COMBINING ABILITY, HETEROSIS AND PHENOTYPIC STABILITY FOR YIELD AND OTHER DESIRABLE CHARACTERS IN HIGH QUALITY PROTEIN MAIZE (*Zea mays* L.)

Thesis

Submitted to the

G.B. PANT UNIVERSITY OF AGRICULTURE & TECHNOLOGY,
PANTNAGAR-263 145 (U.S. NAGAR), UTTARAKHAND, INDIA

By

Jitendra Bhaskar

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Doctor of Philosophy

(GENETICS AND PLANT BREEDING)

AUGUST, 2010

ACKNOWLEDGEMENT

The author, with a sense of deep veneration and genuine appreciation wishes to express his gratitude to his Advisor and Chairman of the Advisory Committee, Dr. S.S. Verma, Professor, Department of Genetics and Plant Breeding, College of Agriculture, G. B. Pant University of Agriculture and Technology, Pantnagar for suggesting and manoeuvring this research work with utmost dexterity. His rare bonhomie and compassionate inspiration during the course of this work has been indispensable.

The author is extremely grateful to Dr. M. Z. K. Warsi, Dr. D. Roy and Dr. Kamendra Singh, Professors, Department of Genetics and Plant Breeding, Dr. A. K. Shukla, Professor and Head, Department of M.S.C.S. as the member of Advisory Committee for providing valuable suggestions during the study of reviewing the manuscript.

The author humbly expresses his thanks to Dr. G. C. Vajpayee, Professor and Head, Department of Genetics and Plant Breeding; Dean, College of Agriculture, Dean, Post Graduate Studies and Director Experiment Station for providing necessary facilities during the course of investigations.

I wish to express my gratitude to Dr. Ram Bhajan, Dr. N. K. Singh, Dr. J. P. Jaiswal, Dr. P. K. Shrortia, Dr. H. S. Chawala and all the faculty members, Sri. Adhekari ji , Sri. Khan ji and other staff members of the Department of Genetics and Plant Breeding for their help and cooperation.

It is beyond my capacity to express my gratitude towards my Parents, elder brothers Mr. Bharat Bhushan and Mr. Jayprakesh, Gunjan Bhabi and Rajni Bhabi, Jijaji Dr. Surendra , elder sisters Reena didi and Dolly didi, Ashok uncle, Sunita aunti, dear Avantika, Istuti, Dichha, Rishu, Abhinav, Manish, Khushi, Ayushi and loving Shivi, who are the pillars of my strength and have always stood by me to care, guide, encourage, support and bestow love.

Time can never erase the immortal memories of golden times and blue moods shared with My friends Dr. Rakesh N., Dr. Vipin, Mr. Atin, Ms. Priyanka, Ms. Pooja,

Ms. Gitika, Ms. Mamta, Ms. Shalini and Ms. Swati whose love & affection and constant encouragement made the most cheerful and unforgettable part of my life.

I would also like to acknowledge the help and continuous encouragement that was forwarded by seniors Dr. Narendra, Dr. Rajneesh, Dr. Pshpak,Dr. Vikram Singh, Dr. D. J., Dr. Jitendra Saini, Dr. Manoj (Mannu da), Dr. Manoj, Dr. Arvind, Dr. Hariom, Dr. Rishika, Dr. Suneeta and Dr. Ankit and Ajay Paliwal sir; batchmates Rajeev, Indiver, Amrita, Neetu and loving Juniors Tara, Naveen Pant, Jakhwal, Santosh Yadav, Navneet, Santosh, Arif, Manjeet, Kalyan (guruji), Yogesh Kumar, Preetam S.P., Yogesh, Vikrant, Ram Lakhan, Vineet, , Ramesh Suyal, Naseer, Sandeep, Kuldeep Tomar, Chandan, , Prakash Bhandari, Pankaj, Priyanka, Piyusha, Pooja, Nandita, Sweta, Nagma and all other juniors and friends for their cheerful company, moral support, all time availability for help and full cooperation during my stay at Pantnagar. I pay my heartly thanks to Mr. Naveen Pant, Tara, Ravindra Sir and Pathak ji.

The author is also grateful to Mewari ji, Ashok Sharma ji, Ramvir Singh ji, Ramavtar ji, Pallu, Bhaskar, Shambu and all labours of Maize Co-ordinated Project for assisting to the best while conducting the experiment.

The Graduate Research Assistantship awarded by the Directorate of Research, Pantnagar during the course of this study is duly acknowledged.

Pantnagar
August, 2010

(***Jitendra Bhaskar***)
Author

Dr. S.S. Verma
Professor

Department of Genetics and Plant Breeding
College of Agriculture
G.B. Pant University of Agri. & Tech.,
Pantnagar- 263 145 (U.S. Nagar),
Uttarakhand, INDIA

CERTIFICATE

This is to certify that the thesis entitled "**COMBINING ABILITY, HETEROSIS AND PHENOTYPIC STABILITY FOR YIELD AND OTHER DESIRABLE CHARACTERS IN HIGH QUALITY PROTEIN MAIZE (*Zea mays* L.)"** submitted in partial fulfilment of the requirements for the degree of **Doctor of Philosophy** with major in **Genetics and Plant Breeding** and minor in **Agricultural Statistics**, of the college of Post-Graduate Studies, G.B. Pant University of Agriculture and Technology, Pantnagar, is a record of *bona fide* research carried out by **Mr. Jitendra Bhaskar, Id. No. 27940,** under my supervision and no part of the thesis has been submitted for any other degree or diploma.

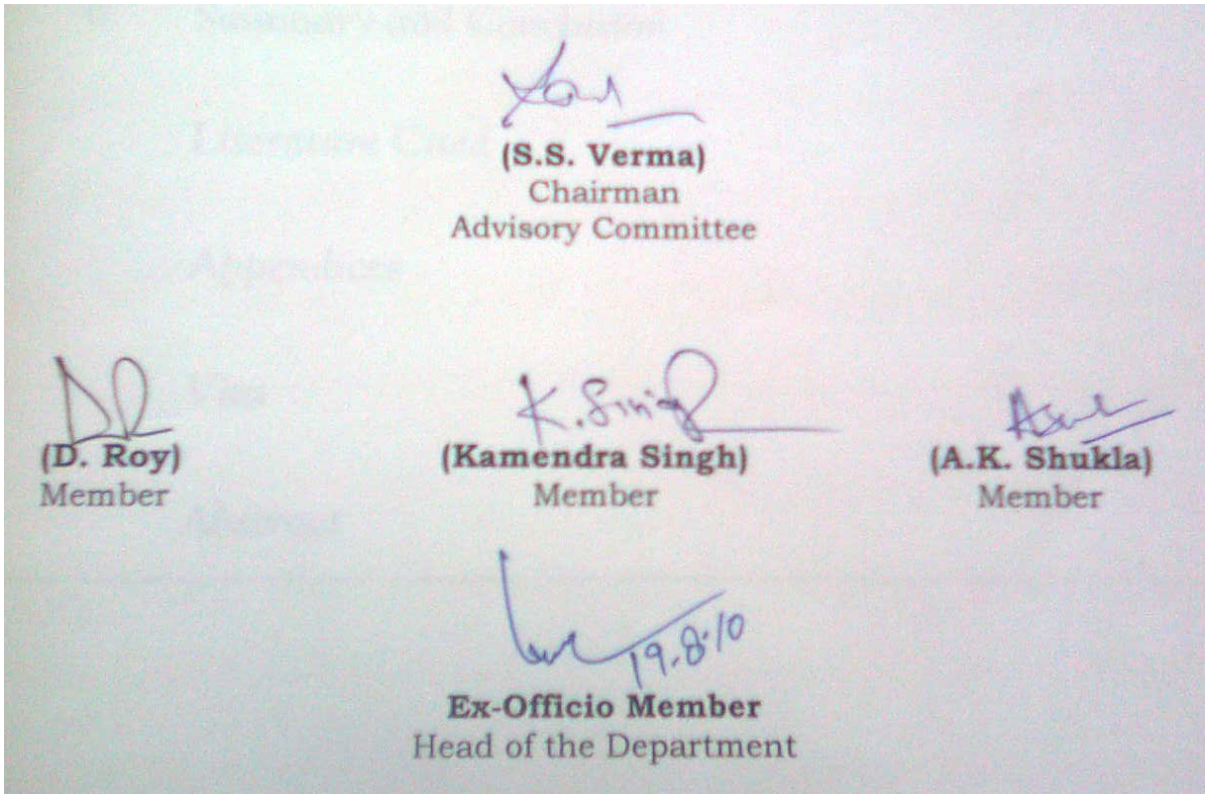
The assistance and help received during the course of this investigation have been duly acknowledged.

(S.S. Verma)
Chairman
Advisory Committee

Pantnagar
August, 2010

CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Mr. Jitendra Bhaskar, Id. No. 27940**, a candidate for the degree of **Doctor of Philosophy** with major in **Genetics and Plant Breeding** and minor in **Agricultural Statistics,** agree that the thesis entitled **"COMBINING ABILITY, HETEROSIS AND PHENOTYPIC STABILITY FOR YIELD AND OTHER DESIRABLE CHARACTERS IN HIGH QUALITY PROTEIN MAIZE (*Zea mays* L.)**" may be submitted in partial fulfilment of the requirements for the degree.



CONTENTS

S. No.	Chapters	Page
1.	*Introduction*	
2.	*Review of Literature*	
3.	*Materials and Methods*	
4.	*Experimental Results*	
5.	*Discussion*	
6.	*Summary and Conclusion*	
	Literature Cited	
	Appendices	
	Vita	
	Abstract	

ABBREVIATIONS

Symbol	Description
%	Per cent
'N'	Nitrogen
bi	Regression coefficient
BP	Batter parent
CD	Critical difference
cm	Centimeter
CP	Check parent
d.f.	Degree of freedom
E	Environment
GCA	General combining ability
ha	Hector
Kg	Kilogram
L	Line
MP	Mid-parent
nm	Nano meter
P	Pooled
S^2di	Deviation from linearity
SCA	Specific combining ability
T	Tester
vs.	Verses
σ^2	variance

Chapter – 1

Introduction

Chapter 1 INTRODUCTION

Maize (*Zea mays* L.) is the world's leading and versatile crop among the cereals. It is a major crop for both livestock feed and human nutrition, grown in more than 160 countries in tropical, sub tropical and temperate regions from sea level to >3000msl. In India, maize is the third most important cereal after rice and wheat that provides food, feed, fodder, and serves as a source of raw material for developing hundreds of industrial products like, starch, glucose, protein, oil, alcoholic beverages, food sweeteners, pharma, cosmetics, ethanol as bio-fuel, etc.

It is cultivated in an area of about 161 m ha with the total production of about 822 m tonnes in the world (2006-07). In India as per the latest report maize area production and productivity are 8.17 m ha, 19.73 mt and 2.4 t/ha, respectively. The maize production has increased >12 times from a mere 1.73mt (1950-51) to 19.73 mt (2008-09). The demand for maize will touch 42 mt by 2025, of which 20-21% will be used for human consumption, >60% as poultry and livestock feed and the remaining 12-13% for industrial raw material. These figures probably would remain constant for another 10-15 years.

With its high content of carbohydrates, fats, proteins, some of the important vitamins and minerals, maize acquired a well-deserved reputation as a "poor man's" nutricereal to several million people, particularly in the developing countries, who use to derive their protein and calorie requirements from maize.

Cereal proteins in general and maize protein, is particular are of poor quality, because of lack of balance in amino acid composition. Hence, genetic manipulation for improved amino acid composition has been considered as a noble goal. The discovery of high lysine mutant opaque-2 (o2), followed by other mutants and modifiers led to the concept of quality protein maize.

CIMMYT scientists have developed "quality protein maize" (QPM) that looks and tastes like normal maize, yields as much or more, and shows equal or superior disease and pest resistance. Moreover, QPM contains nearly twice the amount of lysine and tryptophan, the two amino acids essential for protein synthesis in humans and monogastric animals plus a generally more balanced amino acid content than the normal maize that greatly enhances its nutritive value. Research suggested that QPM can help to reduce protein deficiencies, particularly in young children where maize dominates in diets **(Vasal, 2000)**.

The maize carrying opaque – 2 genes in homozygous condition is referred as opaque-2 maize, whereas, modified opaque-2 maize with hard endosperm and vitreous kernels, is known as quality protein maize (QPM). It means an open pollinated variety or hybrid of maize containing lysine and tryptophan twice than the normal maize varieties along with low amount of leucine. The opaque -2 gene can e incorporated into any maize population, inbred line or any other germplasm through back cross breeding method in the selected genetic back grounds.

Greater the variability, more are the chances of getting desired types. Partitioning of the variability into heritable and non-heritable components helps in effectiveness of selection. High heritability with high genetic advance indicates additive gene action, whereas high heritability with low variability and genetic advance suggest for non-additive gene action of dominance and epistasis.

The phenomenon of heterosis has been exploited extensively in maize. Heterosis or hybrid vigour concept of maize started with the studies reported by **Shull (1908)** in "The composition of a field of maize". A major breakthrough in maize breeding for yield has come through the utilization of heterosis in F_1 generation **(Shull, 1914)**. Hybrids are considered to possess a high degree of biological fitness for a given situation. For the development of promising hybrids, identification of genetically superior parental inbreds is a prerequisite. Combining ability of the inbred lines is the ultimate factor determining future usefulness of these lines for hybrids and synthetics. **Sprague and Tatum (1942)** apparently were the first to propose combining ability concept. Combining ability analysis provides information on the relative importance of additive and non-additive gene effects involved in the expression of the quantitative traits.

Genotype × environment interactions are of major importance to the plant breeder in developing improved varieties. It assumes added importance in the breeding of dry land crops such as maize, which are more subjected to the vagaries of weather. It is, therefore, important that

stable genotypes are evolved which can withstand such uncertain conditions. **Eberhart and Russell (1966)** have provided a dynamic approach for studying and interpreting phenotypic stability from regression analysis. It enables selection of genotypes that may give reasonably stable performance over a range of environments.

Therefore, in the present investigation, 63 single cross hybrids developed from 24 parental lines (21 inbred line + 3 tester) in line x tester design were evaluated along with three checks in different environments viz normal(recommended dose of nitrogen), low–nitrogen and excess soil moisture condition. Keeping in view of the necessity of finding out better heterotic and good combining parents the present investigation has, therefore, been conducted with the following objectives:

1. To identify the promising single cross QPM hybrids based on mean performance and GCA of parent, and SCA of hybrids.
2. To determine the nature and magnitude of heterosis.
3. To estimate heritability, expected genetic advance and coefficient of variation.
4. To study the phenotypic stability of parents and single crosses across three environments.

Chapter – 2

Review of literature

The relevant literature pertaining to present investigation on variability parameters, heterosis, combining ability and phenotypic stability in quality protein maize has been reviewed as under:

2.1 Heritability and expected genetic advance

2.2 Heterosis

2.3 Combining ability

2.4 Phenotypic stability

2.1 Heritability and expected genetic advance

Heritability is defined as the ratio of additive genetic variance to the total phenotypic variance **(Wright, 1921)**.

Lush (1949) partitioned heritability into broad sense and narrow sense. Broad sense heritability is the ratio of total genetic variance and total phenotypic variance expressed in percentage. Narrow sense heritability is the ratio of additive genetic variance and total phenotypic variance expressed in percentage.

Robinson *et al.* (1952) studied heritability of plant height and ear height in maize and reported high heritability for these characters. The ear length, ear diameter and grain yield had considerably lower heritability values.

Scherbak and Zabirova (1979) examined heritability of different yield contributing characters in maize. They reported low heritability

values for different yield contributing traits due to low genetic variance and high error variance.

Singh (1984) reported that broad sense heritability for most of the characters was very low to moderate. Heritability for grain yield per plot, plant height and ear height was 0.21, 0.31 and 0.32, respectively.

Debnath (1987) reported that heritability was higher for days to silking, plant and ear heights but low for grain yield per plant.

Debnath and Sarkar (1987) conducted an experiment with 10 inbreds and all possible F_1s among these without reciprocals and reported on yield per plot and five yield components at two sites. Heritability estimates were higher for ear length and 1000-grain weight than for grain yield in both the environments.

Liao *et al.* (1987) evaluated five crosses for plant height, ear height, ear length, 1000-kernel weight and grain weight per plant. Ear height showed the highest broad sense heritability, whereas, yield contributing characters exhibited lower heritability.

Claudio and Patricio (1988) studied narrow sense heritability for five quantitative characters in 196 progenies of half-sib families and reported that estimates were high for plant height (0.51) and ear length (0.59) but low for leaves per plant (0.30) and grain yield (0.22). Ear per plant had the lowest heritability (0.14).

Dawood and Mohamed (1989) examined seven maize lines and their F_1 hybrids. Heritability was estimated from data on six characters. Ear diameter and kernel rows per ear had high heritability estimates.

Singh *et al.* (1989) conducted an experiment involving 10 varieties, their 45 F_1 and 45 F_2 hybrids from a diallel set of crosses. The genetic variance, heritability and expected genetic advance were estimated on nine characters. High estimates of heritability and expected genetic advance were found for leaf area and 1000-kernel weight.

Arha *et al.* (1990) studied heritability for eight yield contributing characters and found that it was highest for days to silking. Moderate values were obtained for plant height, ear height, number of leaves above the ear and ear length.

Debnath and Khan (1991) estimated heritability, correlation and expected genetic advance from data on yield and its eight components in 21 genotypes. Data revealed that days to silk, plant height, number of kernels per row, 1000-grain weight showed positive contribution towards grain yield.

Reddy and Agrawal (1992) reported genetic variance, heritability and genetic gain from data on grain moisture content at harvest, days to 50 per cent silking, plant height and ear height in full-sib progenies developed in an early population, D742. The heritability estimates were higher for all the traits studied.

Saha and Mukherjee (1993) reported high heritability for number of kernels per row, harvest index and grain yield per plant in four inbred lines and their hybrids.

Osuna *et al.* (1995) obtained estimates of additive genetic variance, narrow sense heritability and expected genetic gain for yield,

plant height and ear height. Heritability estimates were 33.7 per cent for grain yield and 54.6 per cent for plant and ear heights.

Chen *et al.* (1996) studied inheritance of ear length, ear thickness, number of kernelsperrow, 100-grain weight and grain yieldperplant. Heritability estimates for ear length, ear thickness and kernel rowsperear ranged from 50.8 to 8.9 per cent which were higher than those for 100-grain weight and grain yieldperplant.

Satyanarayana and Saikumar (1996) estimated genetic variability in 45 F_1 (single cross) maize hybrids from data on grain yield and number of days to 50 per cent tasselling, 50 per cent silking and 50 per cent dry husk.

Singh *et al.* (1998) studied variation, heritability and expected genetic advance from data on grain yield, biological yield and their components in 10 parental genotypes and their 45 F_1 hybrids evaluated during *Kharif*, 1997 and *Rabi*, 1997-98. Plant height, ear height, ear length, kernels per row, 100-kernel weight, biological yield per plant and grain yield per plot exhibited moderate to high estimates of phenotypic and genotypic variation, heritability and expected genetic advance in both seasons.

Hema *et al.* (1999) reported high narrow sense heritability for 100-grain weight (0.94) and ear diameter (0.64) and low estimates for ear height (0.13), kernel row number (0.46) and kernelsperrow (0.41) from two inbreds and cross between them.

Kabdal (2000) studied heritability and expected genetic advance in 21 crosses and their parents. He reported high heritability as well as

expected genetic advance for grain yield, ear height and ear length. Days to 50 per cent silking and ear diameter had low heritability and expected genetic advance.

Srivastava (2001) reported heritability and expected genetic advance in 80 crosses and their parents over three locations. He reported high heritability for plant height, days to 50 per cent silking, grain yield, ear height, ear length, number of kernelsperrow and 1000-kernel weight, whereas, moderate estimates of heritability were obtained for ear width, number of kernel rowsperear and shelling percentage. Higher expected genetic advance was observed for grain yield, plant height, ear height and 1000-kernel weight, while moderate values for days to 50 per cent silk, ear length, shelling percentage and number of kernelsperrow were obtained. Low estimates of expected genetic advance were shown by ear width and number of kernel rowsperear.

Kabdal *et al.* (2003) studied genetic variability in seven inbred lines of maize and their 21 direct cross combinations. He reported that genotypic and phenotypic coefficient of variation was higher for grain yield, ear height, 100-kernel weight, ear length and number of kernel rowsperear. Genotypic variation was found to be good indication of phenotypic variability. Heritability estimates and genetic advance were higher for grain yield, ear height, plant height and ear length.

Viola *et al.* (2003) examined 24 elite baby corn lines for heritability and genetic advance for 14 traits. Yield contributing traits expressed high heritability coupled with high genetic advance as per cent

of mean. The number of days to 50% silking, number of days to harvesting and number of days to 50% tasselling were characterized by high heritability along with low genetic advance as per cent of mean.

Rezaei *et al.* (2004) evaluated 10 early maturing inbred lines of maize and their crosses and observed high broad sense heritability estimates for most of the traits, however, the estimates of narrow sense heritability were relatively low for kernels per row and grain yield.

Mahmood *et al.* (2004) studied 11 genotypes and recorded observations for days taken to tasselling, number of days taken to silking, plant height, ear length, number of kernel rows per ear, number of kernels per row, 100-grain weight and grain yield per plant. Highest heritability estimates were found in grain yield per plant (0.993) and by plant height (0.990). Values of genetic advance ranged between 43.80 for grain yield per plant to 1.33 for number of kernel rows per ear. Greater magnitude of broad sense heritability coupled with higher genetic advance in characters under study provided the evidence that these plant parameters were under the control of additive genetic effects.

Abirami *et al.* (2005) studied 40 maize genotypes for genetic variability. They observed that phenotypic variance was slightly higher than the genotypic variance. Heritability estimates were high for all the characters coupled with high genetic advance for number of grains per ear.

Singhal *et al.* (2006) evaluated 14 high QPM inbred lines with 3 testers and their 42 top crosses for heritability and genetic advance. They observed high heritability estimates for grain yield followed by ear

diameter, ear length and kernel rowsperear. Maximum amount of genetic advance was found for grain yield.

Bhoite and Sonone (2007) studied genetic parameters in 45 genotypes for the yield and yield components. The phenotypic coefficients of variation (PCV) were higher than the corresponding genetic coefficients of variation (GCV). Both parameters were highest for crude protein yield. High heritability values, coupled with high GCV, PCV and genetic advance, were recorded for green forage yield, dry matter yield, and crude protein yield.

Suvarna *et al.* (2008) evaluated 9 hybrids of maize to study the variability. There were significant differences among the genotypes evaluated for all the characters. Seed yield exhibited moderate GCV and heritability, high PCV and moderately low genetic advance.

Garbuglio *et al.* (2009) studied genetic variability in seven maize populations with a broad genetic base. Estimates of heritability were high for ear weight (0.89 to 0.94), ear length (0.77 to 0.88) and ear diameter (0.77 to 0.92); and lower for plant height (0.58 to 0.80) and ear height (0.54 to 0.84), thus showing the high potential of the populations for recurrent selection based on S1 families.

Yusuf (2010) studied in 36 maize genotypes (15 single cross hybrids, 9 parents and 12 checks). The phenotypic coefficients of variations were higher than the genotypic coefficients of variations for all the traits studied. Thousand seed weight had the highest genotypic coefficients of variation. The highest genetic gain was obtained for plant

height. Thousand seed weight and ear height also recorded high genetic gain.

Rafiq *et al.* (2010) stidied ten local maize inbred lines. Grain yield, ear length, ear height, 100-seed weight and ear diameter had high GCV estimates with high heritability. Genetic advance was higher for plant height, ear length, grains per row and grain yield.

2.2 Heterosis

Heterosis is defined as the phenomenon in which the F_1 population obtained by crossing two genetically dissimilar individuals show increased or decreased vigour over mid parent value (relative heterosis) or over better parent value (heterobeltiosis). A third kind of heterosis is known as standard heterosis or economic heterosis which is expressed as the increased or decreased vigour over the popular / standard check variety has become more relevant and important.

There are two main theories for explaining the genetic base of heterosis. First is the dominance hypothesis which explains the hybrid vigour as the result of the action and interaction of dominant often linked growth factors **(Davenport, 1908)**. The second is the over dominance hypothesis according to which the heterozygosity is necessary for full expression of heterosis **(Shull, 1914)**

The importance and utilization of heterosis depends upon increased yields, the requirement of other desired agronomic characters, case of hybridization, or low cost of seed production.

A new era in maize breeding began in 1909 when G.H. Shull suggested a method for producing hybrid corn seed. He reported in the previous year that an ordinary field of maize is composed of many complex hybrids which decline in vigour with inbreeding and that the breeder should strike to maintain the best hybrid combinations.

Saha and Mukherjee (1985) studied heterosis from a set of crosses among 6 genotypes. The crosses with highest heterosis for 1000 kernal weight and grain yield per plant had high negative heterosis for percent grain conversion.

