) Debnath (1984) Ganguli <i>et al.</i> (1989)

Contd.....

Sl. No	Character	Heterosis	References
		<p>Heterosis over control</p> <p>Heterosis over mid parent</p> <p>Average heterosis of 8.4 per cent for top crosses</p> <p>Heterotic effect</p> <p>55 per cent mid parent heterosis for variety crosses and 105 per cent for inbred crosses</p> <p>midparent heterosis values ranged from 46.10% to 573.12%</p> <p>Range of heterobeltosis 8.23 to 25.78 %</p> <p>heterosis of 53.5 % over standard check</p> <p>highest mid parent heterosis</p> <p>High heterosis</p> <p>Significant positive heterosis</p> <p>High heterosis</p> <p>highest estimates of economic heterosis</p>	<p>Mejia and Lambert (1992)</p> <p>Vasal <i>et al.</i> (1992)</p> <p>Gomes-E-Gamma <i>et al.</i> (1993)</p> <p>Turgut <i>et al.</i> (1995), Perez-Velasquez <i>et al.</i>(1995)</p> <p>Satyanarayana <i>et al.</i> (1994), Perez-Velasquez <i>et al.</i> (1995), Larish and Brewbaker (1999)</p> <p>Unay <i>et al.</i> (2003)</p> <p>Uddin <i>et al.</i> (2006),</p> <p>Wali <i>et al.</i> (2010)</p> <p>Kabdal <i>et al.</i> (2003)</p> <p>Ojo <i>et al.</i> (2007)</p> <p>Choudhary and Chaudhari. (2002)</p> <p>Sumalini and Shobha Rani. (2010)</p> <p>Premlatha <i>et al.</i> (2010)</p>
14	Starch content	Heterosis	Wang <i>et al.</i> (1998)

3. MATERIAL AND METHODS

3.1 Experimental Material

The experimental material for the present investigation comprised of 14 newly developed elite inbred lines of maize (*Zea mays* L.) viz., p1, p2, p3, p4, p5, p6, p7, p8, p9, p10, p11 and p12, p13, p14. The 91 F₁ s single cross hybrids developed by crossing 14 newly developed inbred lines in diallel mating design as suggested by Griffings excluding reciprocals during summer 2010-2011 at MARS, UAS, Dharwad. These 91 cross combinations with 14 parents and 16 checks (that are EH 434042, DMH 2, Super- 900M, Renuka, Prabha, NK-6240, Bio-9681, NK 6240, S 6304, S.6668, NK 30, JMH-203, Jaikisaan 101, VMH-4147, New Top Star, PAC 745) are grown in lattice square design with 2 replications. Each genotype will be planted in two rows of 3 m length with row to row and plant to plant spacing 60cm and 30cm, respectively, during kharif 2011 at MARS, UAS, Dharwad, situated at 15°26' N latitude and 76°07' longitude and at an altitude of 678 meters above mean sea level comes under transitional zone of North Karnataka. The salient features of the inbreds are given in Table 3.

The details of the experimental material and techniques adopted in the present investigation are described below.

3.2 Field plot technique used

The experiment consisting of 121 treatments was laid out at MARS, UAS, Dharwad during *kharif* 2011. The summary of experimental lay out is given below.

1. Experimental design : Lattice square design
2. Number of replications : 2
3. Row length : 3 m
4. Number of rows per plot : 2
5. Spacing between rows : 60 cm
6. Spacing between plants within the row : 30 cm
7. Plot size : 3.0 m × 1.2 m

After thorough land preparation, sowing was done by hand dibbling of seeds with one seed per hill and the plot was irrigated. The recommended doses of fertilizers (150 N, 75 P₂O₅ and 37.5 K₂O kg/ha) was given to the crop. The entire dose of P₂O₅, K₂O and one third of nitrogen was applied as basal dose and remaining two third nitrogen was top dressed in two equal splits at fourth and seventh week after planting. Weeding, irrigation and other recommended cultural practices were followed to raise a healthy crop.

Crossing programme

The 91 F₁ hybrids were developed by crossing the 14 lines among themselves (excluding reciprocals) during *rabi* 2009-10 at MARS, Dharwad. These 121 lines were sown in 11 x 11 LSD design with 2 rows of each line.

Hybridization programme

The crossing programme includes silk cutting, bagging and pollination.

Silk cutting

Three to four days before the pollination silks were cut back on shoot to achieve uniform silk emergence. Then, shoots were bagged with silk bags which pinched securely between shoot and stalk to hold it in place.

Bagging

Bagging was done a day before the pollination according to tassel bag method. Tassel bag method involves the covering the tassel with bag made of heavy kraft paper with water proof glue.

Table 3: Salient features of the Parents

SI.No	Parental inbred	Name	Pedigree	Morphological characters				
				Height	Inter nodal length	Leaf feature	Stem thickness	Yield potential
1	P1	DMIL -1	NK-61-08-5-4-6-11-3-4	Medium	Long	Broad & spreading	Medium	Low <i>per se</i> performance
2	P2	DMIL -2	NK-61-08-8-9-15-9-3-3	Dwarf	Short	Narrow & spreading	Thin	Low <i>per se</i> performance
3	P3	DMIL -3	Ka55-08-9-13-7-10-5-5	Medium	Short	Medium & erect	Thin	good <i>per se</i> performance
4	P4	DMIL -4	DMH55-08-17-4-8-7-7-13	Medium	Short	Narrow & Erect	Medium thick	good <i>per se</i> performance
5	P5	DMIL -5	DMH55-08-17-9-9-4-6-5	Dwarf	Short	Broad & erect	Medium thick	High <i>per se</i> performance
6	P6	DMIL -6	JG11-08-26-4-7-9-9-3	Medium	Long	Narrow & spreading	Thin	Medium <i>per se</i> performance
7	P7	DMIL -7	DKC81-08-36-7-8-7-8-7-3	Dwarf	Short	Medium & erect	Thin	Medium <i>per se</i> performance
8	P8	DMIL -8	Var-08-41-5-9-7-7-8	Dwarf	Short	Broad & erect	Thin	Medium <i>per se</i> performance
9	P9	DMIL -9	Ka44-08-38-4-79-4-3	Tall	Short	Broad & Spreading	Thick	High <i>per se</i> performance
10	P10	DMIL -10	NK30-08-43-2-3-6-9	Tall	Short	Broad & medium erect	Thick	Medium <i>per se</i> performance
11	P11	DMIL -11	Su900-08-23-4-6-7-3-5	Dwarf	Short	Thin & spreading	Medium	High <i>per se</i> performance
12	P12	DMIL -12	MM11-08-8-4-4-6-3	Medium	Long	Broad & spreading	Thick	Good <i>per se</i> performance
13	P13	DMIL -13	IG11-08-28-4-7-4-10-8	Tall	Long	Broad & spreading	Thin	Low <i>per se</i> performance
14	P14	DMIL -14	Ka60-08-39-7-4-7-9-2	Tall	Thick	Broad & spreading	Thick	Medium <i>per se</i> performance

The bag was placed over the tassel and fastened with a paper clip. Pollens were collected 24 hours after bagging the tassel and care had been taken to prevent contamination and to avoid spilling the pollen.

Pollination

Pollens were applied to the silk in such a way that, silk bag is removed without touching or exposing the silks. Bottom of the tassel bag is flipped upwards, causing the pollen to fall upon the silk. The tassel bag is pulled down over the shoot and fastened with stapler or paper clip.

All the F1s obtained from the diallel mating system sown at MARS, UAS, Dharwad by following Lattice Square Design (LSD) with two replications during *kharif* 2011.

3.3 Recording of observations

Observations on fifteen quantitative characters along with biochemical characters were recorded on five randomly selected competitive plants. The average was taken as the mean of the treatment. The observations were recorded is presented below.

3.3.1 Days to 50 per cent tasseling

The number of days taken from the date of sowing to the day on which 50 per cent of plants showed full tassel emergence was recorded as days to 50 per cent tasseling.

3.3.2 Days to 50 per cent silking

The number of days taken from the date of sowing to the day on which 50 per cent of the plants showed complete silk emergence was recorded as days to 50 per cent of silking.

3.3.3 Days to 50 per cent brown husk maturity

Days taken from planting to the day on which 50 per cent of plants showed got first husk cover on the ear dried and turned brown was recorded .

3.3.4 Plant height (cm)

Plant height was expressed in centimeters by measuring the plant stalk from the ground level to the base of the last leaf sheath at maturity.

3.3.5 Ear height (cm)

Ear height was recorded in centimeter from the ground level to the upper most ear bearing node.

3.3.6 Ear length (cm)

Length of the ear was measured in centimeters at the time of harvest from the base to the tip of the ear.

3.3.7 Ear diameter (cm)

Ear diameter was in centimeters as the thickness of the ear at the middle of the ear.

3.3.8 Number of kernels per row

Number of kernels in each kernel row was counted and average was recorded as number of kernels per row.

3.3.9 Number of rows per ear

The number of kernel rows per ear was counted and recorded. . Number of kernels in each kernel row was counted and average was recorded as number of kernels per row.

3.3.10 Test weight (gm)

Weight of 100 grain drawn from a random sun dried sample from each plot was recorded in grams.

3.3.11 Shelling percentage

Average pith weight and average grain weight of the randomly selected plants per plot were used to compute the shelling percentage by using the following formula.

$$\text{Shelling percentage} = \frac{\text{Grain weight}}{\text{Total weight (Grain weight + pith weight)}} \times 100$$

3.3.12 Grain yield per plant (g)

Grain yield per plant expressed in grams was recorded by weighing of the grains obtained after shelling of cobs from individual plant.

3.3.13 Grain yield per ha (kg)

Grain yield per hectare was calculated by converting yields per plot into grain yield per hectare.

$$\text{GY} = (\text{Yield per plot (g)} / \text{Plot size}) \times 10000 \text{ m}^2$$

3.3.14 Protein

The protein content was estimated using Micro- Kjeldahl Method (Jackson, 1967) and expressed in percentage.

3.3.15 Starch content

The starch content was estimated using anthrone reagent (Sadasivam and Manikam 1992) and expressed in percentage

3.4 Statistical Analyses

3.4.1 Analysis of Variance

The mean values of the genotypes were subjected to analysis of variance (Panse and Sukhatme, 1962).

Analysis of variance table

Sources of variation	d.f.	M.S.S	Expected M.S.S	Cal F.
Replication	(r-1)	M ₁	-	
Genotypes	(g-1)	M ₂	$\sigma^2e + \sigma^2g$	M ₂ / M ₃
Error	(r-1) (g-1)	M ₃	σ^2e	
Total	(rg-1)	M ₁ + M ₂ + M ₃		

Where,

r = Number of replications

g = Number of genotypes

3.4 Estimation of Heterosis

The F₁ values excluding the reciprocal crosses averaged over replications were used for estimating heterosis as percentage over mid parent (M.P), better parent (B.P) and standard check (S.C).

Mid parental value was calculated using the formula

$$\text{Mid parental value (M.P)} = \frac{\bar{P}_1 + \bar{P}_2}{2}$$

Heterosis in percentage was calculated as follows

$$F_1 \text{ heterosis over M.P.} = \frac{\bar{F}_1 - \overline{\text{M.P}}}{\overline{\text{M.P}}} \times 100$$

$$F_1 \text{ heterosis over B.P} = \frac{\bar{F}_1 - \overline{\text{B.P}}}{\overline{\text{B.P}}} \times 100$$

$$F_1 \text{ Heterosis over standard check} = \frac{\bar{F}_1 - \overline{\text{S.C}}}{\overline{\text{S.C}}} \times 100$$

The significance of F_1 heterosis was tested by comparing the mean deviations with critical difference (C.D.) values obtained separately for M.P., B.P. and S.C

$$\text{Mean deviation of } F_1 \text{ over M.P.} = \bar{F}_1 - \overline{\text{M.P}}$$

$$\text{Mean deviation of } F_1 \text{ over B.P.} = \bar{F}_1 - \overline{\text{B.P}}$$

$$\text{Mean deviation of } F_1 \text{ over S.C} = \bar{F}_1 - \overline{\text{S.C}}$$

The mean deviations were compared with CD values calculated as follows

$$\text{C.D for Heterosis over M.P.} = \sqrt{\frac{3/2}{r} \text{EMS} \times \text{t}' \text{ value}}$$

$$\text{C.D for Heterosis over B.P. and S.C.} = \sqrt{\frac{2}{r} \text{EMS} \times \text{t}' \text{ value}}$$

Where:

EMS = Error Mean Square

r = Number of replications

t' = Table 't' value at error degrees of freedom

3.5 Combining ability analysis

The variation among the hybrids was further partitioned into genetic components attributed to general combining ability (gca) variances and specific combining ability (sca) variances and effects were analyzed by adopting Model-I, Method-2 of Griffing's (1956a), since the present study includes parents and F_1 s (without reciprocals). The statistical procedure assumes the following mathematical model.

$$X_{ij} = \mu + g_i + g_j + s_{ij} + 1 / bc \sum e_{ijkl}$$

Where,

$$i, j = 1, 2, \dots, n$$

$$k = 1, 2, \dots, b$$

$$l = 1, 2, \dots, c$$

μ = Population mean

g_i = General combining ability (gca) effect of i th parent

g_j = General combining ability (gca) effect of j th parent

S_{ij} = Specific combining ability (sca) effect of $(i \times j)$ th cross

e_{ijkl} = Environmental effect associated with the $ijkl$ th individual observation

n = Number of parents

b = Number of replications

c = Number of individual in each replication

The model assumes that

$$a = \sum_i g_i = 0 \text{ and } \sum S_{ij} = 0 \text{ (for each } i)$$

b = the error (e_{ijkl}) is normally and independently distributed with mean equal to zero and variance equals $\sigma^2 c$

3.5.1 Combining ability variance

The analysis of variance table for combining ability is as follows:

Source	d.f	S.S.	MSS	EMSS
GCA	$(n - 1)$	S_g	M_g	$\sigma^2 + \sigma^2_s + (n+2) \sigma^2_g$
SCA	$\frac{n(n - 1)}{2}$	S_s	M_s	$\sigma^2 + \sigma^2_s$
Error	M	S_e	M_e	σ^2_e

Where,

$$S_g = \frac{1}{(n + 2)} \{ 1 (X_i + X_{ij})^2 \} \frac{4}{n} X^2$$

$$S_s = \sum_i \sum_j X_{ij}^2 \frac{1}{(n + 2)} \sum (X_i + X_{ij})^2 + \frac{2}{(n + 1)(n + 2)} X^2 \dots$$

X_i = Total of i^{th} row

X_{ij} = Value of i^{th} parent

$X_{..}$ = Grand total of the diallel table

X_{ij} = Value of the cross between i^{th} and j^{th} parents

N = Number of parents

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

Where,

$$\sigma^2_g = \frac{(Mg - Me)(n - 1)}{n + 2}$$

$$\sigma^2_s = \frac{(Mg - Me)(n - 1)}{2}$$

The significance was tested by the 'F' ratio against M1 e.

3.5.2 Estimation of combining ability effects

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

$$\text{gca effects} = g_i = \frac{1}{n + 2} [\sum (X_i + X_{ij}) - \frac{2}{n} X \dots \dots]$$

$$\text{sca effects} = S_{ij} = X_{ij} \frac{1}{n + 2} (X_i + X_{ij} + X_j + X_{ij}) + \frac{2}{(n + 1)(n + 2)} X \dots \dots$$

Where,

X_i = Total of j^{th} column

X_{ij} = Value of j^{th} parent

Remaining n , X_i , X_{ij} , X are same as mentioned above.

3.5.3 Test of significance for the combining ability effects

Standard error (SE) for different estimates was obtained from the following formulae.

$$\text{SE}(g_i) = [(n-1) \sigma^2_e / n (n+2)]^{1/2}$$

$$\text{SE}(g_i - g_j) = [2 \sigma^2_e (n+2)]^{1/2}$$

$$\text{SE}(S_{ij}) = [n (n+1) \sigma^2_e / (n-1) (n-2)]^{1/2}$$

Critical difference (CD) for testing the significance of the combining ability estimated was obtained by multiplying the respective standard error with table 't' value at error degrees of freedom.



Plate 1. General view of the crossing block and experimental hybrids evaluation trial

4. EXPERIMENTAL RESULTS

The experiment with 91 hybrids, 14 parents and 16 commercial checks; EH 434042, DMH 2, Super- 900M, Renuka, Prabha, NK-6240, Bio-9681, NK 6240, S 6304, S.6668, NK 30, JMH-203, Jaikisaan 101, VMH-4147, New Top Star, PAC 745 was carried out to determine heterosis, to estimate the combining ability effects and variance for yield and yield components and an attempt was made to study the relationship of combining ability and heterosis.

The results obtained in the present investigation are presented under following headings.

- 4.1 Analysis of variance (ANOVA) in respect of 15 characters in a set of 14 × 14 half diallel crosses in maize
- 4.2 Heterosis over mid parent, better parent and check
- 4.3 ANOVA for combining ability
- 4.4 Combining ability effects

4.1 Analysis of variance

Analysis of variance (ANOVA) was carried out for fifteen characters under study from the data obtained through diallel crosses. F test was conducted to examine the significance of variance. Mean sum of squares for fifteen characters are presented in Table 4.

It was observed that variances among genotype for all fifteen characters were highly significant as indicated by F test. The mean sum of squares for parents were highly significant for all the character studies except for shelling percentage indicating the substantial variation among the parents selected for study.

The F₁ hybrids exhibited significant mean sum of squares for all fifteen characters traits except shelling percentage, generated by diallel crosses. This depicts considerable genetic differences among the hybrids. The significant of mean sum of squares for all fifteen characters in parents vs. Hybrids was observed. This shows the presence of considerable heterosis in resultant F₁ hybrids.

4.2 Heterosis over mid parent, better parent and check

The percentage heterosis over mid parent (relative heterosis), better parent (heterobeltiosis) and over the check (standard heterosis) various characters is given in Table 5. The standard heterosis is worked out against NK 6240 hybrid, which showed good characters for most of the traits with high per se performance among all the checks.

The pertinent data on heterosis over mid parent, better parent and check are detailed in Table 5 to 9.

4.2.1 Days to 50 per cent tasseling

The percentage heterosis over mid parent, better parent and commercial check ranged from -7.94 to 1.6 per cent, -7.94 to 3.23 per cent and - 7.94 to 3.17 per cent, respectively. Out of 91 hybrids 66 crosses over mid parent, 42 crosses over better parent and 18 crosses over standard heterosis exhibited significant heterosis in desirable direction. Among these DMIL 5 x DMIL 2 showed -7.94, -7.94 and -7.94 highest negative heterosis over MP, BP and SH.

The average heterosis for the character was -1.91 per cent indicating the hybrids tasseled earlier than their respective parents.

4.2.2 Days to 50 per cent silking

Seventeen cross exhibited significant negative heterosis over mid parent, thirteen over better parent, seventy one of the crosses showed significant heterosis over standard check and two crosses viz., DMIL 6 x DMIL 5 and DMIL 11 x DMIL 10 exhibited -3.08, -2.33, -5.26 and -3.08, -2.33, -5.26 over MP, BP, SH significant heterosis in negative direction.

Table 4: Analysis of variance for 15 traits in 1DMIL 4 x DMIL 14 half diallel crosses in maize

Sources	DF	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear width (cm)	No of kernels per row
Replicates	1	0.005	42.076*	0.005	69.489	1039.409 *	4.937	6.035	1.376
Treatments	104	3.653**	2.295**	6.221**	940.878 **	472.901 **	10.048 **	5.664 **	52.012 **
Parents	13	2.066**	1.728**	2.956**	617.871 **	846.937 **	10.167 **	4.134 **	32.978 **
Hybrids	90	3.525**	2.356**	5.524**	987.697 **	418.200 **	4.392 **	4.654 **	36.976 **
Parent Vs. Hybrids	1	35.781**	4.176**	111.429**	926.291 **	533.547	517.539 **	116.426 **	1652.750 **
Error	104	0.043	0.163	0.322	126.698	147.314	0.736	1.589	1.655

Sources	DF	No of rows per ear	Test wt (g)	Shelling %	Grain yield per plant	Grain yield per ha	Protein content (%)	Starch content (%)
Replicates	1	5.833 *	3.334	323.068	152.406	40.67	0.145	0.029
Treatments	104	4.411 **	29.838 **	159.753 **	1094.903 **	305.34**	3.050 **	4.928 **
Parents	13	4.651 **	19.423 **	91.008	104.108	28.99	1.442 **	7.651 **
Hybrids	90	4.026 **	26.867 **	69.548	674.614 **	187.25**	3.194 **	3.550 **
Parent Vs. Hybrids	1	35.943 **	432.668 **	9171.909 **	51801.290 **	14526.92**	11.004 **	93.523 **
Error	104	1.372	6.177	61.676	131.416	36.74	0.051	0.043

* - Significant at 5% level

** - Significant at 1% level

Table 5: Per cent relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) for maturity characters in maize

Sl. No.	F ₁ cross	Days to 50% tasseling			Days to 50% silking			Days to 50% brown husking		
		RH	HB	SH	RH	HB	SH	RH	HB	SH
1	DMIL 2 x DMIL 1	1.59 **	1.59 **	1.59 **	2.34 **	3.15 **	-1.50 *	-2.67 **	-2.15 **	-2.15 **
2	DMIL 3 x DMIL 1	-3.94 **	-3.17 **	-3.17 **	-0.78	0	-4.51 **	-1.06 *	-1.06	0
3	DMIL 4 x DMIL 1	0.79 **	1.59 **	1.59 **	3.97 **	4.80 **	-1.50 *	-1.60 **	-1.08	-1.08
4	DMIL 5 x DMIL 1	0	0	0	0.78	1.57 *	-3.01 **	-0.53	0	1.08
5	DMIL 6 x DMIL 1	-1.59 **	-1.59 **	-1.59 **	1.55 **	3.15 **	-1.50 *	-3.16 **	-2.13 **	-1.08
6	DMIL 7 x DMIL 1	-0.79 **	0	0	3.10 **	4.72 **	0	-4.76 **	-4.26 **	-3.23 **
7	DMIL 8 x DMIL 1	-0.80 **	0	-1.59 **	-0.78	0	-4.51 **	-4.81 **	-4.30 **	-4.30 **
8	DMIL 9 x DMIL 1	0	0	0	1.18 *	1.57 *	-3.01 **	-3.19 **	-3.19 **	-2.15 **
9	DMIL 10 x DMIL 1	1.59 **	1.59 **	1.59 **	2.34 **	3.15 **	-1.50 *	-2.65 **	-2.13 **	-1.08
10	DMIL 11 x DMIL 1	-2.36 **	-1.59 **	-1.59 **	3.10 **	4.72 **	0	-0.53	0	0
11	1DMIL 2 x DMIL 1	0	0	0	3.15 **	3.15 **	-1.50 *	0	0	1.08
12	DMIL 13 x DMIL 1	0	1.59 **	1.59 **	3.10 **	4.72 **	0	-1.59 **	-1.06	0
13	1DMIL 4 x DMIL 1	-3.88 **	-1.59 **	-1.59 **	1.55 **	3.15 **	-1.50 *	-3.66 **	-2.13 **	-1.08
14	DMIL 3 x DMIL 2	-3.94 **	-3.17 **	-3.17 **	-1.55 **	-1.55 *	-4.51 **	-2.67 **	-2.15 **	-2.15 **
15	DMIL 4 x DMIL 2	-0.79 **	0	0	1.57 **	3.20 **	-3.01 **	-3.23 **	-3.23 **	-3.23 **
16	DMIL 5 x DMIL 2	-7.94 **	-7.94 **	-7.94 **	0	0	-3.01 **	-2.13 **	-1.08	-1.08
17	DMIL 6 x DMIL 2	-3.17 **	-3.17 **	-3.17 **	0.77	1.55 *	-1.50 *	-1.59 **	0	0
18	DMIL 7 x DMIL 2	-5.51 **	-4.76 **	-4.76 **	-0.77	0	-3.01 **	-1.06 *	0	0
19	DMIL 8 x DMIL 2	-0.80 **	0	-1.59 **	3.10 **	3.10 **	0	-1.08 *	-1.08	-1.08
20	DMIL 9 x DMIL 2	-4.76 **	-4.76 **	-4.76 **	0.39	0.78	-3.01 **	-2.67 **	-2.15 **	-2.15 **
21	DMIL 10 x DMIL 2	-1.59 **	-1.59 **	-1.59 **	1.55 **	1.55 *	-1.50 *	0	1.08	1.08
22	DMIL 11 x DMIL 2	-2.36 **	-1.59 **	-1.59 **	-0.77	0	-3.01 **	1.08 *	1.08	1.08

Contd.....

Sl. No.	F ₁ cross	Days to 50% tasseling			Days to 50% silking			Days to 50% brown husking		
		RH	HB	SH	RH	HB	SH	RH	HB	SH
23	DMIL 12 x DMIL 2	-6.35 **	-6.35 **	-6.35 **	1.56 **	2.36 **	-2.26 **	0	0.54	0.54
24	DMIL 13 x DMIL 2	-3.13 **	-1.59 **	-1.59 **	0.77	1.55 *	-1.50 *	-2.66 **	-1.61 **	-1.61 **
25	DMIL 14 x DMIL 2	-2.33 **	0	0	-0.77	0	-3.01 **	-3.16 **	-1.08	-1.08
26	DMIL 4 x DMIL 3	-3.13 **	-3.13 **	-1.59 **	4.72 **	6.40 **	0	1.07 *	1.61 **	1.61 **
27	DMIL 5 x DMIL 3	0.79 **	1.59 **	1.59 **	0	0	-3.01 **	-0.53	0	1.08
28	DMIL 6 x DMIL 3	-0.79 **	0	0	0.77	1.55 *	-1.50 *	-6.32 **	-5.32 **	-4.30 **
29	DMIL 7 x DMIL 3	-3.13 **	-3.13 **	-1.59 **	2.31 **	3.10 **	0	-2.65 **	-2.13 **	-1.08
30	DMIL 8 x DMIL 3	0	1.61 **	0	0	0	-3.01 **	-0.53	0	0
31	DMIL 9 x DMIL 3	-2.36 **	-1.59 **	-1.59 **	-1.17 *	-0.78	-4.51 **	-4.26 **	-4.26 **	-3.23 **
32	DMIL 10 x DMIL 3	-3.94 **	-3.17 **	-3.17 **	0	0	-3.01 **	-1.59 **	-1.06	0
33	DMIL 11 x DMIL 3	0	0	1.59 **	-0.77	0	-3.01 **	-2.67 **	-2.15 **	-2.15 **
34	DMIL 12 x DMIL 3	-0.79 **	0	0	3.91 **	4.72 **	0	-1.06 *	-1.06	0
35	DMIL 13 x DMIL 3	-0.78 **	0	1.59 **	2.31 **	3.10 **	0	-2.65 **	-2.13 **	-1.08
36	1DMIL 4 x DMIL 3	0	1.56 **	3.17 **	0.77	1.55 *	-1.50 *	-2.62 **	-1.06	0
37	DMIL 5 x DMIL 4	-7.09 **	-6.35 **	-6.35 **	1.57 **	3.20 **	-3.01 **	-2.13 **	-1.08	-1.08
38	DMIL 6 x DMIL 4	-2.36 **	-1.59 **	-1.59 **	3.91 **	6.40 **	0	-3.70 **	-2.15 **	-2.15 **
39	DMIL 7 x DMIL 4	-4.69 **	-4.69 **	-3.17 **	2.34 **	4.80 **	-1.50 *	-4.26 **	-3.23 **	-3.23 **
40	DMIL 8 x DMIL 4	-1.59 **	0	-1.59 **	4.72 **	6.40 **	0	2.15 **	2.15 **	2.15 **
41	DMIL 9 x DMIL 4	-0.79 **	0	0	1.98 **	3.20 **	-3.01 **	4.81 **	5.38 **	5.38 **
42	DMIL 10 x DMIL 4	0.79 **	1.59 **	1.59 **	3.15 **	4.80 **	-1.50 *	0	1.08	1.08
43	DMIL 11 x DMIL 4	-1.56 **	-1.56 **	0	-0.78	1.60 *	-4.51 **	-3.23 **	-3.23 **	-3.23 **
44	DMIL 12 x DMIL 4	-2.36 **	-1.59 **	-1.59 **	1.59 **	2.40 **	-3.76 **	-1.60 **	-1.08	-1.08
45	DMIL 13 x DMIL 4	-2.33 **	-1.56 **	0	0.78	3.20 **	-3.01 **	0	1.08	1.08
46	DMIL 14 x DMIL 4	-6.15 **	-4.69 **	-3.17 **	-2.34 **	0	-6.02 **	-2.11 **	0	0

Contd.....

Sl. No.	F ₁ cross	Days to 50% tasseling			Days to 50% silking			Days to 50% brown husking		
		RH	HB	SH	RH	HB	SH	RH	HB	SH
47	DMIL 6 x DMIL 5	-3.17 **	-3.17 **	-3.17 **	-3.08 **	-2.33 **	-5.26 **	-1.57 **	-1.05	1.08
48	DMIL 7 x DMIL 5	-2.36 **	-1.59 **	-1.59 **	-2.31 **	-1.55 *	-4.51 **	-2.11 **	-2.11 **	0
49	DMIL 8 x DMIL 5	0.80 **	1.61 **	0	1.55 **	1.55 *	-1.50 *	-2.13 **	-1.08	-1.08
50	DMIL 9 x DMIL 5	-3.17 **	-3.17 **	-3.17 **	-1.17 *	-0.78	-4.51 **	-0.53	0	1.08
51	DMIL 10 x DMIL 5	-1.59 **	-1.59 **	-1.59 **	0	0	-3.01 **	-2.11 **	-2.11 **	0
52	DMIL 11 x DMIL 5	-0.79 **	0	0	-0.77	0	-3.01 **	-4.26 **	-3.23 **	-3.23 **
53	DMIL 12 x DMIL 5	0	0	0	1.56 **	2.36 **	-2.26 **	-3.70 **	-3.19 **	-2.15 **
54	DMIL 13 x DMIL 5	-3.13 **	-1.59 **	-1.59 **	-2.31 **	-1.55 *	-4.51 **	-3.16 **	-3.16 **	-1.08
55	DMIL 14 x DMIL 5	-2.33 **	0	0	2.31 **	3.10 **	0	-3.13 **	-2.11 **	0
56	DMIL 7 x DMIL 6	-5.51 **	-4.76 **	-4.76 **	0	0	-1.50 *	-6.81 **	-6.32 **	-4.30 **
57	DMIL 8 x DMIL 6	-0.80 **	0	-1.59 **	-2.31 **	-1.55 *	-4.51 **	-4.76 **	-3.23 **	-3.23 **
58	DMIL 9 x DMIL 6	-4.76 **	-4.76 **	-4.76 **	2.70 **	3.91 **	0	-6.32 **	-5.32 **	-4.30 **
59	DMIL 10 x DMIL 6	-1.59 **	-1.59 **	-1.59 **	0.77	1.55 *	-1.50 *	-3.66 **	-3.16 **	-1.08
60	DMIL 11 x DMIL 6	-0.79 **	0	0	0	0	-1.50 *	-1.59 **	0	0
61	DMIL 12 x DMIL 6	0	0	0	3.10 **	4.72 **	0	-5.26 **	-4.26 **	-3.23 **
62	DMIL 13 x DMIL 6	-7.81 **	-6.35 **	-6.35 **	0	0	-1.50 *	-4.71 **	-4.21 **	-2.15 **
63	DMIL 14 x DMIL 6	-5.43 **	-3.17 **	-3.17 **	1.53 **	1.53 *	0	-4.66 **	-4.17 **	-1.08
64	DMIL 8 x DMIL 7	-1.59 **	0	-1.59 **	0.77	1.55 *	-1.50 *	-3.19 **	-2.15 **	-2.15 **
65	DMIL 9 x DMIL 7	0.79 **	1.59 **	1.59 **	-0.39	0.78	-3.01 **	-1.59 **	-1.06	0
66	DMIL 10 x DMIL 7	0.79 **	1.59 **	1.59 **	0	0.78	-2.26 **	-3.16 **	-3.16 **	-1.08
67	DMIL 11 x DMIL 7	-3.13 **	-3.13 **	-1.59 **	-3.05 **	-3.05 **	-4.51 **	-4.26 **	-3.23 **	-3.23 **
68	DMIL 12 x DMIL 7	-0.79 **	0	0	1.55 **	3.15 **	-1.50 *	-1.59 **	-1.06	0
69	DMIL 13 x DMIL 7	-5.43 **	-4.69 **	-3.17 **	-1.53 **	-1.53 *	-3.01 **	-4.21 **	-4.21 **	-2.15 **
70	DMIL 14 x DMIL 7	-4.62 **	-3.13 **	-1.59 **	-3.05 **	-3.05 **	-4.51 **	-5.21 **	-4.21 **	-2.15 **

Contd.....

Sl. No.	F ₁ cross	Days to 50% tasseling			Days to 50% silking			Days to 50% brown husking		
		RH	HB	SH	RH	HB	SH	RH	HB	SH
71	DMIL 9 x DMIL 8	0.80 **	1.61 **	0	-1.17 *	-0.78	-4.51 **	-1.60 **	-1.08	-1.08
72	DMIL 10 x DMIL 8	1.60 **	2.42 **	0.79 *	0	0	-3.01 **	0	1.08	1.08
73	DMIL 11 x DMIL 8	0.79 **	2.42 **	0.79 *	-2.31 **	-1.55 *	-4.51 **	0	0	0
74	DMIL 12 x DMIL 8	0	0.81 *	-0.79 *	0.78	1.57 *	-3.01 **	0.53	1.08	1.08
75	DMIL 13 x DMIL 8	-0.79 **	1.61 **	0	2.31 **	3.10 **	0	-2.13 **	-1.08	-1.08
76	DMIL 14 x DMIL 8	0	3.23 **	1.59 **	-0.77	0	-3.01 **	-2.11 **	0	0
77	DMIL 10 x DMIL 9	0.79 **	0.79 *	0.79 *	3.50 **	3.91 **	0	-4.76 **	-4.26 **	-3.23 **
78	DMIL 11 x DMIL 9	-0.79 **	0	0	2.70 **	3.91 **	0	-4.81 **	-4.30 **	-4.30 **
79	DMIL 12 x DMIL 9	-0.79 **	-0.79 *	-0.79 *	1.18 *	1.57 *	-3.01 **	-1.06 *	-1.06	0
80	DMIL 13 x DMIL 9	0	1.59 **	1.59 **	1.16 *	2.34 **	-1.50 *	-2.65 **	-2.13 **	-1.08
81	DMIL 14 x DMIL 9	-2.33 **	0	0	-0.39	0.78	-3.01 **	-1.57 **	0	1.08
82	DMIL 11 x DMIL 10	-3.94 **	-3.17 **	-3.17 **	-3.08 **	-2.33 **	-5.26 **	-4.26 **	-3.23 **	-3.23 **
83	1DMIL 2 x DMIL 10	-1.59 **	-1.59 **	-1.59 **	-0.78	0	-4.51 **	-2.65 **	-2.13 **	-1.08
84	DMIL 13 x DMIL 10	-1.56 **	0	0	-2.31 **	-1.55 *	-4.51 **	-4.21 **	-4.21 **	-2.15 **
85	1DMIL 4 x DMIL 10	-0.78 **	1.59 **	1.59 **	-0.77	0	-3.01 **	0	1.05	3.23 **
86	1DMIL 2 x DMIL 11	-0.79 **	0	0	1.55 **	3.15 **	-1.50 *	0.53	1.08	1.08
87	DMIL 13 x DMIL 11	-3.88 **	-3.13 **	-1.59 **	-3.05 **	-3.05 **	-4.51 **	-1.06 *	0	0
88	DMIL 14 x DMIL 11	-3.08 **	-1.56 **	0	-1.53 **	-1.53 *	-3.01 **	-1.05 *	1.08	1.08
89	DMIL 13 x DMIL 12	-1.56 **	0	0	3.10 **	4.72 **	0	-1.59 **	-1.06	0
90	1DMIL 4 x DMIL 12	-0.78 **	1.59 **	1.59 **	1.55 **	3.15 **	-1.50 *	-1.57 **	0	1.08
91	1DMIL 4 x DMIL 13	-3.82 **	-3.08 **	0	1.53 **	1.53 *	0	-3.13 **	-2.11 **	0
	S.E.D.	0.18	0.21	0.21	0.35	0.40	0.40	0.49	0.57	0.57
	CD 95%	0.36	0.41	0.41	0.69	0.80	0.80	0.97	1.13	1.13
	CD 99%	0.48	0.55	0.55	0.92	1.06	1.06	1.29	1.49	1.49

* - Significant at 5% level

** - Significant at 1% level

And cross DMIL 14 x DMIL 4 exhibited -3.08 and -6.02 per cent heterosis over MP and SH, respectively. The mid parent heterosis ranged from -0.433 to 0.536 per cent, while the range of heterobeltiosis and standard heterosis was from -2.25 to 2.00 per cent to -3.08 to 4.72 and, respectively.

The average heterosis for the character was 0.64 per cent indicating the hybrids silking later than their respective parents.

4.2.3 Days to 50% brown husking

Seventy two, forty four and twenty nine crosses exhibited heterosis in negative direction over MP, BP and SH, respectively. Mid parent heterosis ranged from -6.82 to 4.81, better parent heterosis ranged from -6.32 to 5.38 and standard heterosis ranged from -4.30 to 5.38. Crosses DMIL 9 x DMIL 6 and DMIL 7 x DMIL 6 showed -6.32, -5.32, -4.30 and -6.81, -6.32, -4.30 per cent heterosis over mid parent, better parent, standard check, respectively.

The average heterosis for the character was -2.27 per cent indicating the hybrids matured earlier than their respective parents.

4.2.4 Plant height

Twenty nine crosses exhibited significant positive heterosis over the mid parent, thirteen hybrids over the better and four of the experimental hybrids exhibited significant positive heterosis over the standard check, fifteen crosses on the other hand showed significant negative standard heterosis. The per cent heterosis which ranged from -40.39 to 23.51, for relative heterosis from -44.05 to 19.51 and -45.71 to 14.29 for standard heterosis. The highest negative standard heterosis was exhibited by cross DMIL 12 x DMIL 9 (-45.71%).

An average heterosis 3.12 per cent was observed for this character over the parents inferring that hybrids are taller than parents.