Shull (1908) observed and measured a reduction in vigour due to the segregation of these different types in their respective homozygous classes and showed how the F_1 yield from crosses of these types exceeds the parental varieties form which they come.

East and Hayes (1912) attributed the vigour of the F_1 to its heterozygous conditions. Thus the greater the number of the genes in which a plant is heterozygous, higher the heterosis.

Shull (1914) used the term 'heterosis' first time, which may be defined as the superiority of a F_1 hybrid over both of its parents in terms of yield or some other characters. Generally, heterosis is manifested as an increase in vigour, size, growth rate, yield or some other characters.

Jones (1918) suggested crossing two vigorous single crosses and producing double cross seed. This step made production of hybrid maize seed economically feasible.

Powers (1944) suggested that the term heterosis should be used only when the hybrid is either superior or inferior to both the parents.

Shull (1952) defined the heterosis as "the interpretation of increased vigour, size, fruitfulness, rate of development, resistance to disease and insect pests, or climatic rigors of any kind, manifested by cross bred organisms as compared with corresponding inbreds, as the specific results of unlikeness in the constitution of the uniting parental gametes".

Robinson *et al.* (1956) reported from a set of diallel crosses of 6 maize varieties that 19 F_1s were superior to mid-parental value and 11.5 per cent to the better parent.

Moll *et al.* (1962) reported 21 to 39 per cent heterosis for crosses involving varieties from the USA and Puerto Rieo, whereas, the heterosis in varietal crosses among the local varieties was only 9 to 22 per cent.

Paterniani and Lonnquist (1963) presented data on 12 races of corn of diverse origins and their F_1 hybrids grown in Brazil. The heterotic response, measured as deviation from the mid-parent ranged from 11 to 101 per cent.

Moll *et al.* (1965) studied two populations from each of four geographical regions and inter crossed them in all possible combinations and the resulting F_1 populations were advanced upto one generation to generate F_2 populations. The parents, F_1 and F_2 populations were grown in four regions of adaptation in order to study the relationship of heterosis to genetic divergence. They reported that heterosis increased with increased divergence within a restricted range of divergence, but extremely divergent crosses resulted in a decrease in heterosis.

Manoliu (1969) studied twenty inbred lines with ten single cross hybrids. He reported heterosis in F_1 for plant height, ear length and ear weight.

Kovach and Khertseg (1971) made hybrids between sister lines and found that dry grain yield was 50-100 per cent more than parental lines.

Kravenchko *et al.* (1971) studied heterosis for plant height, ear length, 1000-grain weight, yield and other characters in hybrids.

Schnell (1974) studied the progress in maize grain yield of inbred lines and hybrid varieties. He used data from 17 experiments published between 1916 to 1969 and found that the amount of heterosis, measured as difference between single cross hybrids and the mean of inbred lines, remained nearly constant. These investigations showed that it was not possible to increase the yield level of inbred lines to the level of hybrid varieties. The results also indicate that a large number of genes must influence yield in maize, otherwise inbred lines approaching hybrids in yield should have been found.

Dhillon and Singh (1977) observed heterosis in general and all crosses involving Cuba yielded better than the mid-parental value. The hybrids Kisan × Cuba, Antigua-3-D × St Croin, Prolix × Sterix, Yijay × Antigua Gr 1 and A_{23} × Cuba yielded more than the control. The significant yield superiority of these over the best commercial composite (Jawahar) suggested possibility to use commercially.

Gorban (1978) studied F_1 single cross maize hybrids, six forms with high, low and intermediate yields were selected. He found that highest yielding F_1 gave a grain yield of 298 g per plant.

Shakoor and Ataullah (1979) crossed four local and four foreign lines in all possible combinations. Heterosis in the F_1 ranged from 114.89 to 175.65 per cent relative to the better parent and mid-parental value for grain yield. For ear length it varied from –0.62 to 29.39 per cent. It ranged from –12.5 to 27.41 per cent for plant height. Heterosis for 1000-grain weight averaged 23.36 per cent over the parental means.

Ramamurti (1980) evaluated 28 F_1s alongwith reciprocals and their eight parental inbreds for thirteen characters during 1976. He reported mid-parent as well as better parent heterosis.

Zhao and Niu (1981) studied hybrid vigour in 300 single cross hybrids and found heterosis for plant height, earliness and grain weight per ear.

Debnath (1984) obtained hybrids from crosses between 9 elite and diverse maize inbred lines. Heterosis was observed for grain yield, grains per ear and ear length.

Genova (1984) studied grain yield and 3 yield components in lines from stiff stalk synthetic and Lancaster and their hybrids. He reported heterosis for yield and ear length. Negative or non-significant positive heterosis was found for number of kernel rows.

Lamkey (1986) studied crosses among 24 each of high yielding and low yielding inbred lines from Iowa stiff stalk synthetic (BSSS). High × high, high × low and low × low crosses differed significantly for group means and showed heterosis for yield and days to silking.

Debnath (1987) reported positive and significant heterosis over mid-parent and better-parent value for 9 inbred lines and their 36 F_1s.

High heterosis was observed for number of kernel per row followed by ear length and 1000-kernel weight.

Ganguli *et al.* (1989) studied 33 inter population hybrids from crosses between 11 female and 3 male lines. Positive heterosis was observed for grain yield, days to maturity and days to silking.

Beck *et al.* (1990) studied a diallel cross of 10 lines at six locations. They concluded that test for average heterosis in parents vs. crosses was significant for grain yield in the combined analysis of variance. Heterosis for plant height, ear height and days to silking was generally low.

Poskannya *et al.* (1990) observed the expression of heterosis in 28 F_1 hybrids from the crosses of eight early lines. Heterosis for plant height and ear height was low at early stage of development.

Ordas (1991) reported mid parent heterosis of 32.7 % much greater then predicted 17.7 %. This was found in crosses among 4 early US Corn Belt and 5 Spanish populations in a diallel series, tested for 3 years at two locations.

Benti-Tolessa *et al.* (1992) studied 21 F_1's from a diallel cross involve 8 composites of maize. He noticed that F_1 hybrids gave higher grain yield than their better parental composites.

Vassal *et al.* (1992) studied heterosis among CIMMYT's sub tropical and temperate early maturing germplasm. They observed maximum high percentage of heterosis in population 46 x pool 30 under temperate environment. Maximum heterosis (10.2%) was recorded for pool 27 x pools 40.

Jha and Khehra (1992) studied heterosis for 10 quantitative traits in the parents and hybrids involving 16 lines and 5 testers. They found that 16 crosses significantly outyielded the best hybrid check.

Sahu and Kapoor (1993) reported in a study of grain yield per plant and 8 related traits in the lines, Vijay 444 and Expt. 10-5 and their F_1-F_2 hybrids, significant heterosis over the better parent in the F_1 for all traits.

Gupta *et al.* (1994) studied heterosis in inter varital crosses in some local and exotic pools and population of maize. Nineteen pools / populations selected on the basis of their geographical diversity and maturity were crossed with two broad base testers, pop-49 and Sweta in a line x tester design. The 38 F_1 hybrids together with 5 standard checks were evaluated for days to 50 % tassel, days to 50 % silk, plant height, ear height and fresh ear weight.

Kumar (1994) studied 25 F_1 hybrids resulting from crosses between 5 flint and 5 dent parents for grain yield and flowering date. He observed heterosis in 8 F_1 hybrids for yield and earliness.

Ho Chauglee *et al.* (1995) studied the heterotic patterns in maize. Sixty three yellow inbred lines were crossed with two inbred testers. The 126 line x tester combination were tested for ear height, plant height, days to 50% silking and grain yield. The heterotic patters of 63 inbred lines were characterized, 30 of which were grouped for 2 opposite base population for further hybrid development.

Shiesh and Shiesh (1995) studied 15 F_1 hybrids and their 6 parents for grain yield and other quantitative traits. They observed high heterosis for number of kernelsperear and grain yield.

Nagda *et al.* (1995) studied 20 F_1 hybrids involving 10 lines and 2 testers for days to silking, plant height, ear height and grain yield with commercial checks. Fifteen of the crosses significantly out yielded the best check for grain yield. Out of these crosses 14 showed significant negative heterosis for days to silking.

Vasal *et al.* (1995) studied a diallel among 12 high land maize pools and populations over 4 environments. They reported that heterosis over the better parent was 18.2 per cent in Pool 10 A × PABG.

Dehganpour *et al.* (1996) evaluated 8 parental inbred lines and their 28 F_1 hybrids in a replicated field experiment. Mid-parent heterosis ranged from 6 per cent for silking date to 152 per cent for grain yield.

Singh and Mishra (1996) studied a diallel cross of 8 inbred lines of maize over three locations for days to 75 per cent silking, ear girth, ear length, 1000-kernel weight and yield per plant. They found that positive heterosis for ear length, grain yield and ear girth.

Mukherjee (1997) studied heterosis in parental lines and F_1 hybrids involving 8 inbred lines and 4 testers and reported highest significant mid-parent heterosis for grain yield (62.65 per cent) in cross (4 × 3) followed by test weight (37.88 per cent). Better parent heterosis was 28.36 per cent and 24.52 per cent for grain yield and test weight, respectively, in the same cross.

Sinha and Mishra (1997) reported significant positive heterosis for grain yield.

Pradhan (1999) studied heterosis from data on yield and other characters in a diallel cross involving 9 inbred lines. Mid-parent heterosis

ranged from 24.58 per cent for shank weight per ear in cross (4 × 7) to 254.88 per cent for kernel weight per ear in cross (1 × 5). Highest percentage of heterosis for both grain yield and ear diameter was found to be 97.52 and 23.77 per cent, respectively, in cross (2 × 8). Highest percentage (184.25 per cent) of better parent heterosis, was observed in cross (1 × 5) for kernel weightperear.

Chen *et al.* (2000) studied heterosis in parents and hybrids involving 7 inbred lines and 3 testers. They reported that QB21, QB89 and QB91 showed high heterosis compared with the three testers.

Kabdal (2000) studied 7 inbred lines and crosses among them and reported highest mid-parent heterosis (38.37 per cent) in cross (1 × 7) for ear height followed by grain yield (26.74 per cent) in cross (6 × 7) and ear length (25.04 per cent) in cross (6 × 7). Better parent heterosis was observed for ear and plant height and kernel weight.

Dubey *et al.* (2001) evaluated 45 single cross hybrids and 18 parental lines along with four checks. They reported high magnitude of heterosis for grain yield and some other quantitative traits.

Iqbal *et al.* (2001) evaluated 77 single cross hybrids along with four controls during the *Kharif*, 1999. They found that hybrids CML 40 × SYB-2 and K305 × CML66 produced the highest grain yields of 3995 and 3837 kg per ha showed 19 and 14 per cent heterosis, respectively, over the best check, Cargill 707.

Pandey and Kumar (2001) evaluated 10 parents and 25 crosses in four replications for grain yield and flowering date. The results showed

that the average heterotic response over mid-parent was 20 per cent with a range 12.48 to 73.94 per cent. Similarly, heterotic response over better parent was 8 per cent. The highest yielding F_1 cross was CRHF comp × Jellicose (4431 kg per ha) which yielded 40.80 per cent over its better parent and 8.54 per cent higher than check Ganga Safed-2.

Srivastava (2001) studied 80 F_1 hybrids involving 20 lines and 4 testers for yield and other quantitative characters at three different locations during *Kharif*, 2000. He found high heterobeltiosis and relative heterosis for all the characters except days to 50 per cent silking and shelling percentage.

Rodrigues and Chaves (2002) studied heterosis in high quality protein maize populations of distinct grain type groups. For grain yield trait, only variety effects and average heterosis were significant, indicating that the best inter-varietal hybrids can be predicted using the means of the parental populations.

Singh *et al.* (2002) crossed eight diverse inbreds in a half diallel to estimate heterosis. Based on the per se performance, GCA effect and heterosis, P_1 x P_7 was the best hybrid, yielding 14.30 % more grain yield per plant followed by P_4 x P_7 (13.07%) over the superior control (CM-400 x CM-300).

Li-Ming Shung *et al.* (2002) studied heterotic groups among maize inbred lines. Based on sca result, they were presented a study to determine the combining ability and heterotic groups of 18 maize inbred lines predominantly used in China.

Dodiya and Joshi (2003) used line x tester analysis involving 20 lines and 3 testers in maize. Their F1 hybrids were evaluated in three environments to assess heterosis with respect to quality and yield attributes. Single cross, Pop30-25-1-1-1 x W-1076-1 had positive significant sca effect for oil and protein content along with grain yield and 100 kernels weight with highest estimates of economic heterosis for oil content.

Unay *et al.* (2003) evaluated maize populations obtained from half-diallel crossing among 9 inbred lines as parents. The mid parent heterosis values ranged from 46.10% (H.96 x DNB) to 573.12% (ALKD 222 x A 632), whereas the useful heterosis values varied between 46.47% (A 619 x A 632) and 10.78% (N 7A x ALKD 90-1), and only 9 crosses had higher grain yields than that of the check variety. Of these crosses, N 7A x ALKD 90-1, N 7A x DNB and N 7A x IDRN Cornell, were considered promising hybrids.

Yousif *et al.* (2003) estimated heterosis in 10x10 diallel among local inbred lines and observed significant heterosis for all traits except plant leaf area. However, it may be explained due to partial, complete and over dominance gene effects. Maximum heterosis was for grain yield.

Reddy and Ahuja (2004) evaluated 45 maize hybrids derived from a 10x10 diallel cross involving 10 inbred lines for heterotic pattern for grain yield and yield components over 4 environments. Some crosses were superior with high mean *per se* values coupled with high heterosis for grain yield per plant. Heterosis for most of the characters varied

between 4 environments, indicating that the magnitude of heterosis was not stable for the genotypes.

Sinha *et al.* (2004) studied 15 diverse inbreds with 3 testers of yellow kernel maize to develop 45 superior single cross hybrids. They estimated significant positive economic heterosis over best control for oil (28.05%) and protein content (31.90%), respectively.

Rezaei *et al.* (2005) evaluated 10 early maturing inbred lines of maize and observed high heterosis in more than 50% of the crosses for all the characters studied. The highest and lowest degrees of heterosis were observed for grain yield and number of ear rows, respectively.

Singhal *et al.* (2006) studied 14 QPM inbred lines with 3 broad based testers and their 42 top crosses. They estimated significant positive heterosis (MP, BP and SP) for grain yield in 9 crosses.

Bertoia *et al.* (2006) evaluated 28 F_1 population hybrids, the eight parental populations (landraces), and four commercial hybrids using a biplot diallel analysis. Significant mid parent heterosis was observed for ear yield, stover yield and whole plant yield.

Ji *et al.* (2006) determined heterosis for plant and ear heights and relative ear position over plant height (REPH). Average heterosis for the plant and ear heights were 33.3% and 61.9%, respectively. However, REPH showed 21.6% heterotic effect.

Gissa *et al.* (2007) evaluated crosses obtained from 8 inbred lines crossed in a diallel mating system. There were significant differences between the entries for measured traits. Mean mid-parent heterosis

ranged from 2.9% for days to maturity to 89.2% for grain yield and high-parent heterosis from 0.65% for ear diameter to 64% for grain yield. All crosses exhibited positive mean mid-parent heterosis for ear and plant heights, ear length, kernels per row and grain yield.

Ojo *et al.* (2007) analysed seven-parent inbred diallel of white maize and estimated heterosis for grain yield and yield components (ear length, ear diameter and shelling percentage). Hybrid means were significantly higher than the parental means for all traits except shelling percentage. Crosses involving tropical x (tropical x temperature) lines produced hybrids with the highest heterosis for all the traits.

Kumar (2008) studied 36 diallel hybrids developed from nine inbreds (MG 2, MG 7, MG 10, MG 14, MG 19, MG 30, MG 31, MG 36 and MG 37) of maize, and found that hybrids MG 7 x ML 47 and MG-35 x ML 47 were the most suitable for the exploitation of heterosis, followed by hybrids MG 7 x ML 47, MG 2 x ML 47 and MG 37 x CO 1.

Kumari *et al.* (2008) analysed genetic relationship among ten maize inbred lines derived from four different source populations were assessed using forty microsatellite markers. Correlations were estimated between Simple Sequence Repeat (SSR) markers based genetic distance with mid parent heterosis for grain yield, days to silking and plant height. The genetic distances based on SSRs were almost congruent with pedigree information and depicted positive linear relationship with heterosis value for grain yield. Although positive relation was revealed between genetic distance and mid parent heterosis in this analysis but

due to its low magnitude it couldn't be used precisely to predict the F_1 hybrid yield performance.

Stupar *et al.* (2008) observed the distributions of better parent heterosis among a series of 25 maize hybrids. Their findings suggested that heterosis is probably not a consequence of higher levels of additive or non- additive expression, but may be related to transcriptional variation between parents. The lack of correlation between better parent heterosis levels for different traits suggested that transcriptional diversity at specific sets of genes may influence heterosis for different traits.

2.3 Combining ability analysis

While breeding high yielding varieties or hybrids, combining ability analysis seems to be the quickest method of understanding the genetic nature of quantitatively inherited traits. Alongwith the mean performance, it is an important tool for selecting the desirable parents for developing high yielding hybrids.

Sprague and Tatum (1942) defined general combining ability (GCA) as the average performance of a line in hybrid combinations and specific combining ability (SCA) as those in which certain combinations do relatively better or worse than would be expected on the basis of GCA of their parents. Generally speaking, good combiner parents result in higher frequency of heterotic hybrids than poor combiner parents. From the genetic viewpoint, GCA measures additive gene effects and SCA non-additive gene effects including dominance and epitasis.

Henderson (1952) defined GCA as the average merit with respect to some traits or weighted combination of traits of an individual line or lines when mated with a random sample from some specific populations and the merit of progeny is measured in some specific set of environmental circumstances. He defined the SCA as a deviation of an average value of a cross from the value which would be expected on the basis of the known GCA of these two lines or individuals.

Griffing (1956a) and **Carnaham *et al.* (1960)** and many other workers have suggested that GCA included both the additive effects as well as additive × additive interactions. It has been realized that a high yielding line may not necessarily be able to transmit its superiority to the hybrid **(Allard, 1960)**. Hence an estimate of GCA (worth of parents) and SCA (worth of hybrids) effects may be more reliable test rather than *per se* performance.

Matzinger *et al.* (1959) compared the variances of the GCA and SCA and their interactions with locations and years. They observed that variances for SCA were significantly more than that for GCA. The variance for the interaction of GCA × environment was significantly greater than the SCA.

Luchsinger and Violic (1972) examined eight characters in a diallel cross analysis and observed that additive effects were more important than non-additive ones for all the variables studied.

Piovarci (1973) determined combining ability and its components for grain yield in a eight inbred diallel and concluded that additive gene

effects were more important than non-additive effects. The ratio of the value for GCA and SCA were 2:1 for grain yield, 5:1 for ear length and 33:1 for 1000-kernel weight.

Singh (1973) proposed the statistical procedure for the analysis of diallel cross data over different environments for combining ability. Estimates of various effects and their corresponding sum of squares, the expectations of mean squares and the variances of estimates of effects and their differences have been treated separately for each method.

Tkachenko and Gomcharenko (1973) examined a diallel cross of ten inbreds, produced 45 single cross hybrids which were measured for grain yield, plant height, ear height and various other plant characters. They found that GCA was greater than SCA for all the characters.

Kumar (1974) found that additive and non-additive gene effects were important for all characters except 100-kernel weight. SCA effects were high for grain yield and ear weight, while GCA was high only for 100-kernel weight and days to silking.

Crossa and Wiidakas (1975) examined a nine parent diallel. Two inbreds viz., HD 240 and HD 241 showed high estimates of GCA effects for grain yield.

Piovarci and Nestichy (1975) studied an 11 parent diallel and concluded that plant height was under additive control. But it was strongly influenced by non-additive genetic system.

Arnold and Bauman (1976) examined a six parent diallel and reported that GCA as well as SCA both were significant for grain weight.

Singh and Asnani (1979) studied yield components in a set of diallel crosses with reciprocals. Eto, Cuba 24 and DA 1 showed good GCA effects for grain yield.

Thong *et al.* (1980) examined 10 diverse inbred lines in a diallel cross and 10 top crosses. The best combiner for grain yield in top crosses were the local inbreds viz., T_{18} and Swabi White and the exotic inbreds viz., Lal-40-2 and St-221-2, T_{18} and Swabi White were the best combiners in single cross with other inbreds.

Burgos (1982) reported significant variation in GCA and SCA for grain yield and most of the agronomic characters in diallel crosses involving white and yellow inbred lines. The GCA mean squares were greater than SCA mean squares for grain yield and most of the other characters. He further reported that additive effect influenced the expression of heterosis in the crosses under high-density environments.

Petrenko (1985) crossed nine inbred lines and one modified single cross hybrid in a diallel fashion. Lines with high GCA and SCA effect were F 522, Od 214 and GK 26.s

El-Hosary (1985) studied combining ability of 21 inbred lines of maize top crossed to each of 4 different testers. Tester G_2 gave the highest positive GCA effect for grain yield and both of its components, whereas, the tester Sabeeni proved significantly negative combiner for silking date, ear and plant height.

Landi *et al.* (1986) studied 3 sets of half-diallel crosses among 10, 7 and 8 lines, respectively, which were evaluated over 3 environments in

1981-83. Significant variances were reported for grain yield, days to pollen shedding and plant height due to both GCA and SCA.

Debnath and Sarkar (1987) evaluated a diallel cross of 10 inbreds over two environments. B_{49} was the best general combiner for grain yield followed by 382 Syn B. The crosses Aust 25 × B 49 and Kmr 35 × Syn 13 showed high positive SCA effects in both environments.

Mohmoud *et al.* (1990) studied a diallel cross of 6 inbred lines for eight quantitative traits and found additive variance to be important for ear length and number of ears per plant, while non-additive variances were found to be important for plant height, ear weight, grain weight per ear, 100-grain weight and grain yield. G_4 and G_{444} were good general combiners and resultant superior combinations, which showed high SCA effect for most characters, were $G_{444} \times G_{507}$, $G_4 \times G_{444}$ and $G_{444} \times G_{241}$-A.

Jha and Khehra (1992) studied general combining ability from a line x tester analysis involving 16 lines and 5 testers in maize during *Kharif*, 1981 at Ludhiana and Gurdaspur. Non additive gene action was found predominant for grain yield. Significant variance for all characters was observed due to environments and genotype x environment interactions.

Guzman (1992) suggested that high gca estimates for yield were expressed by Mindoro and Sapnit 348. The highest sca estimated was exhibited by Tiniquib x Bataan red and eight other crosses also revealed positive sca estimates.

Stastny (1993) studied combining ability of inbred lines of maize originating from native flint types. Eight superior lines, selected in

preliminary test of inbred lines derived from local populations, were assessed for combining ability by crossing with four elite dent lines. The 12 lines and 66 hybrids from a diallel set of crosses were grown at 3 sites over 2 years to evaluate for grain yield and its components. Only hybrid, BC 2142 x BC 910 was superior in yield and other agronomic traits to the standard, being derived from a cross between flint and dent lines it showed the possibility of developing superior heterotic hybrids from genotypes with diverse grain texture. Among flint lines, BC 2142 and BC 6 1111were selected having the best gca for yield and other traits studied.

El-Hossary and Sedhom (1994) estimated combining ability in 8 maize inbred lines and their F_1 hybrids for 10 yield components. Significant GCA was detected in both years except for mid silking in first season. SCA was significant for plant height, ear diameter, number of rows per ear, number of grains per row, ear weight per plant in both the years. Most of the favorable GCA effects were observed in the inbred lines Giza 2 and DC 202.

Sedhoin (1994) estimated the gca and sca in maize under different planting dates. Nine newly developed inbred lines were crossed in a diallel manner to estimate combining ability for a yield component under 2 planting dates (10th June and 10th July 1993). Results indicated that planting dates were significant for all the traits except plant height, ear height, and 100 grain weight. Significant interaction was observed between combining abilities (gca and sca) and planting date for silking,

ear height, ear length, number of rows per ear and grain yield per plant. Moshtohor (M) 26 was the best combiner for silking date while M24 was the best for plant height, ear height and number of rows per ear and MI3 was best for grain yield per plant. The most desirable sca effects were observed in the crosses, M32 x M99 for silking date and plant height, M13 x M24 for ear length, number of grains per row and grain yield per plant, M12 x M25 for ear diameter, M13 x M32 for number of rows per ear and M 12 x M32 for 100 grain weight.

Nagda *et al.* (1995) estimated combining ability for grain yield and its components in maize using twenty F_1 hybrids from 10 lines x 2 testers maize crosses. These were evaluated for days to silking, plant height, ear height and grain yield at Udaipur during *Kharif,* 1993 with the commercial standard checks, Arun, Kiran and Surya. 15 of the crosses significantly out yielded the best standard Arun for grain yield. Hybrid combinations, CD (W) 67- 1-2 x 3022-3-4-2 and CD (W) 64-2 1 x Xl W exhibited desirable sca effects and could be exploited commercially.