4.2.5 Ear height

Nine and three hybrids exhibited significant positive values for relative heterosis and heterobeltiosis, respectively and one cross showed significant standard values. The per cent heterosis which ranged from -53.89 to 46.97 for relative heterosis, from -60.18 to 34.84 for heterobeltiosis and -51.59 to 26.8 for standard heterosis. One crosses viz., DMIL 11 x DMIL 4 (26.80%) had significant standard heterosis in positive direction.

An average heterosis -4.35 per cent was observed for this character over the parents inferring that hybrids are lower ear height than parents.

4.2.6 Ear length

In case of mid parent and better parent heterosis, 87 and 74 crosses exhibited significant deviation in positive direction, while none of the cross in the negative direction. But, in case of commercial heterosis, nine of the crosses viz., DMIL 14 x DMIL 2, DMIL 7 x DMIL 3, DMIL 8 x DMIL 3, DMIL 9 x DMIL 4, DMIL 10 x DMIL 4, DMIL 9 x DMIL 6, DMIL 14 x DMIL 6, DMIL 12 x DMIL 10, and DMIL 13 x DMIL 10 exhibited significant heterosis in the positive direction. Whereas, other twenty four crosses showed significant standard heterosis in the negative direction. The range was from -2.25 to 76.65 per cent for relative heterosis, -7.71 to 44.75 per cent for heterobeltiosis and -16.99 to 14.35 per cent for standard heterosis.

An average heterosis 29.62 per cent was observed for this character over the parents inferring that hybrids are more ear length than parents.

4.2.7 Ear width

Fourty three and twenty two crosses exhibited significant positive relative heterosis and heterobeltiosis, respectively, while two of the crosses DMIL 9 x DMIL 1 (16.16 %) and DMIL 11 x DMIL 6 (43.18 %) have exhibited significant positive standard heterosis. The magnitude of heterosis ranged from -6.37 to 74.53 per cent for relative heterosis, -13.42 to 73.06 per cent for heterobeltiosis and -20.06 to 43.18 per cent for standard heterosis.

Table 6: Per cent relative heterosis (RH), heterobelitosis (HB) and standard heterosis (SH) for plant characters in maize

Sl. No.	F ₁ cross	Plant height (cm)			Ear height (cm)		
		RH	HB	SH	RH	HB	SH
1	DMIL 2 x DMIL 1	9.27	-2.41	-3.57	-5.68	-11.27	-37.94 **
2	DMIL 3 x DMIL 1	15.93 **	0	7.14	23.11	-1.65	1.44
3	DMIL 4 x DMIL 1	22.59 **	16.39 **	0.6	17.23	-11.09	6.05
4	DMIL 5 x DMIL 1	21.35 **	13.01 *	1.79	-29.15 **	-46.12 **	-36.23 **
5	DMIL 6 x DMIL 1	7.35	-1.53	-8.33	-2.78	-21.67	-21.02
6	DMIL 7 x DMIL 1	15.61 **	5.98	-1.19	28.28 *	8.42	-3.17
7	DMIL 8 x DMIL 1	16.92 **	5.56	1.79	26.00 *	6.94	-5.48
8	DMIL 9 x DMIL 1	22.55 **	17.20 **	-0.24	16.42	1.05	-15.34
9	DMIL 10 x DMIL 1	23.51 **	16.22 **	2.38	8.48	-10.16	-15.62
10	DMIL 11 x DMIL 1	17.80 **	4.12	5.36	6.73	-17.71	-6.4
11	1DMIL 2 x DMIL 1	17.20 **	5.52	2.38	26.21 *	-1.55	8.35
12	DMIL 13 x DMIL 1	22.52 **	10.62	6.67	0.93	-22.94 *	-9.86
13	1DMIL 4 x DMIL 1	16.85 **	0.55	8.33	13.24	-14.68	3.74
14	DMIL 3 x DMIL 2	-0.58	-4.44	2.38	11.88	-6.12	-3.17
15	DMIL 4 x DMIL 2	23.39 **	15.66 **	14.29 **	-0.1	-20.76 *	-5.48
16	DMIL 5 x DMIL 2	-2.05	-6.39	-7.5	8.96	-13.32	2.59
17	DMIL 6 x DMIL 2	-1.24	-4.1	-5.24	5.29	-10.84	-10.09
18	DMIL 7 x DMIL 2	-5.03	-7.71	-8.81	30.28 *	16.16	3.74
19	DMIL 8 x DMIL 2	-5.61	-6.75	-7.86	22.31	9.55	-3.17
20	DMIL 9 x DMIL 2	13.14 *	5.3	4.05	46.97 **	34.84 *	12.97
21	DMIL 10 x DMIL 2	7.01	1.2	0	28.02 *	11.68	4.9
22	DMIL 11 x DMIL 2	2.38	1.18	2.38	-0.85	-19.94 *	-8.94

Contd.....

Sl. No.	F ₁ cross	Plant height (cm)			Ear height (cm)		
		RH	HB	SH	RH	HB	SH
23	DMIL 12 x DMIL 2	5.78	4.82	3.57	7.58	-12.02	-3.17
24	DMIL 13 x DMIL 2	12.20 *	10.84 *	9.52	6.07	-15.25	-0.87
25	DMIL 14 x DMIL 2	2.59	-1.66	5.95	-3.71	-24.16 **	-7.78
26	DMIL 4 x DMIL 3	5.78	-4.44	2.38	-4.64	-11.09	6.05
27	DMIL 5 x DMIL 3	-9.45 *	-16.67 **	-10.71 *	-12.57	-18.19	-3.17
28	DMIL 6 x DMIL 3	-2.5	-8.89	-2.38	-2.8	-3.89	-0.87
29	DMIL 7 x DMIL 3	3.37	-3.33	3.57	17.39	9.52	12.97
30	DMIL 8 x DMIL 3	5.26	0	7.14	-7.56	-14.17	-11.47
31	DMIL 9 x DMIL 3	8.48	-2.67	4.29	3.6	-6.12	-3.17
32	DMIL 10 x DMIL 3	5.61	-3.78	3.1	-12.03	-15.96	-13.32
33	DMIL 11 x DMIL 3	-5.14	-7.78	-1.19	-17.09	-20.96 *	-10.09
34	DMIL 12 x DMIL 3	-7.87	-12.22 *	-5.95	-0.52	-3.64	6.05
35	DMIL 13 x DMIL 3	-9.47 *	-14.00 **	-7.86	-15.79	-20.77 *	-7.32
36	1DMIL 4 x DMIL 3	-18.01 **	-18.23 **	-11.90 *	-19.98 *	-26.05 **	-10.09
37	DMIL 5 x DMIL 4	5.22	3.09	-7.14	-26.27 **	-26.56 **	-12.39
38	DMIL 6 x DMIL 4	-1.86	-5.37	-11.90 *	-9.93	-16.89	-0.87
39	DMIL 7 x DMIL 4	8.14	4.19	-2.86	1.68	-11.09	6.05
40	DMIL 8 x DMIL 4	4.17	-1.23	-4.76	4.35	-9.16	8.35
41	DMIL 9 x DMIL 4	13.81 *	12.95 *	-2.38	-0.09	-14.96	1.44
42	DMIL 10 x DMIL 4	17.33 **	16.22 **	2.38	-4.84	-14.96	1.44
43	DMIL 11 x DMIL 4	9.14	1.18	2.38	8.82	6.3	26.80 *
44	DMIL 12 x DMIL 4	16.81 **	10.43	7.14	-4.7	-8.39	9.28
45	DMIL 13 x DMIL 4	10.68 *	4.94	1.19	-10.23	-11.09	6.05
46	DMIL 14 x DMIL 4	15.27 **	3.87	11.90 *	-23.43 **	-24.16 **	-7.78

Contd.....

Sl. No.	F ₁ cross	Plant height (cm)			Ear height (cm)		
		RH	HB	SH	RH	HB	SH
47	DMIL 6 x DMIL 5	10.49 *	8.7	1.19	-13.34	-19.75 *	-5.02
48	DMIL 7 x DMIL 5	21.57 **	19.51 **	11.43 *	-14.3	-24.81 **	-11.01
49	DMIL 8 x DMIL 5	13.11 **	9.38	5.48	-13.02	-24.04 *	-10.09
50	DMIL 9 x DMIL 5	13.62 *	10.49	-0.48	-24.73 *	-35.72 **	-23.92 *
51	DMIL 10 x DMIL 5	14.93 **	13.67 *	2.38	-19.64 *	-27.93 **	-14.7
52	DMIL 11 x DMIL 5	4.57	-1.18	0	-36.43 **	-37.67 **	-26.23 *
53	DMIL 12 x DMIL 5	18.35 **	14.11 *	10.71 *	-13.2	-16.24	-0.87
54	DMIL 13 x DMIL 5	2.13	-1.23	-4.76	-25.55 **	-25.98 **	-12.39
55	DMIL 14 x DMIL 5	3.51	-4.97	2.38	-20.45 *	-21.50 *	-4.56
56	DMIL 7 x DMIL 6	8.1	8.02	0.71	-0.58	-6.26	-5.48
57	DMIL 8 x DMIL 6	7.54	5.68	1.9	21.83 *	14.31	15.27
58	DMIL 9 x DMIL 6	4.21	-0.26	-7.14	-0.1	-8.55	-7.78
59	DMIL 10 x DMIL 6	-2.76	-5.37	-11.90 *	4.17	0.59	1.44
60	DMIL 11 x DMIL 6	12.75 **	8.24	9.52	0.99	-4.74	8.35
61	DMIL 12 x DMIL 6	6.45	4.29	1.19	-0.74	-4.9	4.67
62	DMIL 13 x DMIL 6	5.53	3.7	0	10.08	2.48	19.88
63	DMIL 14 x DMIL 6	-9.19 *	-15.36 **	-8.81	-0.5	-8.99	10.66
64	DMIL 8 x DMIL 7	5.45	3.7	0	27.14 *	26.48 *	12.97
65	DMIL 9 x DMIL 7	12.13 *	7.25	0	19.87	16.16	3.74
66	DMIL 10 x DMIL 7	18.17 **	14.91 *	7.14	30.85 **	27.64 *	19.88
67	DMIL 11 x DMIL 7	6.54	2.35	3.57	-9.17	-18.93	-7.78
68	DMIL 12 x DMIL 7	7.62	5.52	2.38	-12.12	-20.40 *	-12.39
69	DMIL 13 x DMIL 7	-2.59	-4.2	-7.62	0.58	-11.31	3.74
70	DMIL 14 x DMIL 7	-0.49	-7.18	0	0.57	-12.78	6.05

Contd.....

Sl. No.	F ₁ cross	Plant height (cm)			Ear height (cm)		
		RH	HB	SH	RH	HB	SH
71	DMIL 9 x DMIL 8	4.92	-1.23	-4.76	6.05	3.29	-8.71
72	DMIL 10 x DMIL 8	0.65	-3.7	-7.14	-14.01	-16.54	-21.62
73	DMIL 11 x DMIL 8	2.41	0	1.19	-20.16 *	-29.06 **	-19.31
74	DMIL 12 x DMIL 8	4.62	4.29	1.19	-26.12 **	-33.39 **	-26.69 *
75	DMIL 13 x DMIL 8	4.94	4.94	1.19	-21.42 *	-31.02 **	-19.31
76	DMIL 14 x DMIL 8	5.42	-0.11	7.62	-53.89 **	-60.18 **	-51.59 **
77	DMIL 10 x DMIL 9	18.21 **	16.22 **	2.38	-0.88	-6.23	-11.93
78	DMIL 11 x DMIL 9	-30.99 **	-36.47 **	-35.71 **	-4.3	-16.9	-5.48
79	DMIL 12 x DMIL 9	-40.39 **	-44.05 **	-45.71 **	-11.99	-22.50 *	-14.7
80	DMIL 13 x DMIL 9	-17.38 **	-22.22 **	-25.00 **	-28.80 **	-38.90 **	-28.53 *
81	DMIL 14 x DMIL 9	-7.41	-17.13 **	-10.71 *	1.03	-14.68	3.74
82	DMIL 11 x DMIL 10	-1.13	-7.53	-6.43	-13.41	-20.96 *	-10.09
83	1DMIL 2 x DMIL 10	-8.68	-12.88 *	-15.48 **	1.72	-5.74	3.74
84	DMIL 13 x DMIL 10	-14.84 **	-18.52 **	-21.43 **	-25.67 **	-32.99 **	-21.62
85	1DMIL 4 x DMIL 10	-27.05 **	-33.70 **	-28.57 **	-16.56	-26.05 **	-10.09
86	1DMIL 2 x DMIL 11	-21.68 **	-23.29 **	-22.38 **	-3.17	-4.74	8.35
87	DMIL 13 x DMIL 11	-34.94 **	-36.47 **	-35.71 **	-24.06 **	-25.11 **	-12.39
88	DMIL 14 x DMIL 11	-10.43 *	-13.15 **	-6.43	-13.79	-16.57	1.44
89	DMIL 13 x DMIL 12	-16.31 **	-16.56 **	-19.05 **	-8.61	-11.31	3.74
90	1DMIL 4 x DMIL 12	-11.63 *	-16.02 **	-9.52	-8.44	-12.78	6.05
91	1DMIL 4 x DMIL 13	-14.87 **	-19.34 **	-13.10 *	-45.88 **	-46.91 **	-35.45 **
	S.E.D.	9.75	11.26	11.26	10.51	12.14	12.14
	CD 5%	19.33	22.32	22.32	20.84	24.07	24.07
	CD 1%	25.58	29.54	29.54	27.58	31.85	31.85

* - Significant at 5% level

** - Significant at 1% level

Average heterosis for the character was 14.36 per cent indicating that hybrids and larger ear width than their parents.

4.2.8 Number of kernels per row

Eighty three, sixty five and four crosses showed significant positive value for relative heterosis, heterobeltiosis and standard heterosis, respectively. The magnitude of heterosis ranged from -12.73 to 77.27 per cent for relative heterosis from -17.65 to 77.27 per cent for heterobeltiosis and from -36.84 to 10.53 per cent for standard heterosis, DMIL 4 x DMIL 3 (10.53%), DMIL 10 x DMIL 3 (7.89%) and DMIL 9 x DMIL 5 (10.53%) were the crosses exhibited significant standard heterosis in positive direction.

Average heterosis for the character was 31.48 per cent indicating that hybrids and having more number of kernel per row than their parents.

4.2.9 Number of row per ear

Twenty and eleven hybrids exhibited significant positive relative heterosis and heterobeltiosis respectively, twenty three crosses showed significant positive standard heterosis and magnitude of heterosis varied from -9.68 to 41.67 per cent for relative heterosis from -13.33 to 38.46 per cent per cent for heterobeltiosis and -7.14 to 35.71 per cent for standard heterosis. Crosses viz., DMIL 11 x DMIL 3 (35.712%), DMIL 13 x DMIL 4 (35.71%) and DMIL 7 x DMIL 3 (28.57%) showed highest significant standard heterosis in positive direction.

Average heterosis for the character was 8.67 per cent indicating that hybrids and having more number of rows per ear than their parents.

4.2.10 Test weight

Fourty nine and twenty seven crosses exhibited significant positive relative heterosis and heterobeltiosis, while five crosses exhibited standard heterosis. The magnitude of heterosis ranged from -12.19 to 39.10 per cent for relative heterosis, from -19.12 to 36.16 per cent for heterobeltiosis and from -18.11 to 16.91 per cent for standard heterosis. Experimental crosses DMIL 9 x DMIL 4 (16.91%), DMIL 13 x DMIL 2 (16.11%), DMIL 4 x DMIL 3 (15.85%), DMIL 5 x DMIL 4 (14.65%) and DMIL 12 x DMIL 2 (13.72%) had significant standard heterosis in positive direction. An average heterosis of 13.04 per cent was recorded for hybrids.

4.2.11 Shelling percentage

Sixty one and fifty exhibited significant positive relative heterosis and heterobeltiosis, while ten crosses showed standard heterosis and magnitude of heterosis ranged from -0.27 to 72.04 per cent for relative heterosis, from -2.96 to 48.83 per cent for heterobeltiosis and -12.16 to 24.30 per cent for standard heterosis. Hybrids DMIL 11 x DMIL 8 (6.30%), DMIL 11 x DMIL 9 (24.30%) and DMIL 13 x DMIL 4 (24.24%) recorded highest positive standard heterosis.

Average heterosis of 30.52 per cent was recorded inferring that hybrids had higher shelling percentage compared to their parents.

4.2.12 Grain yield per plant

, seventy six and five crosses showed significant positive relative, heterobeltiosis and standard heterosis, respectively. The magnitude of heterosis ranged from 13.04 to 96.40 per cent for relative heterosis, 4.84 to 87.29 per cent for heterobeltiosis and -31.58 to 22.11 per cent for standard heterosis. DMIL 9 x DMIL 5 (22.11%), DMIL 10 x DMIL 7 (18.95%), DMIL 4 x DMIL 3 (18.60%), DMIL 8 x DMIL 7 (18.60%) and DMIL 14 x DMIL 10 (16.14%) exhibited significant standard heterosis. The average heterosis for the character was 51.97 per cent.

4.2.13 Grain yield per hectare

Out of 91 crosses, eighty six, seventy six and five crosses showed significant positive relative, heterobeltiosis and standard heterosis, respectively.

Table 7: Per cent relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) for ear characters in maize

Sl. No.	F ₁ cross	Ear length (cm)			Ear width (cm)			No of kernels per row		
		RH	HB	SH	RH	HB	SH	RH	HB	SH
1	DMIL 2 x DMIL 1	17.51 **	15.81 **	-14.11 **	-0.35	-0.35	-20.06 **	-4	-7.69	-36.84 **
2	DMIL 3 x DMIL 1	26.42 **	23.31 **	-3.83	19.64 *	15.28	-7.52	43.40 **	40.74 **	0
3	DMIL 4 x DMIL 1	8.95 *	2.87	-14.11 **	8.2	-0.87	-4.46	26.32 **	16.13 **	-5.26
4	DMIL 5 x DMIL 1	18.62 **	15.20 **	-9.33 *	14.29 *	6.27	-0.84	23.08 **	23.08 **	-15.79 **
5	DMIL 6 x DMIL 1	45.84 **	21.61 **	-9.81 *	22.39 **	20.54 *	-0.28	70.21 **	53.85 **	5.26
6	DMIL 7 x DMIL 1	28.81 **	25.48 **	-6.94	23.57 **	19.93 *	2.23	25.00 **	15.38 **	-21.05 **
7	DMIL 8 x DMIL 1	21.43 **	17.07 **	-6.46	12.71	0.82	2.51	16.67 **	2.94	-7.89 *
8	DMIL 9 x DMIL 1	42.27 **	39.20 **	7.89	34.95 **	26.36 **	16.16 *	27.59 **	15.63 **	-2.63
9	DMIL 10 x DMIL 1	30.50 **	23.21 **	2.87	29.81 **	27.78 **	2.51	58.33 **	46.15 **	0
10	DMIL 11 x DMIL 1	30.85 **	24.52 **	-7.66	20.69 **	19.86 *	-2.51	4	0	-31.58 **
11	1DMIL 2 x DMIL 1	40.58 **	25.16 **	-7.18	20.77 **	19.10 *	-4.46	11.11 **	7.14	-21.05 **
12	DMIL 13 x DMIL 1	20.12 **	9.57 *	-1.44	-3.34	-6.77	-19.50 **	16.67 **	7.69	-26.32 **
13	1DMIL 4 x DMIL 1	29.16 **	22.61 **	1.2	12.89	12.5	-9.75	25.93 **	21.43 **	-10.53 **
14	DMIL 3 x DMIL 2	29.51 **	24.54 **	-2.87	12.07	7.99	-13.37	25.49 **	18.52 **	-15.79 **
15	DMIL 4 x DMIL 2	20.92 **	12.61 *	-5.98	14.51 *	4.91	1.11	9.09 *	-3.23	-21.05 **
16	DMIL 5 x DMIL 2	19.05 **	13.98 **	-10.29 *	12.36	4.48	-2.51	36.00 **	30.77 **	-10.53 **
17	DMIL 6 x DMIL 2	48.03 **	24.92 **	-10.05 *	18.97 *	17.17 *	-3.06	60.00 **	50.00 **	-5.26
18	DMIL 7 x DMIL 2	46.55 **	44.85 **	4.31	19.19 *	15.69	-1.39	65.22 **	58.33 **	0
19	DMIL 8 x DMIL 2	24.09 **	17.96 **	-5.74	6.89	-4.38	-2.79	24.14 **	5.88	-5.26
20	DMIL 9 x DMIL 2	33.76 **	29.01 **	0	21.04 **	13.33	4.18	35.71 **	18.75 **	0
21	DMIL 10 x DMIL 2	24.92 **	16.33 **	-2.87	31.92 **	29.86 **	4.18	65.22 **	58.33 **	0
22	DMIL 11 x DMIL 2	30.12 **	25.58 **	-9.57 *	14.83	14.04	-7.24	41.67 **	41.67 **	-10.53 **

Contd.....

Sl.	F ₁ cross	Ear length (cm)	Ear width (cm)	No of kernels per row
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No.		RH	HB	SH	RH	HB	SH	RH	HB	SH
23	DMIL 12 x DMIL 2	44.75 **	30.56 **	-5.98	23.24 **	21.53 *	-2.51	46.15 **	35.71 **	0
24	DMIL 13 x DMIL 2	11.67 **	0.53	-9.57 *	15.38 *	11.29	-3.9	47.83 **	41.67 **	-10.53 **
25	DMIL 14 x DMIL 2	42.11 **	33.04 **	9.81 *	10.8	10.42	-11.42	53.85 **	42.86 **	5.26
26	DMIL 4 x DMIL 3	22.07 **	18.05 **	-1.44	26.92 **	12.43	8.36	44.83 **	35.48 **	10.53 **
27	DMIL 5 x DMIL 3	15.11 **	14.59 **	-9.81 *	10.3	-0.9	-7.52	28.30 **	25.93 **	-10.53 **
28	DMIL 6 x DMIL 3	61.73 **	32.21 **	3.11	15.96 *	10.1	-8.91	58.33 **	40.74 **	0
29	DMIL 7 x DMIL 3	48.06 **	40.80 **	9.81 *	21.12 **	13.4	-3.34	55.10 **	40.74 **	0
30	DMIL 8 x DMIL 3	42.12 **	40.42 **	12.20 **	18.35 **	2.47	4.18	18.03 **	5.88	-5.26
31	DMIL 9 x DMIL 3	26.15 **	25.77 **	-1.91	10.22	-0.3	-8.36	8.47 *	0	-15.79 **
32	DMIL 10 x DMIL 3	18.81 **	14.90 **	-4.07	35.16 **	32.26 **	2.79	67.35 **	51.85 **	7.89 *
33	DMIL 11 x DMIL 3	33.66 **	24.23 **	-3.11	23.79 **	18.49 *	-3.62	56.86 **	48.15 **	5.26
34	DMIL 12 x DMIL 3	38.03 **	20.25 **	-6.22	20.29 *	17.5	-8.36	-12.73 **	-14.29 **	-36.84 **
35	DMIL 13 x DMIL 3	11.68 **	4.26	-6.22	7.8	0.32	-13.37	30.61 **	18.52 **	-15.79 **
36	DMIL 4 x DMIL 3	13.86 **	10.72 *	-8.61 *	35.99 **	31.47 **	4.74	30.91 **	28.57 **	-5.26
37	DMIL 5 x DMIL 4	20.06 **	16.62 **	-2.63	1.62	0	-3.62	12.28 **	3.23	-15.79 **
38	DMIL 6 x DMIL 4	37.77 **	9.74	-8.37 *	6.07	-1.45	-5.01	38.46 **	16.13 **	-5.26
39	DMIL 7 x DMIL 4	32.81 **	22.35 **	2.15	7.67	1.45	-2.23	50.94 **	29.03 **	5.26
40	DMIL 8 x DMIL 4	10.10 *	7.74	-10.05 *	2.67	0	1.67	16.92 **	11.76 **	0
41	DMIL 9 x DMIL 4	34.62 **	29.80 **	8.37 *	3.25	0.87	-2.79	-4.76	-6.25	-21.05 **
42	DMIL 10 x DMIL 4	36.96 **	36.96 **	14.35 **	20.96 **	9.25	5.29	43.40 **	22.58 **	0
43	DMIL 11 x DMIL 4	25.91 **	13.47 **	-5.26	23.51 **	13.87	9.75	16.36 **	3.23	-15.79 **
44	DMIL 12 x DMIL 4	36.04 **	15.19 **	-3.83	10.86	0.29	-3.34	22.03 **	16.13 **	-5.26
45	DMIL 13 x DMIL 4	3.72	0	-10.05 *	5.79	0.29	-3.34	13.21 **	-3.23	-21.05 **
46	DMIL 14 x DMIL 4	17.00 **	16.33 **	-2.87	8.54	-0.87	-4.46	-5.08	-9.68 *	-26.32 **

Contd.....

Sl. No.	F ₁ cross	Ear length (cm)			Ear width (cm)			No of kernels per row		
		RH	HB	SH	RH	HB	SH	RH	HB	SH
47	DMIL 6 x DMIL 5	45.90 **	18.84 **	-6.46	14.87 *	8.36	1.11	10.64 *	0	-31.58 **
48	DMIL 7 x DMIL 5	42.54 **	34.95 **	6.22	12.64	7.76	0.56	66.67 **	53.85 **	5.26
49	DMIL 8 x DMIL 5	7.09	6.29	-15.07 **	1.71	-2.47	-0.84	23.33 **	8.82 *	-2.63
50	DMIL 9 x DMIL 5	25.27 **	24.32 **	-2.15	13.68 *	12.84	5.29	44.83 **	31.25 **	10.53 **
51	DMIL 10 x DMIL 5	15.04 **	11.75 *	-6.7	12.7	3.28	-3.62	50.00 **	38.46 **	-5.26
52	DMIL 11 x DMIL 5	40.89 **	30.40 **	2.63	3.99	-2.69	-9.19	52.00 **	46.15 **	0
53	DMIL 12 x DMIL 5	32.05 **	14.59 **	-9.81 *	20.98 **	11.04	3.62	18.52 **	14.29 **	-15.79 **
54	DMIL 13 x DMIL 5	6.1	-0.53	-10.53 *	8.22	4.18	-2.79	50.00 **	38.46 **	-5.26
55	DMIL 14 x DMIL 5	13.95 **	11.30 *	-8.13	18.20 *	9.55	2.23	25.93 **	21.43 **	-10.53 **
56	DMIL 7 x DMIL 6	58.88 **	35.37 **	-4.78	18.74 *	16.99 *	-0.28	67.44 **	63.64 **	-5.26
57	DMIL 8 x DMIL 6	33.83 **	8.38	-13.40 **	5.74	-4.11	-2.51	16.36 **	-5.88	-15.79 **
58	DMIL 9 x DMIL 6	76.65 **	44.75 **	12.20 **	26.63 **	20.30 **	10.58	50.94 **	25.00 **	5.26
59	DMIL 10 x DMIL 6	45.68 **	16.05 **	-3.11	5.56	2.36	-15.32 *	58.14 **	54.55 **	-10.53 **
60	DMIL 11 x DMIL 6	46.61 **	27.50 **	-14.59 **	74.53 **	73.06 **	43.18 **	60.00 **	50.00 **	-5.26
61	DMIL 12 x DMIL 6	68.37 **	56.20 **	-9.57 *	21.66 **	18.18 *	-2.23	42.86 **	25.00 **	-7.89 *
62	DMIL 13 x DMIL 6	33.79 **	3.72	-6.7	7.74	5.48	-8.91	34.88 **	31.82 **	-23.68 **
63	DMIL 14 x DMIL 6	64.13 **	31.30 **	8.37 *	4.97	3.03	-14.76 *	-2.04	-14.29 **	-36.84 **
64	DMIL 8 x DMIL 7	34.08 **	26.05 **	0.72	-1.04	-9.04	-7.52	0	-17.65 **	-26.32 **
65	DMIL 9 x DMIL 7	36.25 **	29.94 **	0.72	7.86	3.94	-4.46	18.52 **	0	-15.79 **
66	DMIL 10 x DMIL 7	39.04 **	28.08 **	6.94	31.97 **	26.14 **	7.52	18.18 **	18.18 **	-31.58 **
67	DMIL 11 x DMIL 7	37.63 **	34.35 **	-5.5	21.07 **	18.30 *	0.84	47.83 **	41.67 **	-10.53 **
68	DMIL 12 x DMIL 7	50.75 **	37.41 **	-3.35	18.43 *	13.4	-3.34	44.00 **	28.57 **	-5.26
69	DMIL 13 x DMIL 7	26.27 **	12.50 **	1.2	7.79	7.1	-7.52	27.27 **	27.27 **	-26.32 **
70	DMIL 14 x DMIL 7	36.15 **	26.09 **	4.07	30.74 **	26.47 **	7.8	52.00 **	35.71 **	0

Contd....

Sl. No.	F ₁ cross	Ear length (cm)			Ear width (cm)			No of kernels per row		
		RH	HB	SH	RH	HB	SH	RH	HB	SH
71	DMIL 9 x DMIL 8	34.95 **	32.93 **	6.22	0.72	-4.11	-2.51	21.21 **	17.65 **	5.26
72	DMIL 10 x DMIL 8	10.40 *	8.02	-9.81 *	1.55	-10.41	-8.91	28.57 **	5.88	-5.26
73	DMIL 11 x DMIL 8	35.50 **	24.55 **	-0.48	11.72	0.55	2.23	17.24 **	0	-10.53 **
74	DMIL 12 x DMIL 8	42.36 **	22.75 **	-1.91	7.29	-5.21	-3.62	16.13 **	5.88	-5.26
75	DMIL 13 x DMIL 8	-2.25	-7.71	-16.99 **	-6.37	-13.42	-11.98	14.29 **	-5.88	-15.79 **
76	DMIL 14 x DMIL 8	19.00 **	17.10 **	-3.35	-1.69	-12.33	-10.86	29.03 **	17.65 **	5.26
77	DMIL 10 x DMIL 9	16.49 **	12.32 *	-6.22	6.73	-1.52	-9.47	11.11 **	-6.25	-21.05 **
78	DMIL 11 x DMIL 9	22.19 **	13.89 *	-11.72 **	28.94 **	21.52 **	11.7	3.57	-9.38 *	-23.68 **
79	DMIL 12 x DMIL 9	44.52 **	26.23 **	-2.15	19.67 **	10.61	1.67	26.67 **	18.75 **	0
80	DMIL 13 x DMIL 9	10.57 *	2.93	-7.42	-2.5	-5.45	-13.09	33.33 **	12.50 **	-5.26
81	DMIL 14 x DMIL 9	20.48 **	16.81 **	-3.59	0	-6.67	-14.21 *	23.33 **	15.63 **	-2.63
82	DMIL 11 x DMIL 10	40.86 **	26.93 **	5.98	9.63	7.19	-12.81	67.39 **	60.42 **	1.32
83	1DMIL 2 x DMIL 10	53.64 **	30.09 **	8.61 *	10.91	10.71	-13.65	54.00 **	37.50 **	1.32
84	DMIL 13 x DMIL 10	26.07 **	21.54 **	9.33 *	20.88 **	14.84	-0.84	77.27 **	77.27 **	2.63
85	1DMIL 4 x DMIL 10	28.24 **	27.51 **	6.46	18.23 *	16.78	-6.96	44.00 **	28.57 **	-5.26
86	1DMIL 2 x DMIL 11	47.51 **	37.50 **	-7.89	20.98 **	18.49 *	-3.62	30.77 **	21.43 **	-10.53 **
87	DMIL 13 x DMIL 11	17.99 **	2.93	-7.42	22.92 **	19.35 *	3.06	39.13 **	33.33 **	-15.79 **
88	DMIL 14 x DMIL 11	30.88 **	18.55 **	-2.15	14.88	13.7	-7.52	15.38 **	7.14	-21.05 **
89	DMIL 13 x DMIL 12	23.62 **	1.6	-8.61 *	8.81	3.55	-10.58	36.00 **	21.43 **	-10.53 **
90	1DMIL 4 x DMIL 12	21.64 **	3.48	-14.59 **	13.07	11.89	-10.86	14.29 **	14.29 **	-15.79 **
91	1DMIL 4 x DMIL 13	12.07 **	7.45	-3.35	7.72	3.55	-10.58	46.00 **	30.36 **	-3.95
	S.E.D.	0.74	0.86	0.86	1.09	1.26	1.26	1.11	1.29	1.29
	CD 95%	1.47	1.70	1.70	2.16	2.50	2.50	2.21	2.55	2.55
	CD 99%	1.95	2.25	2.25	2.86	3.31	3.31	2.92	3.38	3.38

Contd....

Sl. No.	F ₁ cross	No of rows per cob			Test weight (g)			Shelling %		
		RH	HB	SH	RH	HB	SH	RH	HB	SH
1	DMIL 2 x DMIL 1	4	0	-7.14	5.5	1.53	-13.42 *	20.46	18.96	4.07
2	DMIL 3 x DMIL 1	12	7.69	0	14.23	13.94	-9.69	47.09 **	25.10 *	6.71
3	DMIL 4 x DMIL 1	11.11	0	7.14	1.14	-10.05	-8.92	40.00 **	37.82 **	17.56
4	DMIL 5 x DMIL 1	7.69	0	0	10.67	8.16	-10.65	31.07 **	24.66 *	17.86
5	DMIL 6 x DMIL 1	20.75 **	10.34	14.29	24.38 **	23.78 **	-2.4	17.36	16.52	0.84
6	DMIL 7 x DMIL 1	28.00 **	23.08 *	14.29	12.83	10.89	-9.45	14.05	9.88	1.12
7	DMIL 8 x DMIL 1	0	-7.14	-7.14	-5.38	-13.80 *	-17.31 *	8.64	5.51	-4.5
8	DMIL 9 x DMIL 1	30.77 **	21.43 *	21.43 *	1.08	-10.74	-8.12	3.42	-2.96	-5.58
9	DMIL 10 x DMIL 1	-3.7	-13.33	-7.14	-0.2	-6.67	-15.45 *	20.64	17.17	6.05
10	DMIL 11 x DMIL 1	21.43 **	6.25	21.43 *	14.63 *	12.02	-7.46	19.86	17.61	0.32
11	1DMIL 2 x DMIL 1	21.74 *	16.67	0	3.09	-1.45	-14.78 *	42.10 **	35.66 **	15.72
12	DMIL 13 x DMIL 1	7.14	-6.25	7.14	21.93 **	19.82 *	-2.13	27.98 **	25.55 *	11.33
13	1DMIL 4 x DMIL 1	0	-12.5	0	9.01	8.26	-13.45 *	30.01 **	29.95 *	10.85
14	DMIL 3 x DMIL 2	15.38	15.38	7.14	25.45 **	21.02 **	3.2	39.50 **	17.43	2.73
15	DMIL 4 x DMIL 2	21.43 **	13.33	21.43 *	-12.19 *	-19.12 **	-18.11 **	23.58 *	20.16	5.12
16	DMIL 5 x DMIL 2	25.93 **	21.43 *	21.43 *	7.07	5.4	-10.12	29.97 **	25.11 *	18.29
17	DMIL 6 x DMIL 2	9.09	3.45	7.14	37.76 **	31.95 **	12.52	36.10 **	35.37 **	18.42
18	DMIL 7 x DMIL 2	7.69	7.69	0	14.07 *	11.65	-4.79	21.40 *	18.4	8.96
19	DMIL 8 x DMIL 2	-3.7	-7.14	-7.14	19.19 **	12.58	7.99	21.41 *	19.38	8.05
20	DMIL 9 x DMIL 2	25.93 **	21.43 *	21.43 *	16.17 **	6.21	9.32	21.23 *	15.11	12
21	DMIL 10 x DMIL 2	-7.14	-13.33	-7.14	27.20 **	23.46 **	11.85	35.86 **	33.59 **	20.91
22	DMIL 11 x DMIL 2	-3.45	-12.5	0	30.87 **	28.83 **	9.85	38.05 **	33.81 **	17.06
23	DMIL 12 x DMIL 2	16.67	7.69	0	32.42 **	31.51 **	13.72 *	16.3	9.71	-4.03

Contd....

Sl. No.	F ₁ cross	No of rows per cob			Test weight (g)			Shelling %		
		RH	HB	SH	RH	HB	SH	RH	HB	SH
24	DMIL 13 x DMIL 2	-3.45	-12.5	0	39.10 **	36.16 **	16.11 *	-0.27	-0.94	-12.16
25	DMIL 14 x DMIL 2	-3.45	-12.5	0	13.64	10.09	-6.13	31.91 **	30.21 *	13.91
26	DMIL 4 x DMIL 3	-7.14	-13.33	-7.14	28.36 **	14.41 *	15.85 *	72.04 **	48.27 **	22.52 *
27	DMIL 5 x DMIL 3	18.52 *	14.29	14.29	36.56 **	33.78 **	10.52	30.39 *	6.43	0.63
28	DMIL 6 x DMIL 3	9.09	3.45	7.14	24.41 **	23.49 **	-2.13	66.55 **	40.82 **	21.86 *
29	DMIL 7 x DMIL 3	38.46 **	38.46 **	28.57 **	17.51 *	15.79	-5.46	43.66 **	18.5	9.05
30	DMIL 8 x DMIL 3	11.11	7.14	7.14	7.94	-1.44	-5.46	48.96 **	23.69 *	11.95
31	DMIL 9 x DMIL 3	11.11	7.14	7.14	0.86	-10.74	-8.12	29.75 *	4.75	1.92
32	DMIL 10 x DMIL 3	0	-6.67	0	6.3	-0.35	-9.72	57.08 **	30.43 *	18.06
33	DMIL 11 x DMIL 3	31.03 **	18.75 *	35.71 **	15.17 *	12.83	-6.79	66.52 **	43.91 **	18.15
34	DMIL 12 x DMIL 3	16.67	7.69	0	7.67	3.17	-10.79	68.07 **	48.83 **	15.44
35	DMIL 13 x DMIL 3	10.34	0	14.29	2.93	1.4	-17.18 *	57.81 **	32.12 **	17.16
36	1DMIL 4 x DMIL 3	17.24 *	6.25	21.43 *	28.81 **	28.25 **	2.53	66.57 **	41.72 **	20.78
37	DMIL 5 x DMIL 4	3.45	0	7.14	24.71 **	13.23 *	14.65 *	18.59	11.12	5.06
38	DMIL 6 x DMIL 4	1.69	0	7.14	19.39 **	5.73	7.06	27.92 *	25.04 *	8.21
39	DMIL 7 x DMIL 4	0	-6.67	0	19.69 **	8.1	9.45	34.23 **	27.38 *	17.22
40	DMIL 8 x DMIL 4	10.34	6.67	14.29	12.10 *	9.15	10.52	31.14 **	25.43 *	13.53
41	DMIL 9 x DMIL 4	10.34	6.67	14.29	14.52 *	13.58 *	16.91 *	19.68	10.66	7.67
42	DMIL 10 x DMIL 4	-6.67	-6.67	0	14.24 *	8.23	9.59	41.54 **	35.38 **	22.53 *
43	DMIL 11 x DMIL 4	-3.23	-6.25	7.14	13.12 *	2.71	3.99	33.36 **	32.93 *	9.85
44	DMIL 12 x DMIL 4	7.69	-6.67	0	1.57	-5.84	-4.66	27.11 *	23.21	1.81
45	DMIL 13 x DMIL 4	22.58 **	18.75 *	35.71 **	-8.28	-17.15 *	-16.11 *	45.04 **	40.10 **	24.24 *
46	DMIL 14 x DMIL 4	3.23	0	14.29	-2.26	-12.55	-11.45	33.06 **	31.04 *	11.68

Contd.....

Sl. No.	F ₁ cross	No of rows per cob			Test weight (g)			Shelling %		
		RH	HB	SH	RH	HB	SH	RH	HB	SH
47	DMIL 6 x DMIL 5	5.26	3.45	7.14	21.15 **	17.83 *	-2.66	18.3	13.29	7.11
48	DMIL 7 x DMIL 5	11.11	7.14	7.14	5.38	4.77	-13.45 *	28.94 **	27.22 *	20.29
49	DMIL 8 x DMIL 5	7.14	7.14	7.14	15.60 *	7.58	3.2	13.58	11.15	5.09
50	DMIL 9 x DMIL 5	0	0	0	14.97 *	3.62	6.66	21.94 *	20.21	16.96
51	DMIL 10 x DMIL 5	3.45	0	7.14	1.63	-2.85	-11.98	21.74 *	19.14	12.64
52	DMIL 11 x DMIL 5	0	-6.25	7.14	21.70 **	21.70 **	0.53	35.92 **	26.97 *	20.05
53	DMIL 12 x DMIL 5	12	0	0	27.58 **	24.73 **	7.86	39.64 **	27.10 *	20.17
54	DMIL 13 x DMIL 5	13.33	6.25	21.43 *	7.8	7.19	-11.45	19.86 *	16.14	9.81
55	DMIL 14 x DMIL 5	0	-6.25	7.14	26.15 **	24.11 **	2.53	34.24 **	27.62 *	20.66
56	DMIL 7 x DMIL 6	16.36 *	10.34	14.29	18.37 *	15.79	-5.46	20.27	16.69	7.38
57	DMIL 8 x DMIL 6	12.28	10.34	14.29	6.52	-3.39	-7.32	22.77 *	20.08	8.68
58	DMIL 9 x DMIL 6	19.30 **	17.24 *	21.43 *	16.23 *	2.2	5.19	27.69 **	20.63	17.37
59	DMIL 10 x DMIL 6	-5.08	-6.67	0	21.57 **	13.17	2.53	31.42 **	28.53 *	16.34
60	DMIL 11 x DMIL 6	-1.64	-6.25	7.14	33.08 **	29.43 **	6.92	36.41 **	32.91 **	15.02
61	DMIL 12 x DMIL 6	1.96	-10.34	-7.14	31.41 **	25.04 **	8.12	35.85 **	28.81 *	11.46
62	DMIL 13 x DMIL 6	-1.64	-6.25	7.14	10.02	7.6	-12.12	37.74 **	36.08 **	20.67
63	DMIL 14 x DMIL 6	-1.64	-6.25	7.14	18.81 *	17.42 *	-6.13	23.30 *	22.36	5.89
64	DMIL 8 x DMIL 7	25.93 **	21.43 *	21.43 *	4.68	-3.11	-7.06	25.86 *	24.82 *	14.87
65	DMIL 9 x DMIL 7	25.93 **	21.43 *	21.43 *	-5.06	-14.88 *	-12.38	27.98 **	24.51 *	21.14 *
66	DMIL 10 x DMIL 7	7.14	0	7.14	19.05 **	13.17	2.53	27.91 **	26.86 *	16.74
67	DMIL 11 x DMIL 7	-3.45	-12.5	0	32.30 **	31.53 **	8.66	27.96 **	21.06	11.4
68	DMIL 12 x DMIL 7	41.67 **	30.77 **	21.43 *	25.93 **	22.42 **	5.86	29.63 **	19.45	9.92
69	DMIL 13 x DMIL 7	17.24 *	6.25	21.43 *	35.33 **	35.31 **	10.52	13.42	11.36	2.48
70	DMIL 14 x DMIL 7	17.24 *	6.25	21.43 *	24.92 **	23.61 **	0.93	22.80 *	18.26	8.83

Contd.....

Sl. No.	F ₁ cross	No of rows per cob			Test weight (g)			Shelling %		
		RH	HB	SH	RH	HB	SH	RH	HB	SH
71	DMIL 9 x DMIL 8	14.29	14.29	14.29	8.75	5.05	8.12	20.92 *	16.7	13.55
72	DMIL 10 x DMIL 8	10.34	6.67	14.29	8.51	5.5	1.2	20.95 *	20.94	9.47
73	DMIL 11 x DMIL 8	13.33	6.25	21.43 *	-5.13	-11.72	-15.31 *	46.35 **	39.54 **	26.30 *
74	DMIL 12 x DMIL 8	4	-7.14	-7.14	-9.62	-14.08 *	-17.58 **	16.49	8.16	-2.11
75	DMIL 13 x DMIL 8	13.33	6.25	21.43 *	-1.48	-8.8	-12.52	37.66 **	36.27 **	23.34 *
76	DMIL 14 x DMIL 8	0	-6.25	7.14	-0.97	-9.22	-12.92	20.07	16.57	5.5
77	DMIL 10 x DMIL 9	3.45	0	7.14	-8.9	-14.36 *	-11.85	30.04 **	25.50 *	22.11 *
78	DMIL 11 x DMIL 9	13.33	6.25	21.43 *	-8.71	-17.72 **	-15.31 *	38.58 **	27.76 *	24.30 *
79	DMIL 12 x DMIL 9	12	0	0	12.77 *	3.75	6.79	37.93 **	23.94 *	20.59
80	DMIL 13 x DMIL 9	13.33	6.25	21.43 *	-2.91	-12.94 *	-10.39	15.86	10.73	7.74
81	DMIL 14 x DMIL 9	-6.67	-12.5	0	1.57	-9.77	-7.12	17.56	10.26	7.28
82	DMIL 11 x DMIL 10	-9.68	-12.5	0	15.47 *	10.38	0	26.56 *	20.67	9.23
83	1DMIL 2 x DMIL 10	15.38	0	7.14	22.27 **	19.49 **	8.26	38.05 **	28.18 *	16.02
84	DMIL 13 x DMIL 10	9.68	6.25	21.43 *	25.83 **	19.64 **	8.39	27.30 **	26.01 *	14.06
85	1DMIL 4 x DMIL 10	-3.23	-6.25	7.14	18.83 **	11.85	1.33	11.64	8.38	-1.9
86	1DMIL 2 x DMIL 11	11.11	-6.25	7.14	5.53	3.17	-10.79	37.32 **	33.53 *	9.62
87	DMIL 13 x DMIL 11	6.25	6.25	21.43 *	16.10 *	15.44	-4.63	41.07 **	35.84 **	20.46
88	DMIL 14 x DMIL 11	-6.25	-6.25	7.14	14.15 *	12.31	-7.22	34.96 **	32.48 *	12.91
89	DMIL 13 x DMIL 12	3.7	-12.5	0	3.98	1.09	-12.58	38.99 **	30.28 *	15.53
90	1DMIL 4 x DMIL 12	3.7	-12.5	0	8.02	3.94	-10.12	51.82 **	45.00 **	23.57 *
91	1DMIL 4 x DMIL 13	6.25	6.25	21.43 *	7.1	5.97	-13.45 *	29.89 **	27.36 *	12.94
	S.E.D.	1.01	1.17	1.17	2.15	2.49	2.49	6.80	7.85	7.85
	CD 5%	2.01	2.32	2.32	4.27	4.93	4.93	13.49	15.57	15.57
	CD 1%	2.66	3.07	3.07	5.65	6.52	6.52	17.85	20.61	20.61

* - Significant at 5% level

** - Significant at 1% level

The magnitude of heterosis ranged from -17.09 to 98.08 per cent for relative heterosis, -11.7 to 92.11 per cent for heterobeltiosis and -27.60 to 23.33 per cent for standard heterosis. exhibited significant standard heterosis in desirable direction.

An average heterosis of 55.08 per cent was recorded for this character.

4.4.14 Protein content (%)

Fifty nine and forty one crosses showed significant positive relative heterosis and heterobeltiosis, respectively, while twenty four crosses exhibited standard heterosis in desirable direction. Relative heterosis ranged from -30.84 to 42.12 per cent, heterobeltiosis ranged from -36.62 to 32.39 per cent and standard heterosis ranged from -40.41 to 29.22 per cent. Crosses DMIL 10 x DMIL 3 (29.22%), DMIL 10 x DMIL 9 (14.79%) and DMIL 11 x DMIL 10 (14.61%) showed highest positive significant heterosis over standard check. The average heterosis recorded for this character was 28.71 per cent.

4.2.15 Starch content (%)

Seventy three and forty six crosses recorded positive relative heterosis and heterobeltiosis, respectively. Nineteen crosses exhibited significant positive standard heterosis, among these DMIL 10 x DMIL 3 (3.55%), DMIL 9 x DMIL 3 (3.38%) and DMIL 7 x DMIL 3 (3.22%) crosses showed highest significant positive heterosis over standard check. Relative heterosis ranged from -3.64 to 11.28 per cent, heterobeltiosis ranged from -5.09 to 9.73 per cent and standard heterosis ranged from -6.01 to 3.55 per cent. The average heterosis recorded for this character was 3.06 per cent.

4.3 Combining ability

4.3.1 Combining ability variance

Analysis of variance for combining ability with respect to 15 characters are presented in Table 10. From this analysis it is evident that both GCA and SCA variances were significant for all the 14 characters except for shelling percentage only SCA variance is significant. Thus indicating the importance of both additivity and non additivity in the inheritance of these characters.

It is also evident from the data that the components due to both SCA variances and GCA variance in the all characters. The ratio GCA/SCA was less than unity, which indicated the predominance of dominance variance in control of these traits (Table 10).

4.3.2 Combining ability effects

The GCA effects (*gca*) and SCA effects (*sca*) were estimated for 15 characters in 14 x 14 half diallel crosses without reciprocals. The estimates for all the 15 characters including yield and yield component traits are presented (Table 11 and 12) and results are given below.

4.3.2.1 Days to 50 per cent tasseling

Among 14 parents studied, 3 parents DMIL 5 (-0.487), DMIL 6 (-0.799) and DMIL 7 (-0.237) exhibited desirable significant and negative *gca* effects. The highest positive significant *gca* effect was recorded for parent DMIL 2 (0.924).

Of 91 hybrids evaluated 48 hybrids recorded significant positive *sca* effects, while 39 hybrids exhibited significant negative *sca* effects. The hybrid DMIL 5 x DMIL 2 (-3.108) recorded the highest significant negative *sca* effects followed by DMIL 13 x DMIL 6 (-3.046) and DMIL 5 x DMIL 4 (-2.983).

4.3.2.2 Days to 50 per cent silking

Out of 14 parents, 5 parent DMIL 4 (-0.277), DMIL 5 (-0.433), DMIL 9 (-0.183), DMIL 10 (-0.183) and DMIL 11 (-0.214) exhibited negative *gca* effects and 2 parents exhibited *gca* effects in undesired positive direction.

Among 91 hybrids, 27 hybrids showed significant positive *sca* effects and 21 showed significant negative *sca* effects. Hybrid DMIL 14 x DMIL 4 (-2.248) had a highest negative significant effect followed by DMIL 6 x DMIL 5 (-2.000) and DMIL 8 x DMIL 6 (-1.81).

Table 8: Per cent relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) for yield characters in maize

Sl. No.	F ₁ cross	Grain yield per plant (g)			Grain yield per hectare (q)		
		RH	HB	SH	RH	HB	SH
1	DMIL 2 x DMIL 1	89.68 **	84.91 **	3.16	95.52**	90.29**	3.27
2	DMIL 3 x DMIL 1	13.04	4.84	-31.58 **	22.36	13	-27.60 **
3	DMIL 4 x DMIL 1	22.99 *	13.23	-24.91 **	24.31 *	13.93	-25.77 **
4	DMIL 5 x DMIL 1	58.07 **	43.81 **	-2.11	61.37**	46.06**	-2.18
5	DMIL 6 x DMIL 1	27.54 *	18.28	-22.81 **	29.14 *	19.26	-23.59 **
6	DMIL 7 x DMIL 1	51.83 **	47.34 **	-12.63	55.01 **	50.15**	-13.07
7	DMIL 8 x DMIL 1	38.05 **	30.00 *	-17.89 *	40.31 **	31.67 *	-18.51 *
8	DMIL 9 x DMIL 1	63.32 **	50.00 **	0	66.96**	52.62**	0
9	DMIL 10 x DMIL 1	61.76 **	51.93 **	-3.51	65.41 **	54.80**	-3.63
10	DMIL 11 x DMIL 1	36.96 **	25.79 *	-16.14 *	39.08**	27.14 *	-16.70*
11	1DMIL 2 x DMIL 1	57.55 **	44.66 **	-3.51	60.85**	47.00**	-3.63
12	DMIL 13 x DMIL 1	57.19 **	52.98 **	-9.82	60.70**	56.14**	-10.16
13	1DMIL 4 x DMIL 1	85.40 **	83.65 **	2.46	90.86**	88.95**	2.54
14	DMIL 3 x DMIL 2	29.38 *	17.2	-23.51 **	31.13 *	18.13	-24.32 **
15	DMIL 4 x DMIL 2	59.41 **	43.39 **	-4.91	62.92**	45.68**	-5.08
16	DMIL 5 x DMIL 2	52.46 **	35.57 **	-7.72	55.51 **	37.39**	-7.98
17	DMIL 6 x DMIL 2	67.95 **	52.15 **	-0.7	72.00**	54.95**	-0.73
18	DMIL 7 x DMIL 2	77.50 **	68.05 **	-0.35	82.38**	72.09**	-0.36
19	DMIL 8 x DMIL 2	69.79 **	56.11 **	-1.4	74.03**	59.23**	-1.45
20	DMIL 9 x DMIL 2	85.34 **	66.32 **	10.88	90.62**	70.03**	11.4
21	DMIL 10 x DMIL 2	65.06 **	51.38 **	-3.86	69.00**	54.22**	-3.99
22	DMIL 11 x DMIL 2	37.83 **	23.68	-17.54 *	40.06**	24.93	-18.15*

Contd.....

Sl. No.	F ₁ cross	Grain yield per plant (g)			Grain yield per hectare (q)		
		RH	HB	SH	RH	HB	SH
23	DMIL 12 x DMIL 2	60.07 **	43.61 **	-4.21	63.60**	45.90**	-4.36
24	DMIL 13 x DMIL 2	61.13 **	52.98 **	-9.82	64.99**	56.14**	-10.16
25	DMIL 14 x DMIL 2	70.03 **	67.31 **	-8.42	74.64**	71.66**	-8.71
26	DMIL 4 x DMIL 3	80.27 **	78.84 **	18.60 *	99.08**	92.65**	19.24 *
27	DMIL 5 x DMIL 3	61.58 **	58.25 **	7.72	64.81 **	61.24 **	7.98
28	DMIL 6 x DMIL 3	43.01 **	43.01 **	-6.67	45.32**	45.32**	-6.9
29	DMIL 7 x DMIL 3	75.77 **	67.74 **	9.47	80.23**	71.56**	9.91
30	DMIL 8 x DMIL 3	65.03 **	62.37 **	5.96	68.58**	65.71 **	6.17
31	DMIL 9 x DMIL 3	63.30 **	61.58 **	7.72	66.66**	64.81 **	7.98
32	DMIL 10 x DMIL 3	61.85 **	59.68 **	4.21	65.22**	62.88**	4.36
33	DMIL 11 x DMIL 3	19.68	18.42	-21.05 *	20.73	19.39	-21.78*
34	DMIL 12 x DMIL 3	70.17 **	68.33 **	12.28	73.89**	71.92**	12.7
35	DMIL 13 x DMIL 3	36.72 **	30.11 *	-15.09	38.80**	31.72 *	-15.61
36	1DMIL 4 x DMIL 3	37.43 **	26.34 *	-17.54 *	39.62**	27.76 *	-18.15*
37	DMIL 5 x DMIL 4	35.25 **	33.51 **	-9.12	37.08**	35.23**	-9.44
38	DMIL 6 x DMIL 4	49.33 **	48.15 **	-1.75	51.96**	50.69**	-1.81
39	DMIL 7 x DMIL 4	73.18 **	64.02 **	8.77	79.17**	69.19**	10.24
40	DMIL 8 x DMIL 4	76.15 **	71.96 **	14.04	80.27**	75.75**	14.52
41	DMIL 9 x DMIL 4	70.98 **	70.53 **	13.68	75.76**	75.28**	14.84
42	DMIL 10 x DMIL 4	68.65 **	65.08 **	9.47	73.61 **	69.74**	10.6
43	DMIL 11 x DMIL 4	41.95 **	41.58 **	-5.61	44.16**	43.76**	-5.81
44	DMIL 12 x DMIL 4	25.56 *	25.20 *	-16.49 *	26.91 *	26.52 *	-17.06*
45	DMIL 13 x DMIL 4	35.57 **	28.04 *	-15.09	37.57**	29.52 *	-15.61
46	DMIL 14 x DMIL 4	21.74	11.11	-26.32 **	23	11.7	-27.22**

Contd.....

Sl. No.	F ₁ cross	Grain yield per plant (g)			Grain yield per hectare (q)		
		RH	HB	SH	RH	HB	SH
47	DMIL 6 x DMIL 5	27.37 *	24.74 *	-15.09	28.80 *	26.01 *	-15.61
48	DMIL 7 x DMIL 5	52.07 **	42.27 **	-3.16	54.93**	44.44**	-3.27
49	DMIL 8 x DMIL 5	55.61 **	50.00 **	2.11	58.58**	52.57**	2.18
50	DMIL 9 x DMIL 5	81.25 **	79.38 **	22.11 **	86.02**	84.00**	23.23**
51	DMIL 10 x DMIL 5	25.33 *	21.13	-17.54 *	26.68 *	22.22	-18.15*
52	DMIL 11 x DMIL 5	70.83 **	69.07 **	15.09	75.80**	73.90**	16.46
53	DMIL 12 x DMIL 5	61.42 **	59.79 **	8.77	64.60**	62.86**	9.07
54	DMIL 13 x DMIL 5	60.77 **	50.00 **	2.11	64.13**	52.57**	2.18
55	DMIL 14 x DMIL 5	87.43 **	69.07 **	15.09	92.43**	72.62**	15.61
56	DMIL 7 x DMIL 6	79.15 **	70.97 **	11.58	83.62**	74.78**	11.98
57	DMIL 8 x DMIL 6	48.09 **	45.70 **	-4.91	50.71**	48.15**	-5.08
58	DMIL 9 x DMIL 6	65.43 **	63.68 **	9.12	68.90**	67.03**	9.44
59	DMIL 10 x DMIL 6	24.80 *	23.12	-19.65 *	26.15 *	24.36	-20.32*
60	DMIL 11 x DMIL 6	25.00 *	23.68	-17.54 *	26.33 *	24.93	-18.15*
61	DMIL 12 x DMIL 6	45.17 **	43.61 **	-4.21	47.57**	45.90**	-4.36
62	DMIL 13 x DMIL 6	68.36 **	60.22 **	4.56	72.23**	63.45**	4.72
63	DMIL 14 x DMIL 6	70.18 **	56.45 **	2.11	74.29**	59.48**	2.18
64	DMIL 8 x DMIL 7	93.70 **	87.78 **	18.60 *	84.12**	82.59**	18.97 *
65	DMIL 9 x DMIL 7	39.83 **	32.11 **	-11.93	42.05**	33.79**	-12.34
66	DMIL 10 x DMIL 7	93.71 **	87.29 **	18.95 *	99.08**	92.11**	19.60 *
67	DMIL 11 x DMIL 7	42.06 **	34.21 **	-10.53	44.40**	36.01**	-10.89
68	DMIL 12 x DMIL 7	36.45 **	28.88 *	-14.04	38.48**	30.39 *	-14.52
69	DMIL 13 x DMIL 7	40.65 **	40.24 **	-16.84 *	43.07**	42.63**	-17.42*
70	DMIL 14 x DMIL 7	44.00 **	38.46 **	-17.89 *	46.72**	40.75**	-18.51*

Contd.....

Sl. No.	F ₁ cross	Grain yield per plant (g)			Grain yield per hectare (q)		
		RH	HB	SH	RH	HB	SH
71	DMIL 9 x DMIL 8	77.30 **	72.63 **	15.09	82.49**	77.43**	16.26
72	DMIL 10 x DMIL 8	25.76 *	25.41 *	-20.35 *	27.19 *	26.82 *	-21.05 *
73	DMIL 11 x DMIL 8	16.22	13.16	-24.56 **	17.09	13.85	-25.41 **
74	DMIL 12 x DMIL 8	45.91 **	42.03 **	-5.26	48.38**	44.23**	-5.44
75	DMIL 13 x DMIL 8	35.06 **	30.56 *	-17.54 *	37.08**	32.25 *	-18.15 *
76	DMIL 14 x DMIL 8	41.67 **	32.22 *	-16.49 *	44.16**	34.01 *	-17.06 *
77	DMIL 10 x DMIL 9	25.07 *	22.11	-18.60 *	26.42 *	23.27	-19.24 *
78	DMIL 11 x DMIL 9	44.74 **	44.74 **	-3.51	47.08**	47.08**	-3.63
79	DMIL 12 x DMIL 9	68.90 **	68.86 **	12.63	73.63**	73.58**	13.79
80	DMIL 13 x DMIL 9	32.40 **	24.74 *	-16.84 *	34.21**	26.03 *	-17.42 *
81	DMIL 14 x DMIL 9	53.76 **	40.00 **	-6.67	56.87**	42.10**	-6.9
82	DMIL 11 x DMIL 10	20.75	17.89	-21.40 **	21.87	18.83	-22.14 **
83	1DMIL 2 x DMIL 10	27.19 *	24.15 *	-17.19 *	28.65 *	25.41 *	-17.78 *
84	DMIL 13 x DMIL 10	36.96 **	32.04 *	-16.14 *	39.08**	33.81 *	-16.70 *
85	1DMIL 4 x DMIL 10	96.44 **	82.87 **	16.14 *	98.18**	87.45**	16.70 *
86	1DMIL 2 x DMIL 11	38.38 **	38.35 **	-7.72	40.40**	40.36**	-7.98
87	DMIL 13 x DMIL 11	51.40 **	42.63 **	-4.91	54.27**	44.87**	-5.08
88	DMIL 14 x DMIL 11	52.60 **	38.95 **	-7.37	55.65**	40.99**	-7.62
89	DMIL 13 x DMIL 12	22.31 *	15.2	-23.16 **	23.56 *	16	-23.95**
90	1DMIL 4 x DMIL 12	35.22 **	23.09	-17.89 *	37.26**	24.3	-18.51 *
91	1DMIL 4 x DMIL 13	51.23 **	45.83 **	-14.04	54.42**	48.57**	-14.52
	S.E.D.	9.93	11.49	11.49	5.25	6.06	6.06
	CD 5%	19.69	22.73	22.73	10.41	12.2	12.2
	CD 1%	26.05	30.08	30.08	13.77	15.91	15.91

* - Significant at 5% level

** - Significant at 1% level

Table 9: Per cent relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) for quality characters in maize5 x 2

Sl. No.	F ₁ cross	Protein (%)			Starch (%)		
		RH	HB	SH	RH	HB	SH
1	DMIL 2 x DMIL 1	18.24 **	14.34 **	2.9	2.43 **	1.73 **	-2.28 **
2	DMIL 3 x DMIL 1	23.82 **	23.69 **	4.19 *	0.99 **	-1.19 **	-2.15 **
3	DMIL 4 x DMIL 1	13.03 **	8.35 **	-0.69	0.99 **	-1.85 **	-1.48 **
4	DMIL 5 x DMIL 1	36.30 **	29.39 **	8.76 **	-0.21	-2.37 **	-3.31 **
5	DMIL 6 x DMIL 1	20.10 **	18.26 **	-0.6	2.12 **	1.20 **	-2.36 **
6	DMIL 7 x DMIL 1	14.15 **	13.93 **	-3.87	6.74 **	6.36 **	1.49 **
7	DMIL 8 x DMIL 1	-13.43 **	-16.39 **	-29.72 **	7.29 **	6.44 **	0.85 **
8	DMIL 9 x DMIL 1	5.49 **	-0.1	-6.08 **	3.97 **	3.25 **	-0.80 *
9	DMIL 10 x DMIL 1	16.59 **	8.50 **	5.90 **	3.40 **	2.60 **	-1.27 **
10	DMIL 11 x DMIL 1	-22.59 **	-29.14 **	-28.29 **	1.55 **	1.18 **	-3.45 **
11	1DMIL 2 x DMIL 1	6.90 **	1.07	-4.65 *	2.28 **	-0.53	-0.28
12	DMIL 13 x DMIL 1	13.84 **	8.32 **	0.83	6.24 **	4.64 **	-0.86 **
13	1DMIL 4 x DMIL 1	-11.36 **	-17.52 **	-19.49 **	4.82 **	2.55 **	-2.84 **
14	DMIL 3 x DMIL 2	-8.17 **	-11.11 **	-20.00 **	1.05 **	-0.47	-1.44 **
15	DMIL 4 x DMIL 2	5.58 **	4.63 *	-4.1	0.12	-2.03 **	-1.67 **
16	DMIL 5 x DMIL 2	5.62 *	-2.87	-12.58 **	-3.64 **	-5.09 **	-6.01 **
17	DMIL 6 x DMIL 2	3.41	-1.48	-11.34 **	6.65 **	6.41 **	2.67 **
18	DMIL 7 x DMIL 2	-26.53 **	-28.83 **	-35.94 **	0.89 **	0.55	-3.41 **
19	DMIL 8 x DMIL 2	26.56 **	18.33 **	6.50 **	8.73 **	7.13 **	2.91 **
20	DMIL 9 x DMIL 2	8.04 **	5.74 *	-0.6	5.65 **	5.64 **	1.50 **
21	DMIL 10 x DMIL 2	-19.33 **	-22.47 **	-24.33 **	1.83 **	1.74 **	-2.10 **
22	DMIL 11 x DMIL 2	1.18	-4.42 *	-3.27	3.03 **	2.69 **	-1.35 **

Contd.....

Sl. No.	F ₁ cross	Protein (%)			Starch (%)		
		RH	HB	SH	RH	HB	SH
23	DMIL 12 x DMIL 2	5.55 **	3.13	-2.72	1.18 **	-0.93 **	-0.68 *
24	DMIL 13 x DMIL 2	8.18 **	6.39 **	-0.97	6.37 **	4.06 **	-0.04
25	DMIL 14 x DMIL 2	8.03 **	3.82	1.34	7.20 **	4.18 **	0.07
26	DMIL 4 x DMIL 3	8.62 **	4.22	-4.47 *	-1.31 **	-1.97 **	-1.61 **
27	DMIL 5 x DMIL 3	19.64 **	13.46 **	-4.42 *	-1.22 **	-1.22 **	-2.18 **
28	DMIL 6 x DMIL 3	22.36 **	20.35 **	1.38	-1.06 **	-2.33 **	-3.28 **
29	DMIL 7 x DMIL 3	24.62 **	24.52 **	5.07 *	6.17 **	4.24 **	3.22 **
30	DMIL 8 x DMIL 3	-4.68 *	-8.04 **	-22.53 **	3.04 **	0.03	-0.94 **
31	DMIL 9 x DMIL 3	25.90 **	19.36 **	12.21 **	5.98 **	4.40 **	3.38 **
32	DMIL 10 x DMIL 3	42.12 **	32.39 **	29.22 **	6.07 **	4.57 **	3.55 **
33	DMIL 11 x DMIL 3	6.11 **	-2.78	-1.61	2.33 **	0.47	-0.51
34	DMIL 12 x DMIL 3	-1.57	-6.84 **	-12.12 **	-0.75 **	-1.36 **	-1.11 **
35	DMIL 13 x DMIL 3	8.68 **	3.51	-3.64	2.41 **	-1.28 **	-2.24 **
36	1DMIL 4 x DMIL 3	15.46 **	7.55 **	4.98 *	3.11 **	-1.25 **	-2.21 **
37	DMIL 5 x DMIL 4	13.01 **	3.07	-5.53 **	-2.62 **	-3.27 **	-2.91 **
38	DMIL 6 x DMIL 4	22.44 **	15.64 **	5.99 **	1.33 **	-0.63 *	-0.26
39	DMIL 7 x DMIL 4	10.16 **	5.78 *	-3.04	-0.67 *	-3.12 **	-2.76 **
40	DMIL 8 x DMIL 4	13.88 **	5.58 *	-3.23	0.96 **	-2.63 **	-2.27 **
41	DMIL 9 x DMIL 4	9.95 **	8.58 **	2.07	-0.58 *	-2.71 **	-2.35 **
42	DMIL 10 x DMIL 4	2.22	-0.9	-3.27	0.38	-1.69 **	-1.32 **
43	DMIL 11 x DMIL 4	-8.20 **	-12.52 **	-11.47 **	-1.18 **	-3.61 **	-3.25 **
44	DMIL 12 x DMIL 4	1.78	0.34	-5.35 *	-1.73 **	-1.79 **	-1.42 **
45	DMIL 13 x DMIL 4	3.27	2.48	-4.61 *	3.31 **	-1.05 **	-0.68 *
46	DMIL 14 x DMIL 4	15.36 **	11.85 **	9.17 **	4.85 **	-0.23	0.14

Contd.....

Sl. No.	F ₁ cross	Protein (%)			Starch (%)		
		RH	HB	SH	RH	HB	SH
47	DMIL 6 x DMIL 5	3.55	-0.23	-18.71 **	-0.55 *	-1.83 **	-2.77 **
48	DMIL 7 x DMIL 5	17.35 **	11.20 **	-6.18 **	1.26 **	-0.59	-1.55 **
49	DMIL 8 x DMIL 5	22.35 **	20.19 **	-5.90 **	3.85 **	0.81 *	-0.16
50	DMIL 9 x DMIL 5	-2.15	-11.76 **	-17.05 **	1.07 **	-0.45	-1.41 **
51	DMIL 10 x DMIL 5	2.79	-8.83 **	-11.01 **	0.83 **	-0.6	-1.56 **
52	DMIL 11 x DMIL 5	-8.47 **	-20.08 **	-19.12 **	1.33 **	-0.51	-1.47 **
53	DMIL 12 x DMIL 5	22.63 **	10.41 **	4.15 *	1.50 **	0.89 **	1.14 **
54	DMIL 13 x DMIL 5	6.81 **	-3.27	-9.95 **	2.24 **	-1.45 **	-2.40 **
55	DMIL 14 x DMIL 5	1.36	-10.10 **	-12.26 **	3.12 **	-1.25 **	-2.20 **
56	DMIL 7 x DMIL 6	25.65 **	23.48 **	4.19 *	4.67 **	4.09 **	0.43
57	DMIL 8 x DMIL 6	6.32 **	4.24	-15.07 **	2.96 **	1.23 **	-2.33 **
58	DMIL 9 x DMIL 6	18.96 **	11.03 **	4.38 *	5.23 **	5.01 **	1.32 **
59	DMIL 10 x DMIL 6	-11.22 **	-18.56 **	-20.51 **	2.65 **	2.51 **	-1.09 **
60	DMIL 11 x DMIL 6	11.00 **	0.18	1.38	0.69 *	0.13	-3.39 **
61	DMIL 12 x DMIL 6	8.05 **	0.68	-5.02 *	1.08 **	-0.82 **	-0.57
62	DMIL 13 x DMIL 6	8.87 **	2.08	-4.98 *	6.60 **	4.06 **	0.4
63	DMIL 14 x DMIL 6	2.62	-5.85 **	-8.11 **	4.24 **	1.09 **	-2.47 **
64	DMIL 8 x DMIL 7	10.25 **	6.28 *	-10.32 **	3.66 **	2.48 **	-2.21 **
65	DMIL 9 x DMIL 7	1.63	-3.58	-9.35 **	1.93 **	1.59 **	-2.40 **
66	DMIL 10 x DMIL 7	-3.87	-10.39 **	-12.53 **	0.43	0.02	-3.76 **
67	DMIL 11 x DMIL 7	5.44 **	-3.32	-2.17	3.22 **	3.22 **	-1.50 **
68	DMIL 12 x DMIL 7	-13.15 **	-17.73 **	-22.40 **	-1.39 **	-3.77 **	-3.52 **
69	DMIL 13 x DMIL 7	19.45 **	13.86 **	5.99 **	1.65 **	-0.23	-4.79 **
70	DMIL 14 x DMIL 7	-0.38	-7.13 **	-9.35 **	4.59 **	1.97 **	-2.70 **

Contd....

Sl. No.	F ₁ cross	Protein (%)			Starch (%)		
		RH	HB	SH	RH	HB	SH
71	DMIL 9 x DMIL 8	-30.84 **	-36.62 **	-40.41 **	0.90 **	-0.59	-4.49 **
72	DMIL 10 x DMIL 8	8.36 **	-2.36	-4.70 *	5.24 **	3.61 **	-0.31
73	DMIL 11 x DMIL 8	1.87	-9.65 **	-8.57 **	4.43 **	3.24 **	-1.49 **
74	DMIL 12 x DMIL 8	6.09 **	-2.93	-8.43 **	3.49 **	-0.13	0.12
75	DMIL 13 x DMIL 8	-0.99	-8.86 **	-15.16 **	7.22 **	6.44 **	-0.75 *
76	DMIL 14 x DMIL 8	28.16 **	15.49 **	12.72 **	11.28 **	9.73 **	2.31 **
77	DMIL 10 x DMIL 9	19.82 **	17.61 **	14.79 **	5.79 **	5.70 **	1.71 **
78	DMIL 11 x DMIL 9	-3.21	-6.65 **	-5.53 **	6.28 **	5.92 **	1.76 **
79	DMIL 12 x DMIL 9	-5.21 **	-5.37 *	-10.74 **	-1.27 **	-3.33 **	-3.08 **
80	DMIL 13 x DMIL 9	5.02 *	4.51 *	-1.75	4.81 **	2.53 **	-1.50 **
81	DMIL 14 x DMIL 9	15.01 **	12.89 **	10.18 **	9.34 **	6.25 **	2.08 **
82	DMIL 11 x DMIL 10	15.30 **	13.25 **	14.61 **	5.99 **	5.55 **	1.56 **
83	1DMIL 2 x DMIL 10	-21.30 **	-22.62 **	-24.47 **	-1.26 **	-3.25 **	-3.00 **
84	DMIL 13 x DMIL 10	-4.35 *	-6.56 **	-8.80 **	8.69 **	6.25 **	2.24 **
85	1DMIL 4 x DMIL 10	9.44 **	9.44 **	6.82 **	9.01 **	5.85 **	1.85 **
86	1DMIL 2 x DMIL 11	10.16 **	6.42 **	7.70 **	2.97 **	0.48	0.74 *
87	DMIL 13 x DMIL 11	10.77 **	6.33 **	7.60 **	8.85 **	6.83 **	1.94 **
88	DMIL 14 x DMIL 11	6.44 **	4.55 *	5.81 **	5.05 **	2.42 **	-2.27 **
89	DMIL 13 x DMIL 12	11.97 **	11.24 **	4.93 *	3.77 **	-0.56	-0.31
90	1DMIL 4 x DMIL 12	15.82 **	13.88 **	11.15 **	6.57 **	1.46 **	1.72 **
91	1DMIL 4 x DMIL 13	4.40 *	1.98	-0.46	7.85 **	7.11 **	-1.57 **
	S.E.D.	0.19	0.23	0.23	0.18	0.21	0.21
	CD 5%	0.39	0.45	0.45	0.36	0.41	0.41
	CD 1%	0.51	0.59	0.59	0.47	0.54	0.54

Table 10: Analysis of variance for combining ability in maize

Source	GCA	SCA	Error	GCA variance	SCA variance	GCA variance/SCA variance
Days to 50% tasseling	3.523**	1.584**	0.022	0.219	1.563	0.14
Days to 50% silking	1.084**	1.157**	0.081	0.063	1.075	0.058
Days to 50% brown husking	3.401**	3.069**	0.161	0.203	2.908	0.07
Plant height (cm)	729.849 **	433.381 **	63.349	41.656	370.032	0.113
Ear height (cm)	470.873 **	202.962 **	73.657	24.826	129.305	0.192
Ear length (cm)	5.776 **	4.916 **	0.368	0.338	4.548	0.074
Ear width (cm)	3.776 **	2.697 **	0.794	0.186	1.902	0.098
No. of kernels per row	18.613 **	27.062 **	0.828	1.112	26.235	0.042
No. of rows per cob	5.679 **	1.710 **	0.686	0.312	1.024	0.305
Test weight (g)	25.208 **	13.449 **	3.089	1.382	10.361	0.133
Shelling %	38.215	85.828 **	30.838	0.461	54.99	0.008
Grain yield per plant (g)	471.305 **	558.330 **	65.708	25.35	492.622	0.0515
Grain yield per ha (q/ha)	132.21**	155.59**	18.37	7.12	137.23	0.05
Protein content (%)	2.172 **	1.433 **	0.025	0.134	1.407	0.095
Starch content (%)	1.658 **	2.579 **	0.021	0.102	2.558	0.04

GCA – General combining ability

SCA – Specific combining ability

* - Significant at 5 per cent probability

** - Significant at 1 per cent probability

Table 11: General Combining effects for 14 parents in maize

	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear width (cm)	No of kernels per row	No of rows per cob
DMIL 1	0.326**	0.129	-0.219*	3.616	-9.646 **	-0.352 *	-0.204	-1.281 **	-0.710 **
DMIL 2	0.924**	-0.027	-0.219*	7.332 **	-3.433	-0.330 *	-0.348	-0.031	-0.647 **
DMIL 3	0.326**	0.067	-0.063	7.004 **	2.438	0.348 *	-0.429 *	1.031 **	0.04
DMIL 4	-0.049	-0.277**	0.25*	4.613 *	10.126 **	0.273	0.639 **	0.594 **	0.165
DMIL 5	-0.487**	-0.433**	0.406**	4.460 *	-3.755	-0.405 **	0.402	0.281	-0.085
DMIL 6	-0.799**	0.536**	-0.656**	-0.778	5.198 *	-0.921 **	0.296	-1.031 **	-0.022
DMIL 7	-0.237**	0.098	-0.594**	5.760 **	5.001 *	0.651 **	0.299	-0.781 **	0.415 *
DMIL 8	0.107**	-0.121	-0.094	5.894 **	-6.655 **	-0.139	0.333	1.719 **	0.04
DMIL 9	0.013	-0.183*	-0.219*	-13.403 **	-4.355 *	0.639 **	0.514 *	1.531 **	0.478 *
DMIL 10	0.263**	-0.183*	0.344**	-6.028 **	-2.296	1.076 **	-0.298	0.781 **	-0.397 *
DMIL 11	0.295**	-0.214*	-0.469**	-4.200 *	2.142	-0.511 **	0.608 **	-0.938 **	0.603 **
DMIL 12	0.076*	0.098	0.438**	-6.090 **	5.313 *	-0.824 **	-0.426 *	-0.063	-1.210 **
DMIL 13	0.326**	0.379**	0.063	-9.715 **	-0.983	-0.055	-0.711 **	-1.875 **	1.103 **
DMIL 14	0.763**	0.129	1.031**	1.535	0.907	0.548 **	-0.673 **	0.063	0.228
SEm+	0.035	0.069	0.097	1.917	2.068	0.146	0.215	0.219	0.200
CD at 5%	0.070	0.136	0.192	3.802	4.100	0.290	0.426	0.435	0.396
CD at 1%	0.093	0.180	0.253	5.031	5.425	0.383	0.563	0.575	0.524

Contd.....