Rastogi and Rastogi (1995) evaluated a number of germplasm of diverse origin for their combining ability. Ten early and five late maturing inbred lines were crossed with a genetically broad base extra early composite Chandan Safed-2 (H-62) for determining their gca. H-16 and H-15 were best general combiners for grain yield, 1000-kernel weight, ear weight and early maturity whereas H- 1681 (late maturing) was a good general combiner at both the crop densities for kernel rows, grain yield, 1000-kernel weight. Parent H-8 and H-28 proved to be poor combiners.

Zheng *et al.* (1995) studied genetic parameters of several quantitative characters of maize. The information is derived from data on 7 major quantitative traits in 17 inbred maize lines and their FI hybrids during 1993-94. Genotypes, M 47, 7912 and ES 40 had relatively high gca for yield and plant height.

Singh and Mishra (1996) tested gca, sca and heterosis of eight inbred lines of maize over three locations for days to 75 percent silking, ear girth, ear length, 1000-kernel weight and yield per plant using diallel analysis. Highly significant differences among the lines were observed and best general combiners were identified.

Dass *et at.* (1997) studied the genetics of grain yield and cob traits in maize. Information of combining ability and genetic variance were derived for 6 yield and cob traits in 15 parents and 50 F_1 progenies from 10 lines x 5 testers cross, grown at Uchani. Combining ability variance indicated the importance of these traits. Among these lines, L_5 was the best general combiner for most of the characters, while among the testers, T_2 was a good general combiner for yield.

Sinha and Mishra (1997) estimated heterosis and combining ability from data on yield related traits in 8 varieties of maize and 28 F_1 hybrids grown in *Rabi,* 1994. The cross, Navin x population 26 gave highest grain yield and was best heterotic combination.

Joshi *et at.* (1998) carried out the combining ability analysis in early maturing maize inbred lines for quality and yield attributes. The ratio of additive and non-additive genetic variance revealed that there

was preponderance of non-additive gene action in the expression of yield per plant and 1000-kernel weight.

Mathur *et at.* (1998) evaluated seventy eight single cross maize hybrids involving thirteen diverse inbred lines in non stress and stress environments. Combining ability analysis revealed significant gca variance for days to 50 percent silking, ear length, ear girth, number of grains per row, shelling percentage and grain yield per plant in both the environments. Sca variance was significant for ear length and shelling percentage in normal environment and for grain yield per plant in stress environment.

Petrovic (1998) used the line x tester analysis (Singh and Choudhary, 1976) and studied the mode of inheritance of grain yield, yield components and morphological characteristics of 7 female lines, 3 testers and 21 hybrids of maize. He found that dominant genes play the most important role in the inheritance of plant height, ear base height, kernel number per ear row, 1000-kernel weight, and grain yield per plant in this crop species. Additive gene effects have been found to be more important than dominant ones in the inheritance of the number of kernel rows per ear. In most cases, the combinations of lines with significantly positive gca values produced hybrids with a significantly positive sca. Hybrids having a good sca for 1000-kernel weight and kernel number per row also had a significant sca for grain yield per plant.

Joshi *et al.* (1998) reported that single cross involving inbred lines from Pop 30 and CD white pool had positive significant SCA effects for grain yield per plant and 100-kernel weight.

Choukan (1999) estimated combining ability, additive and dominance variances of characters using 6 maize inbred lines and 3 testes by crossing into line x tester manner. 18 crosses were evaluated under normal and high plant densities in 1998. There were significant differences between crosses for grain yield, number of row per ear and number of kernel per row. Only number of kernel per row under normal and number of row per ear under high density showed significant additive variance, while for other traits under both conditions, additive and dominant variance was significant.

Soliman and Sadek (1999) crossed 10 inbred lines with 3 testers and evaluated for grain yield, days to 50% silking and plant and ear heights. The line x location interaction was significant. Inbred Gm 4, Gm 5, Gm 6, Gm 13, Gm 26 and inbred tester Gm 30 exhibited the highest gca effects for grain yield. The crosses, Gm 26 x Gm 30, Gm 2 x Gm 14, Gm 11 x Gm 21, Gm 13 x Gm 21, Gm 1 x Gm 14 and Gm 3 x Gm 21showed high sca effects.

Srinivasan and Vasal (1999) studied a line x tester analysis including 23 partial inbred lines, derived from seven late white CIMMYT populations and pools, which were test crossed to 4 synthetics testers. The 92 crosses were evaluated during 1988, 1989, 1992 for grain yield, plant height and days to 50 % silking in 6 environments; Venezuela (VE) , Colombia (CU) and Mexico (PR1, PR2, PR3 and TL). Analysis of variance for grain yield showed significant gca effects for lines in all environments except in PR3 and TL; and significant gca effects for testers in all

environments except in PR1. Sca effects for grain yield were significant in all environments except in VE. The analysis for grain yield combined over the 6 environments showed significant sca effects. In all 6 environments and across environments, line 11 and line 23 showed significant positive gca effects. Tester 2 (T2) was a high performing tester with significant positive gca effects across environments and in 4 of the 6 environments. Across environments, 10 crosses were identified with significant positive sca effects.

Chen *et al.* (2000) studied 7 inbred lines crossed wth 3 elite inbred testers. They reported that the inbred differed significantly in their general combining ability. The inbreds which had higher gca were QB 21, QB 89 and QB 91. there were significant or highly significant differences in sca for plant height, ear height, ear length, number of kernels per row and percentage of kernel weight per ear.

Konak *et at.* (2001) studied the combining ability and heterotic effects using 5 maize inbred lines and 3 testers which were crossed in a line x tester manner to select the suitable parents and promising hybrids. In a population involving 8 parents and 15 hybrids, non additive gene effects for ear length and number of rows per ear and, additive gene effects for yield, 1000- kernel weight, plant height, ear height and days to silking were estimated. It was found that 2 parents, A632 and Pa 870 had higher general combining ability values and 3 hybrids: B52 x FR43, B79 x Pa870 and A632 x FR43 had higher sca values for yield.

Venkatesh *et at.* (2001) evaluated combining ability in modified single cross hybrids of maize which were derived and tested at 2 diverse

locations. Line x tester analysis was carried out to determine the combining ability of parents through their crosses. Over all combining study across all the characters were studied. It was inferred that among the sister line crosses used as female parent, (A1 x A'l), (A7 x A'7), (A8 x A'8), (A10 x A'10) and (A11 x A'11) were the best general combiners. The indigenous tester CM lll widely used in the Indian maize programme also showed itspotential as a good tester.

Srivastava (2001) crossed 20 exotic inbred lines with 4 indigenous elite inbred testers, two each belonging to two different heterotic groups. All the parents (24) and test crosses (80) were evaluated over 3 locations. He reported that the GCA effects were high for grain yield and other characters in both individual as well as pooled analysis. The SCA effects of test crosses for grain yield and other characters and inbreds were categorized accordingly in respective groups.

Vacaro *et al.* (2002) evaluated maize population and their crosses for combining ability in Brazil. They reported that the GCA was greater than that of SCA for all evaluated traits indicating the predominance of additive effects.

Srivastava and Singh *(2002)* studied the combining ability effects of 20 exotic lines and 4 indigenous elite inbred testers over 3 locations viz, Pantnagar, Bulandshahar and Ludhiana during *Kharif* 2000 through Line x tester method. Sca variance was more than gca variance indicating the importance of non-additive gene action for all characters studied. L11, L12, L13, L17 and L20 were good general combiners for

grain yield, ear length, 1000-kernel weight and 50 percent silking. Cross combinations including L6 x T3, L14 x T2 and L15 x TI had high mean and sca effects for grain yield and its components.

Nayankar and Wali *(2003)* estimated combining ability, heterosis and per se performance of height characters in maize with 34 female lines and 3 testers. When crossed into line x tester fashion, it was analyzed that the presence of wide genetic diversity among parents, males, females and parents against hybrids for plant height, ear height and grain yield per plant. The variance due to female vs. males was not significant for ear height. The magnitude of sca for all the characters indicated the predominance of non- additive gene actions in the inheritance of the characters.

Dodiya and Joshi, *(2003)* studied the combining ability, heterosis for yield and quality traits using early maturing single cross hybrids of maize, 20 lines and 3 testers as parents in 3 environments of Rajasthan. Combining ability analysis showed the predominant role of non- additive type of genetic component in the inheritance of all the characters. The inbred line Pop-30-25-1-1-1 was a good general combiner for all the quality traits and 1000- kernel weight. Single cross, Pop-30-25- 1- 1- 1 x XI W- 1076-1 had positive significant sca effects for all the characters.

Narro *et al.* (2003) studied general combining ability (GCA) and specific combining ability (SCA) of genotypes. Forty-three lines were crossed to two narrow-based (S3 line and S3 x S3 hybrid) and two broad-based testers, which were open-pollinated varieties (OPVs). Top crosses

(line x tester, L x T) were evaluated in eight acid soil environments. The additive main effect and multiplicative interaction (AMMI) and the site regression (SREG) models were used to study the GCA of the testers and lines and the SCA of the L x T interaction. The SREG biplot contains the effect of the lines plus the L x T interaction and displays both GCA and SCA, whereas the AMMI biplot contains the effect of the L x T interaction and displays only the SCA. One synthetic was developed by recombining six lines identified as superior by each tester. The four synthetics were evaluated in 12 acid and nine nonacid soil environments. The synthetic developed with the S3 line as tester yielded the highest and the one developed with an OPV as tester yielded the lowest. The AMMI and SREG models seem to provide an effective tool to visualize and study GCA and SCA of genotypes.

Ramneek *et al. (2005)* identified promising parental inbred lines for the development of quality protein maize hybrids. Line x tester analysis involving 20 advanced quality protein maize inbred lines used as females and 3 QPM lines used as testers was carried during *Kharif* 2002 *at* Ludhiana, Punjab to identify superior parental lines and crosses on the basis of their combining ability. Data were recorded on 6 morphological and quality traits. Non additive gene effects were found important for all the traits studied except ear girth, grain yield per plot and 1000-kernel weight.

Avila and Rodriguez *(2005)* studied the general and specific combining ability of tropical and subtropical maize lines using 20 maize

inbred lines and 6 inbred as testers. The crosses were evaluated in 3 environments in Mexico during 1997 to estimate the gca and sca effects. CML 264 (1586 kgper ha) and CML 3 19 (1285 kgper ha) were superior in terms of gca in the tropical and subtropical groups, respectively. The greater sca effects were observed in the crosses, CML 322 x M.L.S 4 -1 (1651 kgperha) and CML 258 x SSE 255 -18-19 (1512 kgperha). These results indicated that it is possible to develop a hybrid programme using the best lines released by the International Maize and Wheat Improvement Centre (CIMMYT), and the best testers from UAAAN.

Singhal *et al.* (2006) studied 14 QPM inbred lines with 3 broad based testers and their 42 top crosses. They found good GCA effects for ear length, ear diameter, kernel rowsperear, 100-kernel weight and grain yield in line 8. Good SCA effects were also observed for ear length, ear diameter, 100-kernel weight and grain yield.

Sofi et *al.* (2006) genetically analyzed yield traits in local and CIMMYT inbred lines crosses using line x tester analysis in Hyderabad and J & K, India during *Kharif* 2004. The 15 inbred lines, 3 testers and 45 crosses were evaluated at 2 locations in Kashmir. ANOVA showed significant mean squares due to progenies, crosses and parents Vs crosses for all traits. G x E interaction was significant for all the traits except ear diameter and 1000-kernel weight. Analysis for combining ability revealed significant variances due to general and specific combining ability for all the traits. This study identified various parents and crosses in terms of per se performance, gca and sca effects.

Jaykumar and Sundaram *(2007)* studied combining abilities for grain yield and other yield components using 7 lines, 7 testers and 49 cross combinations produced in a line x tester mating design. The sca variances were higher than the gca for all the characters. UMI 176, UMI 82, UMI 112, UMI 203, UMI 208 and UMI 213 were the best combiners as these genotypes showed significant *per se* performance. UMI 112 x UMI 203 and UMI 123 x UMI 246 were suitable as materials for breeding for earliness. UMI 154 x UMI 246 and UMI 82 x UMI 208 were the superior hybrids based on *per* se performance, sca effects and standard heterosis, thus these hybrids are recommended for heterosis breeding and for possible commercial exploitation.

Dar *et al.* (2007) studied the combining ability for yield and maturity traits in elite inbred lines of maize using line x tester analysis involving 15 female lines and 3 males from diverse origin. None of the parents or crosses was found to be good general or specific combiners for all traits. The 1391, 151A and 142A were good general combiners for grain yield. Crosses viz., 139A x 153A, 106C-2 x C-6, 106C-1 x Super 1 and 106C-1 x 153A showed significant and highest sca effects as well as better parent heterosis. Such crosses are suited to be used directly in hybrid production to utilize the hybrid vigour.

Iqbal *et al.* (2007) assessed the general combining ability effects of parents and specific combining ability effects of hybrids for yield and yield related traits and explore their use in hybrid development. Combining ability analysis using line x tester design was conducted in

maize (*Zea mays* L.) inbred lines by growing 45 F_1's generated by crossing fifteen lines with three well adapted testers. There was a great contribution of lines towards σ^2 gca for all the traits. Inbred lines viz., KDM 334, KDM 342 and KDM 347 were good combiners for yield and yield attributing characters. Tester C6 was high combiner for grain yield, number of kernel rows per ear and number of kernels per row. Among the hybrids, KDM 331 x super-1, KDM-333 x KDM-34, KDM 342 x C6, KDM331 x KDM-346 and KDM 336 x KDM-346 exhibited highest significant sca effects for yield and yield attributing traits.

Fan *et al.* (2008) conducted an experiment with the following objectives: (i) to determine if exotic tropical maize germplasm (TRMG) can increase diversity of Chinese maize germplasm for grain yield and five yield component traits (YCTs), namely, ear length (EL), ear diameter (ED), number of kernel rows per ear (RE), number of kernels per row (KR), and 1000-kernel weight (TKW), and (ii) to estimate general combining ability (GCA) and specific combining ability (SCA) effects to identify a possible new heterotic pattern. Twenty-five temperate maize germplasm (TEMG) from both China and the United States were crossed with four TRMG from the International Maize and Wheat Improvement Center (CIMMYT). The 100 testcrosses were evaluated in field trials for grain yield and five YCTs at three locations in Yunnan, China. Tropical lines YML146 and YML145 showed, in crosses with most of the TEMG, significant positive SCA effects for grain yield and most of the YCTs, indicating that these lines had a different genetic base from that of TEMG and could increase

genetic diversity of Chinese maize germplasm. The GCA effects were more important and reliable than SCA effects for heterotic pattern classification. Exotic line YML146 (derived from Suwan1) was identified as a new heterotic group, different from Reid, Lancaster, Tangsipingtou (TSPT), and Luda Red Cob (LDRC). A new heterotic pattern of temperate x Suwan1 was postulated, which could be as important as the widely accepted flint x dent heterotic pattern.

Gurung *et al.* (2009) studied the combining ability of some nepalese yellow maize populations. Line x tester design was used for making crosses. Ten open pollinated varieties were used as lines and four as testers. Forty crosses along with their parents were evaluated in a randomized complete block design with three replications. Three testers were open pollinated varieties and one tester was a NML-2, an inbred line developed by CIMMYT. Basis of grouping the germplasms into different heterotic groups was specific combining ability (SCA) effects for grain yield. Population 46C1, Rampur So3Eo2, and Rampur So3Fo2 showed positive SCA effects with NML-2, and negative with Arun-4. These germplasms were assigned into heterotic group A. Similarly, Upahar, Across 9331, Population 35C5 and Narayani had positive SCA effects with Arun-4 and negative with NML-2 and grouped into heterotic group B. Likewise, Manakamana-2 and Hill Pool Yellow were placed into AB heterotic group, which displayed positive SCA effects with both testers. Khumal yellow had shown negative effects with both testers and put into undetermined group. This way, three heterotic groups were established

based on the SCA effects. These heterotic groups are potential sources for inbred line development.

Premlatha and Kalamani (2010) studied combining ability and heterosis for grain yield and growth characters in maize through line × 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 ´ UMI 217 and UMI 334 ´ UMI 217 had significant and superior *per se* performances for grain yield per plant. The hybrid UMI 348 ´ UMI 330 exhibited high *sca* effect for plant height. Growth influencing characters positively influenced hybrid performance in grain yield. The hybrid UMI 278 ´ UMI 217 was observed as best and followed by UMI 334 ´ UMI 217 are potential hybrids for exploitation of yield heterosis.

2.6 Phenotypic stability

Genotype × environment interaction is usually present in all cases whether a variety is homozygous or heterozygous, but the magnitude of this interaction varies with varieties, some exhibiting more while others less.

Genotype × environment interactions are of considerable importance in breeding and field-testing phases of plant breeding programmes. Such interactions confound the selection of superior cultivars by altering their relative productivity in different environments. These interactions result due to differential performance of genotypes in changing environments.

Yates and Cochran (1938) proposed method of regression analysis and interpretation of varietal adaptation to natural environments which was developed by **Finlay and Wilkinson (1963)**. According to them, the observed values are regressed on the environmental indexes defined as the differences between the mean of environment and overall mean. The regression coefficient for each genotype is then taken as its stability parameter. Absolute phenotypic stability is expressed by b = 0.

Lerner (1954) adopted the term "homeostasis" to describe the ability of an individual or a population to adjust their life process with environmental changes that tend to upset them. Further, he defined developmental and genetic homeostasis as referring to individual or population, respectively.

Jones (1958) studied phenotypic stability in maize and reported that it was related with the genetic diversity. He compared a series of single crosses and found that double crosses were more consistent in their performance than the single crosses.

Adams and Shank (1959) and **Shank and Adams (1960)** studied homeostasis in eight groups of maize hybrids which had been produced to achieve greatly different levels of heterozygosity. They found that inbred lines were less buffered against various environments for several plant characters than the F_1 hybrids.

Allard and Bradshaw (1964) reported that heterozygous populations offer the best opportunity to produce varieties which show

small genotype × environment interaction. They used the term "well buffered" for the phenotypically stable variety. According to them, a well-buffered variety is one that can adjust its genotypic or phenotypic state in response to transient fluctuations in an environment in such a way that it gives high and stable economic return for the place and year.

Rowe and Andrew (1964) reported phenotypic stability with six genotypic groups representing four level of heterozygosity for kernel row number, ear height, number of days to silking, plant height and grain yield. The phenotypic stability measured by variety × environment variance component suggested that increased heterozygosity reduces the stability for days to silking but increases it for other characters. However, they also advocated no relationship between variety × environmental variance and heterozygosity.

Eberhart and Russell (1966) described deviation parameter (S^2d_i). The residual mean square (MS) of deviation from the regression is the measure of stability of each genotype. A desirable variety is the one which has a high mean $(\overline{X})$, unit regression coefficient (b_i = 1.0) and deviation from regression as small as possible (S^2d_i = 0). Hence, the definition of a stable variety in this context is one with b = 1 and $S+2^{d_i}$ = 0.

Andrew (1967) studied the influence of environment on stability of 10 maize hybrids and five inbred parents under greenhouse and field environments. Measurements were taken on fresh weight, adventitious root number and leaf number at successive ages. Genetic variation in terms of other variability was expressed by ratio between genotypic and

environmental variances. Environmental variance and ratio between field and greenhouse means for individual genotypes usually were higher for hybrids while relative genetic variation in terms of other variability was higher in case of inbreds for fresh weight and adventitious roots. He pointed out that reasons for high stability of inbreds may be because of accumulation of favourable genes for stability due to high selection. These combinations would not necessarily result in hybrids more stable than inbreds themselves. Also the greater potential of hybrid probably contributed to their greater interaction with environment.

Agrawal and Dhawan (1968) reported phenotypic stability of composites over locations and found significant interaction for composite × location. They also reported that days to silk and number of earsperplant were relatively less stable than grain yield, ear length and ear diameter.

Utkhede and Rai (1975) observed genotype × environment interaction for 20 genotypes tested at five locations. They found that hybrids showed below average stability than composites and locals.

Bhargava and Utkhede (1978) studied response of maize varieties to altitude and environment for yield and protein. For this study, 14 maize hybrids and composites were grown at five locations. Seven lines showed yield response to high altitude while they were low yielder at higher altitude.

Diaz and Torregroza (1979) studied phenotypic stability through the analysis of data from over year at nine sites. The most useful

indicators of stability were the coefficient of regression of the genotypes on the environment and the genotype × environment interaction.

Mann *et al.* (1981) studied a diallel of 12 lines in three environments for several qualitative and quantitative traits of the 66 reciprocal crosses, 18 to 35 per cent exceeded the least significant differences. Many reciprocal differences, however, were not stable over environments.

Sharma and Bhalla (1982) evaluated forty two maize genotypes including two checks over six environments as per the model suggested by **Eberhart and Russell (1966)**. The non-linear component of genotype × environment interaction was observed to be significant for days to silk, leaf blight incidence and leaf area, while, linear components were found significant for plant height, ear height and number of nodesperplant.

Jha *et al.* (1986) studied stability for grain development and yield of 36 double cross hybrids and two commercial hybrids grown at six locations. They obtained significant differences among the hybrids for grain filling period and grain yield and genotype × environment interaction for both characters and grain filling rate. Five high yielding hybrids showed wide adaptation for grain yield.

Vulchinkova and Vulchinkov (1990) studied stability for biological yield in some maize hybrids. Six early and mid-early hybrids were grown in six environments over two years and observed significant differences between hybrids, environments and genotype × environment interaction.

Mahajan and Khehra (1992) reported phenotypic stability of eight inbreds and their 28 single cross hybrids over eight environments. They found that PTR × J617 hybrid showed stable performance for yield and had greater ear length. This hybrid had low ear girth and 1000-kernel weight. The inbred line, J617-61-1-1-1-1 performed well in hybrid combination in all environments.

Vulchinkov (1992) studied genotype × environment interaction in inbred lines and 25 hybrids of maize grown at nine environments. Genotype × environment interaction was significant for all traits except leaf area nearest to the ear and ear length. Non-linear interactions, however, were predominant.

Hohls *et al.* (1995) studied a diallel involving 10 inbreds at four sites and reported that inbred, 50507W (M) had the best potential to be used as hybrid and the best general adaptability at all four sites.

Choukan (1999) studied 9 medium maturing hybrids over 10 locations for three years (1995-99) as per **Eberhart and Russell (1966)**. Hybrid (B73 × K1264per1) × MO17per11-1, (K1264per1 × XL17per2-1) × MO17per11-1 were categorized as stable hybrids. However, none of these hybrids was high yielding.

Dehganpour and Moghadam (1999) evaluated seven early maturity hybrids and nine very early maturity hybrids in separate experiments. The stability parameters were variance of genotype across environments (S_2x_i) and the coefficient of variability (cv.), Finlay and Wilkinson's regression coefficient (b_i) and Eberhart and Russell's

deviation parameters. The results of combined analysis and stability parameters showed that one early maturing hybrid (R319 × S61) and two very early maturing hybrids (TVA926 × K1264 and K3030per211 × TVA 926) have higher yield and stability than other hybrids across the six environments.

Agarwal *et al.* (2000) evaluated 22 maize genotypes for stability over three environments with respect to days to 50 per cent silking, plant height, grain yield, ear height, ear length, ear girth and 100-kernel weight. Mean squares due to G × E were observed to be significant for grain yield, ear height, ear length and 100-kernel weight. Out of the 19 genotypes tested for their stability six genotypes viz., EH1, EH5, EH12, EH18 and EH19 were found to be stable for grain yield and other yield components.

Cardoso *et al.* (2000) evaluated fifteen maize cultivars (4 hybrids and 11 varieties) over 18 environments in Brazil and reported that adaptation and stability in grain production showed differences among the cultivars. The hybrids and BR5039 had better stability than other varieties. All the varieties, except BR106 and CMS50 had good production stability in the studied environments.

Cardoso *et al.* (2000) studied 29 maize hybrids for phenotypic stability over nine locations for plant height, ear height, plant stand, number of harvested cobs and grain weight. They reported that pioneer 3041, MR2601, Cargill 901 Braskaeb × L345 and AG5014 had high stability in the studied environments.

Turgut *et al.* (2000) examined stability parameters for yield and yield components of promising hybrids and cultivars of dent corn in different environments. This study showed that hybrid ADA 95-23 and CVP-3163 were most stable than other genotypes in terms of seed yield.

Burak and Broccoli (2001) evaluated 14 hybrids in 10 trials at five locations. Stability analysis was made using bilinear regression models. Genotype × environment interaction exhibited significant differences in the results. For yield, all genotypes slopes are 1 despite the environment. However, for H_2, H_6, H_9, H_{10} and H_{14}, stability response (S^2di) of hybrids was significant.