Table 11 contd...

	Test wt (g)	Shelling %	Grain yield/ pt (g)	Grain yield/ ha	Protein content (%)	Starch content (%)
DMIL -1	-2.701 **	-3.396 *	-7.567 **	-3.994 ***	-0.135 **	-0.351 **
DMIL -2	1.478 **	-1.756	-1.755	-0.926	-0.287 **	0.048
DMIL -3	-0.57	-1.836	2.12	1.119	0.268 **	0.477 **
DMIL -4	2.152 **	0.287	3.183	1.68	0.255 **	-0.009
DMIL -5	0.265	1.747	8.651 **	4.566 ***	-0.515 **	-0.328 **
DMIL -6	0.487	0.289	0.651	0.344	-0.145 **	0.006
DMIL -7	0.086	0.341	3.683	1.944	-0.328 **	-0.491 **
DMIL -8	-0.285	-0.527	1.464	0.773	-0.715 **	-0.06
DMIL -9	1.080 *	1.652	9.776 **	5.160 ***	0.155 **	0.365 **
DMIL -10	0.899 *	1.727	-1.755	-0.926	0.269 **	0.410 **
DMIL -11	-0.279	1.521	-5.942 **	-3.136 **	0.286 **	-0.04
DMIL -12	0.063	-0.8	-0.342	-0.181	0.023	0.465 **
DMIL -13	-1.261 **	0.876	-8.192 **	-4.324 ***	0.257 **	-0.246 **
DMIL -14	-1.415 **	-0.127	-3.974 *	-2.097 *	0.613 **	-0.247 **
SEm+	0.423	1.338	1.952	1.031	0.038	0.035
CD at 5%	0.839	2.653	3.872	2.022	0.076	0.070
CD at 1%	1.109	3.510	5.124	2.704	0.100	0.092

* - Significant at 5 per cent probability

** - Significant at 1 per cent probability

4.3.2.3 Days to 50 per cent brown husk maturity

Of the 14 parents, only 6 parents exhibited desirable significant negative gca effects. 5 out of 14 parents showed positive gca effects. The highest positive gca effect was recorded by DMIL 12 (0.438), which is in undesired positive direction and highest negative effect showed by DMIL 6 (-0.656)

The sca effects were significant for 65 hybrids of which, 39 hybrids had negative sca effects. The hybrids, DMIL 8 x DMIL 1 (-3.188) recorded highest negative sca effects in desirable direction followed by DMIL 11 x DMIL 9 (-2.813) and DMIL 6 x DMIL 3 (-2.781). Totally 26 showed significant positive sca effects.

4.3.2.4 Plant height (cm)

Out of 14 parents, 6 parents exhibited significant positive effects and 5 parents showed negative significant gca effects. The highest positive effect was recorded by DMIL 2 (7.332) followed by DMIL 3 (7.004), DMIL 8 (5.894), DMIL 7 (5.760), DMIL 4 (4.613), DMIL 5 (4.460) and the highest negative gca effect was for DMIL 9 (-13.403).

Among the 91 hybrids 19 showed positive significant sca effect and 15 showed significant negative sca effects. Among these hybrid DMIL 11 x DMIL 6 (31.848), DMIL 10 x DMIL 9 (31.301) and DMIL 12 x DMIL 5 (31.001) exhibited highest positive sca effect .

4.3.2.5 Ear height (cm)

The parents which contributed significant positive gca effects were DMIL 4 (10.126), DMIL 6 (5.198), DMIL 7 (5.001) and DMIL 11 (5.313). Three parents exhibited undesirable negative significant effect.

Out of 91 hybrids, 8 exhibited positive gca effects, among these DMIL 9 x DMIL 2 (26.61), DMIL 10 x DMIL 7 (23.616) and DMIL 8 x DMIL 6 (22.779) had highest positive significant sca effects, and totally 8 hybrids exhibited negative significant sca effect.

4.3.2.6 Ear length (cm)

Out of 14 parents, 5 parents had positive significant gca effects for ear length. Among them one parent DMIL 10 (1.076) had highest positive significant gca effect, 6 parents (DMIL 1, DMIL 2, DMIL 5, DMIL 6, DMIL 11 and DMIL 12) had undesired significantly negative gca effects for this trait.

Though, 30 hybrids out of 91 showed significant sca effect for the trait ear length only 23 hybrids were positively significant with DMIL 9 x DMIL 6 (4.136) having maximum sca effect followed by DMIL 8 x DMIL 3 (3.646) and DMIL 14 x DMIL 6 (3.427). Seven hybrids with negative and significant sca effect.

4.3.2.7 Ear width (cm)

Out of 14 parents, 3 parents DMIL 4 (0.639), DMIL 9 (0.514) and DMIL 11 (0.608) exhibited positive significant gca effects and 4 parents (DMIL 3, DMIL 12, DMIL 13 and DMIL 14) exhibited negative gca effects for the trait, while DMIL 13 (-0.711) exhibited highest but significant negative gca effects.

The sca effects were significant for 40 hybrids, of which 24 hybrids had favourable positive SCA effects. Among them the hybrids DMIL 11 x DMIL 6 (7.652) had maximum sca effect followed by DMIL 9 x DMIL 1 (3.395) and DMIL 14 x DMIL 3 (2.758). Sixteen hybrids were significant negative sca effects.

4.4.2.8 Number of kernels per row

The gca effects of the parents DMIL 3 (1.031), DMIL 4 (0.594), DMIL 8 (1.719), DMIL 9 (1.531) and DMIL 10 (0.781) were found to be significantly positive in favourable direction. Parent DMIL 13 (-1.875) was highly significant in the unfavourable direction.

Significant SCA effects were observed 68 hybrids out of these 46 of the hybrids exhibited significant positive sca effects, these hybrids were DMIL 6 x DMIL 1 (8.946), DMIL 7 x DMIL 5 (7.133) and DMIL 4 x DMIL 3 (7.008) recorded highest significant positive sca effects. Twenty two crosses exhibited significant negative sca effect.

Table 12: Specific combining ability effects of hybrids for 15 quantitative characters in maize

Sl. No.	Crosses	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear width (cm)	No of kernels per row	No of rows per cob	Test weight (g)	Shelling %	Grain yld per plant (g)	Grain yld per ha (q/ha)	Protein (%)	Starch (%)
1	DMIL 2 x DMIL 1	2.08**	0.50	-1.06**	-11.58	-23.30**	-0.96	-2.24**	-8.05**	-0.73	-2.304	1.93	27.384**	14.278**	1.34**	-0.29
2	DMIL 3 x DMIL 1	-2.17**	-1.59**	0.78*	11.25	13.53	0.51	0.09	4.88**	-0.42	1.144	3.97	-25.991**	-10.428*	0.92**	-0.64**
3	DMIL 4 x DMIL 1	1.20*	0.75**	-0.53	-0.11	10.84	-1.57**	-0.43	3.32**	0.45	-1.289	9.91	-17.554*	-9.541*	0.40**	0.30*
4	DMIL 5 x DMIL 1	0.64**	-0.09	1.31**	2.55	-21.13**	0.11	0.46	-0.37	-0.30	-0.051	8.68	9.477	4.779	2.20**	-0.61
5	DMIL 6 x DMIL 1	-0.05	-0.06	0.38	-13.47	-13.58	0.53	0.66	8.95**	1.64*	2.827	-2.52	-12.023	-6.513	0.81**	-0.30
6	DMIL 7 x DMIL 1	0.39**	1.38**	-1.69**	-5.01	5.97	-0.45	1.11	-1.30	1.20	0.578	-2.36	-0.554	-0.518	0.64**	2.77**
7	DMIL 8 x DMIL 1	-0.95**	-1.40**	-3.19**	1.11	15.12	0.45	1.13*	1.20	-1.42	-2.001	-5.67	-5.835	-3.277	-1.78**	1.91**
8	DMIL 9 x DMIL 1	0.14**	-0.34	-1.06**	16.16*	2.12	2.67**	3.40**	3.38**	2.14**	0.084	-8.65	11.352	5.707	-0.08	0.38*
9	DMIL 10 x DMIL 1	0.89**	0.66*	-0.63	14.28	-0.24	1.18*	1.76**	5.13**	-0.98	-2.485	-0.08	17.884*	9.235*	1.11**	0.02
10	DMIL 11 x DMIL 1	-1.14**	1.69**	1.19**	18.70*	5.33	0.57	-0.05	-5.15**	2.02*	1.693	-4.13	4.071	1.942	-2.62**	-0.98**
11	1DMIL 2 x DMIL 1	0.08*	0.38	1.28**	14.35*	18.15*	0.98	0.64	-2.02*	0.83	-1.399	9.63	16.471*	8.493*	0.21	0.63**
12	DMIL 13 x DMIL 1	0.83**	1.10**	0.66	26.97**	4.70	1.41*	-1.78**	-2.21*	-0.48	4.675**	4.70	15.321*	7.919	0.57**	0.95**
13	1DMIL 4 x DMIL 1	-1.61**	0.35	-1.31**	19.22*	17.56*	1.36*	-0.07	1.85*	-0.61	0.579	5.34	28.602**	14.928**	-1.99**	-0.37**
14	DMIL 3 x DMIL 2	-0.92**	-1.44**	-1.22**	-2.47	2.32	0.69	-0.82	-2.37**	0.52	1.805	-0.63	-20.304**	-10.883**	-1.55**	-0.56**
15	DMIL 4 x DMIL 2	1.45**	-0.09	-2.53**	24.93**	-7.87	0.11	0.71	-3.93**	2.39**	-8.917**	-0.98	5.134	2.657	0.19	-0.22
16	DMIL 5 x DMIL 2	-3.11**	0.07	-0.69	-20.67**	14.76	-0.11	0.30	0.38	2.64**	-4.03*	7.35	-4.335	-2.288	0.04	-2.81**
17	DMIL 6 x DMIL 2	0.20**	0.10	1.38**	-10.68	-7.94	0.46	0.31	3.70**	0.58	4.248*	8.91	13.665	7.268	-0.20	2.66**
18	DMIL 7 x DMIL 2	-1.36**	-0.47	1.31**	-24.72**	7.25	1.88**	0.61	5.45**	-0.86	-1.85	1.82	11.134	5.874	-2.69**	-0.91**
19	DMIL 8 x DMIL 2	0.30**	1.75**	-0.19	-22.86**	11.41	0.57	0.32	0.95	-1.48	3.32*	2.02	11.852	6.282	2.31**	2.89**
20	DMIL 9 x DMIL 2	-1.61**	-0.19	-1.06**	21.44**	26.61**	1.00	1.39*	3.13**	2.08*	2.456	2.78	21.04**	11.154**	0.67**	1.52**
21	DMIL 10 x DMIL 2	0.14**	0.82**	1.38**	5.57	15.80	-0.04	2.20**	3.88**	-1.05	3.586*	9.32	11.571	6.126	-2.02**	-0.93**
22	DMIL 11 x DMIL 2	0.11**	-0.15	2.19**	8.74	-3.64	0.15	-0.76	1.60	-1.05	4.014*	6.66	-3.741	-1.958	0.25	0.02

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Table 12 contd...

Sl. No.	Crosses	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear width (cm)	No of kernels per row	No of rows per cob	Test weight (g)	Shelling %	Grain yld per plant (g)	Grain yld per ha (q/ha)	Protein (%)	Starch (%)
23	DMIL 12 × DMIL 2	-2.67**	0.03	0.78*	13.13	-0.56	1.21	1.13*	4.73**	0.77	5.122**	-6.68	9.659	5.12	0.57**	-0.04
24	DMIL 13 × DMIL 2	0.08*	0.25	-0.84*	29.25**	8.24	-0.31	1.16*	2.54**	-1.55*	7.346**	-14.40**	9.509	5.074	0.52**	1.10**
25	DMIL 14 × DMIL 2	0.64**	-0.50	-1.31**	10.50	-1.15	3.14**	-0.22	6.60**	-0.67	-0.849	5.97	7.29	3.903	0.42**	1.18**
26	DMIL 4 × DMIL 3	-0.80**	1.82**	1.81**	0.25	-1.24	0.38	2.10**	7.01**	-2.30**	5.881**	12.04*	34.759**	17.881**	-0.41**	-0.61**
27	DMIL 5 × DMIL 3	1.64**	-0.03	1.16**	-27.09**	2.64	-0.69	-0.52	-0.68	0.95	5.768**	-5.69	13.79	7.062	0.37*	-0.67**
28	DMIL 6 × DMIL 3	0.95**	0.00	-2.78**	-4.36	-3.82	2.53**	-0.66	4.63**	-0.11	0.796	11.55*	1.29	0.52	0.63**	-1.74**
29	DMIL 7 × DMIL 3	-0.61**	1.44**	0.16	1.61	11.38	2.36**	0.34	4.38**	2.45**	-0.052	1.97	21.259**	11.084**	1.21**	3.10**
30	DMIL 8 × DMIL 3	0.05	-0.34	0.66	8.97	-3.46	3.65**	1.65**	-0.12	-0.17	0.318	5.00	18.477*	9.562*	-1.40**	-0.12
31	DMIL 9 × DMIL 3	-0.86**	-1.28**	-2.22**	22.27**	3.24	-0.08	-0.78	-3.93**	-0.61	-2.046	-4.64	12.665	6.406	1.50**	2.35**
32	DMIL 10 × DMIL 3	-2.11**	-0.28	0.22	12.40	-9.82	-0.97	2.03**	5.82**	-0.73	-2.466	7.28	19.196*	9.934*	3.23**	2.42**
33	DMIL 11 × DMIL 3	0.86**	-0.25	-0.97*	1.57	-10.76	0.82	-0.02	6.54**	3.27**	-0.188	7.55	-12.616	-6.858	-0.13	0.15
34	DMIL 12 × DMIL 3	0.08*	1.44**	0.13	-6.54	3.57	0.48	0.16	-10.34**	0.08	-2.03	7.86	29.284**	15.262**	-1.01**	-0.75**
35	DMIL 13 × DMIL 3	0.83**	1.16**	-0.50	-6.92	-4.63	-0.29	-0.46	-0.52	-0.23	-3.106*	7.46	-1.866	-1.146	-0.32*	-0.80**
36	DMIL 14 × DMIL 3	1.39**	0.41	-0.47	-26.67**	-9.53	-1.39*	2.76**	1.54	1.64*	4.449**	11.16*	-9.585	-5.219	0.26	-0.78**
37	DMIL 5 × DMIL 4	-2.98**	0.32	-1.16**	-17.20*	-15.05	0.89	-0.89*	-2.24**	-0.17	4.596**	-4.52	-11.273	-6.051	0.26	-0.68**
38	DMIL 6 × DMIL 4	0.33**	1.35**	-1.09**	-21.97**	-11.50	0.20	-1.03*	3.07**	-0.23	1.524	-0.73	7.227	3.769	1.14**	0.76**
39	DMIL 7 × DMIL 4	-1.23**	0.78**	-2.16**	-9.50	-3.81	0.83	-0.53	6.82**	-1.67*	2.825	5.92	19.196*	10.874**	0.34*	-0.41**
40	DMIL 8 × DMIL 4	-0.58**	2.00**	2.34**	-13.64	10.35	-0.93	0.13	2.32**	0.70	3.596*	4.05	28.915**	15.185**	0.71**	-0.52**
41	DMIL 9 × DMIL 4	0.52**	0.07	5.47**	10.66	0.55	2.14**	-0.85*	-5.49**	0.27	4.631**	-2.49	20.102**	10.946**	0.41**	-1.00**
42	DMIL 10 × DMIL 4	1.27**	1.07**	0.91*	13.29	-1.51	2.96**	1.41*	3.26**	-0.86	2.061	8.48	25.634**	14.03**	-0.28	-0.36**
43	DMIL 11 × DMIL 4	0.24**	-0.90**	-2.28**	11.46	21.55**	0.44	1.31*	-1.02	-0.86	1.14	-0.74	8.321	4.307	-1.19**	-1.20**
44	DMIL 12 × DMIL 4	-0.55**	-0.72**	-1.19**	23.35**	-0.62	1.06	-0.01	2.10*	-0.05	-2.453	-4.39	-12.779	-6.823	-0.26	-0.48**

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Table 12 contd...

Sl. No.	Crosses	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear width (cm)	No of kernels per row	No of rows per cob	Test weight (g)	Shelling %	Grain yld per plant (g)	Grain yld per ha (q/ha)	Protein (%)	Starch (%)
45	DMIL 13 x DMIL 4	0.20**	-0.50	1.19**	14.47	2.18	-1.01	0.28	-2.09*	2.64**	-5.428**	10.60*	-2.929	-1.592	-0.41**	0.73**
46	DMIL 14 x DMIL 4	-2.23**	-2.25**	-0.78*	25.72**	-14.71	-0.12	0.04	-6.02**	0.52	-3.524*	2.27	-23.148	-12.263**	0.73**	1.28**
47	DMIL 6 x DMIL 5	-0.23**	-2.00**	1.75**	5.69	-2.12	1.28*	0.31	-6.62**	0.02	-0.239	-3.00	-17.241	-9.093*	-0.77**	-0.60**
48	DMIL 7 x DMIL 5	0.20**	-1.06**	0.69	20.65**	-8.43	2.36**	0.21	7.13**	-0.42	-3.887**	6.74	-3.273	-1.778	0.77**	0.71**
49	DMIL 8 x DMIL 5	0.86**	1.16**	-0.81*	8.02	4.23	-1.30*	-0.08	1.63**	-0.05	2.733	-3.68	6.446	3.38	1.19**	1.21**
50	DMIL 9 x DMIL 5	-1.05**	-0.78**	1.31**	14.81	-13.07	0.62	0.84*	6.82**	-1.48	2.669	2.96	26.634**	14.213**	-0.89**	-0.05
51	DMIL 10 x DMIL 5	-0.30**	0.22	-0.25	13.44	-5.13	-0.77	0.05	1.57	0.39	-4.151*	-0.33	-18.335	-9.706*	-0.35**	-0.19
52	DMIL 11 x DMIL 5	0.67**	0.25	-2.44**	6.61	-22.07**	2.77**	-1.86**	5.29**	-0.61	1.727	5.38	32.352**	17.665**	-1.25**	0.31
53	DMIL 12 x DMIL 5	0.89**	0.44	-2.34**	31.00**	2.26	0.48	1.48**	-1.59	0.20	4.135*	7.79	17.752**	9.343*	1.54**	1.56**
54	DMIL 13 x DMIL 5	-0.36**	-1.34**	-0.97*	2.13	-3.94	-0.44	0.61	4.23**	0.89	-1.791	-1.58	16.102**	8.505*	-0.22	-0.10
55	DMIL 14 x DMIL 5	0.20**	1.91**	-0.94*	5.88	2.67	-0.54	1.48*	0.29	-0.23	3.614*	7.49	30.384**	16.043**	-0.83**	0.04
56	DMIL 7 x DMIL 6	-1.48**	-0.03	-2.25**	3.39	-11.38	0.57	0.16	4.45**	0.52	-1.109	-1.39	25.727**	13.583**	1.53**	1.71**
57	DMIL 8 x DMIL 6	0.17**	-1.81**	-1.75**	5.75	22.78**	-0.44	-0.27	-2.05*	0.89	-1.439	0.44	4.446	2.38	-0.18	-0.57**
58	DMIL 9 x DMIL 6	-1.73**	1.25**	-2.63**	6.05	-4.52	4.14**	1.90**	6.13**	1.45	1.897	4.72	16.134*	8.46*	1.06**	1.44**
59	DMIL 10 x DMIL 6	0.02	0.25	-0.19	-11.32	3.42	0.50	-1.94**	0.88	-0.67	1.077	3.88	-13.335	-7.012	-1.75**	-0.22
60	DMIL 11 x DMIL 6	0.99**	0.28	1.63**	31.85**	6.48	-0.31	7.65**	4.60**	-0.67	3.905**	3.10	-6.148	-3.221	0.61**	-1.30**
61	DMIL 12 x DMIL 6	1.20**	0.97**	-2.28**	16.24*	-0.69	1.05	0.54	2.73**	-0.86	4.013*	2.78	7.252	3.857	0.18	0.08
62	DMIL 13 x DMIL 6	-3.05**	-0.31	-0.91*	17.36*	22.11**	0.88	-0.38	-1.46	-1.17	-2.263	7.95	27.602**	14.63**	-0.05	1.44**
63	DMIL 14 x DMIL 6	-1.48**	0.94**	-0.88*	-12.39	10.22	3.43**	-1.47*	-8.40**	-0.30	0.142	-2.04	19.884**	10.557**	-0.75**	-0.48**
64	DMIL 8 x DMIL 7	-0.39**	0.63*	-0.81*	-4.78	20.48*	0.94	-1.18*	-6.30**	1.45	-0.937	4.99	34.915**	18.402**	0.52**	0.00
65	DMIL 9 x DMIL 7	1.70**	-0.31	1.31**	14.51	8.18	0.17	-0.81	-2.12*	1.02	-4.302*	7.47	-16.898*	-9.031*	-0.24	-0.55**
66	DMIL 10 x DMIL 7	1.45**	0.19	-0.25	22.14**	23.62**	1.03	2.16**	-7.37**	-0.11	1.478	4.13	38.634**	20.358**	-0.70**	-1.50**

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Table 12 contd...

Sl. No.	Crosses	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear width (cm)	No of kernels per row	No of rows per cob	Test weight (g)	Shelling %	Grain yld per plant (g)	Grain yld per ha (q/ha)	Protein (%)	Starch (%)
67	DMIL 11 x DMIL 7	-0.58**	-1.28**	-1.44**	12.81	-10.82	0.02	0.05	2.35**	-2.11*	4.956**	0.37	0.821	0.399	0.41**	0.46**
68	DMIL 12 x DMIL 7	0.64**	0.41	0.66	12.20	-18.99*	0.78	0.33	3.48**	2.70**	3.564*	1.59	-9.779	-5.19	-1.53**	-1.40**
69	DMIL 13 x DMIL 7	-1.61**	-0.87**	-0.97*	-5.17	4.80	0.96	-0.13	-2.71**	0.39	6.639**	-5.62	-5.929	-3.125	1.32**	-1.54**
70	DMIL 14 x DMIL 7	-1.05*	-1.62**	-1.94**	-0.42	5.41	0.96	2.58**	5.35**	1.27	3.193	0.10	-11.648	-6.143	-0.70**	-0.14
71	DMIL 9 x DMIL 8	0.36**	-1.09**	-0.19	4.38	6.33	2.11**	-0.49	3.38**	0.39	3.769*	2.70	23.821**	12.96**	-3.23**	-2.38**
72	DMIL 10 x DMIL 8	0.61**	-0.09	1.25**	-8.00	-9.73	-1.68**	-0.83*	0.13	1.27	1.349	-0.41	-15.148*	-7.998*	0.54**	0.37**
73	DMIL 11 x DMIL 8	0.58**	-1.06**	1.06**	7.68	-11.67	1.86**	0.26	-0.15	1.27	-3.673*	12.30*	-16.96*	-8.957*	0.10	0.04
74	DMIL 12 x DMIL 8	-0.20**	-0.37	1.16**	9.57	-22.84**	1.87**	0.25	0.98	-0.92	-4.865**	-6.48	4.94	2.607	0.38*	0.60**
75	DMIL 13 x DMIL 8	0.05	1.35**	-0.47	13.19	-8.54	-2.05**	-0.97*	-1.21	0.77	-1.641	10.75*	-4.71	-2.453	-0.59**	0.73**
76	DMIL 14 x DMIL 8	0.61**	-0.40	-0.44	15.44*	-45.43**	0.20	-0.81	4.85**	-0.36	-1.636	-1.50	-7.429	-3.888	2.08**	2.78**
77	DMIL 10 x DMIL 9	0.70**	1.97**	-2.63**	31.30**	-1.53	-1.71**	-1.11**	-5.68**	-0.17	-4.916**	6.80	-20.96**	-11.154**	1.78**	1.30**
78	DMIL 11 x DMIL 9	0.17**	2.00**	-2.81**	-50.53**	1.04	-1.27**	1.78**	-4.96**	0.83	-5.038**	8.64	4.727	2.401	-0.44**	1.79**
79	DMIL 12 x DMIL 9	-0.11**	-0.31	0.28	-69.64**	-12.14	1.04	1.02**	3.17**	-0.36	2.92	8.20	22.127**	12.118**	-0.75**	-1.96**
80	DMIL 13 x DMIL 9	1.14**	0.41	-0.34	-22.51**	-20.84**	-0.83	-1.35**	2.98**	0.33	-2.205	-3.03	-12.023	-6.4	0.00	-0.19
81	DMIL 14 x DMIL 9	-0.30**	-0.34	0.69	-3.76	12.27	-0.63	-1.59**	2.04*	-1.80*	-0.826	-2.36	-1.741	-0.974	0.94**	2.20**
82	DMIL 11 x DMIL 10	-2.08**	-1.50**	-2.38**	3.60	-6.03	1.99**	-1.81**	5.29**	-1.30	0.893	-2.64	-9.241	-4.89	1.63**	1.61**
83	1DMIL 2 x DMIL 10	-0.86**	-1.31**	-1.28**	-13.51	5.80	2.85**	-0.92*	4.42**	1.52	3.651*	4.73	-8.841	-4.673	-2.35**	-1.95**
84	DMIL 13 x DMIL 10	-0.11**	-1.59**	-1.91**	-22.39**	-15.40	2.23**	1.66**	6.73**	1.20	5.025**	1.60	0.509	0.295	-0.88**	2.26**
85	1DMIL 4 x DMIL 10	0.45**	-0.34	2.13**	-48.64**	-4.79	1.03	0.53	1.79*	0.08	2.529	-9.26	42.29**	22.346**	0.46**	2.01**
86	1DMIL 2 x DMIL 11	0.11**	0.72**	1.53**	-29.84**	6.37	0.99	-0.03	1.63	0.52	-2.321	0.18	8.846	4.659	1.12**	1.00**

Contd....

Table 12 contd...

Sl. No.	Crosses	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear width (cm)	No of kernels per row	No of rows per cob	Test weight (g)	Shelling %	Grain yld per plant (g)	Grain yld per ha (q/ha)	Protein (%)	Starch (%)
87	DMIL 13 x DMIL 11	-1.14**	-1.56**	0.91*	-54.22**	-9.84	0.32	1.46*	1.45	0.20	1.313	6.56	20.696**	10.947**	0.88**	2.52**
88	DMIL 14 x DMIL 11	-0.58**	-0.31	0.94*	-3.97	3.27	0.82	-0.48	-2.49**	-0.92	0.497	1.95	12.977	6.873	0.33*	-0.30*
89	DMIL 13 x DMIL 12	0.08*	1.13**	0.63	-17.32*	4.49	0.38	0.04	2.57**	-0.98	-2.014	5.22	-10.904	-5.725	0.85**	0.51**
90	1DMIL 4 x DMIL 12	0.64**	0.38	0.03	-8.57	5.10	-1.47**	-0.05	-1.37	-0.11	-0.935	12.20*	-7.623	-3.993	1.17**	1.86**
91	1DMIL 4 x DMIL 13	-0.61**	1.10**	-0.59	-12.45	-33.60**	0.11	0.29	4.95**	0.58	-0.86	2.62	5.727	3.085	-0.32*	0.37**
	SEm+	0.04	0.27	0.38	7.48	8.07	0.57	0.84	0.85	0.78	1.65	1.65	7.62	4.03	4.02	0.14
	CD at 5%	0.07	0.53	0.75	14.83	16.00	1.13	1.66	1.70	1.54	3.28	3.28	15.11	7.99	7.97	0.27
	CD at 1%	0.09	0.70	0.99	19.63	21.17	1.50	2.20	2.24	2.04	4.33	4.33	19.99	10.57	10.55	0.36

* - Significant at 5 per cent probability

** - Significant at 1 per cent probability

4.4.2.9 Number of rows per cob

The positive gca effects were observed in 4 parents and negative gca effects were observed in 4 parents. Among these DMIL 13 (1.103) exhibited highest significant positive gca effects and DMIL 12 (-1.210) exhibited negative significant gca effects in undesirable direction.

Among 91 hybrids, 11 hybrids had significantly positive sca effects and 5 hybrids registered significantly negative sca effects. The hybrid DMIL 11 x DMIL 3 (3.267), DMIL 12 x DMIL 7 (2.704) and DMIL 13 x DMIL 4 (2.642) had showed higher magnitude of significant positive sca effects.

4.4.2.10 Test weight (g)

Though, 4 of the parents exhibited positive gca effects in favourable direction, DMIL 2 (1.478), DMIL 4 (2.152), DMIL 9 (1.080) and DMIL 10 (0.899) had exhibited significant positive gca effects. Three parents had negative gca effects, among them DMIL 1 (-2.701) exhibited highest negative significant gca effects in undesirable direction.

The sca effects were significant for 35 hybrids, out of which 23 hybrids had highest positive favourable sca effect and 12 hybrids had highest negative sca effects in unfavourable direction. All other hybrids recorded non significant sca effects. Hybrids DMIL 13 x DMIL 2 (7.346), DMIL 13 x DMIL 7 (6.639) and DMIL 4 x DMIL 3 (5.881) recorded highest positive significant sca effect.

4.3.2.11 Shelling percentage

Out of 14 parents, none of the parents showed positive and only one showed negative gca effects. Among them DMIL 5 (1.747) had exhibited highest positive gca effect and DMIL 1 (-3.396) had highest gca effects in negative direction.

In 91 hybrids, 7 crosses showed positive significant sca effect. The hybrids DMIL 11 x DMIL 5 (41.902), DMIL 4 x DMIL 3 (12.04) and DMIL 10 x DMIL 4 (36.684) recorded the positive significant sca effects while one of the hybrids showed significant negative sca effects.

4.3.2.12 Yield per plant (g)

Of the 14 parents, 2 parents exhibited significant positive gca effects and 4 parents showed negatively significant gca effect. The positive effect was recorded DMIL 5 (8.651) and DMIL 9 (9.776) and highest negative effect was recorded by DMIL 13 (-8.192).

Among the 91 hybrids, 30 hybrids showed highest positive significant sca effects among these, DMIL 14 x DMIL 10 (42.29), DMIL 10 x DMIL 7 (38.634) and DMIL 8 x DMIL 7 (36.684) recorded highest positive significant sca effect. And 7 hybrids showed negative significant sca effects.

4.3.2.13 Yield per ha (kg)

Out of 14 parents, 2 parents DMIL 5 (4.566) and DMIL 9 (5.160) exhibited significant positive gca effects. And 4 parents exhibited significant negative effect, among them DMIL 13 (-4.324) had showed highest negative gca effect.

The significant sca effects were observed for 39 hybrids of which 29 hybrids exhibited positive and the remaining 10 hybrids exhibited negative effects for total yield per ha. Out of 29 positive significant hybrids, DMIL 14 x DMIL 10 (22.346) had maximum sca effect followed by DMIL 10 x DMIL 7 (20.358) and DMIL 8 x DMIL 7 (18.402), first one hybrids involved negative x negative general combiners and second one hybrid involved positive x positive general combiners and third hybrid had negative x positive general combiners.

4.3.2.14 Protein content (%)

Out of 14 parents, 7 exhibited significant positive gca effects and 6 exhibited significant negative gca effects, among these DMIL 14 (0.613) showed highest positive gca effect and DMIL 8 (-0.715) exhibited highest negative gca effect.

Out of 91 hybrids, 44 hybrids showed significant positive sca effects and 28 exhibited significant negative sca effect. Among these hybrids DMIL 10 x DMIL 3 (3.232), DMIL 8 x DMIL 2 (2.306) and DMIL 5 x DMIL 1 (2.199) had recorded highest significant positive sca effects.

4.3.2.15 Starch content (%)

Among 14 parents, 4 parents and 5 parents exhibited significant positive and negative gca effects respectively, DMIL 3 (0.477) had a highest positive significant gca effects and DMIL 7 (-0.491) had highest negative significant gca effect.

The sca effects were significant for 71 hybrids, of which 39 hybrids had favourable positive SCA effects, among them the hybrids DMIL 7 x DMIL 3 (3.099) had maximum sca effect followed by DMIL 8 x DMIL 2 (2.89) and DMIL 7 x DMIL 1 (2.767). 32 hybrids were significant negative sca effects, and rest of the hybrids showed non significant sca effects.

5. DISCUSSION

In the recent years considerable emphasis has been given on the development of hybrids and high yielding varieties. The main aim of any plant breeding programme is to develop high yielding genotypes. The breeding programme can efficiently be planned with prior knowledge of the genetic make up of complex quantitative character like yield and its attributes. So there is a need to examine the genetic architecture of various quantitative characters in relation to breeding behaviour of the genetic material available.

Exploitation of heterosis or hybrid vigour is an important method of crop improvement adopted in many of the crops especially in cross pollinated crops. This phenomenon of heterosis was attracted the attention of plant breeders due to its conspicuous effect on economic characters especially grain yield and this heterosis has been successfully exploited in many cross pollinated crops among which maize is the major one.

In order to exploit hybrid vigour/heterosis choice of suitable parents is an important step. The selection of parents depends on factors like *per se* performance of the parents and their combining ability. The concept of general and specific combining ability (Sprague and Tatum, 1942) helps the breeder in assessing many of the lines to be used as parents in the production of hybrids and also in identifying the superior hybrids having additive and non-additive genes. It is therefore necessary to assess the genetic potentialities of the parents in hybrid combination through systematic studies in relation to general and specific combining ability which are due to additive and non-additive gene actions. Thus, the information regarding heterosis, combining ability and nature of gene action are the basic requirements for a thorough understanding of genetic architecture of yield and its components.

The available literature on maize indicated the possibility of exploiting heterosis for realizing higher yield potentiality, being monoecious in nature it provides an ample scope to exploit heterosis commercially.

The knowledge of combining ability provides a useful clue for selection of desirable parents for development of superior hybrids. The present study therefore was undertaken to study the genetics of 15 quantitative characters by using 14 parents through 14 x 14 diallel analysis. The results of the investigation obtained in the present study are discussed here under.

5.1 Analysis of variance

The analysis of variance for treatments characters revealed highly significant treatment variances for all the fifteen characters. This indicates the presence of variability among genotypes.

The analysis of variance for parents was significant for all the characters except for shelling percentage, grain yield per plant and grain yield per hectare. The variance due to hybrids was also significant for all character.

From the analysis of variance of parents and hybrids, it was clear that the MSS for parents and hybrids were highly significant for all the traits indicating sufficient variability among parents and hybrids exhibited for all the traits .

Analysis of variance for combining ability revealed that presence of both additivity and non-additivity in fourteen of the 15 characters studied, which was indicated by the significance of both the GCA and SCA variances except shelling percentage in this only non additivity exists for this trait. The ratio of GCA/SCA was less than unity indicating the involvement of non-additivity. The variances due to SCA were higher in magnitude than GCA for all the traits. These results are encouraging from the view of heterosis exploitation.

5.2 Heterosis

Heterosis is the superiority of F_1 over the mean of the parents or over the better parent or over the standard check (Hayes *et al.*, 1956), with respect to agriculturally useful traits. The primary objective of heterosis breeding is to achieve a quantum jump in yield and quality aspects of crop plants.

In the present study parents formed the base material and in the following paragraphs, heterotic behaviour of hybrids for various traits is presented. The range of heterosis over mid parent, better parent and standard checks, top three hybrids with *per se* performance in respect of each of the character studied and their relative performance is presented in Table 13 and 14, respectively.

5.3 Combining ability

The ultimate choice of parents to be used in a breeding programme is determined by *per se* performance and their behaviour in hybrid combination. Some idea on the usefulness of the parents may be obtained from their individual performance, particularly in respect of yield components. It is therefore, necessary to assess genetic potentialities of the parents in hybrid combination through systematic studies in relation to general and specific combining abilities.

From the Table 10 it is evident that variances due to general combining ability (gca) were significant for all the studied characters. All the Character showed significant variance due to specific combining ability (sca).

Significance variance due to both gca and sca for all important yield attributing characters implied that both additive and non additive genetic variances are important in controlling the expression of these characters.

The knowledge of specific combining ability effects helps to identify the best crosses. Specific combining ability effects are presented in Table 16a and 16b.

5.3.1 Maturity characters

Maturity is an important attribute of a given genotype, which directly or indirectly affects economic yield. Maturity itself is expressed by several components such as days to 50 per cent tasseling, days to 50 per cent silking, days to maturity etc. Normally, in maize it has been reported that the female inflorescence *i.e.*, ear formation is very sensitive to environmental fluctuations and plant density. Whereas male inflorescence *i.e.*, tassel formation is least affected by such situations (Giesbercht, 1960). Therefore, the synchronization between male and female flowering is a very crucial phenomenon which has direct bearing on grain yield.

5.3.1.1 Days to 50 per cent tasseling

Days from planting to pollen shedding is one of the important maturity character (Giesbercht, 1960). The study on gca effects suggested that DMIL 5, DMIL 6 and DMIL 7 are the good general combiners which exhibited earliness in developing tassel (Table 11 and 17).

The combining ability analysis revealed greater importance of GCA variance than SCA variance. Both SCA and GCA variance were significant. Suneeta *et al.* (2000) and Desai and Singh (2004) noticed significant variances for GCA and SCA for this trait.

The ratio of additive to dominance was lesser than unity this indicated the importance of dominance gene action for the inheritance of this character. These results are in agreement with those of Hassaballa *et al.* (1980), Guo *et al.* (1986) Mantesh *et al.* (2006). The 38 hybrids exhibited significant sca effects, among these DMIL 5 x DMIL 2, DMIL 13 x DMIL 6 and DMIL 5 x DMIL 4 showed highest significant sca effect (Table 9 and 14), these hybrids can be used as specific combiners for this trait.

Heterosis study revealed that 66 and 42 crosses exhibited significant relative heterosis and heterobeltiosis respectively (Table 5 and 18) in the desired direction.

Fourty four hybrids exhibited earliness in tasseling compared to standard check. Earlier workers including Satyanarayana *et al.* (1994) reported the heterobeltiosis for earliness. Significant average heterosis was reported by Gomes-e-Gamma *et al.* (1995) and Turgut *et al.* (1995), Perez Velasquez *et al.* (1995) also noticed considerable heterotic effect for this trait.

5.3.1.2 Days to 50 per cent silking

Days to 50 per cent silking is another maturity character often used and more reliable to predict maturity (Shaw and Tham, 1951).

Table 13: Estimates of heterosis over mid parent, better parent, and standard checks for 15 characters in 91 experimental maize hybrids

Sl. No	Characters	Mid parent	Better parent	Standard heterosis
1	Days to 50% tasseling	-7.94 to 1.6	-7.94 to 3.23	-7.94 to 3.17
2	Days to 50% silking	-3.08 to 4.72	-3.05 to 6.4	-5.26 to 0
3	Days to 50% brown husking	-6.82 to 4.81	-6.32 to 5.38	-4.3 to 5.38
4	Plant height (cm)	-40.39 to 23.51	-44.05 to 19.51	-45.71 to 14.29
5	Ear height (cm)	-53.89 to 46.97	-60.18 to 34.84	-51.59 to 26.8
6	Ear length (cm)	-2.25 to 76.65	-7.71 to 44.75	-16.99 to 14.35
7	Ear width (cm)	-6.37 to 74.53	-13.42 to 73.06	-20.06 to 43.18
8	No. of kernels per row	-12.73 to 77.27	-17.65 to 77.27	-36.84 to 10.53
9	No. of rows per cob	-9.68 to 41.67	-13.33 to 38.46	-7.14 to 35.71
10	Test weight (g)	-12.19 to 37.76	-19.12 to 36.16	-18.11 to 16.91
11	Shelling %	-0.27 to 72.04	-2.96 to 48.83	-12.16 to 24.30
12	Grain weight per plant (g)	13.04 to 96.44	4.48 to 87.29	-31.58 to 22.11
13	Grain weight per ha (q/ha)	17.09 to 99.08	11.7 to 92.11	-27.60 to 23.23
14	Protein content (%)	-30.84 to 42.12	-36.62 to 32.39	-40.41 to 29.22
15	Starch content (%)	-3.64 to 11.28	-5.09 to 9.73	-6.01 to 3.55

Table 14: Top three desirable hybrids with *Per se* performance and heterosis for 15 character in maize

Characters	Desirable crosses	<i>Per se</i>			Heterosis		
		Female	male	F ₁	MP	BP	SH
Days to 50% tasseling	DMIL 5 x DMIL 2	63.00	63.00	58.00	-7.94 **	-7.94 **	-7.94 **
	DMIL 12 x DMIL 2	63.00	63.00	59.00	-6.35 **	-6.35 **	-6.35 **
	DMIL 5 x DMIL 4	63.00	64.00	59.00	-7.09 **	-6.35 **	-6.35 **
Days to 50% silking	DMIL 14 x DMIL 4	65.50	62.50	62.50	-2.34 **	0.00	-6.02 **
	DMIL 6 x DMIL 5	65.50	64.50	63.00	-3.08 **	-2.33 **	-5.26 **
	DMIL 11 x DMIL 10	65.50	64.50	63.00	-3.08 **	-2.33 **	-5.26 **
Days to 50% brown husking	DMIL 8 x DMIL 1	93.00	94.00	89.00	-4.81 **	-4.30 **	-4.30 **
	DMIL 7 x DMIL 6	95.00	96.00	89.00	-6.81 **	-6.32 **	-4.30 **
	DMIL 9 x DMIL 6	94.00	96.00	89.00	-6.32 **	-5.32 **	-4.30 **
Plant height (cm)	DMIL 5 x DMIL 2	189.15	207.50	194.25	-2.05	-6.39	-7.50
	DMIL 6 x DMIL 5	195.50	189.15	212.50	10.49 *	8.70	1.19
	DMIL 8 x DMIL 5	202.50	189.15	221.50	13.11 **	9.38	5.48
Ear height (cm)	DMIL 11 x DMIL 4	123.35	129.35	137.50	8.82	6.30	26.80 *
	DMIL 10 x DMIL 7	101.85	96.85	130.00	30.85 **	27.64 *	19.88
	DMIL 8 x DMIL 6	95.85	109.35	125.00	21.83 *	14.31	15.27
Ear length (cm)	DMIL 10 x DMIL 4	17.45	17.45	23.90	36.96 **	36.96 **	14.35 **
	DMIL 8 x DMIL 3	16.70	16.30	23.45	42.12 **	40.42 **	12.20 **
	DMIL 9 x DMIL 6	16.20	10.35	23.45	76.65 **	44.75 **	12.20 **
Ear width (cm)	DMIL 11 x DMIL 6	14.60	14.85	25.70	74.53 **	73.06 **	43.18 **
	DMIL 9 x DMIL 1	16.50	14.40	20.85	34.95 **	26.36 **	16.16 *
	DMIL 11 x DMIL 9	14.60	16.50	20.05	28.94 **	21.52 **	11.70

Contd...

Characters	Desirable crosses	Per se			Heterosis		
		Female	male	F ₁	MP	BP	SH
No. of kernels per row	DMIL 4 x DMIL 3	31.00	27.00	42.00	44.83 **	35.48 **	10.53 **
	DMIL 9 x DMIL 5	32.00	26.00	42.00	44.83 **	31.25 **	10.53 **
	DMIL 10 x DMIL 3	22.00	27.00	41.00	67.35 **	51.85 **	7.89 *
No. of rows per cob	DMIL 11 x DMIL 3	16.00	13.00	19.00	31.03 **	18.75 *	35.71 **
	DMIL 13 x DMIL 4	16.00	15.00	19.00	22.58 **	18.75 *	35.71 **
	DMIL 7 x DMIL 3	13.00	13.00	18.00	38.46 **	38.46 **	28.57 **
Test weigh (g)	DMIL 9 x DMIL 4	38.65	38.02	43.9	14.52 *	13.58 *	16.91 *
	DMIL 13 x DMIL 2	30.67	32.02	43.6	39.10 **	36.16 **	16.11 *
	DMIL 4 x DMIL 3	38.02	29.76	43.5	28.36 **	14.41 *	15.85 *
Shelling %	DMIL 11 x DMIL 8	61.00	67.25	93.84	46.35 **	39.54 **	26.30 *
	DMIL 11 x DMIL 9	61.00	72.30	92.36	38.58 **	27.76 *	24.30 *
	DMIL 13 x DMIL 4	65.89	61.40	92.31	45.04 **	40.10 **	24.24 *
Grain yield per plant (g)	DMIL 9 x DMIL 5	95	97	174	81.25 **	79.38 **	22.11 **
	DMIL 10 x DMIL 7	94.5	93	169.5	93.71 **	87.29 **	18.95 *
	DMIL 4 x DMIL 3	95	97	169	80.27 **	78.84 **	18.60 *
Grain yield per ha (q/ha)	DMIL 9 x DMIL 5	47.64	48.69	89.6	86.02 **	84.00 **	23.23 **
	DMIL 10 x DMIL 7	45.26	42.10	86.96	99.08 **	92.11 **	19.60 *
	DMIL 4 x DMIL 3	47.38	46.58	86.69	99.08 **	92.65 **	19.24 *
Protein content (%)	DMIL 10 x DMIL 3	10.59	9.14	14.02	42.12 **	32.39 **	29.22 **
	DMIL 10 x DMIL 9	10.59	10.20	12.46	19.82 **	17.61 **	14.79 **
	DMIL 11 x DMIL 10	10.98	10.59	12.44	15.30 **	13.25 **	14.61 **
Starch content (%)	DMIL 10 x DMIL 3	64.33	66.21	69.23	6.07 **	4.57 **	3.55 **
	DMIL 9 x DMIL 3	64.23	66.21	69.12	5.98 **	4.40 **	3.38 **
	DMIL 7 x DMIL 3	63.80	66.21	69.01	6.17 **	4.24 **	3.22 **

Table 15: Top parents for gca effects with respect to yield and its component traits

Characters	Top parents	Mean	gca effects
Days to 50% tasseling	6	63	-0.799
Days to 50% silking	5	64.5	-0.433
Days to 50% brown husking	6	96	-0.656
Plant height (cm)	2	129.35	7.332
Ear height (cm)	4	101.85	10.126
Ear length (cm)	10	17.45	1.076
Ear width (cm)	4	17.3	0.639
No. of kernels per row	8	34	1.719
No. of rows per cob	9	14	0.478
Test weight (g)	4	38.02	2.152
Shelling %	5	70.25	1.747
Grain yield per plant (g)	9	95	9.776
Grain yield per ha (q/ha)	9	47.64	5.160
Protein content (%)	14	10.23	0.613
Starch content (%)	3	66.21	0.477

Table 16a: Identified top three crosses based on mean performance and their sca effects, gca status of parents for 15 traits in maize

Sl.No.	Character	Crosses	F ₁ mean	sca effects	gca status
1	Days to 50% tasseling	DMIL 5 x DMIL 2	58	_ _{3.11} **	High x Low
		DMIL 12 x DMIL 2	59	_ _{2.67} **	Low x Low
		DMIL 5 x DMIL 4	59	_ _{2.98} **	High x High
2	Days to 50% silking	DMIL 14 x DMIL 4	62.5	_ _{2.25} **	Low x High
		DMIL 6 x DMIL 5	63	_ _{2.00} **	Low x High
		DMIL 11 x DMIL 10	63	_ _{1.50} **	Low x High
3	Days to 50% brown husking	DMIL 8 x DMIL 1	89	_ _{3.19} **	Low x Low
		DMIL 7 x DMIL 6	89	_ _{2.25} **	High x Low
		DMIL 9 x DMIL 6	89	_ _{2.63} **	High x Low
4	Plant height (cm)	DMIL 5 x DMIL 2	194.25	_ _{20.67} **	High x Low
		DMIL 6 x DMIL 5	212.5	5.69	Low x High
		DMIL 8 x DMIL 5	221.5	8.02	Low x High
5	Ear heigh (cm)	DMIL 11 x DMIL 4	137.5	21.55**	Low x High
		DMIL 10 x DMIL 7	130	23.62**	High x High
		DMIL 8 x DMIL 6	125	22.78**	Low x Low
6	Ear lenght (cm)	DMIL 10 x DMIL 4	23.9	2.96**	High x High
		DMIL 8 x DMIL 3	23.45	3.65**	Low x High
		DMIL 9 x DMIL 6	23.45	4.14**	High x Low
7	Ear width (cm)	DMIL 11 x DMIL 6	25.7	7.65**	Low x Low
		DMIL 9 x DMIL 1	20.85	3.40**	High x Low
		DMIL 11 x DMIL 9	20.05	1.78**	Low x High
8	NO of kernels per row	DMIL 4 x DMIL 3	42	7.01**	High x High
		DMIL 9 x DMIL 5	42	6.82**	High x High
		DMIL 10 x DMIL 3	41	5.82**	High x High
9	NO of rows per cob	DMIL 11 x DMIL 3	19	3.27**	Low x High
		DMIL 13 x DMIL 4	19	2.64**	Low x High
		DMIL 7 x DMIL 3	18	2.45**	High x High

Contd....

Sl.No.	Character	Crosses	F ₁ mean	sca effects	gca status
10	Test weigh (g)	DMIL 9 x DMIL 4	37.4	4.63**	High x High
		DMIL 13 x DMIL 2	37.1	7.35**	Low x Low
		DMIL 4 x DMIL 3	37	5.88**	High x High
11	Shelling %	DMIL 11 x DMIL 8	93.84	12.30**	Low x Low
		DMIL 11 x DMIL 9	92.36	8.64	Low x High
		DMIL 13 x DMIL 4	92.31	2.62	Low x High
12	Grain yield per plant (g)	DMIL 9 x DMIL 5	174	26.63**	High x High
		DMIL 10 x DMIL 7	169.5	38.64**	High x High
		DMIL 4 x DMIL 3	169	34.76**	High x High
13	Grain yield per ha (q/ha)	DMIL 9 x DMIL 5	89.6	14.21**	High x High
		DMIL 10 x DMIL 7	86.96	20.36**	High x High
		DMIL 4 x DMIL 3	86.69	17.88**	High x High
14	Protein (%)	DMIL 10 x DMIL 3	14.02	3.23**	High x High
		DMIL 10 x DMIL 9	12.46	1.78**	High x High
		DMIL 11 x DMIL 10	12.44	1.63**	Low x High
15	Stach (%)	DMIL 10 x DMIL 3	69.23	2.42**	High x High
		DMIL 9 x DMIL 3	69.12	2.35**	High x High
		DMIL 7 x DMIL 3	69.01	3.10**	High x High

Table 16b: Top three crosses exhibiting maximum sca effects, their mean performance with respect to 15 characters in maize

Sl. No	Character	Crosses	F ₁ mean	sca effects	gca status
1	Days to 50% tasseling	DMIL 5 x DMIL 2	58	-3.108	High x Low
		DMIL 13 x DMIL 6	59	-3.046	Low x Low
		DMIL 5 x DMIL 4	59	-2.983	High x High
2	Days to 50% silking	DMIL 14 x DMIL 4	62.5	-2.248	Low x High
		DMIL 6 x DMIL 5	63	-1.998	Low x High
		DMIL 8 x DMIL 6	6.5	-1.81	Low x Low
3	Days to 50% brown husking	DMIL 8 x DMIL 1	89	-3.188	Low x Low
		DMIL 11 x DMIL 9	89	-2.813	Low x High
		DMIL 6 x DMIL 3	89	-2.781	Low x High
4	Plant height (cm)	DMIL 11 x DMIL 6	240	31.848	Low x Low
		DMIL 10 x DMIL 9	215	31.301	High x High
		DMIL 12 x DMIL 5	232.5	31.001	Low x High
5	Ear height (cm)	DMIL 9 x DMIL 2	122.5	26.61	High x Low
		DMIL 10 x DMIL 7	130	23.616	High x High
		DMIL 8 x DMIL 6	125	22.779	Low x Low
6	Ear length (cm)	DMIL 9 x DMIL 6	23.45	4.136	High x Low
		DMIL 8 x DMIL 3	23.45	3.646	Low x High
		DMIL 14 x DMIL 6	22.65	3.427	Low x Low
7	Ear width (cm)	DMIL 11 x DMIL 6	25.7	7.652	Low x Low
		DMIL 9 x DMIL 1	20.85	3.395	High x Low
		DMIL 4 x DMIL 3	18.8	2.758	Low x High
8	No. of kernels per row	DMIL 6 x DMIL 1	40	8.946	Low x Low
		DMIL 7 x DMIL 5	40	7.133	Low x High
		DMIL 4 x DMIL 3	42	7.008	High x High
9	No. of rows per cob	DMIL 11 x DMIL 3	19	3.267	Low x High
		DMIL 12 x DMIL 7	17	2.704	Low x High
		DMIL 13 x DMIL 4	19	2.642	Low x High

Contd....

SI. No	Character	Crosses	Mean	sca effects	gca status
10	Test weigh (g)	DMIL 13 x DMIL 2	43.6	7.346	Low x Low
		DMIL 13 x DMIL 7	41.5	6.639	Low x High
		DMIL 4 x DMIL 3	43.5	5.881	High x High
11	Shelling %	DMIL 11 x DMIL 8	93.84	12.302	Low x Low
		1DMIL 4 x DMIL 12	91.82	12.198	Low x Low
		DMIL 4 x DMIL 3	91.04	12.039	High x High
12	Grain yield per plant (g)	1DMIL 4 x DMIL 10	165.5	41.902	Low x High
		DMIL 10 x DMIL 7	169.5	38.246	High x High
		DMIL 8 x DMIL 7	169	36.684	Low x High
13	Grain yield per ha (q/ha)	1DMIL 4 x DMIL 10	87.35	22.346	Low x High
		DMIL 10 x DMIL 7	89.46	20.358	High x High
		DMIL 8 x DMIL 7	89.19	18.402	Low x High
14	Protein (%)	DMIL 10 x DMIL 3	14.02	3.232	High x High
		DMIL 8 x DMIL 2	11.56	2.306	Low x Low
		DMIL 5 x DMIL 1	11.8	2.199	High x Low
15	Starch (%)	DMIL 7 x DMIL 3	69.01	3.099	High x High
		DMIL 14 x DMIL 8	68.25	2.782	Low x Low
		DMIL 7 x DMIL 1	67.85	2.767	High x Low

Studies on gca effects revealed that parents, DMIL 4 and DMIL 5 showed significant gca effects in desired direction.

In this study, both gca and sca variances were found to be significant for days to 50 per cent silking depicting that importance of both additive and non additive gene effects. Nevertheless, higher magnitude of sca variance obtained in present investigation revealed preponderance of non additive gene action for this trait. Smilar results were reported by Hassaballa *et al.* (1980), Lee *et al.* (1986), Desai and Singh *et al.* (2001).

The hybrids 20 showed significant sca effects, among these DMIL 14 x DMIL 4, DMIL 6 x DMIL 5 and DMIL 8 x DMIL 6 had highest sca effects revealing that these hybrids can be used as good specific combiners for this trait.

Heterosis study revealed that 17 and 12 crosses exhibited significant relative heterosis and heterobeltiosis, respectively, in the desired direction.

Seventy one hybrid exhibited earliness in silking as compared to standard check. Earlier workers Vasal *et al.* (1992), Satynarayana *et al.* (1994), Altinbos (1995) noticed the heterobeltiosis for this character. And Shashidhar C.K (2008) reported the significant heterosis over mid parent, better parent and checks for this character.

Those crosses, which exhibited significant heterosis are obtained from parents with good general combining ability for earliness. Hence, it is suggested that these hybrids will serve as useful genetic material for development of early parents by selection in advanced generations.

5.3.1.3 Days to 50 per cent brown husking

Six parents (DMIL 1, DMIL 2, DMIL 6, DMIL 7, DMIL 9 and DMIL 11) were found to be good general combiners for earliness.

Combining ability studies indicated both GCA variance than SCA variance were found to be significant for days to maturity depicting the importance of both additive and non additive gene effects for this trait.. The finding is in accordance with the report Satyanarayana *et al.* (1994), Mathur and Bhatnagar (1995), Murthy *et al.* (1981) and Alam *et al.* (2008) reported the importance of both components.

The additive to non additive ratio was less than unity indicating importance of non additive gene action from earlier workers Mahantesh (2006).

Twenty eight hybrids exhibited significant sca effects out of which three showed highest negative sca effect in desirable direction (Table 4 and 18). Those three were DMIL 8 x DMIL 1, DMIL 11 x DMIL 9 and DMIL 6 x DMIL 3.

Seventy three and thirty five hybrids exhibited significant relative heterosis and heterobeltiosis respectively.

Twenty nine hybrids exhibited earliness in maturity as compared to standard check. The expression of negative heterosis for this character was also reported by Kalsy and Sharma (1970), Murthy *et al.* (1981), and Alam *et al.* (2008).

Parents *viz.*, DMIL 1, 2, 3, 8, 10, 11, 12, 13 and 14 for days to 50% tasseling, DMIL 6, 13 for days to 50% silking and DMIL 9, 10, 11, 12, 13 for days to 50% brown husk maturity were good general combiners, hence selection can be practiced in the segregation populations these crosses to be develop early parents in respective traits.

5.3.2 Plant characters

Plant height is one of the important plant characters and in the present study increased plant height is considered as desirable.

5.3.2.1 Plant height

Plant height is of major concern to plant breeders since yield has positive correlation with plant height (Rupak *et al.*, 1979).

Among 14 lines, four lines *viz.*, DMIL 2, DMIL 3, DMIL 4, DMIL 5, DMIL 7 and DMIL 8 exhibited good general combiners for increased plant height.

Although both the variances (gca and sca) were found to be significantly important for the trait, similar reports by Suneeta *et al.* (2000) and Saad Imran Malik (2004). Ratio of gca variance to sca variance was lesser than unity. This revealed predominance of non additive gene action and hence heterosis phenomena for height character can be further exploited from material generated. Similar behaviour of non additive gene action with pronounced sca variance for plant height recorded by Mahantesh (2006) Shashidhar (2008) and Alam *et al.* (2008).

Of the 31 crosses that showed significant sca effects, 17 were in positive direction, while the remaining 14 were in negative direction. Hybrid DMIL 11 x DMIL 6, DMIL 10 x DMIL 9, DMIL 12 x DMIL 5 were the best three specific combiners for increased plant height.

. Heterosis study revealed that 29 and 13 hybrids exhibited significant heterosis both in case of mid parent and better parent heterosis in the desired direction.

Only four hybrids exhibited standard heterosis over standard check. Similar results of positive heterosis has been reported by Saidaiah *et al.* (2008), Iqbal *et al.* (2010) and Patel *et al.* (2010).

5.3.2.2 Ear height

Grain yield has positive correlation with ear height (Patil *et al.*, 1969). Based on gca effect study DMIL 4, DMIL 6 and DMIL 7 were good general combiners for increased ear height in maize.

Both gca and sca variances were significant and found to be important for the trait, similar findings were reported reports from Saad Imran Malik (2004) and Uddin *et al.* (2006).

While the higher magnitude of sca variance revealed that predominance of non additive gene effect as for the earlier reported by Amaregouda (2007)

Of the thirty one hybrids which showed significant sca effects, seventeen were in positive direction, while the remaining nineteen were in negative direction. Out of these, DMIL 9 x DMIL 2, DMIL 10 x DMIL 7 and DMIL 8 x DMIL 6 were the best three specific combiners for increased ear height.

Nine and three hybrids exhibited significant positive relative heterosis and heterobeltiosis respectively. Only one hybrid exhibited positive significant heterosis over standard check.

The high positive standard heterosis was exhibited by DMIL 11 x DMIL 4 and same cross also expressed significant relative and heterobeltiosis. The expression of high heterosis coupled with high sca effects and also had combination of parents which were good general combiners ability for this trait. Thus in the present investigation, the preponderances of non additive component for the inheritance of ear height was realized.

Ganguli *et al.* (1989), Petrovic (1998) reported positive heterosis over better parent. Patel *et al.* (2010) reported significant positive heterobeltiosis and economic heterosis for plant height.

Only cross showed significant heterosis for relative heterosis, heterobeltiosis as well as standard heterosis because there existed no genetic variability for this character.

5.3.2.3 Ear length

Ear length has more effect on grain yield and it is the only component, which effects the cob traits like kernel number and lesser degree on kernel weight (Herzogh, 1970).

The general combining ability effect study revealed that DMIL 3, DMIL 7, DMIL 9 and DMIL 14 were good general combiners.

Combining ability studies revealed importance of both gca and sca for the trait based on significance. However, magnitude of sca variance was considerably larger than gca variance depicting predominance of non additive component for the trait. Significant non additive gene action also recorded by Shen and Lai (1987), Amiruzzaman *et al* (2010).

Out of thirty one hybrids which showed significant sca effects, twenty three were in positive direction and among these hybrids DMIL 8 x DMIL 3, DMIL 9 x DMIL 6 and DMIL 14 x DMIL 6 exhibited highly positive significant sca effects for this trait.

Eighty seven and seventy four hybrids exhibited significant relative heterosis and heterobeltiosis respectively. Nine hybrids showed significant positive heterosis over standard check. These results were in accordance with Shashidhara (2008).

Out of 91 hybrids, three hybrids viz., DMIL 10 x DMIL 4, DMIL 8 x DMIL 3 and DMIL 9 x DMIL 6 exhibited highest significant positive standard heterosis over standard check.

From this study, the importance of non-additive gene, action for the inheritance of ear length was evident. Similar results were also reported by Khristova *et al.* (1995) and Ali and Topera (1986).

5.3.2.4 Ear width

There was an indication that selection for a character such as ear width could lead to considerable improvement in the yield (Williams *et al.* 19 65).

From gca effect study revealed that parents viz., DMIL 4, DMIL 9 and DMIL 11 were good general combiner for this trait.

From the combining ability analysis revealed that both GCA variance and the SCA variance were significant for this trait. The Similar findings were reported by Sharma *et al.* (1982), Turgut *et al.* (1995) and Quadri *et al.* (1993).

Out of 91, 17 exhibited significant sca effects. 12 showed significant in desired direction, among these DMIL 11 x DMIL 6, DMIL 9 x DMIL 1 and DMIL 14 x DMIL 3 had highest significant positive heterosis.

Fourty three and twenty two hybrids showed significant relative heterosis and heterobeltiosis, respectively. Two hybrids (DMIL 11 x DMIL 6 and DMIL 9 x DMIL 1) exhibited positive significant heterosis over standard. Turgut *et al.* (1995) reported high heterotic effects for cob girth and Abdel-Moneam *et al.* (2009) reported positive significant heterosis value for ear diameter.

5.3.2.5 Number of kernel rows per ear

This is one of the characters of ear, which positively correlated with grain yield. Parents DMIL 3, DMIL 4, DMIL 8, DMIL 9 and DMIL 10 were good sources of favourable genes for higher of number of kernel rows.

From the combining ability analysis it was clear that, both GCA variance and SCA variance s were found to be significant for this trait indicating the importance of both additive and non additive gene effects.

Out of 91 hybrids, 66 hybrids showed significant sca effect and among these 44 crosses exhibited significant sca effect in desirable direction. Highest sca effect exhibited by the crosses DMIL 6 x DMIL 1, DMIL 7 x DMIL 5 and DMIL 4 x DMIL 3.

Eighty three and sixty five of the crosses exhibited significant positive relative heterosis and heterobeltiosis, respectively. Only three crosses viz., DMIL 4 x DMIL 3, DMIL 9 x DMIL 5 and DMIL 10 x DMIL 3 hybrids showed significant positive heterosis over standard check. These findings are in agreement with Shashidhar (2008) and Amaregouda (2007).

The gca to sca variance ratio was lower than unity, which again confirms the predominance of non-additive gene action for the inheritance of this character. The results were in line with the findings of Pal and Prodhan (1994), Dehganapour *et al.* (1997) and Kumar *et al.* (1998).

Out of 99 crosses, three crosses which had significant positive standard heterosis were obtained from the parents which had good general combining ability, so one can expect transgressive segregants in later these crosses for carrying out selection to improve this trait.

5.3.2.6 Number of kernels per row

The general combining ability effect studies revealed that parents viz., DMIL 7, DMIL 9, DMIL 11 and DMIL 14 were good general combiner.

Table 17: Number of parents and crosses which showed significant gca and sca effects to the positive and negative directions and ranges

Sl. No	Characters	No. of parents with gca effects				No. of hybrids with sca effects			
		Positive	Negative	Total	Range	Positive	Negative	Total	Range
1	Days to 50% tasseling	9	3	12	-0.799 to 0.924	44	38	82	-3.108 to 2.079
2	Days to 50% silking	2	5	7	-0.433 to 0.536	28	20	48	-2.248 to 2.002
3	Days to 50% brown husking	5	6	11	-0.656 to 1.031	26	28	54	-3.188 to 5.469
4	Plant height (cm)	6	5	11	-13.403 to 7.332	17	14	31	-69.637 to 31.848
5	Ear height (cm)	4	2	6	-9.646 to 10.126	8	7	15	-45.431 to 26.61
6	Ear length (cm)	4	6	10	-0.921 to 1.076	23	8	31	-2.051 to 4.136
7	Ear width (cm)	3	4	7	-0.711 to 0.639	12	5	17	-2.242 to 7.652
8	No. of kernels per row	5	5	10	-1.875 to 1.719	44	22	66	-10.335 to 8.946
9	No. of rows per cob	3	4	7	-1.210 to 1.103	14	4	18	-2.296 to 3.267
10	Test weight (g)	4	3	7	-2.891 to 2.617	23	12	35	-6.779 to 7.072
11	Shelling %	0	1	1	-3.396 to 1.747	6	0	6	-14.398 to 12.302
12	Grain yield per plant (g)	2	4	6	-8.192 to 9.776	30	7	37	-25.991 to 42.290
13	Grain yield per ha (q/ha)	2	4	6	-4.324 to 5.160	30	10	40	-12.263 to 22.346
14	Protein content (%)	7	6	13	-0.715 to 0.613	44	27	71	-3.226 to 3.232
15	Starch content (%)	4	5	9	-0.491 to 0.477	40	34	74	-2.806 to 3.099

Table 18: Number of crosses showing significant heterosis level with respect to directions and ranges

SI. NO	Characters	Relative heterosis			Heterobeltois			Standard heterosis		
		Positive	Negative	Range	Positive	Negative	Range	Positive	Negative	Range
1	Days to 50% tasseling	12	66	-7.94 to 1.6	20	42	-7.94 to 3.23	18	44	-7.94 to 3.17
2	Days to 50% silking	40	17	-3.08 to 4.72	51	12	-3.05 to 6.4	0	71	-5.26 to 0.00
3	Days to 50% brown husking	3	73	-6.32 to 4.81	3	35	-6.32 to 5.38	4	29	-4.3 to 5.38
4	Plant height (cm)	29	15	-40.39 to 23.51	13	18	-44.05 to 19.51	4	15	-45.71 to 14.29
5	Ear height (cm)	9	17	-53.89 to 46.97	3	30	-60.18 to 34.84	1	8	-51.59 to 26.8
6	Ear length (cm)	87	0	-2.25 to 76.65	74	0	-7.71 to 44.75	8	24	-16.99 to 14.35
7	Ear width (cm)	43	0	-6.37 to 74.53	22	0	-13.42 to 73.06	2	5	-20.06 to 43.18
8	No. of kernels per row	83	1	-12.73 to 77.27	65	5	-17.65 to 77.27	3	44	-36.84 to 10.53
9	No. of rows per cob	20	0	-9.68 to 38.46	11	0	-13.33 to 38.46	23	0	-7.14 to 35.71
10	Test weight (g)	49	1	-12.19 to 37.76	27	8	-19.12 to 35.31	5	13	-18.11 to 16.91
11	Shelling %	65	0	-0.27 to 72.04	44	0	-2.96 to 48.27	10	0	-16.45 to 20.12
12	Grain weight per plant (g)	86	0	13.04 to 93.70	76	0	4.48 to 87.29	5	28	-31.58 to 22.11
13	Grain weight per ha (q/ha)	86	0	17.09 to 99.08	76	0	11.70 to 92.65	5	28	-27.60 to 23.23
14	Protein content (%)	59	13	-30.84 to 42.12	40	22	-36.62 to 32.39	22	43	-40.41 to 27.69
15	Starch content (%)	73	14	-3.64 to 11.28	46	22	-5.09 to 9.73	19	57	-6.01 to 3.55

Combining ability studies revealed importance of both gca and sca variances for trait based on significant. Similar results by Fan *et al.* (2008) and Kallu *et al.* (2001).

Out of 91 hybrids, 18 hybrids recorded the significant sca effect, among these 14 were in desirable direction and 4 in undesirable direction. Three Hybrids viz., DMIL 11 x DMIL 3, DMIL 12 x DMIL 7 and DMIL 13 x DMIL 4 exhibited significant sca effects in positive direction.

The additive to non additive variance ratio was lesser than unity observed indicating the importance of non-additive gene action in inheritance of this character. These results were in agreement with that of Mahantesh (2006) and Shashidhara (2008).

Twenty hybrids showed significant heterosis over mid parent, seventeen hybrids showed significant heterosis over heterobeltosis. And Twenty three hybrids exhibited positive significant heterosis over standard check. These were in line with the findings of Presolka *et al.* (1991), Salillari and Hoxha (1998) who also reported strong heterotic effect for this trait than other traits, Choudhary and Chaudhari (2002) reported significant heterosis for this trait.

.The relatively few number (five) of crosses with significant sca effect indicated the lower contribution of non-additive gene action in the inheritance of this character.

5.3.2.7 Shelling percentage

Out of 14 parents none of parents were Showed significant positive gca effect and negative significant gca effect was recorded by DMIL 1.

Among the hybrids, Six hybrids showed significant positive sca effect, but none of the hybrid showed significant negative sca effect, which indicated the higher contribution of non additive gene action in the inheritance of this trait.

In this study, the combining ability analysis showed higher SCA variance than GCA variance and also ratio of GCA and SCA was less than unity indicating the predominance of SCA variance.

The hybrid viz., DMIL 11 x DMIL 8, DMIL 14 x DMIL 12 and DMIL 4 x DMIL 3 were found to be good specific combiner, The ratio of gca to sca variance was lesser than unity which indicating non additive gene action for the trait.

Sixty five and fourty four hybrids hybrid showed significant heterosis over mid parent and better parent respectively. Ten hybrid exhibited significant heterosis over standard check.

5.3.2.8 Test weight

Hundred grain weight is one of the important grain characters. Grains, the ultimate economic product from the maize plant are the net result of various components. The total yield in maize is influenced by several grain component characters. Ultimate grain yield of a plant depends mainly on 100 grain weight through various other component characters. The study of hundred-grain weight deserves much often attention because grain yield is product of action and interaction of various grain components and is expressed through changes in its components. So, improvement in these individual component characters will be quite easier and its study will help in understanding the complex metric trait, grain yield.

From the study of general combining ability, it was evident that parents viz., DMIL 4, DMIL 5 and DMIL 10 were good general combiners.

Based on significance test, both additive and non additive gene actions were found to be important for this trait. But comparatively higher magnitude of sca variance compare to gca variance revealed that non additive gene action plays a major role in genetic control of this traits. Similar findings reported by Amiruzzaman *et al.* (2010).

Hybrids viz., DMIL 13 x DMIL 2, DMIL 13 x DMIL 7 and DMIL 4 x DMIL 3 were identified as best three specific combiners. The relatively few number of crosses with significant sca effect indicated the lower contribution of non-additive gene action in the inheritance of this character.