Carvalho *et al.* (2001) evaluated 25 maize cultivars and 30 hybrids in 19 and 16 different environments, respectively. The hybrids showed an average 21.4 per cent higher yield than the cultivars. Hybrids Dina 1000, Cargill 333B, Dina 270, Braskalb XL 360, Master, AG 1051, AG 4051 and Pioneer 3041 expressed yield stability higher than other hybrids tested under different environmental conditions.

Srivastava (2001) studied 80 testcrosses for their phenotypic stability in three different locations. He reported that the mean squares due to genotypes were highly significant for all the eleven traits. The mean squares due to environment were also highly significant for all characters. He found that six test crosses were more stable and desirable than other for grain yield and its component characters.

Tariq *et al.* (2003) tested 6 maize genotypes for their yield performance under four different locations. Keeping in view the mean

yield performance of the genotypes over locations and estimates of different statistics, genotype EV-5098 and EV-5089 considered relatively less sensitive to change in environments and can successfully be grown over varied soil and climatic conditions.

Reddy and Ahuja (2004) evaluated 10 recycled maize inbred lines in 4 environments, during *kharif*, 1995 and 1996 for yield and some yield component traits. The stability analysis revealed that mean squares for genotype × environment interaction effects were significant for all traits. Among the inbreds evaluated, IPA 3 for grain yield, IPA 22 and FSA 17for ear diameter, and IPA 29 for 100-kernel weight were identified as stable inbreds and hence, can be utilized in hybrid maize breeding programmes.

Kumar and Singh (2007) studied 7 inbred maize parents and their 21 single crosses and 2 standard controls at 4 different locations for estimating the stability parameters of yield and its component characters. They reported highly significant variation for genotypes (G), environment (E), G ×E, environment (linear), G × E (linear), and pooled deviation for most of the characters. A large number of crosses were stable, however, no consistency in the stability was observed among the parents.

Singh *et al.* (2009) conducted a experiment during 2005-07 to identify the stable crosses of maize (Zea mays L.) hybrids for grain yield under diverse agroclimatic conditions. Sixty six single cross hybrids developed in line x tester design were evaluated along with 3 standard

checks over 9 environments under irrigated and unirrigated conditions for their yield performance. Data on 10 yield components (days to maturity, plant height, ears/plant, ear length, ear girth, kernel rows/ear, kernels/ row, 100-kernels weight, grain yield/plant, and biological yield/plant) were used to investigate the effects of genotype, environment and G x E on these traits. Highly significant differences were detected among the genotypes and environments for each character. Significant G x E interaction indicated that evaluation of yield components must be taken for different environments. On partitioning these components into linear and non-linear components, both were responsible for expression of the traits. However, the linear component was found larger in magnitude than the non-linear component suggesting that variation in the performance of different cultivars could be predicted. The hybrid combinations 'L2' x 'T3' and 'L22' x 'T2' were found to be stable across environment, whereas 2 hybrids 'L11' x T1', 'L16' x 'T1' were found suitable for irrigated environments for grain yield. For moisture stress environment five crosses 'L2'xT3', 'L3' x 'T2', 'L15' x 'T1', 'L19' x 'T2' and 'L21' x 'T3' were found stable for grain yield. For days to maturity only one hybrid 'L7' x 'T3' was found stable across environment. Thus these genotypes could be used for commercial cultivation. The stability measures are useful in characterizing cultivars by showing their relative performance in various environments.

Abdulai *et al.* (2009) conducted a experiment with the objectives (i) Determine the importance of genotype by environment interaction (GE)

in late maturing lowland maize varieties, (ii) Determine yield stability of the genotypes and (iii) Use the information to exploit GE for the development of high and stable yielding varieties. GE was attributed to climatic factors. Seven out of the nine genotypes were stable, when b-values alone were considered. When the b-values and the deviations from regression (s2d) were considered, (GH24 x 1368) x 5012 and (GH22 x 1368) x 5012, were the most stable, but when the coefficient of determination was added to the b-value and s2d, GH132 - 28 was the most stable genotype. Kpeve consistently produced above average grain yields and was the most stable location. A good level of precision was obtained with two replications, when genotypes were evaluated for 4 years at 8 locations.

Rahman *et al.* (2010) carried out stability analysis to study stability in performance and genotype x environment interactions for 18 maize hybrids across three locations of NWFP i.e., Agricultural University Peshawar (AUP), Agricultural Research Station (ARS), Baffa, (Mansehra) and Cereal Crops Research Institute (CCRI), Pirsabak (Nowshera), during 2006. Data were recorded on different morphological and yield parameters. The hybrid x location interactions also revealed significant differences for days to 50% silking, days to 50% anthesis, ASI, grain moisture at harvest and grain yield per hectare while non significant differences were observed for plant height and ear height. Based on yield performance of hybrids across the three locations, Baffa ranked first as compared to the other two locations. Hybrid DK-1 x EV-9806 was the

highest yielding across the three locations followed by hybrid AGB-108, while the lowest yield was observed for hybrid CSCY. Stability in performance was evident for hybrid CS-2Y2 with regard to days required for silking and anthesis. Stability in anthesis silking interval (ASI) was manifested for hybrid CS-222. Hybrid AGB-108 was comparatively stable for grain yield across the tested locations. Remaining hybrids seemed to be considerably influenced by Genotype x environment interactions encountered at the tested locations and location specific selection has to be made while selecting a maize hybrid for a particular location.

Chapter – 3

Material & Methods

Chapter 3 MATERIALS AND METHODS

3.1 Development of material for the experiment

The present investigation was undertaken with twenty one QPM inbred lines and three QPM testers which were initially screened for their performance under visual observations for various desired characters. Their seed was multiplied through controlled self pollination during *rabi* 2007-08 at Norman E. Borlaug Crop Research Centre, Pantnagar, Uttarakhand, India. These inbred lines were then crossed in line x tester fashion at Pantnagar during *Kharif* 2008to generate 63 F_1 crosses.

Pantnagar is geographically situated at 29.0°N latitude and 79.3°E longitude and at an altitude of 243.84 m above the mean sea level and falls under humid subtropical climate zone and is located at the foothills of the *Shivalik* range of the Himalayas in a narrow belt called '*Tarai*'.

3.2 Basic genetic material

The basic experimental material comprised 21 elite QPM inbred lines, 3 QPM testers and 3 checks. Detailed pedigree of the materials is given in Table 1.

3.3 Field experimentation and evaluation of experimental material

For the present study the experimental material consisted of 90 genotypes i.e., 21 inbred lines, 3 testers, 63 F_1's and 3 checks. All genotypes were grown in Randomized Complete Block Design in single-row plots of

Table 1: Quality Protein Maize inbred lines, testers and checks selected for study

S. No	Pedigree	Pedigree code
Lines		
1	DQPMC-3(Y)⊗101-1-2-1-1	L_1
2	DQPMC-3(Y)⊗112-1-1-1-1	L_2
3	Pool 17C_8(TEYFQPM) -B-1-1-1-1	L_3
4	Pool 17C_8(TEYFQPM) -B-76-1-1-1	L_4
5	Pool 17C_8(TEYFQPM) -B-93-1-1-1	L_5
6	DQPMC-3(Y)⊗56-2-3-1-1	L_6
7	DQPMC-3(Y)⊗135-2-1-1-1	L_7
8	DMRQPM-03-103-#- ⊗ 3-1-1-1	L_8
9	DQPMC-3(Y)⊗31-1-3-2-1-1	L_9
10	DQPMC-3(Y)⊗50-1-1-1-1	L_{10}
11	Pool 18C_8(TEYFQPM) -B-9-1-2-1-1	L_{11}
12	POP 61 C_9(TEYFQPM) -B- 20-1-1-1	L_{12}
13	DMRQPM-03-101-#-⊗ -1-1-1	L_{13}
14	DMRQPM-28-5-⊗ -⊗ -#-⊗3- ⊗ -1-2-1	L_{14}
15	DMRQPM-18-⊗-⊗ -#-⊗2-⊗ -1-2-1	L_{15}
16	DMRQPM-17-⊗ -⊗ -#-⊗1-⊗-2-1-1	L_{16}
17	DQPMC-3(Y)⊗2-1-1-2-1	L_{17}
18	DQPMC-3(Y)⊗4-1-2-1-1	L_{18}
19	DQPMC-3(Y)⊗14-2-1-2-1	L_{19}
20	POP 61 C_9(TEYFQPM) -B-23-1-2-1	L_{20}
21	POP 61 C_9(TEYFQPM) -B-35-2-1-1	L_{21}
Testers		
1	DMRQPM-03-106-#-⊗-1-1-1	T_1
2	DMRQPM-03-103-#-⊗-2-3-1	T_2
3	Pool 17C_8(TEYFQPM) -B-57-2-1-1	T_3
Checks		
1	HQPM-1	C_1
2	Shakti-1	C_2
3	Pragti	C_3

4 m length with three replications following spacing of 0.75 m between rows and 0.25 m between plants in normal, low nitrogen and excess soil moisture conditions at Pantnagar during *Kharif,* 2009. Thus the total plot area for F_{1s} and parents was 3.00 m^2. Initially two seeds per hill were sown within each row, which later on thinned to one plant / hill to ensure uniformity in plant stand per plot. In normal trial recommended dose of nitrogen (120 kg/ha) was supplied, however, in case of low nitrogen only 40 kg N/ha as basal dose was supplied. In excess soil moisture condition continues pounding of water for 7 days at knee height stage was maintained and other cultural practices was done as recommended.

3.4 Methods and procedure of recording experimental data

Observations were recorded on the whole plot basis in respect of days to 50 per cent tasselling, days to 50 per cent silking, and grain yield (kg/ha), However, plant height, ear height, ear length, ear girth, number of kernel-rows/ear, number of kernels/row were recorded on the basis of five randomly selected completive plants and 100-kernel weight, protein (%), tryptophan (g/16gN) and lysine (g/16gN) were calculated from composite seeds of 5 randomly selected plants from a plot for F_1s, parents and checks. The average value of these plants for these characters were calculated and used for the statistical analysis.

3.4.1 Days to 50 per cent tasselling

It was recorded as the number of days taken from the date of planting to the date when tassel appeared in 50 per cent of the plants in a particular plot.

3.4.2 Days to 50 per cent silking

Number of days from the date of sowing to the date when silk appeared in 50 per cent of the plants in a particular plot.

3.4.3 Anthesis – Silking interval

Difference between the days to 50 per cent tasseling and days to 50 per cent silking.

3.4.4 Plant height

It was measured from the base of the plant to the tip of the tassel at dry silk stage in centimeters.

3.4.5 Ear height

Ear height was measured in cm from the ground level to the base of the top-most ear at dry silk stage.

3.4.6 Ear length

The ear length was measured in cm from the base of ear to its tip.

3.4.7 Ear diameter

It was recorded in cm at the maximum girth of the ear.

3.4.8 Number of kernel-rows/ear

Total number of kernel rows in a ear was recorded.

3.4.9 Number of kernels/row

The number of kernels present in a row was counted.

3.4.10 100-kernel weight

Weight of 100 well-developed and fully dried kernels was taken from each plot and weighed in grams.

3.4.11 Nodes bearing adventitious roots / stilt / brace roots

The numbers of adventitious roots containing nodes were counted on five randomly selected plants in each plot.

3.4.12 Grain yield (kg/ha)

After harvesting, ears from each plot were weighed and fresh weight was recorded in kg. The moisture content for every plot was determined by "Steinlite Electronic Moisture Tester" from a representative fresh sample of the shelled grain. The grain yield was adjusted to a uniform moisture level i.e., 15 per cent. The following formula was used to convert this yield in kg/ha.

$$\text{Yield (kg/ha)} = \text{fresh weight} \times \left[\frac{100 - \text{moisture}}{100}\right] \times \left[\frac{1.176 \times 0.8 \times 10000}{3.00}\right]$$

Where,

0.8 is shelling percentage = 80/100

3.00 is plot size in sq. m.

1.176 is constant to adjust yield at 15 % moisture level

3.4.13 Protein (%)

For protein estimation first the nitrogen content is determined by various chemical methods **(A.O.A.C., 1965)** and the per cent protein is calculated by using the factor 6.25 for maize and millets. The important and simple method of N-estimation is Micro-Kjeldahl.

Micro-Kjeldahl Procedure (A.O.A.C., 1965)

The nitrogen in protein is converted to ammonium sulphate by H_2SO_4 during digestion. This salt, on steam-distillation, librates ammonia, which is collected in boric acid solution and titrated against standard acid. Since 1 ml of 0.1 N HCl equivalent to 1.401 mg N, calculation is made to get the nitrogen content of the sample.

$$\%\,N = \frac{(ml\ HCl - ml\ blank) \times normality \times 14.007 \times 100}{mg\ sample}$$

$$\%\ Protein = \%\,N \times 6.25$$

3.4.14 Tryptophan (%)

Next to lysine, tryptophan is a limiting essential amino acid in maize. Because of the simplicity of the estimation of the tryptophan, its content has been used as a criterion for screening materials with superior protein quality. The extensively used method for the estimation of tryptophan is papain hydrolysis method of **Hernandez and Bates (1969)** for the evaluation of opaqe-2 maize materials.

Papain hydrolysis method

A single step papain hydrolysis is utilized for protein solubilization. The iron ions oxidise acetic acid to glyoxylic acid in the presence of sulphuric acid. The indole ring of free tryptophan as well as that bound in soluble proteins reacts with glyoxylic acid and a violet-purple compound is produced. The intensity of the violet- purple colour is measured at 545 nm with help of spectrophotometer. By drawing a standard curve of optical density vs. tryptophan concentration, percent tryptophan in sample is recorded.

$$\%\ tryptophan\ in\ protein = \frac{\%\ tryptophan\ in\ sample}{\%\ protein\ in\ sample} \times 100$$

3.4.15 Lysine (%)

More specifically in maize, because of the relationship observed by **Hernandez and Bates (1969)** between tryptophan and lysine in the

maize endosperm protein (approx. 1 to 4), the tryptophan may be used as a single parameter for protein quality evaluation. So by increasing the value of tryptophan by 4 times the value of lysine is obtained.

3.5 Statistical and genetical analysis

Means of the various observations were subjected to the following statistical/biometrical analyses for drawing appropriate conclusions from the present investigation.

1. Analysis of variance
2. Estimation of heterosis
3. Estimation of variability parameters
4. Combining ability analysis
5. Phenotypic stability

3.5.1 Analysis of variance

The analysis of variance for each character was carried out for the randomized complete block design as suggested by **Fisher (1946)**. The model used was as follows :

$$Y_{ij} = \mu + b_i + t_j + e_{ij}$$

(i = 1, 2, 3 ....., r)

(j = 1, 2, 3 ....., t)

Where,

i = number of treatments

j = number of replications

Y_{ij} = Observed response of i^{th} genotype in the j^{th} replication.

μ = General mean of the population

b_i = Effect of i^{th} block

t_i = Effect of j^{th} treatment

e_{ij} = Random error of i^{th} block and j^{th} treatment

Table 3.5.1.1: Skeleton of ANOVA for RCBD is given below:

Source of variation	d. f.	Mean squares	Variance ratio (F)
Replication	(r-1)	MSr	MSr / MSe
Treatment	(t-1)	MSt	MSt / MSe
Error	(r-1) (t-1)	MSe	
Total	(rt-1)		

Where,

r = number of replications

t = number of treatments

MSr = mean squares for replications

MSt = mean squares for treatments

MSe = mean squares for error

The significance of difference among the treatment means was tested by F test and whenever the 'F' test was found to be significant, critical difference (CD) was calculated to test the significance of difference between any two treatment means.

C.D. (at 5 %) = $(2MSe / r)^{1/2}$ x t (5 %) at error d. f.

C.D. (at 1 %) = $(2MSe / r)^{1/2}$ x t (1 %) at error d. f.

The treatment variance was further partitioned into various components to test the significance of difference between parents and crosses individually. Significance of overall difference among genotypes means was tested by 'F' test.

For analysis of variance for RBD in line x tester, a two way table is prepared for pooled data in line x tester.

Table 3.5.1.2: Pooled data on Line x Tester in a two way table

Lines	**Testers**			**Total**
	T_1	**T_2**	**T_3**	
L_1	$L_1 \times T_1$	$L_1 \times T_2$	$L_1 \times T_3$	
L_2	$L_2 \times T_1$	$L_2 \times T_2$	$L_2 \times T_3$	
L_3	$L_3 \times T_1$	$L_3 \times T_2$	$L_3 \times T_3$	
L_4	$L_4 \times T_1$	$L_4 \times T_2$	$L_4 \times T_3$	
L_5	$L_5 \times T_1$	$L_5 \times T_2$	$L_5 \times T_3$	
.	.	.	.	
.	.	.	.	
.	.	.	.	
L_{21}	$L_{21} \times T_1$	$L_{21} \times T_2$	$L_{21} \times T_3$	
Total				

From the above table the analysis of variance for line x tester was performed and following ANOVA table was prepared:

Table 3.5.1.3: Analysis of variance for line x tester Analysis including parents

Source of variation	d.f.	Mean Square	'F' value
Replication	(r-1)	M_r	M_r/M_e
Parents	(l+t-1)	M_p	M_p/M_e
Lines	(l-1)	M_l	M_l/M_{lvst}
Testers	(t-1)	M_t	M_t/M_{lvst}
Line vs testers	1	M_{lvst}	M_{lvst}/M_e
Crosses	(lt-1)	M_c	M_c/M_e
Parent vs crosses	1	M_{pvc}	M_{pvc}/M_e
Error	(l+t+lt-1)	M_e	

For 'F' test, significance for lines and testers was tested against M_{lvst} while for others it was tested against M_e and compared with the table value of 'F' at respective degrees of freedom.

Pooled analysis of variance over years

Observations recorded for different characters were averaged in respect of each entry in three replications for each of the two years. Plot means were subjected to the pooled analysis of variance in simple RBD. The analysis of variance for the RBD over years in line x tester design is given below:

Table 3.5.1.4: Analysis of variance pooled over environment

Source of variation	d.f.	Mean square	'F' value
Year	(y-1)	M_1	M_1/ M_{14}
Parents	(l+t-1)	M_3	M_2/ M_{14}
Lines	(l-1)	M_4	M_3/ M_5
Testers	(t-1)	M_5	M_4/ M_5
Lines vs. testers	1	M_6	M_5/ M_{14}
Crosses	(lt-1)	M_7	M_6/ M_{14}
Parent vs. crosses	1	M_8	M_7/ M_{14}
Parent x year	(l+t-1) (y-1)	M_9	M_8/ M_{14}
Line x year	(l-1) (y-1)	M_{10}	M_9/ M_{14}
Tester x year	(t-1) (y-1)	M_{11}	M_{10}/ M_{14}
(Line vs. tester) vs. year	1	M_{12}	M_{11}/ M_{14}
Crosses x years	(lt-1) (y-1)	M_{13}	M_{12}/ M_{14}
(Parent vs. crosses) x years	1	M_{14}	M_{13}/ M_{14}
Error	(l+t+lt-1) (r-1) y	M_{15}	

3.5.1.1 Analysis of variance over the environments

Observations recorded for different characters were averaged for each entry in three-replications separately in each environment. Plot means were subjected to pooled analysis of variance in RCBD.

Table 3.5.1.1.1: Skeleton of ANOVA for the randomized complete block design over environments is given below:

Source of variation	d.f.	Mean square	F-value
Environment (L)	(L-1)	MsL	MsL/Mse
Replication (b)	(b-1)	Msb	Msb/Mse
Environment × Replication (L×b)	(L-1) (b-1)	MsLb	MsLb/Mse
Treatment (V)	(V-1)	MsV	MsV/Mse
Environment × Treatment (L×V)	(L-1) (V-1)	MsLV	MsLV/Mse
Error	L (t-1) (b-1)	Mse	

For F-test each Ms was tested against Mse and compared with the table value of F at respective degree of freedom for treatment, environment, replication, environment × replication and environment × treatment. Standard error of mean (SEM) and coefficient of variation (CV) were calculated as follows :

$$SEM = (2\ MSe/r)^{1/2}$$

$$CV\ (\%) = \frac{SD}{\bar{x}} \times 100$$

where,

MSe = Error mean square

r = Number of replications

$\bar{x}$ = Mean of the character

3.5.2 Estimation of heterosis

Heterosis, expressed as per cent increase or decrease in the performance of F_1 hybrid over the mid-parent (average or relative

heterosis), better parent (heterobeltiosis) and check parent (standard heterosis) was computed for each character using the following formula:

$$\text{Relative heterosis} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

$$\text{Heterobelt iosis} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Standard heterosis} = \frac{\overline{F_1} - \overline{CP}}{\overline{CP}} \times 100$$

Where,

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

$\overline{P_1}$ = Mean performance of parent one

$\overline{P_2}$ = Mean performance of parent two

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

$\overline{CP}$ = Mean performance of check parent

$\overline{MP}$ = Mean mid-parental value i.e. $(P_1+P_2)/2$

The significance of heterosis was tested with 't' test as given below :

(a) For heterobeltiosis

$$t = \frac{\overline{F_1} - \overline{BP}}{\sqrt{2Me/r}}$$

(b) For standard heterosis

$$t = \frac{\overline{F_1} - \overline{CP}}{\sqrt{2Me/r}}$$

(c) For relative heterosis

$$t = \frac{\overline{F_1} - \overline{MP}}{\sqrt{3Me/2r}}$$

where,

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

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

$\overline{CP}$ = Mean of check parent

$\overline{MP}$ = Mean of mid-parental value

Me = Error mean square from ANOVA table and

r = Number of replications

3.5.3 Estimation of variability parameters

3.5.3.1 Heritability

Heritability is broad sense (h^2_b) was estimated as the ratio of genotypic variance to the phenotypic variance **(Allard, 1960)**. The heritability estimates were calculated as follows:

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

where,

(h^2_b) = Heritability in broad sense

$\sigma^2 g$ = Genotypic variance

$\sigma^2 p$ = Phenotypic variance

3.5.3.2 Expected genetic advance

Expected genetic advance was estimated as suggested by **Allard (1960)**.

$$GA = K \times \sigma p \times h^2_b$$

where,

K = Selection differential expressed in standard unit

σp = Phenotypic standard deviation calculated as square root of phenotypic variance

h^2_b = Heritability in broad sense

GA = Expected genetic advance

3.5.3.3 Coefficient of variation

Genotypic, phenotypic and environmental coefficients of variation were calculated as the ratio of their standard deviation to the mean of the character expressed in percentage.

1. Phenotypic coefficient of variation

$$PCV\% = \frac{\sigma P_i}{\overline{X}i} \times 100$$

2. Genotypic coefficient of variation

$$GCV\% = \frac{\sigma G_i}{\overline{X}i} \times 100$$

3. Environmental coefficient of variation

$$ECV\% = \frac{\sigma E_i}{\overline{X}i} \times 100$$

where,

σP_i, σG_i and σE_i are the phenotypic, genotypic and environmental standard deviations, respectively, for i^{th} characters,.

$\overline{X}i$ = Mean of i^{th} character

3.5.4 Combining Ability Analysis

Combining ability analysis in line x tester was done following the method given by **Kempthorne (1957)** and later on modified by **Arunachalam (1974)**. This design is related to North Carolina Design (II) of **Comstock and Robinson (1952).**

The following model of Kempthorne (1957) was used for estimating the gca and sca effect in combining ability analysis.

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

where,

μ = general mean

g_i = gca effect of I th line; i = 1, 2, 3,.....l

g_j = gca effect of j th tester; j = 1, 2, 3,.....t

S_{ij} = sca effect of ij th combination and

e_{ijk} = error associated with the observation X_{ijk} ; k = 1, 2, 3,...r

In the analysis of variance for combining ability analysis, the components due to lines, testers and line x tester were calculated by splitting the cross sum of squares (Table 3.5.4.1).