Table 19: Scoring of parents based on their gca effects for 15 characters in maize

Sl. No.	Parents	Days to 50% tasseling	Days to 50% silking	Days to 50% brow husking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear width (cm)	No of Kernels per row	No of rows per cob	Test wt (g)	Shelling %	Grain yield per plant (g)	Grain yield/ha (q/ha)	Protein content (%)	Starch content (%)	Total score	Rank	gca status
1	DMIL -1	-1	0	1	0	-1	-1	0	-1	-1	-1	-1	-1	-1	-1	-1	-10	10	Low
2	DMIL -2	-1	0	1	1	0	-1	0	0	-1	1	0	0	0	-1	0	-1	7	Low
3	DMIL -3	-1	0	0	1	0	1	-1	1	0	0	0	0	0	1	1	3	3	high
4	DMIL -4	0	1	-1	1	1	0	1	1	0	1	0	0	0	1	0	6	2	high
5	DMIL -5	1	1	-1	1	0	-1	0	0	0	0	0	1	1	-1	-1	1	5	High
6	DMIL -6	1	-1	1	0	1	-1	0	-1	0	0	0	0	0	-1	0	-1	7	Low
7	DMIL -7	1	0	1	1	1	1	0	-1	1	0	0	0	0	-1	-1	3	3	High
8	DMIL -8	-1	0	0	1	-1	0	0	1	0	0	0	0	0	-1	0	-1	7	Low
9	DMIL -9	0	1	1	-1	-1	1	1	1	1	1	0	1	1	1	1	9	1	High
10	DMIL -10	-1	1	-1	-1	0	1	0	1	-1	1	0	0	0	1	1	2	4	High
11	DMIL -11	-1	1	1	-1	0	-1	1	-1	1	0	0	0	-1	1	0	0	6	Low
12	DMIL -12	-1	0	-1	-1	1	-1	-1	0	-1	0	0	-1	0	0	1	-5	8	Low
13	DMIL -13	-1	-1	0	-1	0	0	-1	-1	1	-1	0	-1	-1	1	-1	-7	9	Low
14	DMIL -14	-1	0	-1	0	0	1	-1	0	0	-1	0	-1	-1	1	-1	-5	8	Low

Scoring – 1 = Significant gca effects in desired direction, 0 = Non-significant gca effects and -1 = Significant gca effects in undesired direction

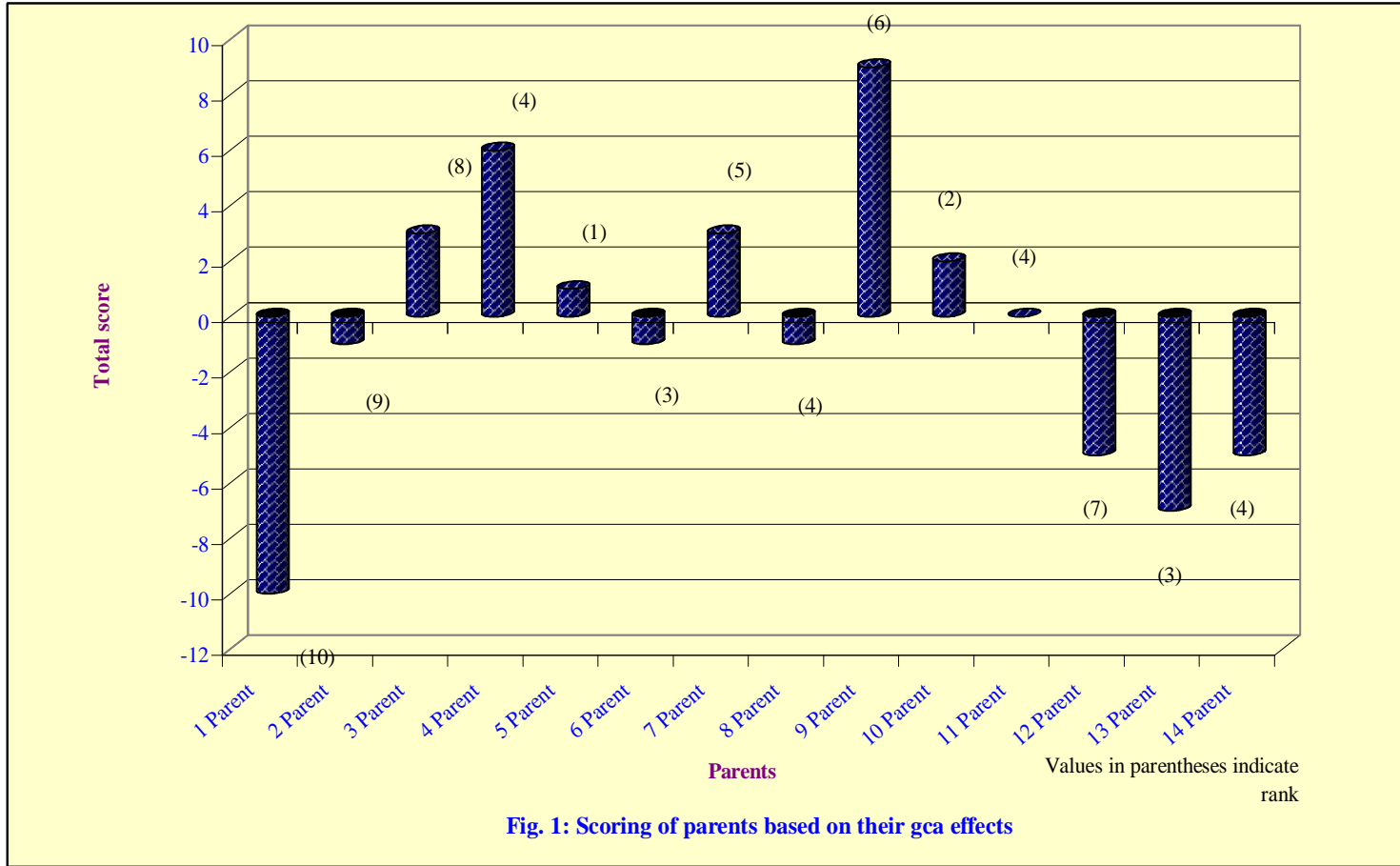


Fig. 1: Scoring of parents based on their gca effects

Fourty nine and twenty seven hybrids showed significant positive relative heterosis and heterobeltiosis while five hybrids exhibited significant standard heterosis over standard check. Similar expression of heterosis for this character was reported by Shashidhara (2008) and Patel *et al.* (2010).

5.3.3 Grain yield characters

Grain yield per hectare and grain yield per plant are the two important yield characters. Grain yield is a complex quantitative character which is influenced by other ancillary and component characters. Hence all changes in the components would not be expressed as changes in yield but all changes in yield would be accompanied by changes in one or more components. Johanson (1973) reported that genetic variability for grain yield in single ear is attributable to additive and non-additive genetic variance expressed through yield components. Because of influence from various ancillary characters and environmental factors, comprehensive studies become very difficult and it is the focal point about which plant breeding experiments are centered around.

5.3.3.1 Grain yield per plant

From the study of general combining ability of parents DMIL 5 and DMIL 9 were good general combiners for this trait.

In the present study variances due to general and specific combining ability were found to be significantly important for the trait. The studies made by Kumar *et al.* (1998), Mathur *et al.* (1998) and Amiruzzaman *et al.* (2010).

Magnitude of sca variance was greater than gca variance. This revealed predominance of non additive gene action for grain yield per plant. Similar kinds of observations were made by Mahantesh (2006) and Shashidhar (2008).

As many as thirty seven hybrids showed significant sca effects in desirable direction. The best three specific combiners were DMIL 14 x DMIL 10, DMIL 10 x DMIL 7 and DMIL 8 x DMIL 7.

Eighty six and seventy six hybrid exhibited significant heterosis over relative heterosis and heterobeltiosis respectively. Five hybrids showed significant heterosis over standard check. Similar results of highest percentage of heterosis over mid parent and better parent reported by Alam *et al.* (2008) and Shashidhara (2008).

5.3.3.2 Grain yield per hectare

From the gca effect studies parents DMIL 5 and DMIL 9 were identified as good combiners with significant high gca effects.

Combining ability studies revealed both gca variance than sca variances were found to be significant for grain yield per hectare depicting the importance of both additive and non additive gene effects. Similar reports made by Pal and Prodhan (1994), Turgut *et al.* (1995) Desai and Singh *et al.* (2001) and Shanthi *et al.* (2011).

The ratio of gca variance to sca variance was lesser than unity. This reveals that preponderance of non additive gene action for this trait. These results were in line with findings of Singh *et al.* (1983), Paul and Duara (1991) and Sedhom (1994), Mohammad (1993) and Satyanarayana *et al.* (1994).

Among 91 crosses, 37 crosses which exhibited significant sca effects, 30 were in the positive direction and among these hybrids DMIL 14 x DMIL 10, DMIL 10 x DMIL 7 and DMIL 8 x DMIL 7 which were good specific combiners.

Eighty six and seventy six hybrids showed significant heterosis over relative heterosis and heterobeltiosis respectively. Five hybrids exhibited significant heterosis over standard check. Similar levels of heterosis were also reported by Verma and Singh (1980), Debnath (1984), Jha and Khehra (1992), Larish and Brewbaker (1999) and Amaregouda (2007).

Among those which exhibited significant positive standard, relative heterosis and heterobeltiosis in the desired direction, only five hybrids, DMIL 9 x DMIL 5, DMIL 10 x DMIL 7, DMIL 4 x DMIL 3 , DMIL 8 x DMIL 7 and DMIL 14 x DMIL 10 .

Table 20: Performance of top ten superior e x perimental hybrids over checks with respect to per se value of 15 characters in maize

E x perimental hybrids	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear width (cm)	No of kernels per row	No of rows per cob	Test weight (g)	Shelling %	Grain yld per plant (g)	Grain yld per ha (q/ha)	Protein content (%)	Starch content (%)
DMIL 9 x DMIL 5	61**	63.5**	94	209	82.5	20.45	18.9	42**	14	40.05	86.91	174**	89.6**	9	65.92
DMIL 10 x DMIL 7	64	65**	92*	225	130	22.35	19.3	46**	15	38.5	86.74	169.5*	86.96*	9.49	64.34
DMIL 4 x DMIL 3	62**	66.5	94.5	215	115	20.6	19.45	42**	13	43.5*	91.04*	169*	86.69*	10.37	65.78
DMIL 8 x DMIL 7	62**	65.5**	91**	210	122.5	21.05	16.6	28	17**	34.9	85.35	169*	86.5*	9.73	65.38
1DMIL 4 x DMIL 10	64	64.5**	96	150	97.5	22.25	16.7	36	15	38.05	72.89	165.5*	84.85*	11.59**	68.1**
DMIL 11 x DMIL 5	63	64.5**	90**	210	80	21.45	16.3	38**	15	37.75	89.2*	164	84.68*	8.78	65.87
DMIL 9 x DMIL 8	63	63.5**	92*	200	99	22.2	17.5	40	16	40.6	84.37	164	84.53*	6.47	63.85
DMIL 14 x DMIL 5	63	66.5	93	215	103.5	19.2	18.35	34	15	38.5	89.65*	164	84.06*	9.52	65.38
DMIL 9 x DMIL 4	63	64.5**	98	205	110	22.65	17.45	30	16	43.9**	80	162	83.5*	11.08	65.29
DMIL 8 x DMIL 4	62**	66.5	95	200	117.5	18.8	18.25	38	16	41.5	84.35	162.5	83.26	10.5	65.34
Mean	62.67	64.97	92.61	200.05	103.68	19.75	17.16	32.88	15.0124	35.9438	79.5411	127.4632	64.83	10.0976	65.8958
Checks															
NK 6240 (Best Check)	63	66.5	93	210	108.44	20.9	17.95	38	14	37.55	74.3	142.5	72.71	10.85	66.86
S.6668	64	64.5	91	204.5	108.22	22.25	17.3	38	13	37.4	74.29	137	69.81	10.7	66.32
PAC 745	66	67.5	92	202	108.44	22.5	17.15	32	15	36.95	69.19	114.5	57.93	9.3	68.3
Jaikisaan 101	65	67.5	91	193	108.44	20.55	17.4	30	13	36.65	75.42	115	58.19	8.97	64.39
New top star	64	65.5	92	183	108.44	20.9	17.45	26	15	36.37	84.26	113.5	57.4	6.78	65.09
S 6304	65	64.5	94	175.5	108.44	20.4	18	32	15	36.88	76.47	113.5	57.4	9.13	65.37

Contd....

Table 20 contd....

Checks	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear width (cm)	No of kernels per row	No of rows per cob	Test weight (g)	Shelling %	Grain yld per plant (g)	Grain yld per ha (q/ha)	Protein content (%)	Starch content (%)
NK 30	62	65.5	93	190.5	108.44	21.55	17.95	28	14	35.58	71.71	112	56.61	8.94	66.44
VMH 4147	61	64.5	93	205.5	108.44	20.45	18.2	24	18	29.7	74.65	114.5	57.93	9.38	66.38
NK-6241	63	63.5	96	188	89.94	19.35	15.9	32	14	30.7	73.45	108	54.5	9.48	67.16
surer 900M	64	65.5	95	155.5	98.44	18.75	15.4	24	16	33.15	68.45	108.5	54.76	10.07	64.17
Bio-9681	62	64.5	91	165.5	62.94	23.7	18.4	32	16	33.2	72.8	125	63.47	9.81	65.29
JMH-203	62	63.5	94	188	108.44	20.75	17.5	28	15	35.7	75.33	115	58.19	9.63	65.54
cp 818	64	65.5	95	160.5	93.44	24.5	18.05	30	13	36.8	72.38	122.5	62.15	8.81	65.35
Arjun	65	67.5	94	163	145.94	21.85	19.3	32	14	36.92	71.11	108	54.5	7.22	64.95
Prabha	65	66.5	95	148	94.94	17	15.3	26	14	36.6	65.41	112	56.61	7.9	65.2
Renuka	64	65.5	94	145.5	98.44	17.8	15.55	24	13	35.2	63.91	123	62.42	8.46	64.47
SEm±	0.1369	0.2661	0.3736	8.0056	9.5135	0.7021	0.8342	0.8473	0.8404	1.6366	5.233	7.7678	4.107	0.1543	0.1383
CD 5%	0.3832	0.7452	1.0461	22.4162	26.6383	1.9658	23357	2.3725	2.353	4.5826	14.6527	21.7504	11.5	0.4319	0.3871
CD 1%	0.5066	0.9852	1.3829	29.6333	35.2147	2.5987	3.0877	3.1364	3.1106	6.058	19.3703	28.753	15.203	0.571	0.5118

* - Significant at 5% level

** - Significant at 1% level

Table 21: Performance of promising hybrids identified for grain yield and their sca effects in maize

Sl. No	Hybrid	Mean grain yield (q/ha)	Heterosis			gca effects of the parents	sca effects	Other traits with significant sca effect
			MP	BP	SH			
1	DMIL 9 x DMIL 5	89.6	86.02 **	84.00 **	23.23 **	High x High	14.213**	DT, DS, EW, NK/R, YP
2	DMIL 10 x DMIL 7	86.96	99.08 **	92.11 **	19.60 *	High x High	20.358**	PH, EH, EW, YP
3	DMIL 4 x DMIL 3	86.69	99.08 **	92.65 **	19.24 *	High x High	17.881**	DT, EW, NK/R, TW, S, YP
4	DMIL 8 x DMIL 7	86.5	84.12 **	82.59 **	18.97 *	Low x High	18.402**	DT, DBH, EH, YP,P
5	DMIL 4 x DMIL 10	84.85	98.18 **	87.45 **	16.70 *	Low x High	22.346**	NK/R, YP, P, ST
6	DMIL 11 x DMIL 5	84.68	75.80 **	73.90 **	16.46	Low x High	17.665**	DBH, EL, NK/R, YP
7	DMIL 9 x DMIL 8	84.53	82.49 **	77.43 **	16.26	High x Low	12.96**	DS, EL, NK/R, TW, YP
8	DMIL 14 x DMIL 5	84.06	92.43 **	72.62 **	15.61	Low x High	16.043**	DBH, EW, TW, YP
9	DMIL 9 x DMIL 4	83.5	75.76 **	75.28 **	14.84	High x High	10.946**	EL, TW, YP, P
10	DMIL 8 x DMIL 4	83.26	80.27 **	75.75 **	14.52	Low x High	15.185**	DT, NK/R, TW, P

TW – Test weight;
row;

EH – Ear height;

YP – Yield per plant,

PH – Plant height;

NK/R – No. of kernels per

EW – Ear width

S – Shelling percentage;

EL – Ear length

ST-Starch

P-Protein

NR/E-No.of rows per ear
weight

DS-Days to 50% silking DT-Days to 50% tasseling

DBH-Days to 50% brown husking

TW- test

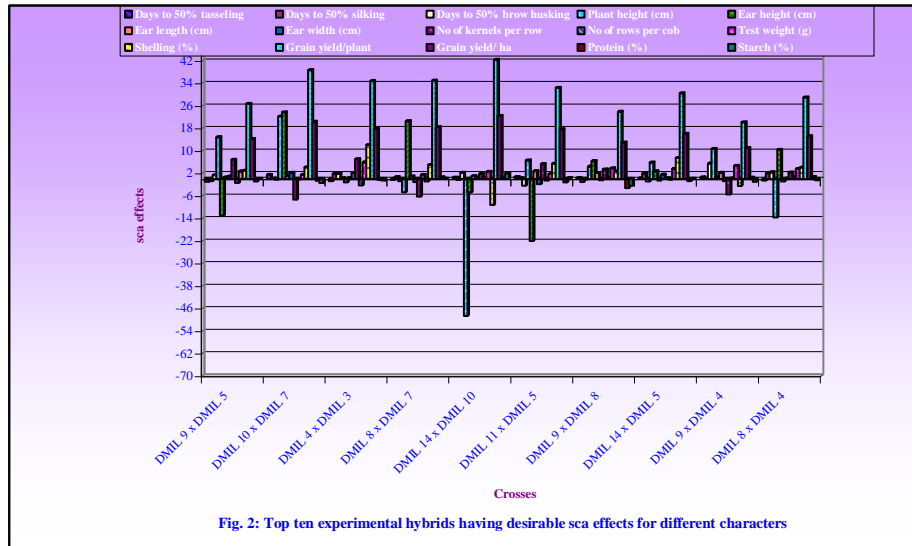


Fig. 2: Top ten experimental hybrids having desirable sca effects for different characters

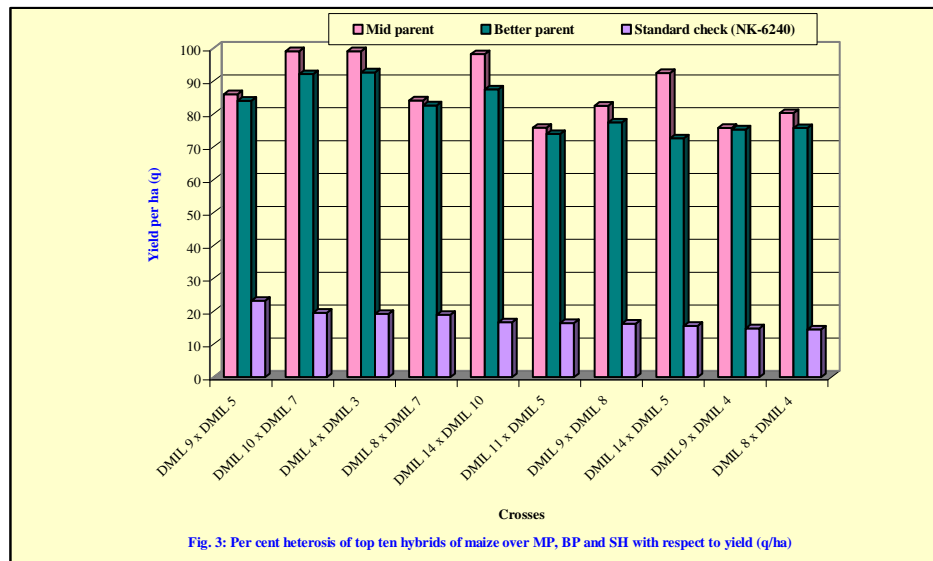


Fig. 3: Per cent heterosis of top ten hybrids of maize over MP, BP and SH with respect to yield (q/ha)

Hybrids like DMIL 9 x DMIL 5, DMIL 10 x DMIL 7 and DMIL 4 x DMIL 3 involved parents with high gca effects, So one can go for selection in segregating generations to improve yield per hectare. But for the rest of the crosses, hybrid development is the only way of attaining high grain yield per hectare as the non-fixable component is operating in these crosses with high sca effects.

5.4 Genetic analysis for quality parameters

Starch and protein are two important constituents of grain yield and these are very complex characters, which are influenced by other important characters, mainly yield and its attributes. So, comprehensive study becomes very different.

5.4.1 Protein

The general combining ability effects revealed that parents viz., DMIL 3, DMIL 4, DMIL 9, DMIL 10, DMIL 11, DMIL 13 and DMIL 14 were expressed significant gca effects.

Combining ability studies revealed that both gca and sca variances were significant with higher gca variance for this trait, the magnitude of sca variance was much higher compare to gca variance. This inferred predominance of non additive gene action for protein content. This conclusion was supported by Shanthy *et al.* (2011).

Among 71 crosses, which exhibited significant sca effects, 44 were in the positive direction and among these hybrids DMIL 10 x DMIL 3, DMIL 8 x DMIL 2 and DMIL 5 x DMIL 1 which were good specific combiners. Relatively large number of crosses with significant sca effect indicated the higher contribution of non-additive gene action in the inheritance of this character.

Fifty nine and fourty hybrids exhibited significant heterosis over relative heterosis and heterobeltois respectively. Twenty two hybrids showed significant heterosis over standard check. Similarly Mohan Lal *et al.* (2011) reported hybrids were identified to be significantly superior in quality traits.

5.4.2 Starch

The general combining ability effects revealed that parents viz., DMIL 3, DMIL 9, DMIL 10 and DMIL 12 were expressed significant gca effects.

Combining ability studies revealed that both gca and sca variances were significant with higher gca variance for this trait. The ratio of gca variance to sca variance was lesser than unity indicating predominance of non additive gene action for this trait. These results were in accordance earlier reports reported by Alika and Ojomo (1996),

Among 74 hybrids, which exhibited significant sca effects, 40 were in the positive direction and among these hybrids DMIL 7 x DMIL 3, DMIL 14 x DMIL 8 and DMIL 7 x DMIL 1 which were good specific combiners, remaining thirty four hybrids had sca effects in undesirable direction.

Seventy three and fourty six hybrids exhibited significant heterosis over relative heterosis and heterobeltois respectively. Nineteen hybrids showed significant heterosis over standard check. Similar expression of heterosis in this character was reported by Wang *et al.* (1998) and Pradeepa (2007).

5.5 Mean performance of hybrids for yield and its componental characters

An attempt to identify significantly superior hybrid over best check mean for yield and its componental characters. Hybrids exhibited significant differences for character under study, out of 91 hybrids, when top ten hybrids were identified based on their mean performance for important traits viz., days to 50% tasseling, days to 50% silking, days to 50% brown husking, plant height, ear height, ear length, ear width, number of kernels per row, number of rows per ear, test weight, shelling %, grain yield per plant, grain yield per hectare, protein content and starch content exhibited significant difference for yield and its componental character.(table 20)

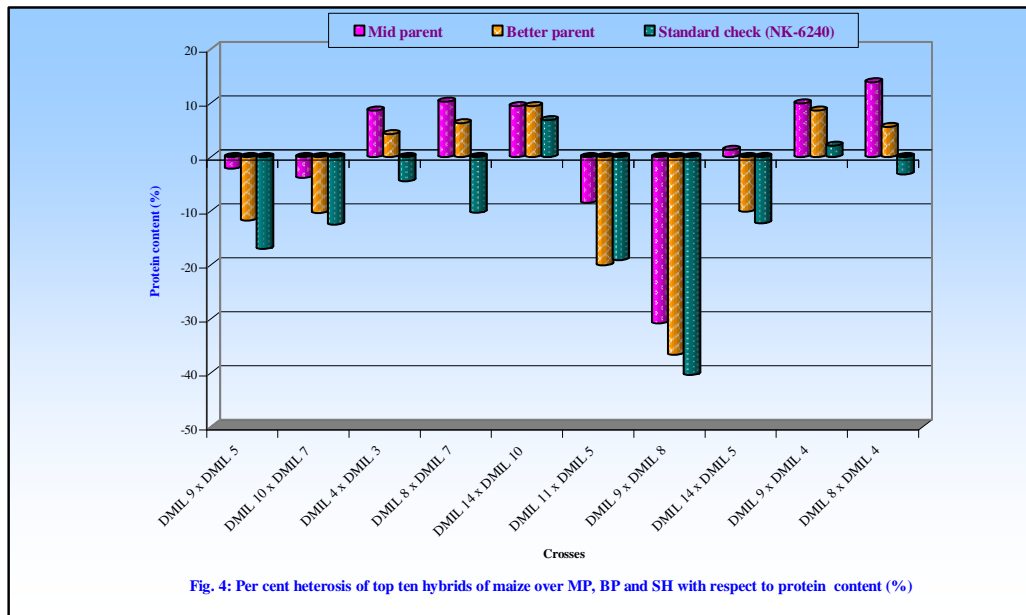


Fig. 4: Per cent heterosis of top ten hybrids of maize over MP, BP and SH with respect to protein content (%)

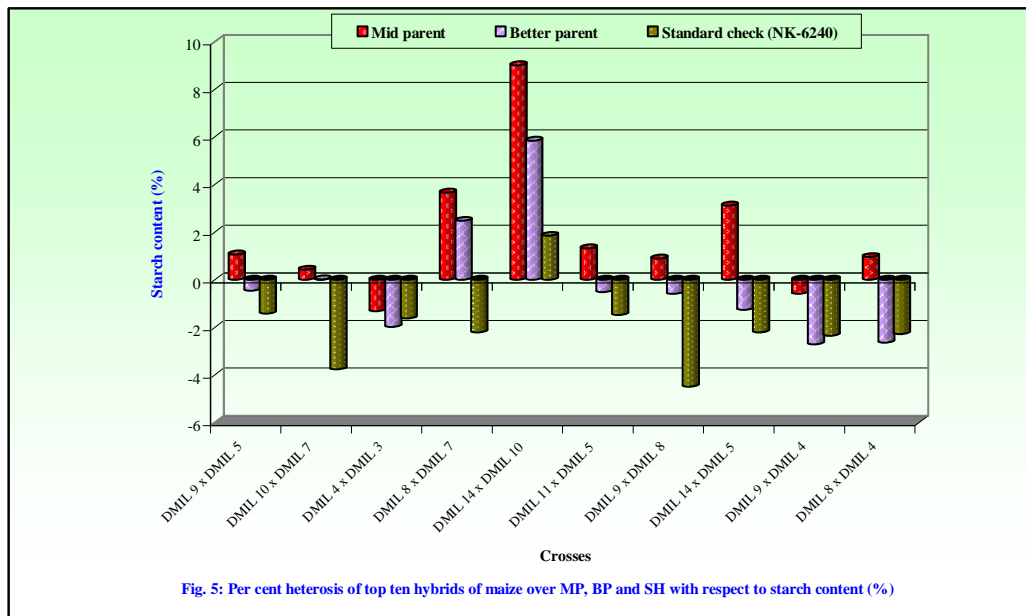


Fig. 5: Per cent heterosis of top ten hybrids of maize over MP, BP and SH with respect to starch content (%)

Table 22: Performance of top five experimental hybrids identified protein content and their sca effects in maize

Sl. No	Hybrid	Mean grain yield (q/ha)	Heterosis			gca effects of the parents	sca effects	Other traits with significant sca effect
			MP	BP	SH			
1	DMIL 10 x DMIL 3	14.02	42.12 **	32.39 **	29.22 **	High x High	3.23**	DT, EW, NK/R, YP, ST
2	DMIL 10 x DMIL 9	12.46	19.82 **	17.61 **	14.79 **	High x High	1.78**	DBH, PH, ST
3	DMIL 11 x DMIL 10	12.44	15.30 **	13.25 **	14.61 **	Low x High	1.63**	DT, DS, EL, NK/R, ST
4	DMIL 14 x DMIL 8	12.18	25.90 **	19.36 **	12.21 **	Low x Low	2.08**	PH, NK/R, ST
5	DMIL 9 x DMIL 3	12.23	28.16 **	15.49 **	12.72 **	High x High	1.50**	DT, EW, NK/R, YP, ST

Table 23: Performance of top five experimental hybrids identified starch content and their sca effects in maize

Sl. No	Hybrid	Mean grain yield (q/ha)	Heterosis			gca effects of the parents	sca effects	Other traits with significant sca effect
			MP	BP	SH			
1	DMIL 10 x DMIL 3	69.23	6.07 **	4.57 **	3.55 **	High x High	2.42**	DT, EW, NK/R, YP, P
2	DMIL 9 x DMIL 3	69.12	5.98 **	4.40 **	3.38 **	High x High	2.35**	DT, EW, NK/R, YP, P
3	DMIL 7 x DMIL 3	69.01	6.17 **	4.24 **	3.22 **	High x High	3.10**	DT, EL, NK/R, NR/E, YP
4	DMIL 8 x DMIL 2	68.8	8.73 **	7.13 **	2.91 **	High x Low	2.89**	TW, P
5	DMIL 6 x DMIL 2	68.64	6.65 **	6.41 **	2.67 **	Low x Low	2.66**	NK/R, TW



DMIL 9



DMIL 5



DMIL 9 x DMIL 5

Plate 2a. First high yielding F₁ hybrid



DMIL 10



DMIL 7



DMIL 10 x DMIL 7

Plate 2b. Second high yielding F₁ hybrid



DMIL 4



DMIL 3



DMIL 4 x DMIL 3

Plate 2c. Third high yielding F₁ hybrid



DMIL 8



DMIL 7



DMIL 8 x DMIL 7

Plate 2d. Fourth high yielding F₁ hybrid



DMIL 14



DMIL 10



DMIL 14 x DMIL 10

Plate 2e. Fifth high yielding F₁ hybrid

Based on mean performance of hybrids viz., DMIL 9 x DMIL 5, DMIL 10 x DMIL 7, DMIL 4 x DMIL 3, DMIL 8 x DMIL 7, DMIL 14 x DMIL 10, DMIL 11 x DMIL 5, DMIL 9 x DMIL 8 and DMIL 8 x DMIL 4, were top performing hybrids these recorded significant superior *per se* performance compare to over check mean, Among these top single cross hybrids it was observed that the cross DMIL 9 x DMIL 5 exhibited highest yield compare to check hybrid which exhibited significantly superior performance for most of traits namely days to 50% tasseling, days to 50% brown husking, number of kernels per row, grain yield per plant, these are the component traits may be resulted in high yielding and DMIL 10 x DMIL 7 also exhibited highest yield over check because it exhibited significant performance for days to 50 % silking, days to 50% brown husking, number of kernels per row, grain yield per plant followed by DMIL 4 x DMIL 3 exhibited significantly superior performance for days to 50% tasseling, number of kernels per row, test weight, shelling percentage, grain yield per plant and DMIL 8 x DMIL 7 also exhibited significantly superior performance for days to 50% tasseling, days to 50% silking, days to 50% brown husking, number of rows per ear, grain yield per plant like this remaining top performing hybrids exhibited significantly superior performance for some yield componental characters and these componental characters may contribute for the superior performance of these experimental hybrids. Out of 10 top performing single crosses only five crosses, DMIL 9 x DMIL 5, DMIL 10 x DMIL 7, DMIL 4 x DMIL 3, DMIL 8 x DMIL 7 and DMIL 14 x DMIL 10 also exhibited significant standard heterosis.

There fore, from all considerations DMIL 9 x DMIL 5, DMIL 10 x DMIL 7, DMIL 4 x DMIL 3 and DMIL 8 x DMIL 7 hybrids appear to be excellent for commercial cultivation and hybrid DMIL 14 x DMIL 10 also recorded high yield with high protein and starch content. It is worth while to take up trails on farmers field to study the performance of this potential crosses, so as to make commercial exploitation of hybrid vigour a reality.

5.6 Selection of useful/promising lines and hybrids for future use

Based on their general combining ability effects best lines were identified using scoring techniques (Table 11 and 19 and Fig 1).

Among 14 parents, the parent DMIL 9 exhibited significant gca effects for maximum number of yield contributing characters. This was evident from the pooled score of gca analysis combiners with highest pooled score of 9. The second rank was taken by parent DMIL 4 with pooled score of 6. Parents DMIL 3 and DMIL 7 with pooled score of 3 ranked 3rd, parent 10 with pooled score of 2 ranked 4th, fifth rank was taken by parent DMIL 5 with pooled score of 1 and sixth rank by parent DMIL 10 with pooled score of 0. These are identified as good general combiners which can be used for the development of synthetic varieties after confirmation their combining ability in later generations.

Based on the performance, top ten. hybrids are selected for trait of each, which had higher grain yield (Table 21 and Fig 3, 4, 5).

The hybrids viz., DMIL 9 x DMIL 5, DMIL 10 x DMIL 7, DMIL 4 x DMIL 3, DMIL 8 x DMIL 7, DMIL 14 x DMIL 10, DMIL 11 x DMIL 5, DMIL 9 x DMIL 8, DMIL 8 x DMIL 4, DMIL 9 x DMIL 4, DMIL 12 x DMIL 9 and DMIL 9 x DMIL 2 were top performing crosses based on grain yield per hectare. The high yielding ability of these hybrids was on account of desirable contribution from days to 50 per cent tasseling, silking, plant height, cob length, cob girth, number of kernel rows per cob. Number of kernels per row, test weight, grain yield per plant, shelling percentage, protein and starch these also had considerably high sca effects though they were significant (Fig 2). Thus these can be directly used as hybrids or apply standard selection procedure.

The hybrids, DMIL 10 x DMIL 3, DMIL 10 x DMIL 9, DMIL 11 x DMIL 10, DMIL 14 x DMIL 8, DMIL 9 x DMIL 8 and DMIL 10 x DMIL 3, DMIL 9 x DMIL 3, DMIL 7 x DMIL 3, DMIL 8 x DMIL 2, DMIL 6 x DMIL 2 were the top performing crosses with respect to protein and starch content respectively (Table 22 and 23).

Future line of work

1. Ten promising single cross hybrids identified for grain yield need to be tested in multi-location trials for their stability across locations/seasons on large scale basis before their commercial utilization.

2. From this investigation, promising single cross hybrid for starch and protein are identified. Hence it is suggested to test these hybrids in multilocation trails to study the performance of these hybrids across different environments for their wider adoptability
3. Promising single crosses having good general combining parents can be used for further improvement of parents in later generations.
4. An attempt has to be made to strike a balance between protein content and yield while developing hybrids

6. SUMMARY AND CONCLUSIONS

The present study on half diallel analysis in maize (*Zea mays* L.; $2n=20$) was conducted during *kharif* 2011 at MARS, University of Agricultural Sciences, Dharwad. The experiment comprised of fourteen parents and their 91 F_1 s was conducted in Lattice square design with two replications.

The objective were to study the extent of heterosis, to assess the combining ability of parents and to know the nature of gene action in respect of yield and its component characters viz., days to 50 per cent tasseling, days to 50 per cent silking, days to 50 per cent brown husk maturity, Plant height (cm), ear height (cm), ear length (cm), ear diameter (cm), number of kernel rows per row, number of kernels per row 100 grain weight (gm), shelling percentage, grain yield per plant (g), grain yield per ha (kg), and for quality parameters like protein and starch content. It was also intended to genetic material for future breeding programme to develop high yielding genotype.

Analysis of variance closely indicated the presence of significant difference among parents, hybrids and checks, for all traits indicating the presence of genetic variability in the materials used for the study.

The ANOVA revealed that both SCA variance and GCA variance significant for all characters. Hence, the ratio of additive to dominance variance was lesser for all the traits. Hence, this indicates that all traits possess higher dominance variance than additive variance.

The parent DMIL 5 and DMIL 9 were identified as good general combiner for yield per ha. Similarly, for yield per plant, DMIL 4 and DMIL 9, for test weight DMIL 2, DMIL 4, DMIL 9 and DMIL 10, for number of rows per cob DMIL 7, DMIL 9, DMIL 11 and DMIL 13, for number of kernels per row DMIL 3, DMIL 4, DMIL 8, DMIL 9 and DMIL 10, for ear width DMIL 4, DMIL 9 and DMIL 11, for ear length DMIL 3, DMIL 6, DMIL 8, DMIL 9 and DMIL 14, for shelling percentage none of the parents were good general combiners, for ear height DMIL 4, DMIL 6, DMIL 7 and DMIL 12, for plant height DMIL 2, DMIL 3, DMIL 4, DMIL 5, DMIL 7 and DMIL 8, for days to 50 per cent brown husking DMIL 1, DMIL 2, DMIL 6, DMIL 7, DMIL 9 and DMIL 11, for days to 50 per cent silking DMIL 4, DMIL 5, DMIL 9, DMIL 10 and DMIL 11 for days to 50 per cent tasseling DMIL 5, DMIL 6 and DMIL 7 were identified as good general combiners. And for quality parameters like protein content DMIL 3, DMIL 4, DMIL 9, DMIL 10, DMIL 11, DMIL 13 and DMIL 14, for starch DMIL 3, DMIL 9, DMIL 10 and DMIL 12 were identified as good general combiners.

The hybrids DMIL 14 x DMIL 10 and DMIL 10 x DMIL 7 were identified as good specific combiner for yield per ha in order to their merit. Similarly, for yield per plant DMIL 14 x DMIL 10, DMIL 10 x DMIL 7 for shelling percentage DMIL 11 x DMIL 8, DMIL 14 x DMIL 12, DMIL 4 x DMIL 3 for test weight DMIL 13 x DMIL 2, DMIL 13 x DMIL 7, for number of rows per cob DMIL 11 x DMIL 3, DMIL 12 x DMIL 7, for number of kernels per row DMIL 6 x DMIL 1, DMIL 7 x DMIL 5, for ear width DMIL 11 x DMIL 6, DMIL 9 x DMIL 1, for ear length DMIL 9 x DMIL 6, DMIL 8 x DMIL 3, ear height DMIL 9 x DMIL 2, DMIL 10 x DMIL 7, for plant height DMIL 11 x DMIL 6, DMIL 10 x DMIL 9, for brown husk maturity DMIL 8 x DMIL 1, DMIL 11 x DMIL 9, for silking DMIL 14 x DMIL 4, DMIL 6 x DMIL 5, for tasseling DMIL 5 x DMIL 2, DMIL 13 x DMIL 6 were identified as good specific combiners. For quality parameter like protein DMIL 10 x DMIL 3, DMIL 8 x DMIL 2 and for starch DMIL 7 x DMIL 3, DMIL 14 x DMIL 8 were identified as good specific combiners.

Among 14 parents, Parent DMIL 9 was the best general combiners for days to 50 per cent brown husking, ear length, ear width, number of kernels per row, number of rows per cob, test weight, grain yield per plant, grain yield per hectare.

And parent DMIL 4 was good general combiner for days to 50% silking, plant height, ear height, ear width, number of kernels per row, test weight, protein content, also parent DMIL 5 was good general combiner for days to 50% tasseling, days to 50% silking, plant height, grain yield per plant, grain yield per ha.

Out of 91 hybrids viz., DMIL 9 x DMIL 5, DMIL 10 x DMIL 7, DMIL 4 x DMIL 3, DMIL 8 x DMIL 7, DMIL 14 x DMIL 10, DMIL 11 x DMIL 5, DMIL 9 x DMIL 8, DMIL 14 x DMIL 5 , DMIL 9 x DMIL 4 and DMIL 8 x DMIL 4 were top performers with highest sca effects for grain yield and these single cross hybrid were obtained from parents with high x high, high x high, low x high, low x high, low x high, high x low, low x high, high x high, low x high, high x low respectively.

The hybrids, DMIL 10 x DMIL 3, DMIL 10 x DMIL 9, DMIL 11 x DMIL 10, DMIL 14 x DMIL 8, DMIL 9 x DMIL 8 and DMIL 10 x DMIL 3, DMIL 9 x DMIL 3, DMIL 7 x DMIL 3, DMIL 8 x DMIL 2, DMIL 6 x DMIL 2 were the top performing crosses with respect to protein and starch content respectively. And all most these crosses were obtained from the parents with high x high gca effects.

From the present investigation it is proposed to evaluate in multi-location trial on large scale basis before their commercial cultivation of identified promising hybrids for grain yield and their stability over locations/seasons.

Promising single cross hybrids involving high x high parental gca effects for grain yield and protein content may be used for further improvement of lines by selection in advanced generations.