Table 3.5.4.1: Analysis of Variance for combining ability

Source of variation	d. f.	S.S.	M.S.
Replication	(r-1)	$\sum_{k=1} \frac{X^2.....k}{lt} - \frac{X^2...}{lt}$	
Treatments (Parents + crosses)	(lt-1)	$\sum_{i=1}\sum_{j=t} \frac{X_{ii}^2...}{r} \frac{X^2...}{ltr}$	M_0

Lines	(l-1)	$\sum_{i=1} \frac{X_i^2 \ldots}{tr} \frac{X^2 \ldots}{ltr}$	M_1
Testers	(t-1)	$\sum_{i=1} \frac{X_i^2 \ldots}{lt} \frac{X^2 \ldots}{ltr}$	M_2
Line X testers	(l-1)(t-1)	$\sum_{i=1} \sum_{j=t} \frac{X_{ii}^2 \ldots}{r} \frac{X^2 \ldots}{tr} - \frac{X_i^2 \ldots}{lr} + \frac{X^2}{ltr}$	M_3
Error	(lt -1)(r -1)	By differences	M_4
Total	(ltr-1)	$\sum_{i=1} \sum_{j=t} \sum_{k=1} X_{ijk}^2 - \frac{X_{\ldots}^2}{ltr}$	

Where,

l = number of lines

t = number of testers

r = number of replication

X... k = sum of all the (l x t) crosses in k^{th} replication,

X... = sum of all the (l x t) crosses over all replication,

X_{ij} = sum of $(ij)^{th}$ combination over all the replication,

X_{i}... = total of i^{th} line over all the testers and replication,

X_{j}... = total of j^{th} tester over all the lines and replication,

X_{ijk} = total of ij th observation in k^{th} replication,

M_o = mean square due to treatment,

M_1 = mean square due to lines,

M_2 = mean square due to testers,

M_3 = mean square due to lines x tester interaction and,

M_4 = mean square due to error,

Expectations of mean squares in above table for the analysis of variance of combining ability are presented as below:

M.S.	Expected mean square
M_1	$\sigma^2 e + r$ [Cov. (F.S.) – 2 Cov. (H.S.)] + tr Cov. (H.S.)
M_2	$\sigma^2 e + r$ [Cov. (F.S.) – 2 Cov. (H.S.)] + lr Cov. (H.S.)
M_3	$\sigma^2 e + r$ [Cov. (F.S.) – 2 Cov. (H.S.)]
M_4	$\sigma^2 e$

The combining ability analysis model was further extended to include the effect of year and genotype x year interaction. Analysis of variance for combining ability pooled over years is as follows.

Table 3.5.4.2: Analysis of variance for combining ability pooled over years

Source of variation	Degree of freedom	Mean square	'F' value
Lines	(l-1)	M_5	M_5/M_{10}
Testers	(t-1)	M_6	M_6/ M_{10}
Line x tester	(lt-1)	M_7	M_7/ M_{10}
Line x year	(l-1) (y-1)	M_8	M_8/ M_{10}
Tester x year	(t-1) (y-1)	M_9	M_9/ M_{10}
(Line x tester) x year	(lt-1) (y-1)	M_{10}	M_{10}/ M_{10}
Error	(lt-1) (r-1) y	M_{11}	M_{11}/ M_{10}

M.S. due to lines, testers, line x testers, line x year, tester x year were tested against (line x tester) x year, which in turn was tested against error mean square (M_{15}) from analysis of variance table for pooled analysis over years.

3.5.4.1 Estimation of general combining ability and specific combining effect

The individual effect was calculated as follows:

$$\mu = \frac{X....}{l + r}$$

Where, X.... = total of all hybrid combinations

3.5.4.1.1 Estimation of gca effects

a) For lines:

$$g_i = \frac{X_i...}{tr} - \frac{X...}{ltr}$$

Where,

gi = general combining ability effect of i^{th} line,

Xi... = total of i^{th} line over all the testers and replications,

X... = sum of all the (lxt) crosses over all the replications

b) For testers:

$$g_i = \frac{X_j....}{tr} - \frac{X_{....}}{ltr}$$

Where,

g_j = general combining ability effect of j^{th} tester,

Xj... = total of j^{th} tester over all the lines and replications,

X... = sum of all the (l x t) crosses over all the replications

3.5.4.1.2 Estimation of SCA effects

$$S_{ij} = \left(\frac{X_{ij}}{r}\right) - \left(\frac{X_{i...}}{tr}\right) - \left(\frac{X_{j...}}{lr}\right) + \left(\frac{X_{...}}{ltr}\right)$$

Where,

S ij = specific combining ability of the cross between i th line and j th tester

X ij = total of (ij)th combination over all the replications

3.5.4.1.3 Standard error for combining ability effects and their differences

SEm gi (for lines) = $[Me\ (l\ -1)\ /\ ltr]^{1/2}$

SEm g_j (for testers) = $[Me.\ (t\ -1)\ /\ ltr]^{1/2}$

SEm S_{ij} (for crosses) = $[Me.\ (l\ -1)(t\ -\ 1)\ /\ ltr]^{1/2}$

SEd ($g_i - g_j$) for lines = $[2Me.\ (l\ -1)\ /\ ltr]^{1/2}$

SEd ($g_i - g_j$) for testers = $[2Me.\ (t\ -1)\ /\ ltr]^{1/2}$

SEd ($S_{ij} - S_{kj}$) for hybrids of same tester = $[2Me.\ (t\ -1)\ /\ tr]^{1/2}$

SEd ($S_{ij} - S_{il}$) for hybrids of same line = $[2Me.\ (l\ -1)\ /\ lr]^{1/2}$

SEd ($S_{ij} - S_{kl}$) for other hybrids = $[2Me.\ (r\ -1)\ /\ r]^{1/2}$

Where,

Me = Error mean square

SEm = Standard error of mean

SEd = Standard error of difference between two mean values

3.5.4.1.4 Testing the significance of GCA and SCA effects

Significance of gca and sca effects was tested by 't' test as below:

t value for gca effects in lines = g_i / SEm g_i

t value for gca effects in testers = g_j / SEm g_j

t value for sca effects in crosses = S_{ij} / SEm S_{ij}

where,

g_i = gca effect of i^{th} line

g_j = gca effect of j^{th} tester

S_{ij} = sca effect of the ij^{th} combination

SEm g_i = standard error of mean for lines

SEm g_j = standard error of mean for testers

SEm S_{ij} = standard error of mean for crosses

Calculated value of 't' was tested against table value of 't' **(Fisher and Yate, 1963)** at error degree of freedom at 5 per cent and 1 per cent levels of significance.

3.5.4.1.5 Estimation of genetic components

Covariance of full sibs and covariance of half sibs were calculated from the expectations of mean squares as follows:

$$\text{Cov. (H.S.)} = \frac{(M_1 - M_2) + (M_2 - M_3)}{r(1+t)}$$

$$\text{Cov. (F.S.)} = \frac{(M_1 + M_4) + (M_2 - M_4) + (M_3 - M_4)}{3r} + \frac{6\,\text{Cov.(H.S.)} - r(1-t)\,\text{Cov/(H.S.)}}{3r}$$

3.5.4.1.6 Per cent contribution of lines, testers and line x tester interaction of the hybrid sum of squares

1. per cent contribution of lines = $\frac{\text{S.S. due to lines}}{\text{S.S. due to hybrids}} \times 100$

2. per cent contribution of tester = $\frac{S.S.\ due\ to\ tester}{S.S.\ due\ to\ hybrids} \times 100$

3. per cent contribution of lines×tester interaction= $\frac{\text{S.S. due to lines} \times \text{Tester}}{\text{S.S. due to hybrids}} \times 100$

3.5.5 Phenotypic stability analysis

The mean values for different quantitative traits for each genotype were used for phenotypic stability analysis. The stability parameters were calculated as per the procedure given by **Eberhart and Russell (1966)**. They suggested following three parameters to categorize the genotypes for their stability:

1. Mean
2. Regression of individual mean performance on environmental index, and
3. Deviation from regression

These parameters are defined in the following model:

$$Y_{ij} = \mu + b_i I_j + \delta_{ij}$$

where,

Y_{ij} = Mean performance of the i^{th} genotype in the j^{th} environment

g = Number of genotypes

n = Number of environments

μ = Mean performance of i^{th} genotypes over all the environments

b_i = Regression coefficient that measure the response of the i^{th} genotype to varying environments

I_j = j^{th} environment index

δ_{ij} = Deviation from regression of the i^{th} genotype at the j^{th} environment

The environmental index is defined as the deviation of the mean of all the genotypes at the i^{th} environment from the overall mean and can be expressed as :

$$I_j = \left[\left(\frac{\sum_{i=1}^{g} Y_{ij}}{g}\right) - \left(\frac{\sum_{i=1}^{g}\sum_{i=1}^{n} Y_{ij}}{gn}\right)\right]$$

$$\sum_{j=1}^{n} I_j = 0$$

The regression coefficient (bi) was estimated using the following formula:

$$b_i = \frac{\sum_{j=1}^{n} Y_{ij} I_j}{\sum_{j=1}^{n} I_j^2}$$

The deviation from regression (S^2d_i) was computed using the following formula:

$$S^2 d_i = \frac{\sum_{j=1}^{n} \delta_{ij}}{n-2} - \text{Pooled error}$$

The average of error mean squares overall the environments was taken as the estimate of pooled error (S^2e/n).

The skeleton of analysis of variance for the estimation of stability parameters is given in Table 7.

This model provides a way of partitioning the genotype × environment interaction of each genotype into two parts.

1. The variation due to the response of the variety in the varying environmental indices, and
2. The unexplained deviation from the regression on the environmental index.

Test of significance

Deviation from regression from each genotype was tested using the 'F' test. An appropriate test for the deviation from linear regression for each variety can be obtained by –

$$F = \left(\sum_j \sigma_{ij}^2 \Big/ n-2 \right) \Big/ \text{Pooled error}$$

Test of significance of different mean sum of squares

This was done by 'F' test as follows :

1. MS due to genotypes: Tested against MS due to G × E at (g-1) and (g-1) (n-1) degrees of freedom.
2. MS due to environments: Tested against MS due to genotype × environment at (n-1) and (g-1) (n-1) degrees of freedom.
3. MS due to G × E interaction: Tested against MS due to pooled error and (g-1) (n-1) and n (r-1) (g-1) degrees of freedom.
4. MS due to environment (linear): Tested against MS due to pooled deviation at 1 and g (n-2) degrees of freedom.
5. MS due to G × E (linear): Tested against MS due to pooled deviation at (g-1) and g (n-2) degree of freedom.

6. MS due to pooled deviation: Tested against MS due to pooled error, obtained as pooled error MS / number of environments at g (n-2) and n (r-1) (g-1) degree of freedom.
7. The genetic differences among genotypes for their regression of environment index were tested as MS_g/MS_d.
8. Deviation from regression for each genotype was tested using 'F' test at n-2 degree of freedom.

$$F = \frac{\sum_{j=1}^{n} \delta_{ij}}{MSe \text{ (Pooled error)}}$$

9. The deviation of b_i value from unity was tested using 't' test at g (n-2) degree of freedom.

$$t = \frac{b_i - 1}{SE(b_i)}$$

Where,

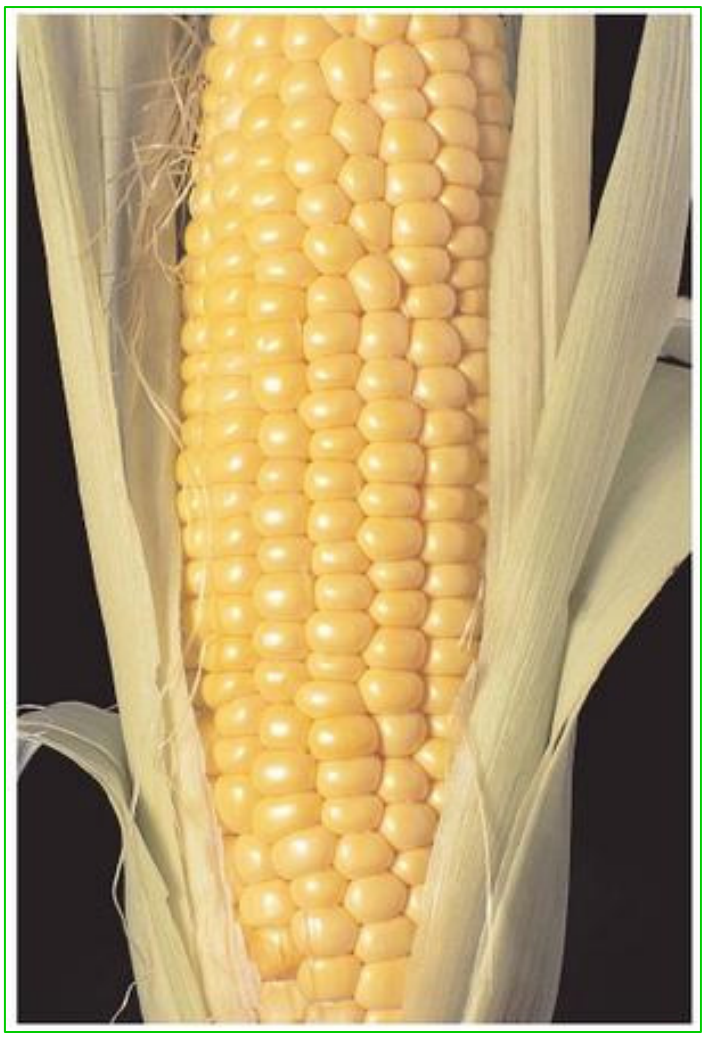
$$SE(b_i) = \frac{\sqrt{\text{Pooled deviation MS}}}{\sum_{j=1}^{N} I_j^2}$$

Table 3.5.5.1: Analysis of variance for estimates of stability parameters over environments

Source of variation	d.fs.	S.S.	M.S.	F-value
Total	(gn-1)	$\sum\sum_j Y_{ij}^2 - CF = SS_T$		
Genotype (G)	(g-1)	$(1/n)\sum Y_i^2 - CF = SS_g$	MS_g	MS_g / MS_{ge}
Environment (E)	(n-1)	$(1/g)\sum_j Y_j^2 - CF = SS_{en}$	MS_{en}	MS_{en}/MS_{ge}
G × E	(g-1) (n-1)	$SS_T - SS_g - SS_{en} = SS_{ge}$	MS_{ge}	MS_{ge}/MS_e
Environment +G × E	g (n-1)	$\sum_i \sum_j Y_{ij}^2 - 1/n \sum Y_i = SS_e + g_e$	–	–
E (linear)	1	$(1/g)\left(\sum_j Y_j I_j\right)^2 / \sum_j I_i^2 = SS_e(I)$	$MS_e(I)$	$MS_e(I)/MS_d$
G × E (linear)	(g-1)	$\sum_i \left[\left(\sum_j Y_{ij} I_j\right)^2 / \sum_j I_i^2\right] - \text{Env.(linear)}SS = SS_e(II)$	$MS_{ge}(II)$	$MS_{ge}(II)/MS_d$
Pooled deviation	g (n-2)	$\sum_i \sum_j S_{ij}^2 = \sum_i \left[\sum_j Y_{ij}^2 - \left(Y_j^2/n\right)\right] \left(\sum_j Y_{ij} I_j\right)^2 / \sum_j I_j^2$	MS_d	MS_d/MS_e
Genotype 1	(n-2)	$\sum_j Y_{ij}^2 - \left(Y_{ij}/n\right) - \left(\sum_j Y_{ij} I_j\right)^2 / \sum_j I_j^2 = \sum_j \delta_{ij}^2$	–	–
G	(n-2)	$\sum_j Y_{gi}^2 - \left(Y_g^2/n\right) - \left(\sum_j Y_{gi} I_j\right)^2 / \sum_j I_j^2 = \sum_j \delta_{gj}^2$		
Pooled error	n (r-1) (g-1)	$\sum_j (1/n) Se_r^2$	–	MS_e

where, S_{ej}^2 = Estimate of error mean squares at each environment
G = Number of genotypes
r = Number of replications
CF = Correlation factor – $Y^2.../gn$
n = Number of environments

Chapter – 4



Experimental Results

The experiment was conducted in three different environments i.e., normal (recommended dose of nitrogen), low-nitrogen and excess soil moisture during *Kharif,* 2009 which will be abbreviated as E_1, E_2 and E_3, respectively, on the following pages. The results of the present investigation are presented under the following heads:

4.1 Analysis of variance

4.2 Heterosis

4.3 Variability parameters

4.4 Combining ability

4.5 Phenotypic stability

4.1 Analysis of Variance

The analysis of variance for different characters in three environments (E_1, E_2 and E_3) is presented in Table 4.1.1 which indicated highly significant differences among the treatments for all the characters under all the environments.

The analysis of variance under line x tester for various characters with respect to parents and crosses in normal (E_1), low nitrogen (E_2), excess soil moisture (E_3) environments and pooled over environments are presented in the Table 4.1.2 and 4.1.3.

The results indicated highly significant differences among parents for all the characters in E_1, E_2 and E_3. Partitioning of variance due to lines, testers and line x tester also revealed significant differences for

Table 4.1.1: Analysis of variance for important economic characters in Quality Protein Maize (QPM) under normal (recommended dose of nitrogen), low -nitrogen and excess soil moisture and pooled over environments

Source of variation	d.f.	Environment	Mean sum of square														
			Plant height (cm)	Ear height (cm)	100 kernels weight (g)	Ear length (cm)	Ear diameter (cm)	kernel rows/ ear	No. of kernel /row	No. of nodes bearing brace roots	Days to 50% tasselling	Days to 50% silking	Anthesis-Silking interval	Protein (%)	Lysine (%)	Tryptophan (%)	Grain yield (kg/ha)
Replication	2	E_1	1151.27	95.75	3.29	3.55	0.398	3.76	12.52	0.009	32.19	32.77	0.048	0.054	0 .015	0.009	766128.4
		E_2	2259.561	1183.48	11.62	2.53	0.24	1.25	21.97	0.19	30.23	28.29	2.73	0.136	0.301	0.018	4791760
		E_3	323.62	12.92	5.08	0.32	0.14	3.85	29.19	0.003	10.07	43.04	12.73	0.138	0.039	0.634	2253804
		P	4921.21	4100.88	773.33	52.50	2.73	19.38	449.48	0.74	28.61	16.72	18.43	0.38	1.24	0.04	33273160
Treatment	89	E_1	407.16**	118.52**	10.32**	5.24**	0.552**	2.43**	22.39**	0 .253**	3.62**	4.57**	1.465**	5.134**	0 .53**	0.035**	6184655**
		E_2	465.94**	207.94**	16.62*	4.02**	0.16**	1.44**	18.87**	0.062**	30.23**	6.15**	1.75**	5.124**	0.566**	0 .035**	2534476**
		E_3	624.69**	211.45**	21.10**	4.69**	0.23**	2.98**	15.52**	0.073**	1.62*	5.08**	2.64**	5.123**	0.035**	0.563**	3074348**
		P	418.43**	109.94**	4.92**	2.48**	0.12*	1.08**	8.18**	0.083**	1.50**	2.32**	1.78**	5.16**	0.56**	0.038**	3018490**
Error	178	E_1	235.82	67.89	5.89	1.27	0.166	0.85	7.05	0 .152	2.02	2.64	0.759	0 .036	0 .011	0 .007	1374042
		E_2	231.85	64.76	11.02	1.84	0.11	0.79	10.89	0 .035	2.01	2.25	1.31	0.036	0.006	0.003	1175042
		E_3	243.25	36.92	8.58	1.53	0.15	1.83	10.38	0.026	1.15	2.80	1.25	0.036	0.007	0.011	736980
		P	144.805	34.717	2.550	1.083	0.093	0.608	5.372	0.042	0.913	1.472	0.682	0.001	0.002	0.001	464621.90

*, ** Significant at 5% and 1% probability levels, respectively.
E_1-Normal (recommended dose of nitrogen)**,** **E_2**-low nitrogen, **E_3**- Excess soil moisture, **P**- Pooled environment

Table 4.1.2: Analysis of variance for line x tester with respect to different characters under normal (recommended dose of nitrogen, E_1), low nitrogen (E_2) and excess soil moisture (E_3) environments

Source of variation	d.f.	Eviron.	Plant height (cm)	Ear height (cm)	100 kernels weight (g)	Ear length (cm)	Ear diameter (cm)	kernel rows/ ear	Number of kernel /row	No. of nodes bearing brace roots	Days to 50% tasselling	Days to 50% silking	Anthesis-Silking interval	Protein (%)	Lysine (%)	Tryptophan (%)	Grain yield (kg/ha)
Replication	2	**E1**	47.14	49.16	47.41	1.80	1.80	1.81	45.52	1.80	16.43	16.44	15.95	15.95	0.234	0.226	276.60
		E2	47.61	49.27	47.69	1.803	1.804	1.805	45.539	1.804	16.448	16.448	15.951	15.950	0.023	0.0226	206.7126
		E3	47.25	49.240	47.387	1.801	1.804	1.806	45.532	1.804	16.449	16.44	15.95	15.95	0.023	0.0225	258.94
Parent (P)	23	**E1**	1031.51**	217.135**	5.1**	6.08**	1.13**	6.08**	29.37**	0.63**	3.11**	8.65**	5.73**	5.52**	0.468**	0.555**	2904449**
		E2	789.70**	455.31**	21.51**	2.32**	0.51**	2.15**	58.10**	0.17**	1.95**	2.41**	1.52**	5.52**	0.468**	0.0462**	1679910**
		E3	1149.75**	199.53**	53.04**	4.88**	0.50**	4.59**	30.41**	0.129**	1.086**	1.829**	2.311**	5.525**	0.468**	0.0453**	2879508**
Line (L)	20	**E1**	819.38**	288.45**	32.44	9.92**	0.77**	3.97**	29.68**	1.16	18.85**	20.80**	4.21**	3.56**	0.625*	0.387*	11495922**
		E2	578.87**	457.34**	43.55**	6.509**	0.53*	1.897*	53.46*	0.220*	8.202*	13.100	4.562	3.564**	0.624*	0.387**	5129838**
		E3	651.04**	192.504	27.551	6.062**	0.321**	7.94**	43.612	0.168	4.724*	8.31	3.09	3.56**	0.629**	0.0387*	4389945**
Tester (T)	2	**E1**	728.69**	50.23**	33.53**	14.68**	0.35*	3.46**	22.88**	1.47	3.34	8.88*	2.37**	11.18**	0.126*	0.758**	27557990**
		E2	215.46**	68.40**	49.73**	7.614**	1.08*	6.09**	1.045*	0.30	7.54**	7.440**	2.180**	11.18**	0.125*	0.71**	7001589**
		E3	165.82**	48.844**	93.20**	0.924**	0.557**	0.98**	40.792	2.59**	4.14**	10.11**	6.48**	11.18**	0.25**	0.0075*	3168386**
L x T	40	**E1**	740.53**	248.76**	20.31**	8.18**	0.685**	4.17**	55.54**	0.50**	1.99**	2.48**	1.64**	5.65**	0.643**	0.401**	7267835**
		E2	410.03**	217.35**	54.71**	5.18**	0.31**	3.04**	28.08**	0.116**	4.134**	8.35**	4.48**	5.65**	0.643**	0.0402**	3459082**
		E3	705.99**	273.36**	50.67**	7.009**	0.37**	8.42**	33.22**	0.143**	2.737**	7.156**	3.120**	5.655**	0.644**	0.0411**	5136878**
Crosses (C)	62	**E1**	765.58**	255.16**	24.65**	8.95**	0.70**	4.08**	46.14**	0.75**	7.47**	8.59**	2.49**	5.15**	0.621**	0.3862**	9286254**
		E2	451.77**	312.54**	49.98**	5.68**	0.41**	2.77**	35.39**	0.146**	5.55**	9.85**	4.43**	5.15**	0.621**	0.386**	4112310**
		E3	670.84**	240.04**	44.58**	6.50**	0.34**	8.01**	36.81**	0.149**	3.326**	7.622**	3.219**	5.159**	0.621**	0.0386**	4832432**
P. vs. C.	1	**E1**	13196.25**	3847.87**	0.07	30.89**	0.192**	1.43**	5.40**	0.42**	187.78**	87.35**	23.98**	0.43	0.071**	0.011	3959000**
		E2	6522.20**	4060.75**	6.69**	18.52**	1.28**	1.02**	19.80**	0.18**	0.438	71.32**	52.17**	0.43	0.071**	0.0002*	2633120**
		E3	6165.5**	2285.73**	2.007**	80.70**	0.22**	1.86**	0.33**	0.163**	9.437**	37.44**	12.94**	0.45	0.072*	0.0022*	3395136**
Error.	172	**E1**	0.89	0.65	0.71	0.02	0.02	0.02	0.07	0.03	0.21	0.21	0.20	0.20	0.004	0.005	4.598
		E2	0.08	0.67	0.07	0.240	0.246	0.246	0.700	0.247	0.208	0.208	0.198	0.198	0.0004	0.00005	-0.91526
		E3	0.80	0.069	0.069	0.002	0.246	0.002	0.698	0.002	0.208	0.21	0.20	0.20	0.0023	0.00054	-1.52

, * Significant at 5% and 1 % probability levels, respectively.