REFERENCES

- Abdel-Moneam, A. N., Attia, A. N., El-emery, M. I and Fayed, E. A., 2009, Combining ability and heterosis for some agronomic traits in crosses of maize. *Pakistan J. Biol. Sci.*, **12** (5) : 433-438
- Abelardo, J., De la Vega and Scott, C. C., 2006, Multivariate analysis to display interactions between environment and general or specific combining ability in hybrid crops. *Crop Sci.*, **46** : 957-967.
- Akhtar, S. A. and Singh, T. P., 1981, Heterosis in varietal crosses of maize. *Madras Agric. J.*, **68** : 47-51.
- Alam, A. K. M. M., Ahmed, S., Begum, M and Sultan, M. K., 2008, Heterosis and combining ability for grain yield and its contributing characters in maize. *Bangladesh J. Agril. Res.* **33**(3) : 375-379.
- Ali Akeel Wannows., Hasan Kameel Azzam and Samir Ali AL- Ahmad., 2010, Genetic variances, heritability, correlation and path coefficient analysis in yellow maize crosses (*Zea mays* L.) *Agric. Biol. J. N. Am.*, **1**(4) : 630-637.
- Ali, M. L. and Topera, N. M., 1986, Comparative performance of four types of factors for evaluating corn lines from two populations. *Philippines J. Crop Sci.*, **3** : 175-179.
- Alika, J. E and Ojomo, I. O., 1996, Combining ability and reciprocal effects of physicochemical and grain quality characteristics in maize. *Food Chemistry*, **57** : 317-335.
- Alika, J. E., 1994, Diallel analysis of ear morphological characters in maize (*Zea mays* L.). *Indian J. Genet.*, **54** : 22-36.
- Altinbos, M. and Tosum, M., 1998, A study on utilizing combining ability covariances in hybrid maize (*Zea mays* L.) breeding. *Anadohi*, **8** : 90-100.
- Altinbos, M., 1995, Heterosis and combining ability in maize for grain yield and some plant characters. *Adadolu*, **5**(2) : 35-51.
- Alvarez, A., Garay, G., Gimenez, J., Ruiz, D. E. and Galarreta, J. I., 1993, Heterosis in two synthetic varieties of maize based on morphological and reproductive traits. *Investigation Agraria*, **8**(3) : 333-340.
- Amaregouda H. M., 2007, Combining ability analysis of s2 lines derived from yellow pool population in *rabi* maize. *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci. Dharwad, Karnataka (India).
- Amiruzzaman, M., Islam, M. A., Hassan, L and Rohman, M. M., 2010, Combining ability and heterosis for yield and component characters in maize. *Academic J. Pl. Sci.*, **3** (2) : 79-84.
- Amit Dadheech and Joshi V. N., (2007), Heterosis and Combining Ability for Quality and Yield in Early Maturing Single Cross Hybrids of maize (*Zea mays* L.). *Indian J. Agric. Res.*, **3**(41) : 45-48
- Anonymous, 2011, Quarterly Bulletin of statistics 2011, *FAO*, pp. 12-30.
- Appadurai, R. and Nagarajan, R., 1975, Hybrid vigour in popcorn. *J. Madras Agric. Univ.*, **62** : 122-126.
- Arunachalam, V., 1976, Evaluation of diallel crosses and combining ability by graphical methods, *Indian J. Genet. Pl. Breed.*, **36** : 358-366.
- Ashby, E., 1930, Studies on the inheritance of physiological characteristics. I. physiological investigation of the nature of hybrid vigour in maize. *Annals of Botany*, **44** : 457-467.
- Ashby, E., 1932, Studies in the inheritance of physiological characters. II. Further experiments upon the basic of hybrid vigour and upon the inheritance of efficiency index and respiration rate in maize. *Annals of Botany*, **46** : 1007-1032.

- Aurelio Mendes Aguiar., Luciana Aparecida Carlini-Garcia., Adelmo Resende da Silva., Mateus Figueiredo Santos., Antonio Augusto Franco Garcia., Cláudio Lopes de Souza Jr., (2003), Combining ability of inbred lines of maize and stability of their respective single-crosses *Scientia Agricola*, **60**(1) : 83-89.
- Beck, D. L., S. K. Vassal and J. Crossa, 1991. Heterosis and combining ability among subtropical and temperate intermediate-maturity maize germplasm. *Crop Sci.*, **31** : 68-73
- Beck, D. L., Vasal, S. K. and Crossa, J., 1990, Heterosis and combining ability of CIMMYT's tropical early and intermediate maturity maize (*Zea mays* L.) germplasm. *Maydica*, **35** (3) : 279-285.
- Bello, O. B and Olaoye, G., 2009 Combining ability for maize grain yield and other agronomic characters in a typical southern guinea savanna ecology of Nigeria. *African J. Biotechnol.*, **8**(11) : 2518-2522.
- Betran, F. J., Ribaut, J. M., Beek, D. and Gonzalez de leon, D., 2003, Genetic diversity, specific combining ability and heterosis in tropical maize under stress and nonstress environments. *Crop Sci.*, **43** : 797-806.
- Bhalla, S. K. and Khehra, A. S., 1977, Analysis of combining ability in maize at varying plant densities. *Maydica*, **22** : 19-26.
- Bhatnagar, S. K., Ranwaz, B. R. and Sunderesan, R., 1993, Heterosis in early maize. *Indian J. Genet.*, **53** : 94-96.
- Bruce, A. B., 1910, The Mendelian theory of heredity and the augmentation of vigour. *Science*, **32** : 627-628. *Theor. Appl. Genet.*, **49** : 117-112.
- Catherine, M. and Pollak, L. M., 1988, Heterotic patterns among ten corn belt and exotic maize populations. *Crop Sci.*, **28** : 500-504.
- Choudhary, A. K., Chaudhari, L. B., 2002, Heterosis pattern of some early generation inbreds derived from two maize (*Zea mays* L.) populations. *Indian J. Genet.*, **62** (2) : 159-160.
- Choudhary, A. K., Chaudhary, L. B. and Sharma, K. C., 2000, Combining ability estimates of early generation inbred lines derived from to maize populations. *Indian J. Genet.*, **60**(1) : 55-61.
- Crossa, I., Gardaner, C. O. and Mumm, R. F., 1987, Heterosis among populations of maize (*Zea mays* L.) with different levels of exotic germplasm. *Theor. Appl. Genet.*, **73** : 445-450.
- Crossa, J., Vesal, S. K. and Beck, D. L., 1990, Combining ability estimates of CIMMYT's tropical late yellow maize germplasm. *Maydica*, **35** (3) : 273-278.
- Damborsky, M., Chloupek, O. and Ehrenbergerova, J., 1994, Variability of maize lines and diallel cross hybrids. *Gebetika-a-Slechtenti*, **30** (4) : 297-303.
- Daneswar, M. H. and Dickinson, D. B., 1999, Investigation of phyto glycogen sugar and starch content in sugar and starch corn (*Zea mays* L.). *Crop Res.*, **17** : 199-208.
- Dass, S., Aror, P. and Singh, M., 1997, Genetics of grain yield and cob traits in maize. *Ann. Biol.*, **13** : 288-287.
- Davis, R. L., 1927, Report of the plant breeder. Uerto Rico Agricultural Experimental Station. *Annual Report*, pp. 14-15
- Debnath, S. C. and Sarkar, K R., 1987, Genetic analysis of grain yield and some of its attributes in maize (*Zea mays* L.). *Thailand J. Agric. Sci.*, **20** : 263-276.
- Debnath, S. C. and Sarkar, K. R., 1990, Combining ability analysis of grain yield and some of its attributes in maize (*Zea mays* L.). *Indian J. Genet.*, **50** : 57-61.
- Debnath, S. C., 1984, Heterosis in maize I : grain yield and some of its attributes (in India). *Bangladesh J. Agric. Res.*, **9** (2) : 78-83.

- Debnath, S. C., 1987, Heterosis in maize (*Zea mays* L.) *Bangladesh J. Agric. Res.*, **12**(3) : 161-168.
- Dehghanpour, Z., Ehdaie, B., Moghaddam, M., Griffin, B. and Hayman, B., 1997, Diallel analysis of agronomic characters in white endosperm corn. *J. Genet. Pl. Breed.*, **50** (4) : 357-365.
- Desai, S. A. and Singh, R. D., 2001, Combining ability studies for some morphological, physiological and biochemical traits related to drought tolerance in maize. *Indian J. Genet. Pl. Breed.*, **61** : 34-36.
- Dhillon, B. S. and Singh, J., 1976, Diallel analysis of yield and other traits of maize varieties. *SABRAO J.*, **8** : 147-152.
- Diallel Analyses of Agronomic Traits Using Chinese and U. S. Maize Germplasm. *Crop Sci.*, **45** : 1096-1102.
- Dickert, T. E. and Tracy, W. F., 2002, Heterosis for flowering time and agronomic traits among early open-pollinated sweet corn cultivars. *J. American Soc. Hort. Sci.*, **127**(5) : 793-797.
- Dodiya, N. S. and Joshi, V. N., 2003, Heterosis and combining ability for quality and yield in early maturing single cross hybrids of maize (*Zea mays*). *Crop Res.*, **26**(1) : 114-118.
- Downswell, C. R., Paliwal, R. L. and Cantrell, R. P., 1996, Maize in the third world, West View Press, pp. 1-37. EAST, E. M., 1936, Heterosis. *Genetics*, **21** : 375-397.
- Dubey, R. B., Joshi, V. N. and Pandiya, N. K., 2001, heterosis and combining ability for quality, yield and maturity traits in conventional and non-conventional hybrids of maize. *Indian J. Genet. Pl. Breed.*, **61**(4) : 353-355.
- Dutu, H., 1998, Phenotypic and genetic correlations between vegetative period and grain yield and other agronomic trait in early maize. *Analeta Institutului de Cercetari pentru cereale Si plante Technice Fundulea*, **65** : 101-109.
- East, E. M. and Hayes, H. K., 1912, Heterozygosis in evolution and in plant breeding. *U. S. Department Agricultural Bulletin*, p. 243.
- East, E. M., 1936, Heterosis. *Genetics*, **21** : 375-397.
- El-Hosary, A. A. Mohamed, M. K., Sedhom, S. A. and Abo-El-Hassan, G. K. A., 1994a, Performance and combining ability in diallel crosses of maize, *Annals of Agricultural Sciences*, **32**(1) : 203-216.
- El-Hosary, A. A., Mohamed, M. K., Sedhom, S. A. and Abo-El-Hassan, G. K. A., 1994b, General and specific combining interactions with year in maize. *Ann. Agric. Sci.*, **32** : 247-288.
- El-Moula, M. A. A., Barakat, A. A. and Ahmed, A. A., 2004, Combining ability and typed gene action for grain yield and other attributes in maize (*Zea mays* L.). *Aust. J. Agric. Sci.*, **35**(3) : 129-142.
- Fan, X. M., Chen, H. M., Tan, J., Xu, C. X., Zhang, Y. D., Luo, L. M., Huang, Y. X and Kang, M. S., 2008, Combining abilities for yield and yield components in maize. *J. Maydica*, **53** : 39-46
- Ganguli, D. K., Haque, M. F. and Sinha, P. K., 1989, Heterosis in inter-population crosses in maize. *J. Res.*, Birsa Agricultural University, **1** (1) : 59-65.
- Gardner, C. O., 1963, Estimation of genetic parameters in cross-pollinated plants and their implications in plant breeding. *Statistical Genetics and Plant Breeding*. NASNRS Washington D. C. Publication, **982** : 228-24.
- Geetha, K. and Jayaraman, N., 2000a, Path analysis in maize (*Zea mays* L.). *Agric. Sci. Digest*, **20** : 60-61.
- Geetha, K. and Jayaraman, N., 2000b, Genetic analysis of yield in maize (*Zea mays* L.). *Madras Agric. J.*, **87** : 638-640.

- Geetha, K., 1997, Genetic analysis of yield, starch and downy mildew resistance in maize (*Zea mays* L.). *Ph. D. Thesis*, Tamil Nadu Agricultural University, Coimbatore.
- Geetha, K., 2001, Heterosis in maize (*Zea mays* L.). *Agric. Sci. Digest*, **21** : 202-203.
- Giesbrecht, J., 1960, Inheritance of maturity in maize. *Canadian J. Genet. Cytol.*, **40** : 490-499.
- Giridharan, S., Prasad, M. N. and Rangaswamy, S. R., 1996, Diallel, triallel and quadriallel analysis for grain yield in maize. *Madras Agric. J.*, **83**(4) : 230-236.
- Glover M. A., David B. Willmot., Larry L. Darrah., Bruce E. Hibbard., and Xiaoyang Zhu., 2005, , A study of the genetic effects of maize ears and related traits. *Zhejiang Nongye Texue*, **1** : 21-24.
- Gomes-E-Gama, E. E., Hallauer, A. R., Lopes, M. A., Pa Entoni, S. N., Santos, Mx-Dos, Guimaraes, P E. O. and Dos, Santos, M. X., 1995, Combining ability among fifteen early cycle maize populations in Brazil. *Brazilian Journal of Genetics*, **18** (4) : 569-577.
- Gomes-E-Gama, E. E., Mahnavaca, R., Parentoni, S. N., Acjcep Cap and Griffing, B. and Zsiros, E., 1971, Heterosis associated with genotype \times environment
- Gomes-E-Gama, E. E., Mahnavaca, R., Parentoni, S. N., Acjcep Cap and Guimaraes, P.E.O., 1993, Evaluation of maize top crosses for their potential use in breeding programme. *Pesquisa-Agropecua ria-Brasilerria*, **28** (4) : 481-487.
- Griffing, B. and Zsiros, E., 1971, Heterosis associated with genotype- environment interactions. *Genetics*, **68** : 443.interactions. *Genetics*, **68** : 443.
- Griffing, B., 1956a, A generalized treatment of diallel crosses in quantitative inheritance. *Heredity*, **10** : 31-50
- Griffing, B., 1956b, Concept of general combining ability and specific combining ability in relation to diallel crossing system. *Australian J. Biol. Sci.*, **9** : 463-493.
- Guimaraes, P. E. O., 1993, Evaluation of maize top crosses for their potential use in breeding programme. *Pesquisa-Agropecua ria-Brasilerria*, **28** (4) : 481-487.
- Guo, P. Z., Gardner, C. O. and Obaidi, M., 1986, Genetic variations and gene effect controlling prolificacy and other traits in maize (*Zea mays* L.) *Acta Genetica Sinica*, **13** : 35-42.
- Gupta, S. C. and Nagda, A. K., 2000, Analysis of variety diallel cross for yield and its components in winter maize. *Indian J. Genet. Pl. Breed.*, **60** : 301-303.
- Gupta, S. C., Nagda, A. K. And Kulmi, G. K., 1994, Economic heterosis in double cross hybrids of maize. *Crop Res.*, **8** : 634-636.
- Habtamu Zelleke., 2000, Combining abilityfor grain yield and other agronomic characters in inbred lines of maize (*Zea mays* L.). *Indian J. Genet.*, **60** (1) : 63-70.
- Hallauer, A. R., Lamkey, K. R., Russell, W. A. and White, P. R., 1994, Regression of B97 and B98. Tow parental inbred lines of maize. *Crop Science*, **34** : 318- 319.
- Hassaballa, E. S., El-Morshidy, M. A., Kalifa, M. A. and Shal Aby, E. M., 1980, Combining ability analysis in maize, I. *Flowering Research Bulletin Faculty of Agriculture*, Ain Sham's University, 1291, p. 8.
- Hayes, H. K., Immer, F. F. and Smith, D. L., 1956, *Methods of Plant Breeding*. McGraw Hill Book Publishing Company, Inc., New Delhi, pp. 21-34.
- Hayman, B. I., 1954b, The analysis of variance of diallele tables. *Biometrics*, **10** : 235-242.
- Hayman, B. I., 1958, The theory and analysis of diallele crosses II, *Genetics*, **43** : 63-85.
- Hayman. B. I., 1954a, The theory and analysis of diallele crosses, *Genetics*, **39** : 789-809.
- Heidrch-Sobrinho and Cordeiro, A. R., 1975, Co-dominant isoenzymic alleles as makers of genetic diversity correlated with heterosis in maize (*Zea mays* L.) *Theor. Appl. Genet.*, **46** : 197-199.

- Herbert, Y. and Gallis, A., 1986, Heterosis and genetics and variation for quantitative characters in a 12 x 12 diallel mating design maize, *in* : Biometrics in Plant Breeding. (M. J. Kearse and C. P. Werner, (eds.) Briminlgham, U. K., pp. 140-152.
- Herzogh, M., 1970, Importance of yield components in the phenotype. In : *Some Methodological Achievements of the Hungraian Hybrid Maize Breeding*, pp. 229-236.
- Hossain, F., Tripathi, S, and Warsi, M, Z, K., 2004., Combining ability analysis in flood tolerant maize inbred lines and their hybrids under waterlogged situation. *Crop Res.*, **27**(2 & 3) : 266-269
- Hull, F. H., 1945, Recurrent selection for specific combining ability in corn. *Agron. J.*, **37** : 134-145.
- Hull, F. H., 1946, Over-dominance and corn. Breeding where hybrid seed is not feasible. *Agron. J.*, **38** : 1100-1103.
- Hull, F. H., 1948, Evidence of over-dominance in yield of corn. *Genetics*, **33** : 20-25.
- Hull, F. H., 1952, Recurrent selection and over-dominance. *Heterosis*, Iowa State Co. Press America, pp. 40-52.
- Iqbal, M., Khan, K., Rahanan, H., Khalil, I. H. Sher, Hand Bhkat, J., 2010, Heterosis for morphological traits in subtropical maize (*Zea mays* L.). *Maydica* **55** : 41-48.
- Jackson, M. L., 1967, *Soil Chemical Analysis*. Prentice Hall of India Private Limited, New Delhi, pp. 111-203.
- Jebaraj, S., Selvakumar, A., Shanthi, P., 2010, Study of gene action in maize hybrids. *Indian J. Agric. Res.*, **2**(44).
- Jha, P. B. And Khehra, A. S., 1992, Evaluation of maize inbred lines derived from two heterotic populations. *Indian J. Genet. Pl. Breed.*, **52**(2) : 126-131.
- Jenkins, M. T. and Brunson, A. M., 1932, Methods of testing inbred lines of maize ill crosses bred combinations. *Agronomy Journal*, **24** : 523-530.
- Jinks, J. L. and Hayman, B. I., 1953, The analysis of diallele crosses, *Maize genetics coop. News Letter*, **27** : 48-54.
- Jinks, J. L., 1954, The analysis of continuous variation in a diallele cross of *Nicotiana rustica* varieties, *Genetics*, **39** : 767-788.
- Johanson, G. R., 1973, Relationship between yield and several yield components in a set of maize hybrids. *Crop Sci.*, **13** : 649-652.
- Johnson, I. J. and Hayes, H. K., 1940, The value in hybrid combinations of inbred lines of corn selected from single crosses by the pedigree method of breeding. *Agron. J.*, **32** : 479-485.
- Jones, D. F., 1918, The effects of inbreeding and cross breeding upon, development of corn. *Agronomy Experimental Station Bulletin*, p. 207.
- Jones, D. F., 1922, The productiveness of single and double first generation corn hybrids. *Agron. J.*, **14** : 241-252.
- Joshi, V. N., Pandiya, N. K. and Dubey, R. B., 1998, Heterosis and combining ability for quality and yield in early maturing single cross hybrids of maize (*Zea mays* L.). *Indian J. Genet. Pl. Breed.*, **58**(4) : 519-524.
- Jugenheimer, R. W., 1949, Efficient development and testing of corn inbred lines and hybrids. *American Society of Agronomy Abstracts*, p. 6.
- Kabdal, M. K., Verma, S. S., Kumar, A., Panwar, U. B. S., 2003, Combining ability and heterosis analysis for grain yield and its components in maize (*Zea mays* L.). *Indian J. Agric. Res.*, **37**(1) : 39-43.

- Kadlubiec, W. I., Karwowka, C., Kuzezych, Z., Kuriata, R. and Walczowska – Kurizych, S., 2000, Combining ability of maize inbred lines. *Biuletyn Instytutu Hodowlii Aklimatyzacji Roslin*, **216** : 371-378.
- Kallu, V., Kumar, R., Basandrai, A. K., 2001. Combining ability analysis and gene action estimates of yield and yield contributing characters in maize (*Zea mays* L.) crop res. **22** (1) : 102-106.
- Kalsy, H. S. and Sharma, D., 1970, Study of genetic parameters and I heterotic effects in crosses of maize (*Zea mays* L.) varieties with varying chromosome knob numbers. *Euphytica*, **19** : 522-530.
- Kanta, G., Singh, H. B. and Sharma, J. H., 2002, Combining ability studies for yield and its related traits in maize (*Zea mays* L.). *Crop Improvement*, **29**(2) : 177-183.
- Kara, P. M., 2001, Evaluation of yield and components in inbred maize lines. I Heterosis and line \times tester analysis of combining ability. *Turkish J. Agric. Forest.*, **25** : 383-391.
- Katna, G., Singh, J. K., Sharma, J. K. and Guleria, S. K., 2005, Heterosis and combining ability studies for yield and its related traits in Maize (*Zea mays* L.). *Crop Res*, **30**(2) : 221-226.
- Keeble, F. and Pellow, E., 1910, The mode of inheritance of stature and time of flowering in peas. *Genetics*, **1** : 47-56.
- Khehra, A. S., Malhi, N. S. and Pal, S. S., 1980, Estimation of genetic parameters in open pollinated varieties of maize. *Crop Improvement*, **12** : 137-140.
- Khotyleva, L. V., Tarutina, L. A. and Kapusta, I. P., 1986, Genetic interpretation of the combining ability of maize lines for quantitative characters following use of different crossing systems. *Sel'skokhozyaist Vennaya Biologia*, **8** : 78-82.
- Khristova, I., Todorova, L. and Lindanski, T., 1985, Inheritance of economic characters in intergeneric hybrids of maize with teosinte. *Genetika i Selaktsiya*, **18** : 99-110.
- Kimani, P. M., 1984, Diallel analysis of rate and duration of grain fill and other economic traits in eight inbred lines of maize (*Zea mays* L.). *Diss. Abst. Intl.*, **44** : 3262B.
- Konak, C., Unay, A., Basal, H. and Serter, E., 2001, Combining ability and heterotic effect in some characteristics of second crop maize. *Turkish J. Field Crops*, **16** : 64-70.
- Kravencheko, V. A., Kozol Chuk, M. C. and Morshed, G. A., 1971, Heterosis in maize in respect of some economically valuable characters after interline crossing. *Nauk Pratse Ukr, sils kogospod Akad*, **40** : 47-49.
- Krishnaveni, S., 1983, Biochemical constituents of certain promising maize cultures. *Madras Agric. J.*, **70** : 139-140.
- Kumar Jagdish., Kumar Sanjee., Sood B. C., (2010), Gene Action for Yield and Yield Contributing Characters in Indigenous Maize (*Zea mays* L.) Germplasm of Himachal Pradesh. *J. Crop Improvement.*, **2** (37) : 114-119.
- Kumar, A., Ganshetti, M. G. and Kumar, A., 1998, Gene effects in some metric traits of maize (*Zea mays* L.). *Ann. Agric. Boil. Res.*, **3**(2) : 139-143.
- Kumar, P., 1995, Heterosis in varietal crosses of maize (*Zea mays* L.). *Maize Abstract*, **11** : 755.
- Lamkey, K. R., 1995, Mean performance of heterosis for high \times high, high \times low and low \times low crosses of maize synthetic. *Dissertation Abstracts – International*, **4699** : 2884.
- Larish, L. L. B. and Brewbaker, J. L., 1999, Diallel analyses of temperature and tropical popcorns. *Maydica*, **44**(4) : 279-284.
- Larissa, M. W., Shorry, R. White, Ana, M., Torbert R., Rocheford, Major, M. G. and Edwards Buckler, 2004, Dissection of maize kernel composition and starch production by candidate gene association. *Plant Cell*, **16** : 2719-2733.

- Lee, T. C., 1983, Test cross and diallel cross analysis of maize. *J. Agric. Res., of China*, **32** : 312-324.
- Lee, T. C., Shieh, G. S., Ho, C. L. and Juang, J. R., 1986, Analysis of diallel sets of dent and flint maize inbreds of combining ability and heterosis. *J. Agric. Res., of China*, **35** : 145-164.
- Leng, E. R., 1954, Effects of heterosis on the major components of grain yield in corn. *Agron. J.*, **46** : 502-506.
- Li-Jizhu, Wang-Shung, Guo-Baogui and Tang-Weiguang, 2004, Genetic study of ear kernel characters of maize. *Journal of Jilin Agric. Univ.*, Chang Chaun, **26**(6) : 494-498.
- Lindstorm, E. W., 1931, Prepotency of inbred sires of commercial varieties in I maize. *Agronomy Journal*, **23** : 652-661.
- Mahajan, V., Khehra, A., Dhillon, B. S. and Sharma, V. K., 1991, Inter-relationship of yield and other traits in maize in monsoon and winter season. *Crop Improv.*, **17** : 128-132.
- Mahantesh., 2006, Combining ability of and heterosis analysis for grain yield components in single cross hybrids of maize (*Zea mays* L.) *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad, Karnataka (India).
- Mahomoud, I. M., Rashed, M. A., Fahmy, E. M. and Abodheaf, M. H., 1990, Heterosis combining ability and types of gene action in a 6 × 6 diallel of maize. *In : Proc. of the 3rd Conf. of Agricultural Development Research*, pp. 307-317.
- Mahto, R. N. and Ganguly, D. K., 2001, Heterosis and combining ability studies in maize (*Zea mays* L.). *J. Res. Birsa Agricultural University*, **13** : 197- 199.
- Malik, S. I., Malik, H. N., Minhas, N. M., Muhammad, M., 2004, General and specific combining ability studies in maize diallel crosses. *Int. J. Agric. Biol.*, **6**(5) : 856-859
- Mandal, S. S., Mandal, H. K., Verma, D. K. and Akhtam, S. A., 2001, Combining ability analysis for grain yield and component traits in maize. *J. Inter Academicia*, **5** : 132-137.
- Martin, J. H. and Hallauer, A. R., 1976, Relation between heterozygosis and yield for four types of maize inbred lines. *Egyptian J. Genet.*, pp. 119-135.
- Mathur, R. K. and Bhatnagar, S. K., 1995, Partial diallel cross analysis for grain yield and its component characters in maize (*Zea mays* L.). *Ann. Agric. Res.*, **16**(3) : 324-329.
- Mathur, R. K., Chunilal, Bhatnagar, S. K. and Singh, V., 1998, Combining ability for yield, phenological and ear characters in white seeded maize. *Indian J. Genet. Pl. Breed.*, **58**(2) : 117-182.
- Mazzoni, M. R. and Robutti, J. L., 1990, Evaluation of a method for predicting industrial yield of maize starch. *Maize Abstract*, **49** : 1487.
- Mejia, M. J. and Lambert, R. J., 1992, Improving for maize for adapted corn hybrid using exotic inbred. *Crop Sci.*, **32**(2) : 55-62.
- Mikhailov, H. E. and Chernov, A. A., 1999, Genetic-statistical of kernel row number in maize. *Tsitologiya-i-Gnetika*, **35** : 19-25.
- Mohammad Basheruddin, M., Balakrishna Reddy and Phaik Mohammad, 1999, Correlation coefficient and path analysis of component character as influenced by the environments in forage maize. *Crop Res.*, **17** : 85-89.
- Mohammad, A. A., 1993, Effect of nitrogen fertilization levels on the performance and combining ability of maize hybrids (*Zea mays* L.). *Ann. Agric. Sci.*, **38**(2) : 531-549.
- Mohan Lal., Dhirendra Singh and Sain Dass, 2011, General and specific combining ability studies in maize using line x tester design. *Agric. Sci. Dig.*, **1**(30) : 45-49..

- Moll, R. H., Lonquist, J., Fortuno, J. V. and Johnson, E. C., 1967, The relation of heterosis and genetic divergence in maize. *Genetics*, **52** : 139-144.
- Moll, R. H., Salhauna, W. S. and Robinson, 1962, Heterosis and genetic diversity in varietal crosses of maize. *Crop Sci.*, **2** : 197-198.
- Mufti, M. U. and Rao, H. R., 1995, Quantitative studies on heterosis in maize (*Zea mays* L.) diallel crosses. *Sarhad J. Agric.*, **11**(1) : 71-77.
- Mukherjee, B. K. and Saha, B. C., 1984, An analysis of heterosis and manifest for yield characteristics in intervarietal crosses of maize (*Zea mays* L.). *Egyptian J. Genet. Cytol.*, **13** : 41-52.
- Mukherjee, B. K., Agarwal, K. N., Singh, S. B., Gupta, N. P. and Singh, N. N., 1974, Studies on diverse germplasm complexes of maize. Gene effects and nature of heterosis in germplasm complexes and their crosses. *Genetica*, **6** : 33-41.
- Murthy, A. R., Kajjari, N. B. and Goud, J. V., 1981, Diallel analysis of yield and maturity components in maize. *Indian J. Genet. Pl. Breed.*, **41** : 30-33.
- Mustyaysa, S. I., Nuzhnaya, I. P., Pozhoga, V. N. and Litun, P. P., 1991, Combining ability of source material for producing early maize hybrids. *Urozhai-i- Adaptivni Potential Ekologicheskoi Sistemy Polya*, pp. 88-93.
- Muthiah, A. R., 1989, Genetic analysis and inheritance of sorghum downy mildew resistant in maize (*Zea mays* L.). *Ph. D. Thesis*, Tamil Nadu Agricultural University, Coimbatore.
- Nagda, A. K., Dubey, R. B. and Pandiya, N. K., 1995, Studies on combining ability in rabi maize (*Zea mays* L.). *Crop Res.*, **9** : 309-312.
- Nagesh Kumar, M. V., Sudheer Kumar, S. and Ganesh, M., 1999, Combining ability studies for oil improvement in maize (*Zea mays* L.). *Crop Res.*, **18** : 93-99.
- Nawar, A. A., 1986, Genetic variances in a synthetic variety of maize (*Zea mays* L.). *Egyptian Journal of Genetics and Cytology*, **15** : 1-8.
- Nawar, A. A., Fahmi, A. I. and Salma, S. A., 1999, Genetic analysis of yield components and callus growth characters in maize (*Zea mays* L.). *J. Genet. Pl. Breed.*, **53** : 119-127.
- Netaji, S. V. S. R. K., Satyanarayana, E. and Suneetha, V., 2000, Heterosis studies for yield and yield component characters in maize (*Zea mays* L.). *The Andhra Agric. J.*, **47** : 39-42.
- Oja, G. O. S., Adedzwa, D. K. and Bello, L. L., 2007, Combining ability estimates and heterosis for grain yield and yield components in maize (*Zea mays* L.). *J. Sust. Dev. Agric. Environ.*, **3** : 49-57.
- Packiaraj, D., 1995, Genetic studies of yield and its components in maize (*Zea mays* L.). *Ph. D. Thesis*, Tamil Nadu Agric. Univ., Coimbatore (India).
- Pal, A. K. and Prodhhan, H. S., 1994, Combining ability analysis of grain yield and oil content along with some other attributes in maize (*Zea mays* L.). *Indian J. Genet. Pl. Breed.*, **54**(4) : 376-380.
- Pal, S. S., Khera, A. S. and Dhillon, B. S., 1986, Genetic analysis and selection advance in maize population. *Maydica*, **31** : 153-162.
- Panse, V. G. and Sukhatme, P. V., 1962, *Statistical Methods for Agricultural Workers*, ICAR Publication, New Delhi, p. 145.
- Parcial, E. C. C. V. M. E. C., Gorgulho, E. P., Filho, J. B. M., (2001), Evaluation of maize varieties in the partial diallel mating scheme. *Bragantia, Campinas.*, **60**(1) : 1-8.
- Pasztor, K., Gyori, Z. and Szilagyi, S., 1998, Changes in the protein, starch, ash, fibre and fat contents of maize parental lines and hybrids. *Noventy Texmeles*, **47** : 271-278.
- Patel, C. G., Patel, D. B., Prajapati, N. D., Patel, M. D., Patel, K. R., 2010, Heterosis breeding in maize (*Zea mays* L.), *Res. on Crops*, **11** (2) : 429-431.

- Paterniani, E. and Lonquist, J. H., 1964, Heterosis in intervarietal crosses of corn. *Crop Sci.*, **4** : 504-507.
- Paterniani, E., 1990. Maize breeding in the tropics. *CRC Critical Rev. Plant Sci.*, **9** : 125–54
- Patil, S. J., Hayavadana, P. V. and Mahadevappa, M., 1969, Inter relationship between grain yield, ear height and internodal characters in *Zea mays* L. *Mysore J. Agric. Sci.*, **3** : 273-276.
- Paul, K. K. and Debanth, S. C., 1999, Combining ability analysis in maize (*Zea mays* L.). *Pakistan J. Sci. Ind. Res.*, **42**(3) : 141-144.
- Paul, S. K. and Duara, P. K., 1991, Combining ability for yield and maturity in maize (*Zea mays* L.). *International Journal of Tropical Agriculture*, **9**(4) : 205-254.
- Perez-Velasquez, J. C., Ceballos, H., Pandei, S. and Diaz-Amaris, C., 1995, Analysis of diallel crosses among Colombian landraces and improved populations of maize. *Crop Sci.*, **35**(2) : 572-578.
- Petrenko, A. L., 1980, Heterosis in maize hybrids under irrigated and unirrigated conditions in South of Ukraine. *Plant Breeding Abstract*, **52** : 186.
- Petrovic, Z., 1998, Combining abilities and mode of inheritance of yield and yield components in maize (*Zea mays* L.). *Novi Sad* (Yugoslavia), p. 85.
- Pradeepa B. P., 2007, Genetic studies on quantitative and quality traits of three way cross hybrids and evaluation of germplasm in maize (*Zea mays* L.) *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad, Karnataka (India)
- Prasad, R., Singh, S. and Paddar, R. S., 1988, Combining ability analysis in a maize diallel. *Indian J. Genet.*, **48** (1) : 19-23.
- Prasad, S. K. and Singh, T. P., 1986, Heterosis in relation to genetic divergence in maize (*Zea mays* L.). *Euphytica*, **35** : 919-924.
- Premlatha, M., Kalamani, A., 2010, Heterosis and Combining Ability Studies for Grain Yield and Growth Characters in Maize (*Zea mays* L.). *Indian J. Agric. Res.*, **1** (44) :
- Presolka, P. A. and Kamara, A. I., 1991, Expression of heterosis and the extent of dominance for some characters in the single interline hybrid KnezhaVp556 and the modified single hybrid Knezha MVP556, II. Number of rows per ear and number of grains per row. *Genetika-i-Seletsiya*, **24**(2) : 120-125.
- Quadri, I., Agrawal, K. N. and Sanghi, A. K., 1993, Combining ability under two population sizes for ear trait in maize. *Indian J. Genet. and Plant Breeding*, **43** : 201-211.
- Raghuram Reddy, P., Vidyasagar, R., Kishen, N. and Mehaboobali, S., 1987 Relationship of single crosses to double and three way cross hybrids in maize for yield. *Genetica (Iberica)*, **39** : 117-129.
- Ramamurthy, A., 1980, Genetic analysis of some quantity characters in maize (*Zea mays* L.). *Mysore J. Agric. Sci.*, **14** : 126.
- Rameeh, V., Rezai, A. and Arzani, A., 2000, Estimates of genetic parameters for yield and yield components in corn inbred lines using diallel crosses. *J. Sci. and Technology of Agric. and Natural Resources*, **4** : 95-104.
- Reddy, K. H. D. and Agarwal, B. D., 1992, Estimation of genetic variation in an improved population of maize (*Zea mays* L.). *Madras Agric. J.*, **79** : 714- 719.
- Reif, J. C., Hallauer, A. R. and Melchinger, A. E., 2005, Heterosis and heterotic patterns in maize. *Maydica*, **50** : 215-223.
- Rim Ahmad Al-Abd Al-Hadi., 2010, Inheritance of some yield and quality traits of maize (*Zea mays* L.) using half diallel cross.
- Rojas, B. A. and G. F. Sprague, 1952. A comparison of variance components in corn yield trials : III. General and specific combining ability and their interaction with locations and years. *Agron. J.*, **44** : 462–6

- Rosa, A., De. La., Leon, De. H., Hartinez, G. And Rincon, F., 2000, Heterosis combining ability and genetic diversity in commercial hybrids of maize (*Zea mays* L.). *Agronomic Mesoamericana*, **11** : 113-122.
- Rupak, K., Verma and Singh, T. P., 1979, Interrelations among certain quantitative traits in popcorn. *Mysore J. Agric. Sci.*, **13** : 1-17.
- Russell, W. A., 1968, Development and evaluation of maize inbred lines. In *Proceedings of 23rd Corn Research Conference*, American Seed Trade Association, pp.37-44.
- Saad ImranMalik., Haq Nawaz Malik., Nasir Mahmood Minhas and Muhammad Munir, 2004, General and specific combining Ability studies in maize diallel crosses. *Int. J. Agri. Biol.*, **6** (5) : 856-859.
- Sadasivam, S., Manickam, A., 1992, Biochemical Methods. New Age International Limited, New Delhi, pp. 9-10.
- Saha, B. C. and Mukherjee, B. K., 1993, Grain yield of maize in relation to grain forming potential and other traits. *J. Res.*, Birsa Agricultural University, **5** : 27-31.
- Saidaiah, P., Satyanarayana, E., Sudheer Kumar, S., (2008), Heterosis for Yield and Yield Component Characters in Maize (*Zea mays* L.). *Agricultural Science Digest.*, **3** (28).
- Saindass., Mohindersiongh., Sehtya., H. I., Aneja, D. R., Anilkumar, Dass, S., Singh, M. and Kumar, A., 1992, Genetics of harvest index in maize. *Agricultural Science, Digest*, **12**(3) : 117-120.
- Salazar, F., Narro, L., Charcosset, A. and Horst, W, J., 2005 heterosis and combining ability for tropical acid soils : implications for future breeding strategies. *Crop Sci*, **45** : 2405-2413
- Saleh, G. B., Abdullah, D. and Anuar, A. R., 2002, Performance of heterosis and heritability in selected, tropical maize single, double and three way cross hybrids. *J. Agric. Sci.*, **138** : 21-28.
- Salillari, A. and Hoxha, S., 1998, The performance of kernel and spike characters some maize hybrid crossings in relations to parental inbred lines. *Bulletini-i-Shkenacave Bujqesore*, (Albania), **3** : 51-54.
- Sandeep Kumar, T., Mohan Reddy, D., Saida Naik, V., Isha Parveen, S. and Subbaiah., 2012, Gene action for yield and morpho-physiological traits in maize (*Zea mays* L.) Inbred Lines. *J. Agric. Sci.*, **4** : 13-16.
- Sanghi, A. K., Agarwal, K. N. and Qadri, M. I., 1982, Gene effects and heterosis for grain yield and ear traits in maize. *Indian J. Genet.*, **42** : 360-363.
- Satyanarayana, E., 1994, Genetic analysis of flowering period in *rabi* maize (*Zea mays* L.) involving different maturity groups. *Crop Improvement*, **9** : 42-47.
- Satyanarayana, E., Kumar, R. S. and Sharma, M. Y., 1994, Inheritance studies of maturity components and yield in selected hybrids of maize (*Zea mays* L.). *Mysore J. Agric. Sci.*, **28**(1) : 25-30.
- Sedhom, S. A., 1994, Estimation of general and specific combining ability in maize under different planting dates. *Ann. Agric. Sci.*, **28**(1) : 25-30.
- Sergio Dona., Maria Elisa Ayres Guidetti Zagatto Paterniani., Paulo Boller Gallo. And Aildson Pereira Duarte., 2011, Heterosis and its components in F₂ populations of maize hybrids. *Bragantia, Campinas*, **4** (70) : 767-774.
- Seshu, G., Farzana Jabeen. and Jhansi Raniá, K., 2010, Combining Ability Studies for Grain Yield and Itscomponents in Maize (*Zea mays* L.). *J. Res.*, ANGRAU, **1 & 2** (38) : 47-54
- Setiyono, R. T. and Subandi, 1996, Heterosis and combining ability analysis of maize in a diallel cross. *Penelitian Pertanian* (Indonesia), **15**(1) : 30-34.

- Shahi, J. P. and Singh, I. S., 1985, Estimation of genetic variability for grain yield and its components in a random mating population of maize. *Crop Improvement*, **12** : 126-129.
- Shahi, J. P. and Singh, I. S., 1986, Analysis of genetic variation in Navin population of maize (*Zea mays* L.). *Crop Improvement*, **13** : 181-185.
- Shahwani, M. N., Salarzai, A., Bangulzai, B. A., Shahwani, M. A. and Hengl, N. M., 2001, Hybrid vigour for grain yield and its components in maize crosses. *Sarhad J. Agric.*, **17** : 571-576.
- Shakoor, A., 1988, Effect of heterosis on the stover yield components of some local and exotic inbred lines of maize. *Pakistan J. Agric. Res.*, **9** : 61-66.,
- Shalygina, G. H., Ghikhova, V. M. and Chmeleva, Z. V., 1990, Grain quality in inbred lines of maize under irrigation in lower volga area. *Genetike-i-Seletsii*, **124** : 14-19.
- Shanthi, P., Satyanarayana, E., Suresh Babu, G and Sai Kumar, R., 2011, Combining ability studies for grain yield and quality parameters in quality protein maize (QPM) (*Zea mays* L.). *Crop Res.*, **41** (1, 2 & 3) p;182- 187.
- Shanthi, p., Suresh Babu, G., Satyanarayana, E., and Sal Kumar, R., 2010, Combining ability and stability studies for grain yield and quality parameters in QPM (*Zea mays* L.) inbred lines crosses, *Indian J. Genet.*, **70**(1) : 22-28.
- Shanti, P., Satyanarayana, E. and Reddy, G. J. M., 2002, Genetic studies for grain yield and oil improvement in maize. *Research on Crops*, **3**(3) : 588-591.
- Sharma, S. R., Khera, A. S., Dhillon, B. S. and Malhotra, V. V., 1982, Evaluation of S1 lines of maize crossed in a diallelic system. *Crop Improvement*, **9** : 42-47.
- Shashidhara C. K., 2008, Early generation testing for combining ability in maize (*Zea mays* L.) *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad, Karnataka (India).
- Shaw, R. H. and Thom, H. C. S., 1951, Study on phenology of field corn, silking to maturity. *Agron. J.*, **43** : 541-546.
- Shen, G. Z. and Lai, Z. M., 1987, Studies on interactions of combining ability I with environment for main traits of maize inbreds. *Acta Agronomica Sinica*, **13** : 69-76.
- Shreenivasa A. Desai and Singh, R. D., 2001, Combining ability studies for some morphophysiological and biochemical traits related to drought tolerance in maize (*Zea mays* L.). *Indian J. Genet.*, **61**(1) : 34-36.
- Shull, G. H., 1908, *The Composition of a Field Maize*. American Breeders Association Republic, **4** : 296-301.
- Shull, G. H., 1911, The genotypes of maize. *American Naturalist*, **45** : 234-252.
- Singh, D. N. and Singh, I. S., 1998, Line × tester analysis in maize (*Zea mays* L.). *J. Res.*, Birsa Agricultural University, **10** : 177-182.
- Singh, S. N., Singh, K. N. and Sinch, H. G., 1983, Combining ability studies in maize. *Crop Improv.*, **10**(1) : 6-9.
- Singh, S. N., Singh, K. N. and Singh, H. G., 1983, Combining ability studies in maize (*Zea mays* L.). *Crop Improv.*, **10** : 6-9.
- Sinobas, J. and Monteagudo, I., 1994, Genetic analysis of a diallel cross between Spanish and American maize populations. *Investigation Agraria Productiony- Protection Vegetables*, **9**(2) : 167-179.
- Sprague, G. F. and Tatum, L. A., 1942, General Vs specific combining ability in single crosses of corn. *Agron. J.*, **34** : 923-932.
- Srivastava, A. and Singh, I. S., 2003, Heterosis and combining ability for yield and maturity involving exotic and indigenous inbred lines of maize (*Zea mays* L.). *Indian J. Genet. Pl. Breed.*, **63**(4) : 345-346.

- Subramanian, A and Subbaraman, N., 2006, Genetic analysis in maize (*Zea mays* L.). *Indian J. Agric. Res.*, **40** (3) : 195 – 199.
- Sumalini, K., and Shobha Rani, T., 2010, Heterosis and Combining Ability for Polygenic Traits in Late Maturity Hybrids of Maize, *Zea mays* (L.). *Madras Agric. J.*, **97** (10-12) : 340-343.
- Suneetha, Y., Patel, J. R. and Srinivas, T., 2000, Studies on combining ability for forage characters in maize (*Zea mays* L.). *Crop Res.*, **9** : 226-270.
- Surya Prakash and Ganguli, D. K., 2004, Combining ability for various yield component characters in maize (*Zea mays* L.). *J. Res.*, Birsa Agric. Univ., **16**(1) : 55-60.
- Talleei, A. and Kochaksaraei, H. N. K., 1999, Study of combining ability and cytoplasmic effects in maize diallel crosses. *Iranian J. Agric. Sci.*, **30**(4) : 761-769.
- Tandan, J. P., Joshi, A. B. and Jain, K. B. L., 1970, Comparison of graphic and combining ability analysis of diallel crosses in wheat. *Indian J. Genet.*, **30** : 91-103.
- Tarutina, L. H. and Khotyleva, L. V., Polonetskaya, L. and Kapusta, I. B., 1980, Variability of the heterotic effect diallel maize hybrids under different environmental conditions. *Referativnyi Zhurnal*, **10**(65) : 192.
- Thompson, P. R., Geyer, A. B., Lotz, L. D., Siegrist, H. J. and Dobbels, T. L., 2002, Top cross high oil corn production : Agronomic performance. *Agron. J.*, **94**(2) : 290- 299.
- Turgut, I., Yuce, S. and Altinbos, M., 1995, Inheritance of some agronomic traits in a diallel cross of maize inbreds II. Grain yield and its components. *Anadolu*, **5**(1) : 74-92.
- Uddin, M. S., Firoza Khatun., Ahmed. S., Ali, M. R and Shamim Ara Bagum., 2006, Heterosis and combining ability in corn (*Zea mays* L.). *Bangladesh J. Bot.* **35** (2) : 109-116.
- Unay, A., Seyien Basal, H., Cahit Konak., 2003, Inheritance of Grain Yield in a Half-Diallel Maize Population. *Turk J Agric.*, **28** : 239-244.
- Vacaro, E., Barbosa, Neto, J. F., Pegoraro, D. G., Nuss, C. N. and Conceicao, L. D. H., 2002, Combining ability of 12 populations. *Pesuisa Gropecuria Brasilerira*, **37** : 67-72.
- Vaidya, S. B., 1986, Studies on the performance of single cross hybrids in maize (*Zea mays* L.). *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad, Karnataka (India).
- Vasal, K., Ganeson Srinivasan, F., Gonzalez, C., David Beck, L. and Crassa, J., 1993, Heterosis and combining ability of CIMMYT's quality protein, maize germplasm II. sub-tropical. *Crop Sci.*, **33** : 51-57.
- Vasal, S. K., Srinivasan, G., Beck, D. L., Crossa, J., Pandey, S. and De Leon, C., 1992, Heterosis and combining ability of CIMMYT's tropical late white maize germplasm. *Maydica*, **37**(2) : 217-223.
- Venkatesh, S., Singh, N.N. and Gutpa, N.P., 2001, Early generation identification and utilization of potential inbred lines in modified single cross hybrids of maize (*Zea mays* L.). *Indian J. Genet.*, **61**(3): 213-217.
- Verma, R. K. and Singh, T. P., 1980, Heterosis and combining ability studies for certain quantitative traits in popcorn. *Mysore J. Agric. Sci.*, **14** : 15-17.
- Verma, R. P. S. and Singh, I. S., 1996, Residual heterosis in population crosses in maize (*Zea mays* L.) involving different maturity groups. *Crop Improvement*, **9** : 42- 47.
- Vidal Martinez, V. A., Clegg, M., Johnson, B. and Valdivia, Be Rnal, R., 2001, Phenotypic and genotypic relationship between pollen and grain yield components in maize. *Agrociencia* (Montecillo), **35** : 503-511.
- Wali, M. C., Kachapur, R. M., Chandrashekhar, C. P., Kulkarni, V. R and Devaranavadagi, S. B., 2010, Gene action and combining ability studies in single cross hybrids of maize (*Zea mays* L.). *Karnataka J. Agric. Sci.*, **23** (4) : 557- 562.

- Wang, Z. H., Wang, Y. B., Wang, Y. P., Zhang, X. and Zhudin, M., 1998, Classification, utilization and improvement of the main germplasm heterosis of maize in China. *J. Henan Agric. Sci.*, **2** : 3-6.
- Welcker, C., andreau, B., De Leon, C., Parentoni, S.N., Bernel, J., Felicite, J., Zonkeng, C., Salazar, F., Narro, L., Charcosset, A. and Horst, W.J., 2005 heterosis and combining ability for tropical acid soils: implications for future breeding strategies. *Crop Sci*, **45**: 2405-2413.
- Wellhausen, E. J., 1965, Exotic germplasms for improvement of corn belt maize. In : *Proc. of 20th Annual Indian Research Conf.*, pp. 31-34.
- Williams, J. C., Penny, L. H. and Sprague, G. F., 1965, Full sib and half sib estimates of genetic variance in an open pollinated variety of corn. *Crop Sci.*, **5** : 125-129.
- Yan, W. and L. A. Hunt, 2002. Biplot analysis of diallel data. *Crop Sci.*, **42** : 21–30
- Yang, A. G., 1982, Gene effects for several economic characters in maize. *Acta Agronomica Sinica*, **8** : 153-162.
- Yurankov, S. I., Tsitok, U. V., Rusinova, V. and Ramhes, V. A., 1996, Features of the expression of heterosis for yield components in first generation maize hybrids. *Vesti-Akadenji-Navuk, USSR*, **2** : 40-44.
- Zambezi, B. T., Horner, E. S., and Martin, F. G., 1986, Inbred lines as testers for general combining ability in maize. *Crop Sci.*, **26** : 908-610.
- Zargar, G. H. and Singh, R. H., 1990, Genetic architecture of an improved version of a maize composite. In L Genetic analysis of grain yield, yield components and same agronomic traits. *Indian J. Genet.*, **50** : 221-227.
- Zelleka, H., 2000, Combining ability for grain yield and other agronomic characters in inbred lines of maize (*Zea mays* L.). *Indian J. Genet. Pl. Breed.*, **60** : 63 70.
- Zheng-Zuping, Du-Kenzhu, Z. P. and Du, K. Z., 1995, A study of the genetic parameters of several quantitative characters of maize. *J. Southwest Agric. Univ.*, **17**(4) : 359-362.

Appendix I: Monthly meteorological data for the experimental year 2010-2011 at Meteorological Observatory, Main Agricultural Research Station, College of Agriculture, University of Agricultural Sciences, Dharwad

Months	Rainfall (mm)		Temperature (°C)				Relative humidity (%)	
	2010	2011	Mean maximum		Mean minimum		2010	2011
			2010	2011	2010	2011		
January	0.8	0	28.2	29.2	15.4	12.5	63	59
February	0.4	21.6	32.4	30.8	17.3	14	50	48
March	Trace	0.8	35.6	35.2	20.3	18.6	49	44
April	43.8	77.4	37.6	34.9	22.0	20.2	55	57
May	63.1	66.6	35.7	34.7	22.4	21.3	63	61
June	63.4	194	31.2	27.5	21.8	21.3	75	84
July	155.0	131	27.6	26.9	20.8	20.6	84	85
August	190.7	124.2	27.7	26.2	20.7	20.7	84	87
September	164.9	82.8	27.9	28.1	20.2	19.9	83	80
October	177.0	219.7	29	29.9	19.5	19.5	77	73
November	92.8	4.6	28.4	29.8	19.0	15.8	79	55
December	0.6	0	27.4	29/6	14.1	13.7	65	57
Total	952.5	922.7						

Appendix II: Mean performance of parents, hybrids and Checks with respect to yield and its component characters

Parents	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear width (cm)	No of kernels per row	No of rows per cob	Test weight (g)	Shelling %	Grain yld per plant (g)	Grain yld per ha (q/ha)	Protein content (%)	Starch content (%)
1	63.00	63.50	94.00	163.15	66.85	15.50	14.40	26.00	12.00	29.61	63.38	79.5	39.46	9.12	63.34
2	63.00	64.50	93.00	207.50	75.85	15.05	14.40	24.00	13.00	32.02	65.00	75.5	37.35	9.77	64.22
3	64.00	64.50	94.00	225.00	111.85	16.30	13.35	27.00	13.00	29.76	44.43	93	46.58	9.14	66.21
4	64.00	62.50	93.00	181.50	129.35	17.45	17.30	31.00	15.00	38.02	61.40	94.5	47.38	9.95	67.11
5	63.00	64.50	95.00	189.15	128.35	16.45	16.75	26.00	14.00	31.02	70.25	97	48.69	8.20	66.21
6	63.00	65.50	96.00	195.50	109.35	10.35	14.85	21.00	14.50	29.32	64.30	93	46.58	8.84	64.51
7	64.00	65.50	95.00	195.80	96.85	14.70	15.30	22.00	13.00	30.66	68.38	84.5	42.10	9.16	63.80
8	62.00	64.50	93.00	202.50	95.85	16.70	18.25	34.00	14.00	36.02	67.25	90	45.00	8.50	62.34
9	63.00	64.00	94.00	178.75	90.85	16.20	16.50	32.00	14.00	38.65	72.30	95	47.64	10.20	64.23
10	63.00	64.50	95.00	185.00	101.85	17.45	13.95	22.00	15.00	34.02	67.25	90.5	45.26	10.59	64.33
11	64.00	65.50	93.00	212.50	123.35	14.00	14.60	24.00	16.00	31.02	61.00	95	47.64	10.98	63.80
12	63.00	63.50	94.00	203.75	119.35	12.10	14.00	28.00	11.00	32.47	57.63	95.05	47.67	10.24	67.03
13	65.00	65.50	95.00	202.50	126.85	18.80	15.50	22.00	16.00	30.67	65.89	84	41.83	10.10	61.44
14	66.00	65.50	97.00	226.25	131.85	17.25	14.30	28.00	16.00	30.02	63.32	78	38.67	10.59	60.60
Crosses															
DMIL 2 x DMIL 1	64.00	65.50	91.00	202.50	67.30	17.95	14.35	24.00	13.00	32.51	44.43	147	75.08	11.17	65.33
DMIL 3 x DMIL 1	61.00	63.50	93.00	225.00	110.00	20.10	16.60	38.00	14.00	33.91	79.29	97.5	52.64	11.31	65.42
DMIL 4 x DMIL 1	64.00	65.50	92.00	211.25	115.00	17.95	17.15	36.00	15.00	34.2	87.35	107	53.97	10.78	65.87
DMIL 5 x DMIL 1	63.00	64.50	94.00	213.75	69.15	18.95	17.80	32.00	14.00	33.55	87.57	139.5	71.13	11.80	64.64
DMIL 6 x DMIL 1	62.00	65.50	92.00	192.50	85.65	18.85	17.90	40.00	16.00	36.65	74.92	110	55.56	10.79	65.28
DMIL 7 x DMIL 1	63	66.5	90	207.5	105	19.45	18.35	30.00	16.00	34.00	75.13	124.5	63.21	10.43	67.85

Contd....

Appendix II contd...

Crosses	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear width (cm)	No of kernels per row	No of rows per cob	Test weight (g)	Shelling %	Grain yld per plant (g)	Grain yld per ha (q/ha)	Protein content (%)	Starch content (%)
DMIL 8 x DMIL 1	62.00	63.50	89.00	213.75	102.50	19.55	18.40	35.00	13.00	31.05	70.96	117	59.25	7.63	67.42
DMIL 9 x DMIL 1	63.00	64.50	91.00	209.50	91.80	22.55	20.85	37.00	17.00	34.5	70.16	142.5	72.71	10.19	66.32
DMIL 10 x DMIL 1	64.00	65.50	92.00	215.00	91.50	21.50	18.40	38.00	13.00	31.75	78.80	137.5	70.07	11.49	66.01
DMIL 11 x DMIL 1	62.00	66.50	93.00	221.25	101.50	19.30	17.50	26.00	17.00	34.75	74.54	119.5	60.57	7.78	64.55
DMIL 12 x DMIL 1	63.00	65.50	94.00	215.00	117.50	19.40	17.15	30.00	14.00	32	85.98	137.5	70.07	10.35	66.67
DMIL 13 x DMIL 1	64.00	66.50	93.00	224.00	97.75	20.60	14.45	28.00	15.00	36.75	82.72	128.5	65.32	10.94	66.28
DMIL 14 x DMIL 1	62.00	65.50	92.00	227.50	112.50	21.15	16.20	34.00	14.00	32.5	82.37	146	74.56	8.74	64.96
DMIL 3 x DMIL 2	61.00	63.50	91.00	215.00	105.00	20.30	15.55	32.00	15.00	38.75	76.33	109	55.03	8.68	65.90
DMIL 4 x DMIL 2	63.00	64.50	90.00	240.00	102.50	19.65	18.15	30.00	17.00	30.75	78.10	135.5	69.01	10.41	65.74
DMIL 5 x DMIL 2	58.00	64.50	92.00	194.25	111.25	18.75	17.50	34.00	17.00	33.75	87.89	131.5	66.9	9.49	62.84
DMIL 6 x DMIL 2	61.00	65.50	93.00	199.00	97.50	18.80	17.40	36.00	15.00	42.25	87.99	141.5	72.18	9.62	68.64
DMIL 7 x DMIL 2	60.00	64.50	93.00	191.50	112.50	21.80	17.70	38.00	14.00	35.75	80.96	142	72.44	6.95	64.58
DMIL 8 x DMIL 2	62.00	66.50	92.00	193.50	105.00	19.70	17.45	36.00	13.00	40.55	80.28	140.5	71.65	11.56	68.80
DMIL 9 x DMIL 2	60.00	64.50	91.00	218.50	122.50	20.90	18.70	38.00	17.00	41.05	83.22	158	81	10.79	67.86
DMIL 10 x DMIL 2	62.00	65.50	94.00	210.00	113.75	20.30	18.70	38.00	13.00	42	89.84	137	69.81	8.21	65.45
DMIL 11 x DMIL 2	62.00	64.50	94.00	215.00	98.75	18.90	16.65	34.00	14.00	41.25	86.97	117.5	59.51	10.50	65.95
DMIL 12 x DMIL 2	59.00	65.00	93.50	217.50	105.00	19.65	17.50	38.00	14.00	42.7	71.31	136.5	69.54	10.56	66.40
DMIL 13 x DMIL 2	62.00	65.50	91.50	230.00	107.50	18.90	17.25	34.00	14.00	43.6	65.27	128.5	65.32	10.75	66.83
DMIL 14 x DMIL 2	63.00	64.50	92.00	222.50	100.00	22.95	15.90	40.00	14.00	35.25	84.64	130.5	66.37	11.00	66.91
DMIL 4 x DMIL 3	62.00	66.50	94.50	215.00	115.00	20.60	19.45	42.00	13.00	43.5	91.04	169	86.69	10.37	65.78
DMIL 5 x DMIL 3	64.00	64.50	94.00	187.50	105.00	18.85	16.60	34.00	16.00	41.5	74.77	153.5	78.51	10.37	65.40

Contd....

Appenix II contd...

Crosses	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear width (cm)	No of kernels per row	No of rows per cob	Test weight (g)	Shelling %	Grain yld per plant (g)	Grain yld per ha (q/ha)	Protein content (%)	Starch content (%)
DMIL 6 x DMIL 3	63.00	65.50	89.00	205.00	107.50	21.55	16.35	38.00	15.00	36.75	90.55	133	67.69	11.00	64.67
DMIL 7 x DMIL 3	62.00	66.50	92.00	217.50	122.50	22.95	17.35	38.00	18.00	35.5	81.03	156	79.92	11.40	69.01
DMIL 8 x DMIL 3	63.00	64.50	93.00	225.00	96.00	23.45	18.70	36.00	15.00	35.5	83.18	151	77.19	8.41	66.23
DMIL 9 x DMIL 3	62.00	63.50	90.00	219.00	105.00	20.50	16.45	32.00	15.00	34.5	75.73	153.5	78.51	12.18	69.12
DMIL 10 x DMIL 3	61.00	64.50	93.00	216.50	94.00	20.05	18.45	41.00	14.00	33.9	87.72	148.5	75.88	14.02	69.23
DMIL 11 x DMIL 3	64.00	64.50	91.00	207.50	97.50	20.25	17.30	40.00	19.00	35	87.79	112.5	56.88	10.68	66.52
DMIL 12 x DMIL 3	63.00	66.50	93.00	197.50	115.00	19.60	16.45	24.00	14.00	33.5	85.77	160	81.94	9.54	66.12
DMIL 13 x DMIL 3	64.00	66.50	92.00	193.50	100.50	19.60	15.55	32.00	16.00	31.1	87.05	121	61.36	10.46	65.36
DMIL 14 x DMIL 3	65.00	65.50	93.00	185.00	97.50	19.10	18.80	36.00	17.00	38.5	89.74	117.5	59.51	11.39	65.38
DMIL 5 x DMIL 4	59.00	64.50	92.00	195.00	95.00	20.35	17.30	32.00	15.00	43.05	78.06	129.5	65.85	10.25	64.91
DMIL 6 x DMIL 4	62.00	66.50	91.00	185.00	107.50	19.15	17.05	36.00	15.00	40.2	80.40	140	71.39	11.50	66.68
DMIL 7 x DMIL 4	61.00	65.50	90.00	204.00	115.00	21.35	17.55	40.00	14.00	41.1	87.10	155	80.15	10.52	65.01
DMIL 8 x DMIL 4	62.00	66.50	95.00	200.00	117.50	18.80	18.25	38.00	16.00	41.5	84.35	162.5	83.26	10.50	65.34
DMIL 9 x DMIL 4	63.00	64.50	98.00	205.00	110.00	22.65	17.45	30.00	16.00	43.9	80.00	162	83.5	11.08	65.29
DMIL 10 x DMIL 4	64.00	65.50	94.00	215.00	110.00	23.90	18.90	38.00	14.00	41.15	91.05	156	80.42	10.50	65.97
DMIL 11 x DMIL 4	63.00	63.50	90.00	215.00	137.50	19.80	19.70	32.00	15.00	39.05	81.62	134.5	68.49	9.61	64.68
DMIL 12 x DMIL 4	62.00	64.00	92.00	225.00	118.50	20.10	17.35	36.00	14.00	35.8	75.65	119	60.31	10.27	65.91
DMIL 13 x DMIL 4	63.00	64.50	94.00	212.50	115.00	18.80	17.35	30.00	19.00	31.5	92.31	121	61.36	10.35	66.40
DMIL 14 x DMIL 4	61.00	62.50	93.00	235.00	100.00	20.30	17.15	28.00	16.00	33.25	82.98	105	52.92	11.85	66.95
DMIL 6 x DMIL 5	61.00	63.00	94.00	212.50	103.00	19.55	18.15	26.00	15.00	36.55	79.58	121	61.36	8.82	65.00
DMIL 7 x DMIL 5	62.00	63.50	93.00	234.00	96.50	22.20	18.05	40.00	15.00	32.5	89.37	138	70.33	10.18	65.82

Contd....

Appenix II contd...

Crosses	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear width (cm)	No of kernels per row	No of rows per cob	Test weight (g)	Shelling %	Grain yld per plant (g)	Grain yld per ha (q/ha)	Protein content (%)	Starch content (%)
DMIL 8 x DMIL 5	63.00	65.50	92.00	221.50	97.50	17.75	17.80	37.00	15.00	38.75	78.09	145.5	74.29	10.21	66.75
DMIL 9 x DMIL 5	61.00	63.50	94.00	209.00	82.50	20.45	18.90	42.00	14.00	40.05	86.91	174	89.6	9.00	65.92
DMIL 10 x DMIL 5	62.00	64.50	93.00	215.00	92.50	19.50	17.30	36.00	15.00	33.05	83.70	117.5	59.51	9.66	65.82
DMIL 11 x DMIL 5	63.00	64.50	90.00	210.00	80.00	21.45	16.30	38.00	15.00	37.75	89.20	164	84.68	8.78	65.87
DMIL 12 x DMIL 5	63.00	65.00	91.00	232.50	107.50	18.85	18.60	32.00	14.00	40.5	89.29	155	79.31	11.30	67.62
DMIL 13 x DMIL 5	62.00	63.50	92.00	200.00	95.00	18.70	17.45	36.00	17.00	33.25	81.59	145.5	74.29	9.77	65.25
DMIL 14 x DMIL 5	63.00	66.50	93.00	215.00	103.50	19.20	18.35	34.00	15.00	38.5	89.65	164	84.06	9.52	65.38
DMIL 7 x DMIL 6	60.00	65.50	89.00	211.50	102.50	19.90	17.90	36.00	16.00	35.5	79.78	159	81.42	11.31	67.15
DMIL 8 x DMIL 6	62.00	63.50	90.00	214.00	125.00	18.10	17.50	32.00	16.00	34.8	80.75	135.5	69.01	9.22	65.30
DMIL 9 x DMIL 6	60.00	66.50	89.00	195.00	100.00	23.45	19.85	40.00	17.00	39.5	87.21	155.5	79.57	11.33	67.74
DMIL 10 x DMIL 6	62.00	65.50	92.00	185.00	110.00	20.25	15.20	34.00	14.00	38.5	86.44	114.5	57.93	8.63	66.13
DMIL 11 x DMIL 6	63.00	65.50	93.00	230.00	117.50	17.85	25.70	36.00	15.00	40.15	85.46	117.5	59.51	11.00	64.59
DMIL 12 x DMIL 6	63.00	66.50	90.00	212.50	113.50	18.90	17.55	35.00	13.00	40.6	82.82	136.5	69.54	10.31	66.48
DMIL 13 x DMIL 6	59.00	65.50	91.00	210.00	130.00	19.50	16.35	29.00	15.00	33	89.66	149	76.14	10.31	67.13
DMIL 14 x DMIL 6	61.00	66.50	92.00	191.50	120.00	22.65	15.30	24.00	15.00	35.25	78.68	145.5	74.29	9.97	65.21
DMIL 8 x DMIL 7	62.00	65.50	91.00	210.00	122.50	21.05	16.60	28.00	17.00	34.9	85.35	169	86.5	9.73	65.38
DMIL 9 x DMIL 7	64.00	64.50	93.00	210.00	112.50	21.05	17.15	32.00	17.00	32.9	90.01	125.5	63.74	9.84	65.25
DMIL 10 x DMIL 7	64.00	65.00	92.00	225.00	130.00	22.35	19.30	46.00	15.00	38.5	86.74	169.5	86.96	9.49	64.34
DMIL 11 x DMIL 7	62.00	63.50	90.00	217.50	100.00	19.75	18.10	34.00	14.00	40.8	82.78	127.5	64.79	10.62	65.85
DMIL 12 x DMIL 7	63.00	65.50	93.00	215.00	95.00	20.20	17.35	36.00	17.00	39.75	81.67	122.5	62.15	8.42	64.50
DMIL 13 x DMIL 7	61.00	64.50	91.00	194.00	112.50	21.15	16.60	28.00	17.00	41.5	76.14	118.5	60.04	11.50	63.65

Contd....

Appenix II contd...

Crosses	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear width (cm)	No of kernels per row	No of rows per cob	Test weight (g)	Shelling %	Grain yld per plant (g)	Grain yld per ha (q/ha)	Protein content (%)	Starch content (%)
DMIL 14 x DMIL 7	62.00	63.50	91.00	210.00	115.00	21.75	19.35	38.00	17.00	37.9	80.86	117	74.29	9.84	65.05
DMIL 9 x DMIL 8	63.00	63.50	92.00	200.00	99.00	22.20	17.50	40.00	16.00	40.6	84.37	164	89.6	6.47	63.85
DMIL 10 x DMIL 8	63.50	64.50	94.00	195.00	85.00	18.85	16.35	36.00	16.00	38	81.34	113.5	59.51	10.34	66.65
DMIL 11 x DMIL 8	63.50	63.50	93.00	212.50	87.50	20.80	18.35	34.00	17.00	31.8	93.84	107.5	84.68	9.92	65.86
DMIL 12 x DMIL 8	62.50	64.50	94.00	212.50	79.50	20.50	17.30	36.00	13.00	30.95	72.74	135	79.31	9.93	66.94
DMIL 13 x DMIL 8	63.00	66.50	92.00	212.50	87.50	17.35	15.80	32.00	17.00	32.85	91.64	117.5	74.29	9.21	66.35
DMIL 14 x DMIL 8	64.00	64.50	93.00	226.00	52.50	20.20	16.00	40.00	15.00	32.7	78.39	119	84.06	12.23	68.40
DMIL 10 x DMIL 9	63.50	66.50	90.00	215.00	95.50	19.60	16.25	30.00	15.00	33.1	90.73	116	81.42	12.46	68.00
DMIL 11 x DMIL 9	63.00	66.50	89.00	135.00	102.50	18.45	20.05	29.00	17.00	31.8	92.36	137.5	69.01	10.25	68.03
DMIL 12 x DMIL 9	62.50	64.50	93.00	114.00	92.50	20.45	18.25	38.00	14.00	40.1	89.60	160.5	79.57	9.68	64.80
DMIL 13 x DMIL 9	64.00	65.50	92.00	157.50	77.50	19.35	15.60	36.00	17.00	33.65	80.05	118.5	57.93	10.66	65.86
DMIL 14 x DMIL 9	63.00	64.50	94.00	187.50	112.50	20.15	15.40	37.00	14.00	34.88	79.71	133	59.51	11.96	68.25
DMIL 11 x DMIL 10	61.00	63.00	90.00	196.50	97.50	22.15	15.65	38.50	14.00	37.55	81.16	112	69.54	12.44	67.90
DMIL 12 x DMIL 10	62.00	63.50	92.00	177.50	112.50	22.70	15.50	38.50	15.00	40.65	86.20	118	76.14	8.20	64.85
DMIL 13 x DMIL 10	63.00	63.50	91.00	165.00	85.00	22.85	17.80	39.00	17.00	40.7	84.75	119.5	74.29	9.90	68.35
DMIL 14 x DMIL 10	64.00	64.50	96.00	150.00	97.50	22.25	16.70	36.00	15.00	38.05	72.89	165.5	86.5	11.59	68.10
DMIL 12 x DMIL 11	63.00	65.50	94.00	163.00	117.50	19.25	17.30	34.00	15.00	33.5	81.45	131.5	63.74	11.69	67.35
DMIL 13 x DMIL 11	62.00	63.50	93.00	135.00	95.00	19.35	18.50	32.00	17.00	35.81	89.50	135.5	86.96	11.68	68.16
DMIL 14 x DMIL 11	63.00	64.50	94.00	196.50	110.00	20.45	16.60	30.00	15.00	34.84	83.89	132	64.79	11.48	65.34
DMIL 13 x DMIL 12	63.00	66.50	93.00	170.00	112.50	19.10	16.05	34.00	14.00	32.83	85.84	109.5	62.15	11.39	66.65
DMIL 14 x DMIL 12	64.00	65.50	94.00	190.00	115.00	17.85	16.00	32.00	14.00	33.75	91.82	117	60.04	12.06	68.01
DMIL 14 x DMIL 13	63.00	66.50	93.00	182.50	70.00	20.20	16.05	36.50	17.00	32.5	83.91	122.5	71.45	10.80	65.81

Contd.....

Appenix II contd...

Checks	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear width (cm)	No of kernels per row	No of rows per cob	Test weight (g)	Shelling %	Grain yld per plant (g)	Grain yld per ha (q/ha)	Protein content (%)	Starch content (%)
Checks															
NK 6240	63.00	66.50	93.00	210.00	108.44	20.90	17.95	38.00	14.00	37.55	74.30	142.50	72.71	10.85	66.86
S.6668	64.00	64.50	91.00	204.50	108.22	22.25	17.30	38.00	13.00	37.40	74.29	137.00	69.81	10.70	66.32
PAC 745	66.00	67.50	92.00	202.00	108.44	22.50	17.15	32.00	15.00	36.95	69.19	114.50	57.93	9.30	68.30
Jaikisaan 101	65.00	67.50	91.00	193.00	108.44	20.55	17.40	30.00	13.00	36.65	75.42	115.00	58.19	8.97	64.39
New top star	64.00	65.50	92.00	183.00	108.44	20.90	17.45	26.00	15.00	36.37	84.26	113.50	57.40	6.78	65.09
S 6304	65.00	64.50	94.00	175.50	108.44	20.40	18.00	32.00	15.00	36.88	76.47	113.50	57.40	9.13	65.37
NK 30	62.00	65.50	93.00	190.50	108.44	21.55	17.95	28.00	14.00	35.58	71.71	112.00	56.61	8.94	66.44
VMH 4147	61.00	64.50	93.00	205.50	108.44	20.45	18.20	24.00	18.00	29.70	74.65	114.50	57.93	9.38	66.38
NK-6241	63.00	63.50	96.00	188.00	89.94	19.35	15.90	32.00	14.00	30.70	73.45	108.00	54.50	9.48	67.16
surer 900M	64.00	65.50	95.00	155.50	98.44	18.75	15.40	24.00	16.00	33.15	68.45	108.50	54.76	10.07	64.17
Bio-9681	62.00	64.50	91.00	165.50	62.94	23.70	18.40	32.00	16.00	33.20	72.80	125.00	63.47	9.81	65.29
JMH-203	62.00	63.50	94.00	188.00	108.44	20.75	17.50	28.00	15.00	35.70	75.33	115.00	58.19	9.63	65.54
cp 818	64.00	65.50	95.00	160.50	93.44	24.50	18.05	30.00	13.00	36.80	72.38	122.50	62.15	8.81	65.35
Arjun	65.00	67.50	94.00	163.00	145.94	21.85	19.30	32.00	14.00	36.92	71.11	108.00	54.50	7.22	64.95
Prabha	65.00	66.50	95.00	148.00	94.94	17.00	15.30	26.00	14.00	36.60	65.41	112.00	56.61	7.90	65.20
Renuka	64.00	65.50	94.00	145.50	98.44	17.80	15.55	24.00	13.00	35.20	63.91	123.00	62.42	8.46	64.47
CD at 5%	0.38	0.75	1.05	22.42	26.64	1.97	2.34	2.37	2.35	4.58	14.65	21.75	11.50	0.43	0.39
CD at 1%	0.51	0.99	1.38	29.63	35.22	2.60	3.09	3.14	3.11	6.06	19.37	28.75	15.20	0.57	0.51

DEVELOPMENT OF HIGH YIELDING SINGLE CROSS HYBRIDS FROM NEWLY DEVELOPED INBRED LINES OF MAIZE (*Zea mays* L.)

NETRAVATI

2012

**Dr. G. SHANTHKUMAR
MAJOR ADVISOR**

ABSTRACT

A study was conducted to assess the combining ability, nature of gene action and extent of heterosis in respect to grain yield, its componental traits and quality characters, involving 91 hybrids (developed through half diallel), 14 inbreds and 16 commercial checks in maize during kharif 2011-12 at MARS, University of Agricultural Sciences, Dharwad. The analysis of variance indicated significant amount of variability among genotypes for 15 quantitative characters studied. The computed variance ratios (GCA:SCA variance) revealed the predominance of non-additive gene action in the inheritance of all the traits. The study on the combining ability revealed that the lines DMIL 9 (5.160) and DMIL 5 (4.566) were found to be best general combiners for grain yield per plant and grain yield per hectare than the rest. The study on standard heterosis revealed that 5 hybrids viz., DMIL 9 x DMIL 5 (23.23 %), DMIL 10 x DMIL 7 (19.60 %), DMIL 4 x DMIL 3 (19.24 %), DMIL 8 x DMIL 7 (18.97 %) and DMIL 14 x DMIL 10 (16.70 %) exhibited significant positive heterosis over best commercial check NK 6240 and also exhibited significant sca effect for grain yield and its components, obtained from the parents with high x high gca effects. It is suggested to evaluate the identified hybrids in large scale trail to confirm their superiority. The hybrids, DMIL 10 x DMIL 3 (29.22 %), DMIL 10 x DMIL 9 (14.79 %), DMIL 11 x DMIL 10 (14.61 %) and whereas DMIL 10 x DMIL 3 (3.55 %), DMIL 9 x DMIL 3 (3.38 %), DMIL 7 x DMIL 3 (3.22 %) were top crosses showed the significant heterosis as well as sca effects for protein content and starch content, respectively. Most of these were obtained from the parents with high x high gca effects. These results revealed the possibility of realizing higher yield and quality through heterosis breeding.