Table 4.1.3: Pooled analysis of variance for line x tester for fifteen characters in Quality Protein Maize (QPM) over three (E_1, E_2 and E_3) environments

Source of variation	Degree of freedom	Mean Squares														
		Plant height (cm)	Ear height (cm)	100 kernels weight (g)	Ear length (cm)	Ear diameter (cm)	kernel rows/ ear	No. of kernel / row	No. of nodes bearing brace roots	Days to 50% tasselling	Days to 50% silking	Anthesis-Silking interval	Protein (%)	Lysine (%)	Tryptophan (%)	Grain yield (kg/ha)
Environment (E)	2	10822.35	9611.53**	2212.46**	223.22**	9.05**	94.80**	1021.34**	1.87**	304.37**	158.90**	60.87**	0.73**	4.31**	0.26**	11370.56**
Parent (P)	23	1260.39**	583.23**	22.20**	3.45**	0.92**	4.17**	42.33**	0.17**	2.31**	4.46**	3.32**	16.57**	0.84**	0.052**	637.79**
Line (L)	20	1105.28**	596.80**	23.41**	3.76**	0.66**	4.20**	48.02**	0.18**	2.22**	4.73**	3.73**	16.85**	0.71**	0.044**	518.22**
Tester (T)	2	251.05**	124.35**	5.29**	1.64**	1.29**	0.45**	4.19**	0.12**	4.33**	4.00**	0.33	17.17**	0.87**	0.045**	18.13**
Line vs. tester	1	6381.26**	1229.58**	31.72**	0.87**	5.50**	10.8**	4.79**	0.14**	0.12	0.002	1.08*	9.74**	3.36**	0.228**	4268.44**
Crosses	62	2957.80**	337.47**	33.23**	10.90**	0.62**	5.30**	44.62**	0.39**	8.23**	10.66**	3.70**	15.47**	1.86**	0.115**	1076.65**
Parent vs. crosses	1	34107.33**	1043.11**	0.59**	118.38**	1.40**	0.23**	2.51**	0.64**	42.64**	45.38**	0.53	1.32**	0.96**	0.059**	266.33**
Parent vs. Env.	46	855.28**	144.37**	28.73**	4.91**	0.61**	4.33**	37.77**	0.35**	1.92**	4.21**	3.12**	0.01	0.002	0.00008	54.31**
Line vs. Env.	40	883.82**	160.56**	31.32**	5.06**	0.30**	4.90**	33.67**	0.33**	1.75**	3.88**	3.10**	0.02	0.003	0.00004	57.10**
Tester vs. Env.	4	358.33**	28.85**	14.70**	4.49**	3.27**	0.41**	36.48**	0.64**	3.33**	9.50**	3.33**	0.01	0.002	0.00084	39.56**
(Line vs. tester) vs. Env.	2	1278.40**	51.81**	4.84**	2.83**	1.51**	0.71**	122.44**	0.06**	2.39**	0.29	3.11**	0.01	0.001	0.0002	28.09**
Crosses vs. Env.	124	3382.95**	235.12**	42.99**	5.12**	0.42**	4.78**	36.86**	0.32**	4.06**	7.70**	3.22**	0.02	0.002	0.00003	373.11**
(Parent vs. crosses) vs. Env.	2	526.11**	76.48**	4.08**	5.86**	0.15**	2.03**	11.55**	0.03**	77.52**	75.41**	44.26**	0.01	0.001	0.00002	2146.79**
Error	516	0.069	0.069	0.070	0.002	0.002	0.002	0.069	0.002	0.208	0.208	0.198	0.198	0.0005	0.00005	0.00004

, * Significant at 5% and 1 % probability levels, respectively.
E_1: Normal (recommended dose of nitrogen**), E_2:** Low-nitrogen, **E_3:** Excess soil moisture, **Env.** : Environment

most of the characters except 100-kernel weight and number of nodes bearing brace roots in E_1 and E_3; number of kernels per row in E_3; days to 50 per cent silking and anthesis-silking interval in E_2 and E2, environments respectively, for lines, whereas for testers, all characters except number of nodes bearing brace roots in E_1 and E_2, days to 50 per cent tasselling in E_1 environment (Table 4.1.2).

Variances due to line x tester interaction and crosses were significant for all the characters in E_1, E_2 and E_3 environments. All the characters except 100-kernel weight in E_1, days to 50 per cent tasselling in E_2; protein per cent in E_1, E_2, & E_3 and tryptophan per cent in E_1 environment showed non-significant differences for parents vs. crosses interaction.

In pooled analysis significant environmental differences were observed for most of the characters except plant height. Lines and crosses showed significant differences for all the characters, whereas for testers, all the traits except anthesis-silking interval had non significant difference. Variance due to line x tester interaction was also significant for all the characters except days to 50per cent tasselling and days to 50per cent silking. Parent vs. crosses component of variance was significant for all the characters except anthesis-silking interval. Parent vs. environment interaction was significant for most of the characters except quality traits. Further partitioning of parent vs. environment interaction indicated that variance due to line vs. environment and testers vs. environment were significant for most of the characters except quality traits.

Table 4.1.4: Combined analysis of variance for important economic characters in Quality Protein Maize (QPM) over three environments

Source of variation	Degree of freedom	Mean sum of square														
		Plant height (cm)	Ear height (cm)	100 kernels weight (g)	Ear length (cm)	Ear diameter (cm)	Number of kernel rows/ear	Number of kernel / row	No. of nodes bearing brace roots	Days to 50% tasselling	Days to 50% silking	Anthesis-Silking interval	Protein (%)	Lysine (%)	ryptophan (%)	Grain yield (kg/ha)
Environment	**2**	89651.29**	43309.20**	564.12**	695.41**	14.59**	34.47**	6418.37**	0.34**	3.13*	22.22**	15.65**	47.77	3.20	0.13	2674.4**
Replication with in Environment	**6**	1358.56**	343.65**	17.63**	5.90**	0.03	0.55	8.65*	0.08**	12.42**	5.24**	8.67*	18.46**	2.83**	0.22**	779.43**
Genotype	**89**	1174.16**	332.32**	18.31	8.41	0.51	6.51*	65.61*	0.43*	5.39	4.12	4.64	16.53**	3.62**	0.35**	172.81**
Genotype × Environment	**178**	357.71**	243.03**	19.47**	6.45**	0.49**	5.45**	48.58**	0.89**	4.87**	3.78**	3.78**	0.04**	0.01	0.01	879.08**
Error	**450**	37.50	13.90	1.42	0.68	0.03	0.47	2.35	0.06	1.24	1.12	0.32	0.01	0.002	0.001	16.06

, * Significant at 5% and 1 % probability levels, respectively.

Variance due to (line vs. tester) vs. environment was significant for most of the characters except days to 50per cent silking and quality traits. All the characters except protein per cent, lysine per cent and tryptophan per cent showed significant variation for crosses vs. environment and (parents vs. crosses) vs. environment component (Table 4.1.3).

The pooled analysis of variance over environments for fifteen characters is presented in Table 4.1.4. The partitioning of variance into various components revealed that mean squares due to environment were highly significant for all the characters except quality traits. The mean squares due to genotypes showed highly significant differences for plant height, ear height, brace root, grain yield and quality traits. It showed significant effect of environments and the genotypes and varying performance of genotypes over environments except quality traits as protein, lysine and tryptophan contents. Variance due to replication within environment was also significant for all the characters except ear diameter and number of kernel rowsperear.

4.2 Heterosis

4.2.1 Plant height (cm)

The estimates of per cent heterobeltiosis, relative heterosis and standard heterosis for plant height in E_1, E_2, E_3 and across the environments are presented in Table 4.2.1. This Table indicated that most of the crosses showed significant positive heterobeltiosis in E_1 and E_2 environments and also across the environments. The range of

Table 4.2.1: Estimation of heterosis (%) over better-, mid- and check- parent in three environments (E_1, E_2, E_3)

Cross	Plant height (cm)											
	Normal			Low nitrogen			Excess soil moisture			Pooled		
	BP	MP	CP	BP	MP	CP	BP	MP	CP	BP	MP	CP
$L_1 \times T_1$	8.19	9.76	-7.05	2.61	-3.03	3.02	14.95	1.77	-6.06	-0.38	3.87	-0.38
$L_1 \times T_2$	4.95	5.13	-9.83	5.90	7.67	6.36	33.98**	-25.60**	-30.69 *	-8.36	-4.84	-8.36
$L_1 \times T_3$	-10.80	-9.49	-23.56**	0.77	-3.54	1.15	12.05	6.02	-8.43	-3.07	-1.44	-3.07
$L_2 \times T_1$	31.14**	21.62**	-5.38	8.96	4.21	5.71	30.81**	13.64	3.35	4.43	13.11 **	4.43
$L_2 \times T_2$	19.13 *	8.92	-14.67 *	15.37**	15.67**	12.65 *	13.99	-2.24	-9.92	-0.77	7.05	-0.77
$L_2 \times T_3$	22.63**	13.70 *	-11.21 *	15.42**	12.11 *	12.15 *	15.90	7.73	-8.41	15.13**	11.16 *	5.13
$L_3 \times T_1$	7.78	3.45	-17.64**	7.84	7.12	12.55 *	5.01	-2.65	-6.66	-1.53	2.48	-1.53
$L_3 \times T_2$	19.72**	13.30 *	-7.85	4.80	8.59	9.44	7.98	-1.13	-4.02	2.85	6.61	2.85
$L_3 \times T_3$	19.40**	14.67 *	-8.05	4.59	5.27	9.13	-6.64	-7.74	-17.02	2.32	3.84	2.32
$L_4 \times T_1$	36.10**	26.96**	-1.73	4.21	5.33	12.55 *	0.51	-4.37	-6.18	4.43	8.21	4.43
$L_4 \times T_2$	34.03**	22.58**	-3.28	8.74	14.53**	17.43**	0.85	-5.20	-5.87	16.36**	19.76**	16.36**
$L_4 \times T_3$	21.55**	12.77 *	-12.70 *	5.10	7.61	13.54 *	3.40	4.71	-3.48	7.11	8.22	7.11
$L_5 \times T_1$	44.94**	30.12**	-1.43	8.03	8.49	25.24**	27.04**	16.04	9.88	11.08 *	-17.81 **	11.08 *
$L_5 \times T_2$	12.77	-3.19	-23.56**	-6.22	-1.86	0.01	18.39	6.80	2.40	-3.61	1.82	-3.61
$L_5 \times T_3$	26.04**	13.11 *	-14.67 *	-10.3	-8.64	-4.25	1.01	-1.56	-12.63	-2.76	3.61	-2.76
$L_6 \times T_1$	19.99 *	7.43	-18.61**	-3.48	-6.09	-3.40	-1.46	-12.9	-19.79	-11.68 *	-4.34	-11.68 *
$L_6 \times T_2$	12.40	-3.78	-23.55**	8.92	10.49 *	8.94	2.15	-10.91	-16.85	-8.08	-3.83	-8.08
$L_6 \times T_3$	23.09**	10.13	-16.64**	-2.46	-3.87	-2.4	13.87	7.53	-7.30	-1.15	4.52	-1.15
$L_7 \times T_1$	-8.24	-4.58	-17.64**	-0.36	-1.54	2.86	23.66**	7.68	-1.89	-2.73	3.53	-2.73
$L_7 \times T_2$	-9.28	-6.87	-17.63**	-0.38	2.65	2.86	17.04	3.60	-7.14	-4.13	-1.33	-4.13
$L_7 \times T_3$	-11.66	-7.73	-19.60**	-5.887	-5.74	-2.8	13.43	5.66	-10.00	-3.48	-2.75	-3.48
$L_8 \times T_1$	2.65	2.69	-14.67 *	-4.79	-3.73	2.86	34.54**	10.65	-3.32	-2.22	3.15	-2.22
$L_8 \times T_2$	9.58	8.11	-8.64	-0.66	4.57	7.27	39.8 **	13.33	0.36	3.47	8.71	3.47
$L_8 \times T_3$	6.77	6.69	-10.96	-12.63 *	-10.51 *	-5.67	28.56**	13.44	-7.62	0.02	2.92	0.02
$L_9 \times T_1$	20.12**	18.21**	22.52**	16.14**	16.14**	12.23 *	20.40**	18.41*	27.45**	-20.03**	-14.49**	10.03
$L_9 \times T_2$	1.06	3.63	19.85**	5.79	10.04 *	11.75 *	9.18	-4.77	-11.12	-3.52	3.36	-3.52
$L_9 \times T_3$	-6.24	-8.29	-24.79**	-1.67	-3.39	4.08	9.38	3.28	-10.96	-3.57	-1.77	-3.57
$L_{10} \times T_1$	23.46**	18.25**	-5.38	9.38	4.77	6.28	0.54	-8.83	-13.82	-1.53	4.24	-1.53
$L_{10} \times T_2$	19.97**	13.294 *	-8.05	5.84	5.86	2.86	13.29	1.99	-2.37	1.38	6.89	1.38
$L_{10} \times T_3$	16.49 *	11.43	-10.72	4.61	1.67	1.72	17.72	14.51	1.44	5.85	9.33	5.85

Table 4.2.1: Contd....

$L_{11} \times T_1$	36.59**	22.69**	-7.17	7.83	2.26	-0.95	37.25**	13.17	-0.93	0.22	11.96 *	0.22
$L_{11} \times T_2$	41.10**	24.92**	-4.05	18.45**	15.13**	8.79	32.23**	7.56	-4.56	3.90	15.63 **	3.90
$L_{11} \times T_3$	36.72**	22.79**	27.06**	19.63**	12.73 *	19.85**	34.78**	19.22**	32.72**	8.33	18.24 **	8.33
$L_{12} \times T_1$	-14.89 *	-9.39	-19.21**	1.95	3.74	5.26	11.49	-4.58	-14.20	-7.23	-4.54	-7.23
$L_{12} \times T_2$	-6.47	-1.65	-11.21 *	-20.62**	-18.25**	-18.04**	15.09	-2.7	-11.44	-9.41	-7.17	-9.41
$L_{12} \times T_3$	0.63	7.10	-4.49	9.56	9.72 *	13.14 *	15.71	6.02	-10.96	7.29	7.62	-1.65
$L_{13} \times T_1$	-14.82 *	-12.81 *	-28.74**	0.17	1.68	9.16	20.63**	6.80	-1.41	-5.20	-1.23	-8.4
$L_{13} \times T_2$	-2.02	-5.67	-22.97**	-7.77	-2.56	0.47	17.60	2.79	-3.89	-5.26	-1.69	-9.32
$L_{13} \times T_3$	21.95**	18.77**	-3.11	0.10	2.94	9.06	14.13	7.99	-6.73	8.11	9.85	-0.89
$L_{14} \times T_1$	38.20**	19.43**	12.09 *	27.99**	14.66**	19.72**	14.87	23.70**	-14.71	-3.51	9.56	-6.85
$L_{14} \times T_2$	35.79**	15.13 *	24.67**	34.54**	26.16**	15.04**	30.21**	27.71**	30.32**	2.41	15.85 **	-1.97
$L_{14} \times T_3$	42.94**	22.91**	-9.83	37.01**	24.71**	17.83**	30.21**	17.00	-3.32	9.44	21.48 **	0.33
$L_{15} \times T_1$	29.29**	15.71 *	-12.69 *	50.62**	24.32**	11.95 *	13.64	6.64	3.35	3.58	14.84 **	0.77
$L_{15} \times T_2$	10.07	-2.54	-25.03**	41.13**	22.65**	4.95	1.66	-5.75	-7.54	-6.45	3.32	-10.45
$L_{15} \times T_3$	46.44**	31.58**	32.58**	34.85**	13.29 *	0.39	-2.79	-2.83	-11.59	4.60	13.28 **	-4.11
$L_{16} \times T_1$	15.79 *	14.29 *	-5.98	32.56**	12.21 *	2.67	2.32	-1.36	-2.05	1.36	7.80	-2.14
$L_{16} \times T_2$	-0.79	-3.41	-19.61**	23.64**	9.25	-4.72	-9.64	-13.93	-13.50	-9.28	-3.92	-13.17 **
$L_{16} \times T_3$	1.62	3.23	-17.13**	40.80**	20.54**	8.56	-4.48	-2.07	-8.57	1.54	5.37	-6.91
$L_{17} \times T_1$	2.51	-1.588	-21.09**	3.39	-3.94	-5.10	-23.9**	-24.76**	-23.37	-14.32 **	-11.06 *	-17.28 **
$L_{17} \times T_2$	7.53	1.83	-17.13**	12.47	9.24	3.24	-4.73	-6.79	-3.96	-2.58	3.71	-6.75
$L_{17} \times T_3$	18.92 *	13.80 *	-8.64	23.53**	16.57**	13.54 *	3.78	9.09	4.63	11.60 *	12.96 **	2.30
$L_{18} \times T_1$	3.57	3.71	-15.65**	5.75	7.34	15.24**	3.86	-5.12	-10.16	-1.53	3.87	-4.94
$L_{18} \times T_2$	0.43	-1.15	-16.15**	-1.56	4.05	7.23	12.69	1.65	-2.53	-0.52	1.49	-4.77
$L_{18} \times T_3$	14.01 *	14.65 *	-4.10	-5.23	-2.54	3.24	-10.48	-12.76	-22.57	-0.36	-3.22	-8.39
$L_{19} \times T_1$	-18.94**	-17.16**	-30.47**	2.84	3.43	2.86	22.60**	18.47*	35.66**	59.15 **	64.05 **	53.65 **
$L_{19} \times T_2$	-7.38	-7.48	-20.59**	3.98	5.49	4.00	-2.69	-11.08	-13.82	-7.22	-4.77	-11.19 *
$L_{19} \times T_3$	-1.00	3.20	-15.66**	13.13 *	11.43 *	13.14 *	3.53	-3.83	-10.96	2.98	3.48	-5.60
$L_{20} \times T_1$	-2.53	3.07	-14.17 *	-4.09	-8.04	-6.62	2.04	-2.83	-4.59	-5.46	-3.48	-8.72
$L_{20} \times T_2$	-6.67	-5.34	-17.13**	2.58	3.68	-2.07	-10.72	-16.01	-16.53	-8.94	-7.43	-12.84 **
$L_{20} \times T_3$	-8.35	-6.50	-19.35**	7.02	4.03	4.19	3.51	3.82	-6.98	-1.16	-3.66	-8.48
$L_{21} \times T_1$	-5.38	-3.94	-18.12**	-0.11	-4.16	-2.64	-8.05	-11.2	-11.75	-8.52	-6.66	-11.69 *
$L_{21} \times T_2$	-2.22	-2.58	-16.64**	8.06	8.23	5.33	-6.31	-10.64	-10.08	-3.87	-2.32	-7.98
$L_{21} \times T_3$	-2.98	-4.796	-16.15**	-0.11	-2.84	-2.64	-6.56	-4.08	-10.32	-3.12	7.62	-10.20

*,** Significant at 5% and 1 % probability levels , respectively.

heterobeltiosis in E_1, E_2, E_3 and across environments was -18.94 to 46.44, -20.62 to 50.62, -23.99 to 39.80 and -20.03 to 59.15, respectively. The most heterotic combinations for maximum plant height were L_2 X T_1 (31.14), L_2 X T_2 (19.13), L_2 X T_3 (22.63) L_3 X T_2 (19.72), L_3 X T_3 (19.40), L_4 X T_1 (36.10) L_4 X T_2 (34.03), L_4 X T_3 (21.55), L_5 X T_1 (44.94) L_5 X T_3 (26.04), L_6 X T_1 (19.99), L_6 X T_3 (23.09) L_9 X T_1 (20.12), L_{10} X T_1 (23.46), L_{10} X T_2 (19.97) L_{10} X T_3 (16.49), L_{11} X T_1 (36.59), L_{11} X T_2 (41.10) L_{11} X T_3 (36.72), L_{13} X T_3 (21.95), L_{14} X T_1 (38.20) L_{14} X T_2 (35.79), L_{14} X T_3 (42.94), L_{15} X T_1 (29.29) L_{15} X T_3 (46.44), L_{16} X T_1 (15.79), L_{17} X T_3 (18.92) and L_{18} X T_3 (14.01) in **E_1**; L_2 X T_2 (15.37), L_2 X T_3 (15.42) L_9 X T_1 (16.14), L_{11} X T_2 (18.45), L_{11} X T_3 (19.63), L_{14} X T_1 (27.99) L_{14} X T_2 (34.54), L_{14} X T_3 (37.01), L_{15} X T_1 (50.62) L_{15} X T_2 (41.13), L_{15} X T_3 (34.85), L_{16} X T_1 (32.56), L_{16} X T_2 (23.64) L_{16} X T_3 (40.80), L_{17} X T_3 (23.53) and L_{19} X T_3 (13.13) in **E_2**; L_1 X T_2 (33.98) L_2 X T_1 (30.81), L_5 X T_1 (27.04) L_7 X T_1 (23.66) L_8 X T_1 (34.54), L_8 X T_2 (39.80), L_8 X T_3 (28.56) L_9 X T_1 (20.40), L_{11} X T_1 (37.25), L_{11} X T_2 (32.23) L_{11} X T_3 (34.78), L_{13} X T_1 (20.63), L_{14} X T_2 (30.21), L_{14} X T_3 (30.21) and L_{19} X T_1 (22.60) in **E_3** and L_2 X T_3 (15.13) L_4 X T_2 (16.36), L_5 X T_1 (11.08), L_{17} X T_3 (11.60) and L_{19} X T_1 (59.15) across the environments.

The estimates of relative heterosis indicated a range of -1.15 to 31.58, -1.54 to 26.16, -1.36 to 18.47 and -1.23 to 64.04 in E_1, E_2, E_3 and across the environments, respectively. Hybrids with significantly higher estimates of heterosis for plant height were L_2 X T_1 (21.62), L_2 X T_3 (13.70) L_3 X T_2 (13.30), L_3 X T_3 (14.67), L_4 X T_1 (26.96) L_4 X T_2 (22.58), L_4 X T_3 (12.77), L_5 X T_1 (30.12) L_5 X T_3 (13.11), L_9 X T_1 (18.21),

L_{10} X T_1 (18.25), L_{10} X T_2 (13.29), L_{11} X T_1 (22.69), L_{11} X T_2 (24.92) L_{11} X T_3 (22.79), L_{13} X T_3 (18.77), L_{14} X T_1 (19.43) L_{14} X T_2 (15.13), L_{14} X T_3 (22.91), L_{15} X T_1 (15.71) L_{15} X T_3 (31.58), L_{16} X T_1 (14.29), L_{17} X T_3 (13.80) and L_{18} X T_3 (14.65) in **E_1**, ; L_2 X T_2 (15.67), L_2 X T_3 (12.11), L_4 X T_2 (14.53), L_6 X T_2 (10.49) L_9 X T_1 (16.14), L_9 X T_2 (10.04), L_{11} X T_2 (15.13), L_{11} X T_3 (12.73), L_{14} X T_1 (14.66) L_{14} X T_2 (26.16), L_{14} X T_3 (24.71), L_{15} X T_1 (24.32) L_{15} X T_2 (22.65), L_{15} X T_3 (13.29), L_{16} X T_1 (12.21), L_{16} X T_3 (20.54), L_{17} X T_3 (16.57) and L_{19} X T_3 (11.43) in **E_2**, L_9 X T_1 (18.41), L_{11} X T_3 (19.22), L_{14} X T_1 (23.70) L_{14} X T_2 (27.71) and L_{19} X T_1 (18.47) in **E_3** and L_2 X T_1 (13.11), L_2 X T_3 (11.16), L_4 X T_2 (19.76), L_{11} X T_1 (11.96), L_{11} X T_2 (15.63), L_{11} X T_3 (18.24), L_{14} X T_2 (15.85), L_{14} X T_3 (21.48), L_{15} X T_1 (14.84), L_{15} X T_3 (13.28), L_{17} X T_3 (12.96) and L_{19} X T_1 (64.05) in pooled analysis.

The estimates of standard heterosis ranged from -30.47 to 32.58, -18.04 to 25.24, -30.69 to 35.66 and -17.28 to 53.65 in E_1, E_2, E_3 and across the environments, respectively. Hybrids with significantly higher estimates of heterosis for plant height were L_9 X T_1 (22.52), L_9 X T_2 (19.85), L_{11} X T_3 (27.06), L_{14} X T_1 (12.09) L_{14} X T_2 (24.67) and L_{15} X T_3 (32.58) in **E_1**, L_2 X T_2 (12.65), L_2 X T_3 (12.15), L_3 X T_1 (12.55), L_4 X T_1 (12.55), L_4 X T_2 (17.43), L_4 X T_3 (13.54), L_5 X T_1 (25.24), L_9 X T_1 (12.23), L_9 X T_2 (11.75), L_{11} X T_3 (19.85), L_{12} X T_3 (13.14), L_{14} X T_1 (19.72) L_{14} X T_2 (15.04), L_{14} X T_3 (17.83), L_{15} X T_1 (11.95) L_{17} X T_3 (13.54), L_{18} X T_1 (15.24) and L_{19} X T_3 (13.14) in **E_2**; L_9 x T_1 (27.45), L_{11} x T_3 (32.72), L_{14} x T_2 (30.32) and L_{19} x T_1 (35.66) in **E_3**, L_4 x T_2, L_5 X T_1 (11.08) and L_{19} X T_1 (53.65) across the environments.

On the basis of study for all the environments, 4 crosses for BP, 1 for CP and 4 for MP showed positive and significant heterosis. However, crosses L_9 x T_1 L_{11} x T_3 and L_{14} x T_2 exhibited significantly positive heterosis (BP, CP and MP) in all the environments.

4.2.2 Ear height (cm)

The estimates of per cent heterobeltiosis, relative heterosis and standard heterosis for ear height are given in Table 4.2.2. Results on per cent heterobeltiosis among the all hybrids indicated a wide range of -22.97 to 59.32, -33.69 to 64.31, -41.64 to 89.36 and -26.05 to 32.76 in E_1, E_2, E_3 and in pooled analysis, respectively. Among the hybrids most heterotic ones were L_1 x T_1 (31.10), L_1 x T_2 (36.94), L_1 x T_3 (30.70), L_2 x T_1 (39.67), L_3 x T_3 (48.81), L_4 x T_1 (39.62), L_4 x T_2 (47.33), L_4 x T_3 (24.21), L_5 x T_1 (45.22), L_6 x T_1 (35.59), L_6 x T_2 (40.87), L_6 x T_3 (29.00), L_8 x T_3 (21.25), L_{10} x T_1 (36.84), L_{11} x T_2 (20.73), L_{11} x T_3 (25.06), L_{14} x T_1 (43.77), L_{14} x T_2 (49.44), L_{14} x T_1, L_{14} x T_3 (59.32), L_{15} x T_3 (25.39), L_{16} x T_1 (46.11), L_{16} x T_2 (24.55), L_{16} x T_3 (44.91), L_{20} x T_1 (18.96), L_{20} x T_2 (31.86), L_{21} x T_2 (24.22) in **E_1**; L_2 x T_2 (35.33), L_3 x T_2 (28.48), L_4 x T_2 (34.22), L_5 x T_1 (33.06), L_5 x T_2 (56.97), L_{10} x T_2 (38.12), L_{10} x T_3 (25.92), L_{11} x T_1 (64.31), L_{11} x T_2 (48.82), L_{12} x T_1 (36.90), L_{13} x T_3 (32.21), L_{14} x T_1 (37.69), L_{14} x T_2 (32.46), L_{14} x T_3 (83.09), L_{15} x T_1 (56.61), L_{15} x T_2 (32.90), L_{15} x T_3 (26.68), L_{17} x T_2 (54.07), L_{20} x T_1 (49.19) and L_{21} x T_3 (64.31) in **E_2**; L_2 x T_1 (23.57), L_4 x T_1 (23.53), L_4 x T_2 (34.37), L_4 x T_3 (36.28), L_5 x T_1 (34.35), L_5 x T_2 (43.98), L_6 x T_3 (40.11), L_8 x T_1 (21.45), L_8 x T_2 (21.03), L_{10} x T_2 (33.46), L_{12} x T_1 (22.06), L_{12} x T_3 (23.86), L_{13} x T_3

Table 4.2.2: Estimation of heterosis (%) over better-, mid- and check- parent in three environments (E_1, E_2, E_3)

Cross	Ear height (cm)											
	Normal			Low nitrogen			Excess soil moisture			Pooled		
	BP	MP	CP	BP	MP	CP	BP	MP	CP	BP	MP	CP
$L_1 \times T_1$	31.10**	18.32 *	-1.99	-20.20	-19.85 *	-28.09**	-3.33	-4.04	-16.20	-25.23**	-16.97**	-15.14 *
$L_1 \times T_2$	36.94**	27.97**	2.37	3.23	11.00	-6.97	-41.64**	-41.34**	-49.44**	0.34	0.83	16.12 *
$L_1 \times T_3$	30.70**	26.46**	-2.2	-33.69**	-31.11**	-30.22**	15.30	20.60 *	-0.04	2.09	3.76	14.65 *
$L_2 \times T_1$	39.67**	30.47**	11.24	8.99	-7.62	-28.40**	23.57 *	13.08	-8.31	2.59	12.85	-8.14
$L_2 \times T_2$	3.77	.22	-17.34 *	35.33**	24.21 *	-11.07	15.53	7.17	-14.27	3.59	9.91	14.25 *
$L_2 \times T_3$	3.30	3.20	-17.72 *	.60	-11.45	-33.92**	16.77	13.06	-13.36	-3.57	1.21	21.98 **
$L_3 \times T_1$	12.58	1.58	-15.83 *	12.58	5.17	-11.86	9.34	9.91	-2.80	-0.14	5.37	-10.58
$L_3 \times T_2$	16.40	8.74	-12.98	28.48**	29.15**	.59	8.62	10.56	-3.44	14.21	16.03 **	-5.45
$L_3 \times T_3$	48.81**	43.96**	11.24	-5.53	-8.61	-26.04**	-13.89	-8.85	-23.42**	9.00	9.50	-11.80
$L_4 \times T_1$	39.62**	19.83**	-4.55	16.51	3.67	-16.58	23.53 *	11.19	-11.06	-0.14	11.69	-10.58
$L_4 \times T_2$	47.33**	31.09**	.71	34.22**	28.85**	-3.98	34.37**	22.64 *	-3.26	18.34 *	27.76 **	-2.04
$L_4 \times T_3$	24.21 *	14.62	-15.08 *	20.14	11.57	-13.43	36.28**	29.90**	-1.88	10.51	18.05 **	-10.58
$L_5 \times T_1$	45.72**	25.85**	.71	33.06**	46.52**	5.47	34.35**	54.82**	17.40 *	19.86 *	41.13 **	7.33
$L_5 \times T_2$	7.07	-4.14	-25.99**	56.97**	29.81**	-14.22	43.98**	22.70 *	-8.31	0.64	14.65 *	16.69 *
$L_5 \times T_3$	-1.08	-8.18	-31.64**	33.16	5.30	-27.22**	3.96	-7.23	-33.79**	-14.39	-3.43	-30.73 **
$L_6 \times T_1$	35.59**	4.57	-22.61**	.65	-15.25	-34.31**	8.80	-2.06	-21.67 *	-19.73*	-24.33**	-26.33 **
$L_6 \times T_2$	40.87**	12.94	-19.60**	-7.79	-15.41	-30.44**	-7.71	-15.77	-33.56**	-16.08	-5.64	-30.53 **
$L_6 \times T_3$	29.00 *	7.58	-26.37**	17.39	3.32	-22.89 *	40.11**	33.56**	.87	2.46	14.05 *	17.09 *
$L_7 \times T_1$	-22.97**	-22.66**	-29.38**	-13.52	-7.82	-11.86	7.36	6.57	-6.93	-11.15	-9.10	-16.69 *
$L_7 \times T_2$	-3.28	.21	-11.32	.38	14.05	2.32	-6.93	-6.44	-19.33 *	-2.91	3.14	-8.95
$L_7 \times T_3$	-8.20	-1.84	-15.83 *	-20.48 *	-12.61	-18.95	-11.70	-7.64	-23.46**	-13.76	-7.41	-19.13 *
$L_8 \times T_1$	8.50	1.32	-13.58	-2.25	-2.25	-12.68	21.45 *	21.41**	6.84	3.64	6.05	-7.20
$L_8 \times T_2$	9.54	5.79	-12.75	-29.46**	-24.46 *	-36.99**	21.03 *	22.59**	6.47	-1.00	0.58	15.38 *
$L_8 \times T_3$	21.25 *	21.14**	-3.42	-19.85	-17.18	-28.40**	-5.16	-0.11	-16.57 *	-1.57	1.13	15.87 *
$L_9 \times T_1$	9.06	1.85	-13.13	9.06	5.33	-9.02	-20.18 *	-17.17 *	-24.28**	-5.05	-2.84	14.98 *
$L_9 \times T_2$	.945	-2.50	-19.60**	-6.14	-2.69	-21.70 *	-21.24 *	-17.25 *	-25.29**	-8.71	-7.26	-21.98 **
$L_9 \times T_3$	-14.17	-14.25	-31.64**	12.75	12.64	-5.95	-10.60	-2.48	-15.19	-3.95	-1.32	-17.91 *
$L_{10} \times T_1$	36.84**	27.79**	8.99	19.82	11.33	-7.13	-9.85	-13.52	-26.95**	3.73	9.98	-7.12
$L_{10} \times T_2$	14.17	10.26	-9.06	38.12**	38.12**	7.05	33.46**	29.71**	8.21	32.76 **	25.35 **	1.63
$L_{10} \times T_3$	2.83	2.73	-18.09 *	25.92*	21.18 *	-2.40	18.17	19.66 *	-4.17	13.03	14.12 *	-8.55

Table 4.2.2: Contd....

$L_{11} \times T_1$	16.65	5.26	-12.79	64.31**	35.87**	-10.20	.67	2.47	-10.51	0.18	11.03	-10.30
$L_{11} \times T_2$	20.73 *	12.78	-9.74	48.82**	17.73	-18.63	11.31	17.82 *	-1.05	8.60	16.14 **	-10.09
$L_{11} \times T_3$	25.06**	20.98**	-6.50	5.58	-3.79	-21.08 *	2.26	-5.80	-23.18**	12.42	18.95 **	-9.04
$L_{12} \times T_1$	-1.92	-4.63	-15.61 *	36.90**	34.42**	2.32	22.06 *	13.98	-8.31	-10.32	-4.69	-19.70
$L_{12} \times T_2$	-20.55 *	-20.20**	-31.64**	3.69	-2.09	-22.49 *	11.06	8.21	-16.57 *	5.06	7.55	-13.02
$L_{12} \times T_3$	-2.18	1.49	-15.83 *	-3.28	.21	-7.13	23.86 *	12.27	-9.68	0.96	2.19	-18.32 *
$L_{13} \times T_1$	-14.97	-20.20**	-31.64**	.16	10.85	-3.82	19.71	10.01	-12.71	-6.95	-3.76	-16.69 *
$L_{13} \times T_2$	11.41	8.12	-10.42	-2.21	4.56	-6.10	21.72	16.79	-11.24	9.10	9.64	-8.79
$L_{13} \times T_3$	14.31	14.74	-8.08	32.21**	48.83**	-2.24	73.61**	27.95**	-10.88	9.69	11.48	-8.30
$L_{14} \times T_1$	43.77**	30.88**	27.96 **	37.69**	67.23**	25.03**	73.26**	29.73**	21.06**	0.05	28.19 **	-10.42
$L_{14} \times T_2$	49.44**	19.82 *	-14.70 *	32.46**	55.39**	-2.40	89.36**	49.08**	-2.80	10.47	37.52 **	-8.55
$L_{14} \times T_3$	59.32**	32.85**	29.06**	83.09**	46.77**	39.41**	31.02**	19.87 *	22.80**	17.56	45.07 **	-4.88
$L_{15} \times T_1$	21.56 *	12.65	-4.55	56.61**	36.45**	-6.34	22.98 *	14.06	-8.77	12.59	25.74 **	0.81
$L_{15} \times T_2$	-4.79	-8.72	-25.24**	32.90 *	10.88	-20.58 *	32.20**	28.04**	-1.88	4.08	12.19	-13.84
$L_{15} \times T_3$	25.39**	24.38**	-1.54	26.68 *	14.72	-6.34	40.12**	11.62	-18.11 *	13.53	21.08 **	-8.14
$L_{16} \times T_1$	46.11**	19.34 *	-8.31	-0.21	-2.54	-26.22**	16.4	-5.80	-32.15**	-0.14	15.51 *	-10.58
$L_{16} \times T_2$	24.55 *	5.59	-21.85**	1.59	-4.60	-24.82 *	48.08**	25.52 *	-13.82	-11.06	-0.55	-26.37 **
$L_{16} \times T_3$	44.91**	27.61**	-9.06	33.16	1.09	-27.22**	-35.40**	-36.15**	-44.12**	3.97	15.09 *	-15.87 *
$L_{17} \times T_1$	-8.55	-17.48 *	-31.6**	26.38	4.53	-30.93**	5.24	5.80	-8.77	-26.05**	-17.70 **	33.78 **
$L_{17} \times T_2$	7.54	.47	-19.60**	54.07**	21.83	-15.80	8.42	13.40	-6.015	-3.69	3.43	-20.27 **
$L_{17} \times T_3$	13.58	9.88	-15.08 *	0.66	-10.47	-27.62**	10.38	10.95	-1.88	8.00	14.75 *	-12.62
$L_{18} \times T_1$	-2.46	-2.06	-10.57	19.59	15.5	-13.43	7.28	9.20	-4.63	-3.77	-0.84	-13.84
$L_{18} \times T_2$	-9.23	-5.95	-16.78 *	6.53	-1.11	-22.82 *	-23.09 *	-19.25 *	-32.18**	4.44	5.36	-12.01
$L_{18} \times T_3$	7.38	14.83 *	-1.54	-11.33	-14.37	-26.04**	34.75**	23.27**	-0.04	-2.56	-0.59	-17.91 *
$L_{19} \times T_1$	-19.85 *	-22.47**	-31.64**	17.00	21.30 *	-2.40	23.57 *	14.63	-8.31	-11.05	-6.81	20.35 **
$L_{19} \times T_2$	1.32	1.32	-13.58	8.50	8.40	-9.49	34.75**	30.47**	-0.04	10.96	11.90	-8.14
$L_{19} \times T_3$	6.61	10.16	-9.06	16.10	-1.26	-23.26 *	17.68	6.27	-14.73	14.85	15.20 *	-6.51
$L_{20} \times T_1$	18.96 *	7.05	-11.51	49.19**	37.32**	-1.41	11.97	2.54	-18.87 *	-6.73	4.06	-16.48 *
$L_{20} \times T_2$	31.86**	22.85**	-1.91	22.36	8.05	-19.19 *	42.39**	36.12**	3.16	12.68	21.33 **	-6.72
$L_{20} \times T_3$	10.62	6.73	-17.72 *	-5.44	-11.76	-26.13**	-12.24	-8.60	-16.11	8.75	15.86 *	-12.01
$L_{21} \times T_1$	16.03	.09	-19.97**	10.28	10.73	-13.83	-3.60	1.62	-7.85	-21.68**	-16.72**	-20.92 **
$L_{21} \times T_2$	24.22 *	11.07	-14.33 *	-0.33	-3.65	-22.10 *	-6.48	2.36	-10.60	6.05	7.85	-12.21
$L_{21} \times T_3$	16.03	7.58	-19.97**	64.31**	35.87**	-10.20	.67	2.47	-10.51	1.46	2.02	-17.91 *

*,** Significant at 5% and 1 % probability levels , respectively.

(73.61), L_{14} x T_1 (73.26), L_{14} x T_2 (89.36), L_{14} x T_3 (31.02), L_{15} x T_1 (22.98), L_{15} x T_2 (32.20), L_{15} x T_3 (40.12), L_{16} x T_2 (48.08), L_{18} x T_3 (34.75), L_{19} x T_1 (23.57), L_{19} x T_2 (34.75) and L_{20} x T_2 (42.39) in **E_3**; and L_4 x T_2 (18.34), L_5 x T_1 (19.86) and L_{10} x T_2 (32.76) in pooled environment which had maximum heterobeltiosis for ear height.

The range of per cent relative heterosis in each environment and also in pooled over environments was -22.66 to 43.96, -31.11 to 67.23, -41.34 to 54.82 and -24.33 to 45.07, respectively. Hybrids having better heterotic expression for ear height were L_1 x T_1 (18.32), L_1 x T_2 (27.97), L_1 x T_3 (26.46), L_2 x T_1 (30.47), L_3 x T_3 (43.96), L_4 x T_1 (19.83), L_4 x T_2 (31.09), L_5 x T_1 (25.85), L_8 x T_3 (21.14), L_{10} x T_1 (27.79), L_{11} x T_3 (20.98), L_{14} x T_1 (30.88), L_{14} x T_2 (19.82), L_{14} x T_3 (32.85), L_{15} x T_3 (24.38), L_{16} x T_1 (19.34), L_{16} x T_3 (27.61), L_{18} x T_3 (14.83) and L_{20} x T_2 (22.85) in **E_1**; L_2 x T_2 (24.21), L_3 x T_2 (29.15), L_4 x T_2 (28.85), L_5 x T_1 (46.52), L_5 x T_2 (29.81), L_{10} x T_2 (38.12), L_{10} x T_3 (21.18), L_{11} x T_1 (35.87), L_{12} x T_1 (34.42), L_{13} x T_3 (48.83), L_{14} x T_1 (67.23), L_{14} x T_2 (55.39), L_{14} x T_3 (46.77), L_{15} x T_1 (36.45), L_{19} x T_1 (21.30), L_{20} x T_1 (37.32) and L_{21} x T_3 (35.87) in **E_2**; L_1 x T_3 (20.60), L_4 x T_2 (22.64), L_4 x T_3 (29.90), L_5 x T_1 (54.82), L_5 x T_2 (22.70), L_6 x T_3 (33.56), L_8 x T_1 (21.41), L_8 x T_2 (22.59), L_{10} x T_2 (29.71), L_{10} x T_3 (19.66), L_{11} x T_2 (17.82), L_{13} x T_3 (27.95), L_{14} x T_1 (29.73), L_{14} x T_2 (49.08), L_{14} x T_3 (19.87), L_{15} x T_2 (28.04), L_{16} x T_2 (25.52), L_{18} x T_3 (23.27), L_{19} x T_2 (30.47) and L_{20} x T_2 (36.12) in **E_3**; and L_3 x T_2 (16.03), L_4 x T_2 (27.76), L_4 x T_3 (18.05), L_5 x T_1 (41.13), L_5 x T_2 (14.65), L_6 x T_3 (14.05), L_{10} x T_2 (25.35), L_{10} x T_3 (14.12), L_{11} x T_2 (16.14),

L_{11} x T_3 (18.95), L_{14} x T_1 (28.19), L_{14} x T_2 (37.52), L_{14} x T_3 (45.07), L_{15} x T_1 (25.74), L_{15} x T_3 (21.08), L_{16} x T_1 (15.51), L_{16} x T_3 (15.09), L_{17} x T_3 (14.75), L_{19} x T_3 (15.20), L_{20} x T_2 (21.33) and L_{20} x T_3 (15.86) in the pooled analysis across the environments.

The estimates of per cent standard heterosis ranged from -31.64 to 29.06 in E_1; -36.99 to 39.41 in E_2; -49.44 to 22.80 in E_3; and –30.73 to 33.98 across the environments. Hybrids with significantly higher estimates of heterosis over check for higher ear height were L_{14} × T_1 (27.96) and L_{14} × T_3 (29.06) in **E_1**, L_{14} × T_1 (25.03) and L_{14} × T_3 (39.41) in **E_2**; L_5 × T_1 (17.40), L_{14} × T_1 (21.06) and L_{14} × T_3 (22.80) in **E_3**; and L_1 × T_2 (16.12), L_1 × T_3 (14.65), L_2 × T_2 (14.25), L_2 × T_3 (21.98), L_5 × T_2 (16.69) L_6 × T_3 (17.09), L_8 × T_2 (15.38) L_8 × T_3 (15.87) L_9 × T_1 (14.98), L_{17} × T_1(33.78) and L_{19} × T_1 (20.35) across the environments.

On the basis of study for all the environments, 7 crosses for BP, 5 for MP and 2 for CP showed positive and significant heterosis. However, crosses, L_{14} × T_1 and L_{14} × T_3 exhibited significantly positive heterosis (BP, CP and MP) in all the environments.

4.2.3 100-kernel weight (g)

The estimates of per cent heterobeltiosis, relative heterosis and standard heterosis for 100-kernel weight are given in Table 4.2.3. In pooled analysis, 5 crosses exhibited significant negative better parent heterosis alongwith 5 for mid-parent and 3 for standard heterosis. Better parent heterosis in E_1, E_2, E_3 and pooled analysis ranged from -19.63 to 26.97, -25.18 to 32.55, -29.27 to 62.10 and -19.14 to 12.87 per

Table 4.2.3: Estimation of heterosis (%) over better-, mid- and check- parent in three environments (E_1, E_2, E_3)

Cross	100 kernels weight (g)											
	Normal			Low nitrogen			Excess soil moisture			Pooled		
	BP	MP	CP	BP	MP	CP	BP	MP	CP	BP	MP	CP
$L_1 \times T_1$	6.56	3.29	1.82	1.52	6.90	14.92	6.26	4.21	-1.88	4.48	4.68	4.05
$L_1 \times T_2$	3.20	4.43	-1.38	-3.78	-0.81	8.90	4.64	2.04	-3.37	1.47	2.01	0.68
$L_1 \times T_3$	-2.06	-0.71	-6.41	12.45	8.98	27.29**	7.78	4.13	-0.47	2.33	4.00	4.90
$L_2 \times T_1$	-10.91	-11.82	-11.8	-16.12 *	-12.95	-7.87	-26.46**	-16.81**	-7.55	-18.55 **	-14.01 **	-9.30
$L_2 \times T_2$	11.23	14.26**	9.60	3.64	5.30	13.87	-29.27**	-20.21**	-10.94	-7.08	-1.23	3.47
$L_2 \times T_3$	-4.40	-1.62	-5.81	8.04	3.10	18.71*	-22.38**	-12.92	-1.98	-8.20	-4.40	2.23
$L_3 \times T_1$	20.68**	17.15**	15.63**	-25.18**	-19.83**	-12.11	2.29	3.97	1.45	-0.01	1.63	2.89
$L_3 \times T_2$	1.25	2.59	-2.97	-1.95	2.88	15.16	6.52	7.67	5.65	2.03	4.43	4.98
$L_3 \times T_3$	3.35	4.92	-0.96	-11.47	-12.57	3.98	12.20	12.41	11.27	1.67	1.86	4.62
$L_4 \times T_1$	16.83**	13.17**	11.50	-14.34	-12.31	-8.56	-5.60	-4.39	-7.06	-0.25	-0.23	-0.66
$L_4 \times T_2$	3.64	4.81	-1.07	-14.49	-14.35	-8.71	-0.07	.63	-1.62	-3.02	-2.35	-3.47
$L_4 \times T_3$	10.65	9.62	8.25	27.6**	10.28	36.28**	11.04	10.84	9.32	12.87 **	24.53 **	15.71 **
$L_5 \times T_1$	16.81**	13.23**	15.71**	27.6**	19.98**	24.69**	23.68**	20.59**	17.87**	18.43**	16.10**	11.35 **
$L_5 \times T_2$	-12.66**	-10.61	-14.69**	-3.53	3.96	19.94 *	10.00	6.61	.39	-2.53	-0.33	0.10
$L_5 \times T_3$	.65	3.14	-1.69	-15.85 *	-14.53 *	4.62	16.54	11.91	6.35	0.09	0.18	2.79
$L_6 \times T_1$	-9.89	-10.37	-9.50	-5.89	.97	10.88	-0.83	1.11	-1.02	-5.60	-3.14	-0.97
$L_6 \times T_2$	3.78	7.55	4.14	-15.62 *	-11.40	-0.66	-2.83	-1.48	-3.02	-4.47	-1.31	0.21
$L_6 \times T_3$	-6.52	-2.94	-6.20	-0.30	-1.38	17.46	17.47 *	18.07**	17.25 **	3.43	4.62	8.50
$L_7 \times T_1$	-8.22	-8.83	-7.98	4.17	4.33	6.37	-14.23 *	-3.07	6.94	-7.43	-3.14	1.15
$L_7 \times T_2$	-7.91	-4.61	-7.67	14.10	11.75	16.51	-20.08**	-23.88**	-27.76**	-19.14 **	-14.20 **	-11.64 **
$L_7 \times T_3$	-10.72	-7.41	-10.56	5.58	-3.09	7.81	-16.63**	-6.97	3.95	-8.91	-6.00	-0.46
$L_8 \times T_1$	4.34	1.21	-0.16	-3.29	4.09	14.72	-7.82	-3.5	-2.92	-2.31	0.43	2.89
$L_8 \times T_2$	-6.95	-5.79	-10.97	-3.74	1.48	14.19	1.38	5.52	6.77	-3.03	0.38	2.14
$L_8 \times T_3$	-3.24	-1.84	-7.42	-4.44	-5.15	13.35	-2.39	.72	2.79	-3.32	-2.01	1.83
$L_9 \times T_1$	10.24	4.33	.61	26.74**	27.43**	30.43**	-11.53	-5.74	-3.20	6.59	7.23	7.42
$L_9 \times T_2$	-1.47	-2.57	-10.08	12.41	10.53	15.67	-7.84	-2.33	.83	0.01	1.32	0.79
$L_9 \times T_3$	26.97**	25.81**	15.88**	24.39**	14.63 *	27.99**	-11.03	-6.50	-2.65	9.85	10.79	22.61 **
$L_{10} \times T_1$	5.62	3.29	2.68	20.51 *	15.00	11.91	14.80	13.99	8.62	7.68	10.21	7.23
$L_{10} \times T_2$	-7.19	-5.29	-9.77	32.55**	23.55**	23.07**	-2.91	-4.15	-8.14	1.66	3.32	-0.21
$L_{10} \times T_3$	2.94	5.25	.08	25.52**	9.28	16.51	4.61	2.34	-1.02	1.60	5.46	4.15

Table 4.2.3: Contd....

$L_{11} \times T_1$	-2.35	-5.99	-7.91	-11.48	-13.68	1.41	-2.64	-1.27	-1.05	3.12	4.55	5.59
$L_{11} \times T_2$	-4.02	-3.52	-9.49	7.37	11.73	18.56 *	11.15	14.62 *	13.54	-10.32	-8.43	-8.17
$L_{11} \times T_3$	.50	1.22	-5.22	11.21	13.26	22.79 **	-4.69	-2.26	-2.64	-4.41	-4.35	-2.01
$L_{12} \times T_1$	-1.72	-3.28	-3.27	26.27**	20.81**	39.43**	-9.77	-8.27	-7.83	5.46	7.22	8.58
$L_{12} \times T_2$	6.64	9.48	4.96	8.95	11.12	15.4	-17.32 *	-8.90	-2.64	4.04	6.52	7.13
$L_{12} \times T_3$	-3.06	-0.28	-4.58	17.83	17.5 *	24.82**	-6.88	2.087	9.65	3.29	3.52	6.35
$L_{13} \times T_1$	1.18	-1.63	-2.77	14.14	6.84	20.98 *	-14.12*	-6.604	1.13	-3.88	-0.73	2.21
$L_{13} \times T_2$	-8.53	-7.19	-12.11**	-1.53	2.22	8.18	31.02**	30.67**	25.06**	-0.64	3.33	5.66
$L_{13} \times T_3$	17.5**	19.48**	12.93**	5.39	7.07	15.79	-12.69	-13.42	-16.66 **	4.28	6.20	10.90
$L_{14} \times T_1$	-13.68**	-13.68**	-12.36**	-6.62	-10.89	2.59	-4.87	-6.51	-9.19	4.70	5.76	6.41
$L_{14} \times T_2$	-19.63**	-16.22**	-14.31**	6.02	12.52	22.03 *	29.27**	20.17**	7.74	-9.87	-8.31	-8.40
$L_{14} \times T_3$	-4.54	-0.30	-3.02	-7.70	-4.09	6.22	35.43**	25.13**	12.87	-6.08	-5.68	-3.73
$L_{15} \times T_1$	13.56**	9.06	6.58	5.90	3.51	21.89 *	18.69	8.61	-1.07	14.63**	13.71 **	11.17 **
$L_{15} \times T_2$	12.37**	12.7	5.47	8.02	13.13	20.88 *	-0.88	3.99	4.95	13.21**	14.47 **	8.19
$L_{15} \times T_3$	8.18	8.71	1.54	2.15	4.72	14.32	-8.36	-4.38	-2.97	3.56	6.98	6.16
$L_{16} \times T_1$	13.58**	8.32	5.17	-20.82 *	-23.71**	-11.9	-13.50	-10.51	-8.42	6.66	8.21	9.34
$L_{16} \times T_2$	13.63**	13.19**	5.21	-20.47**	-9.18	7.74	-7.43	-1.43	1.15	2.19	4.40	4.76
$L_{16} \times T_3$	11.16	10.94	2.92	-18.00**	-8.14	11.09	1.74	7.77	11.18	-7.43	-7.43	-5.10
$L_{17} \times T_1$	-6.20	-5.88	-4.05	-14.14	-9.08	16.31	-6.76	-2.07	1.88	-11.31	-5.39	0.95
$L_{17} \times T_2$	-8.05	-3.83	-5.95	-2.91	3.97	13.93	-6.20	-1.65	-0.82	-8.02	-1.23	4.70
$L_{17} \times T_3$	-10.83	-6.56	-8.79	21.39**	27.33**	42.47**	-10.09	-6.25	-4.94	-10.55	-5.87	1.82
$L_{18} \times T_1$	-9.48	-9.86	8.80	.61	-0.67	18.08 *	14.77	18.66**	21.36**	-6.36	-2.99	0.21
$L_{18} \times T_2$	-4.58	-0.92	-3.86	12.55	11.43	12.32	-8.47	-1.25	2.86	1.37	5.74	8.48
$L_{18} \times T_3$	-4.11	-0.25	-3.38	29.99**	25.82**	29.72**	-13.37	-7.03	-2.63	3.88	6.11	11.16 **
$L_{19} \times T_1$	.02	.17	1.93	-17.47	-25.19**	-17.62	19.03**	26.69**	33.79**	0.12	2.73	5.04
$L_{19} \times T_2$	-10.66	-6.728	-8.95	-39.74**	-13.90	-25.58**	28.88**	14.63	-0.95	-1.00	2.29	3.87
$L_{19} \times T_3$	-9.71	-5.56	-7.98	-3.89	3.26	18.72 *	24.97*	10.45	-3.95	-0.93	0.22	3.94
$L_{20} \times T_1$	15.40**	-5.82	-4.75	19.46**	-18.37**	-0.44	62.10**	41.84**	24.57**	-8.86	-8.38	-9.24
$L_{20} \times T_2$	-11.29	-7.92	-10.68	1.94	4.10	8.28	1.22	7.90	10.85	1.21	1.40	-0.27
$L_{20} \times T_3$	-9.75	-6.14	-9.12	11.44	11.34	18.37 *	-5.03	.69	4.00	2.46	4.49	5.03
$L_{21} \times T_1$	.18	-0.48	.43	24.82**	17.00*	32.57**	-17.77 *	-13.50 *	-9.95	1.06	3.76	6.18
$L_{21} \times T_2$	-0.35	3.21	-0.10	-11.48	-13.68	1.41	-2.64	-1.27	-1.05	1.23	4.66	6.36
$L_{21} \times T_3$	6.90	10.93	7.16	7.37	11.73	18.56 *	11.15	14.62 *	13.54	2.87	4.13	8.08

*,** Significant at 5% and 1 % probability levels , respectively.

cent, respectively. The promising hybrids with significant higher estimates of better parent heterosis for 100-kernel weight were L_3 x T_1 (20.68), L_4 x T_1 (16.83), L_5 x T_1 (16.81), L_9 x T_3 (26.97), L_{13} x T_3 (17.50), L_{15} x T_1 (13.56), L_{15} x T_2 (12.36), L_{16} x T_1 (13.58), L_{16} x T_2 (13.63) and L_{20} x T_1 (15.40) in **E_1**; L_4 x T_3 (27.6), L_5 x T_1 (25.52), L_9 x T_1 (26.27), L_9 x T_3 (24.39), L_{10} x T_1 (20.51), L_{10} x T_2 (32.55), L_{10} x T_3 (25.52), L_{12} x T_1 (26.27), L_{17} x T_3 (21.39), L_{18} x T_3 (29.99), L_{20} x T_1 (19.46) and L_{21} x T_1 (24.82) in **E_2**; L_5 x T_1 (23.68), L_{13} x T_2 (17.47), L_{14} x T_2 (31.02), L_{14} x T_3 (29.27), L_{19} x T_1 (35.43), L_{19} x T_2 (19.03), L_{19} x T_3 (28.88) and L_{20} × T_1 (62.10) in **E_3**; and L_4 × T_3 (12.87), L_5 x T_1 (18.43), L_{15} x T_1 (14.63) and L_{15} × T_2 (13.21) across the environments.

The estimates of mid-parent heterosis revealed the range of -16.22 to 25.81, -23.71 to 27.43, -23.88 to 41.84 and -14.20 to 24.53 in E_1, E_2, E_3 and pooled analysis, respectively. Among hybrids, L_2 x T_2 (14.26), L_3 x T_1 (17.15), L_4 x T_1 (13.17), L_5 x T_1 (13.23), L_9 × T_3 (25.81), L_{13} × T_3 (19.48) and L_{16} × T_2 (13.19) in **E_1**; L_5 x T_1 (19.48), L_9 x T_1 (27.43), L_9 x T_3 (14.63), L_{10} x T_2 (23.55), L_{12} x T_1 (20.81), L_{12} x T_3 (17.50), L_{17} x T_3 (27.33), L_{18} x T_3 (25.82) and L_{21} × T_1 (17.00) in **E_2**; ; L_5 x T_1 (20.59), L_6 x T_3 (18.07), L_{11} x T_2 (14.62), L_{13} x T_2 (30.67), L_{14} x T_2 (20.17), L_{14} x T_3 (25.13), L_{18} x T_1 (18.66), L_{19} x T_1 (26.69), L_{20} x T_1 (41.84) and L_{21} × T_3 (14.62) in **E_3**; and L_4 × T_3 (24.53), L_5 x T_1 (16.10) L_{15} x T_1 (13.71) and L_{15} x T_2 (14.47) in the pooled analysis showed high mid-parent heterosis for 100-kernel weight.

The magnitude of standard heterosis ranged from -14.31 to 15.88, -25.58 to 42.47, -27.76 to 33.79 and -11.64 to 15.71 in E_1, E_2,

E_3 and for pooled analysis, respectively. The most heterotic cross combinations for 100-kernel weight were $L_3 \times T_1$ (15.63), L_5 x T_1 (15.71), L_9 x T_3 (15.88) and L_{13} x T_3 (12.93) in **E_1**; L_1 x T_3 (27.29), L_2 x T_3 (18.71), L_4 x T_3 (36.28), L_5 x T_1 (24.69), $L_5 \times T_2$ (19.94), $L_9 \times T_1$ (30.43), L_9 x T_3 (27.99), L_{10} x T_2 (23.07), L_{11} x T_2 (18.56), L_{11} x T_3 (22.79), $L_{12} \times T_1$ (39.43), $L_{12} \times T_3$ (24.82), L_{13} x T_1 (20.98), L_{14} x T_2 (22.03), L_{15} x T_1 (21.89), L_{15} x T_2 (20.88), $L_{17} \times T_3$ (42.47), $L_{18} \times T_1$ (18.08), $L_{18} \times T_3$ (29.72), $L_{19} \times T_3$ (18.72), $L_{20} \times T_3$ (18.37) , $L_{21} \times T_1$ (32.57) and $L_{21} \times T_3$ (18.56) in **E_2**; L_5 x T_1 (17.87), L_6 x T_3 (17.25), L_{13} x T_2 (25.06), L_{18} x T_1 (21.36), $L_{19} \times T_1$ (33.79) and $L_{20} \times T_1$ (24.57) in **E_3** and $L_4 \times T_3$ (15.71), L_5 x T_1 (11.35), L_9 x T_3 (22.61), L_{15} x T_1 (11.17) and $L_{18} \times T_3$ (11.16) in the pooled analysis.

On the basis of study for all environments, 2 cross for BP, 1 for MP and 1 for CP showed positive and significant heterosis. However, cross $L_5 \times T_1$ exhibited significantly positive heterosis (BP, CP and MP) in all the environments.

4.2.4 Ear length (cm)

The nature and magnitude of per cent heterobeltiosis, relative heterosis and standard heterosis among hybrids for ear length are presented in Table 4.2.4The range of heterobeltiosis or in each of the environments and pooled over environments wase -19.49 to 42.17, -22.84 to 30.60, -14.52 to 56.26 and -6.36 to 20.92 in E_1, E_2, E_3 and across the environments, respectively. The results of heterobeltiosis revealed that $L_3 \times T_1$ (16.34), $L_4 \times T_1$ (47.17), $L_4 \times T_2$(31.70), $L_4 \times T_3$

Table 4.2.4: Estimation of heterosis (%) over better-, mid- and check- parent in three environments 7 (E_1, E_2, E_3)

Cross	Ear length (cm)											
	Normal			Low nitrogen			Excess soil moisture			Pooled		
	BP	MP	CP	BP	MP	CP	BP	MP	CP	BP	MP	CP
$L_1 \times T_1$	6.19	6.62	10.25	28.91**	22.09**	2.40	6.08	8.50	-20.94**	11.05	11.82	-10.42 **
$L_1 \times T_2$	-9.36	-4.11	-23.40**	29.45**	15.87**	2.83	-14.52	-19.78**	36.30**	-6.36	-3.31	-20.50 **
$L_1 \times T_3$	-13.36	-7.96	-26.78**	7.62	1.93	-14.50*	15.90*	10.59	-13.63 *	0.43	1.32	-18.67 **
$L_2 \times T_1$	-6.97	-3.90	-16.68**	10.43	10.97	-1.51	.65	7.97	-17.08**	0.64	4.40	-12.52
$L_2 \times T_2$	.20	8.90	-10.25	7.54	2.45	-4.09	4.42	3.22	-13.97 *	3.75	4.97	-9.82
$L_2 \times T_3$	5.84	15.49 *	-5.20	9.95	10.48	-1.94	4.42	4.87	-13.97 *	6.57	10.34	-7.37
$L_3 \times T_1$	16.34*	23.61**	15.30**	14.84 *	16.24**	4.54	17.68*	23.83**	-6.96	12.61	14.09 *	-6.74
$L_3 \times T_2$	.54	2.83	-20.35**	.67	-3.42	-8.44	2.18	-1.09	-19.25**	-1.74	-0.52	-16.57 **
$L_3 \times T_3$	12.68	16.32 *	-10.25	14.18*	16.24**	4.54	-8.80	-10.29	-27.96**	5.94	7.13	-12.27
$L_4 \times T_1$	42.17**	23.49**	-8.58	29.03**	24.78**	6.68	-11.73	-2.61	-22.60**	12.56	14.65 *	-9.21
$L_4 \times T_2$	31.70**	21.37**	-15.33**	2.88	-5.86	-14.93 *	-3.78	-1.92	-15.77**	-0.28	4.12	-15.34 **
$L_4 \times T_3$	30.60**	20.93**	-16.00**	30.60**	26.30**	7.98	5.35	9.05	-7.69	15.74 *	18.12 **	-6.28
$L_5 \times T_1$	.65	-2.89	-20.85**	-13.17 *	-8.45	-14.5 *	38.38**	30.68**	-11.85*	4.27	5.23	-15.89 **
$L_5 \times T_2$	21.66**	23.18**	20.34**	20.20**	20.04**	28.42**	40.54**	20.99**	18.47**	-2.45	0.94	-17.18 **
$L_5 \times T_3$	5.31	8.42	-16.67**	-4.39	.81	-5.84	16.46	2.06	-25.81**	2.73	3.87	-16.81 **
$L_6 \times T_1$	9.24	4.08	-16.64**	-5.91	1.03	-3.65	-2.96	.47	25.82**	0.07	1.94	-16.21 **
$L_6 \times T_2$	9.49	8.88	30.96**	-22.84**	-21.17**	-20.99**	-2.96	-7.70	25.82**	13.23	12.64	26.34 **
$L_6 \times T_3$	2.62	3.76	-21.7**	-14.9**	-8.63	-12.87 *	3.88	.44	-20.59**	-3.06	-1.43	-18.82 **
$L_7 \times T_1$	-5.35	-4.98	-20.0**	7.05	5.59	-8.00	-3.96	3.19	-20.59**	-1.29	0.87	-16.81 **
$L_7 \times T_2$	-15.33*	-10.43	-28.51**	17.10 *	9.38	.62	.27	-0.69	-17.08**	-1.30	-0.94	-16.21 **
$L_7 \times T_3$	14.54*	21.68**	-3.19	17.10 *	15.5**	.62	-8.21	-7.64	-24.10**	7.43	9.57	-9.47
$L_8 \times T_1$	-5.34	-10.24	-28.45**	-11.25	-7.39	-14.50 *	8.76	14.69*	-13.63 *	-2.54	-1.25	-19.28 **
$L_8 \times T_2$	-3.14	-2.92	-26.78**	-6.74	-7.56	-10.15	8.76	5.52	-13.63*	-2.75	-1.55	-17.44 **
$L_8 \times T_3$	7.55	6.93	30.11**	-7.88	-3.88	-11.25	-8.76	-10.05	-27.55**	8.07	7.04	23.87 **
$L_9 \times T_1$	7.22	.96	-20.01**	.50	-1.37	-14.52 *	5.22	7.12	-22.32**	0.09	2.23	-19.26 **
$L_9 \times T_2$	7.22	6.75	-20.01**	8.14	.47	-8.00	-8.96	-14.98 *	32.79**	-7.07	-2.71	-21.10 **
$L_9 \times T_3$	8.62	8.6	31.83**	15.77 *	13.60 *	-1.51	7.56	2.13	-20.59**	-0.32	2.00	-19.28 **
$L_{10} \times T_1$	.58	3.90	-9.91	-9.59	-6.49	-14.52 *	5.18	9.38	-18.86**	-1.13	2.39	-14.36 *
$L_{10} \times T_2$	-14.44 *	-7.04	-23.41**	15.60 *	13.51**	9.329	5.18	.519	-18.86**	1.00	2.01	-12.52
$L_{10} \times T_3$	-12.61	-4.64	-21.74**	-2.72	.604	-8.00	7.48	4.4	-17.08**	-3.25	2.67	-16.21 **

Table 4.2.4: Contd.....

$L_{11} \times T_1$	18.64*	15.46 *	-5.72	6.55	8.98	-1.51	18.75 *	23.50**	-8.39	15.66 *	17.13 **	-6.70
$L_{11} \times T_2$	19.49**	17.30**	36.02**	4.23	1.15	-3.65	-6.08	-10.24	-27.5**	15.40 *	12.16	28.18 **
$L_{11} \times T_3$	21.82**	25.66**	-3.19	22.92**	25.72**	13.61*	19.72*	6.59	-15.35**	20.92 **	22.70 **	-2.08
$L_{12} \times T_1$	-6.3	-6.00	-20.87**	-3.84	.87	-8.00	1.85	4.16	-24.10**	5.75	8.00	-10.99
$L_{12} \times T_2$	-1.41	4.29	-16.68**	-6.08	-7.24	-10.15	29.95**	21.95**	-3.15	-2.02	-1.59	-16.81 **
$L_{12} \times T_3$	26.49**	34.37**	6.90	23.30**	28.23**	17.96**	-0.46	-5.02	-25.82**	19.98 **	22.29 **	0.98
$L_{13} \times T_1$	19.90 **	12.76 *	-10.77	15.22*	14.38**	4.97	30.92**	21.84**	-18.86**	5.78	5.90	-14.68 *
$L_{13} \times T_2$	32.33**	31.58**	-1.53	3.40	1.90	-1.51	56.26**	32.41**	-3.15	12.43	15.43 *	-4.55
$L_{13} \times T_3$	30.09**	29.9**	-3.19	14.79 *	19.12**	9.32	36.58**	17.84**	-15.35**	17.13 *	17.49 **	-5.16
$L_{14} \times T_1$	.54	4.50	-8.24	5.22	7.12	-3.65	33.62**	28.52**	-11.85*	11.55	12.65	-8.23
$L_{14} \times T_2$	-11.00	-2.21	-18.35**	4.01	.45	-4.76	36.24**	19.62**	-10.12	8.09	9.79	-8.23
$L_{14} \times T_3$	-2.75	7.27	-10.77	10.63	12.6 *	1.29	38.33**	23.61**	-8.74	13.43	14.33 *	-6.69
$L_{15} \times T_1$	25.23**	17.92**	-6.58	.45	4.59	-3.65	13.25	11.13	-22.32**	14.54 *	17.67 **	-7.61
$L_{15} \times T_2$	-0.70	-1.13	-25.92**	-4.08	-5.14	-8.00	8.14	-2.96	-25.82**	0.87	6.20	-14.36 *
$L_{15} \times T_3$	13.54	13.54*	-15.30**	-1.85	2.19	-5.86	25.92**	14.95*	-13.63*	13.26	16.57 *	-8.29
$L_{16} \times T_1$	-8.63	-8.63	-23.40**	-9.43	-7.79	-17.07**	-4.75	-3.03	29.68**	0.83	1.60	-17.42 **
$L_{16} \times T_2$	-6.64	-1.60	-21.73**	-3.07	-6.39	-11.25	9.90	2.62	-18.86**	-4.92	-3.21	-19.28 **
$L_{16} \times T_3$	3.41	9.44	-13.30 *	-10.16	-8.54	-17.74**	14.65	8.86	-15.35**	8.30	8.91	-11.31 **
$L_{17} \times T_1$	-16.08*	-13.62*	-25.40**	-5.29	-2.48	-11.25	14.38*	22.16**	-6.61	10.55	8.55	24.55 **
$L_{17} \times T_2$	-8.14	-0.51	-18.35**	5.10	2.72	-1.51	16.45*	14.61*	-4.88	-1.67	-1.35	-16.52 **
$L_{17} \times T_3$	-10.01	-2.15	-20.01**	2.35	5.38	-4.09	-11.73	-11.73	27.90**	-2.47	-0.48	-17.73 **
$L_{18} \times T_1$	-10.16	-12.40 *	-28.45**	9.33	11.31*	.10	3.88	7.56	-20.59**	-0.28	1.94	-15.89 **
$L_{18} \times T_2$	27.88**	31.50**	1.85	12.31	8.47	2.83	10.73	5.32	-15.35**	16.05 *	16.43*	-1.47
$L_{18} \times T_3$	12.68	16.37 *	-10.25	-7.09	-5.41	-14.93*	8.01	4.43	-17.43**	1.11	3.17	-14.71 *
$L_{19} \times T_1$	36.24**	17.58**	-13.30 *	8.60	8.60	-4.09	4.75	6.64	-22.67**	9.02	12.22	-12.06
$L_{19} \times T_2$	36.24**	24.84**	-13.30 *	-3.67	-8.71	-14.93*	-4.75	-11.06	29.68**	6.66	12.52	-9.45
$L_{19} \times T_3$	25.15**	15.2 *	-20.35**	6.10	6.10	-6.29	-2.34	-7.27	27.90**	1.52	4.70	-17.79 **
$L_{20} \times T_1$	7.50	4.16	-15.30**	-3.43	-7.12	-20.99**	44.18**	38.67**	-4.88	5.73	6.34	-14.71 *
$L_{20} \times T_2$	-5.32	-3.14	-25.40**	20.37**	9.50	-1.51	28.30**	12.66	-15.35**	10.41	7.61	23.94 **
$L_{20} \times T_3$	7.50	10.43	-15.30**	7.11	3.02	-12.35 *	16.40	4.01	-23.21**	2.27	3.06	-17.18 **
$L_{21} \times T_1$	13.68	8.30	-13.30*	6.55	8.98	-1.51	18.75*	23.50**	-8.39	8.45	12.96	-12.52
$L_{21} \times T_2$	16.99*	17.77**	-10.77	4.23	1.15	-3.65	-6.08	-10.24	-27.55**	6.29	13.43	-9.76
$L_{21} \times T_3$	9.24	10.45	-16.68**	22.92**	25.72**	13.61 *	9.72	6.59	-15.35**	1.57	5.99	-17.75 **

*,** Significant at 5% and 1 % probability levels , respectively.

(30.60), $L_5 \times T_2$ (21.66), $L_7 \times T_3$ (14.54), $L_{11} \times T_1$ (18.64), $L_{11} \times T_2$ (19.49), $L_{11} \times T_3$ (21.82), $L_{12} \times T_3$ (26.49), $L_{13} \times T_1$ (19.90), $L_{13} \times T_2$ (32.33), $L_{13} \times T_2$ (32.33), $L_{13} \times T_3$ (30.09), $L_{15} \times T_1$ (25.23), $L_{18} \times T_2$ (27.88), $L_{19} \times T_1$ (36.24), $L_{19} \times T_2$ (36.24), $L_{19} \times T_3$ (25.15) and $L_{21} \times T_2$ (16.99), in $\mathbf{E_1}$; $L_1 \times T_1$ (28.91), $L_1 \times T_2$ (29.45), $L_3 \times T_1$ (14.84), $L_3 \times T_3$ (14.18), $L_4 \times T_1$ (29.03), $L_4 \times T_3$ (30.60), $L_5 \times T_2$ (20.20), $L_7 \times T_2$ (17.10), $L_7 \times T_3$ (17.10), $L_9 \times T_3$ (15.77), $L_{10} \times T_2$ (15.60), $L_{11} \times T_3$ (22.92), $L_{12} \times T_3$ (23.30), $L_{13} \times T_1$ (15.22), $L_{13} \times T_3$ (14.79), $L_{20} \times T_2$ (20.37) and $L_{21} \times T_3$ (22.92) in $\mathbf{E_2}$; $L_1 \times T_3$ (15.90), $L_3 \times T_1$ (17.68), $L_5 \times T_1$ (38.38), $L_5 \times T_2$ (40.54), $L_{11} \times T_1$ (18.75), $L_{11} \times T_3$ (19.72), $L_{12} \times T_2$ (29.95), $L_{13} \times T_1$ (30.92), $L_{13} \times T_2$ (56.26), $L_{13} \times T_3$ (36.58), $L_{14} \times T_1$ (33.62), $L_{14} \times T_2$ (36.24), $L_{14} \times T_3$ (38.33), $L_{15} \times T_3$ (25.92), $L_{17} \times T_1$ (14.38), $L_{17} \times T_2$ (16.45), $L_{20} \times T_1$ (44.18), $L_{20} \times T_2$ (28.30) and $L_{21} \times T_1$ (18.75) in $\mathbf{E_3}$; and $L_4 \times T_3$ (15.74), $L_{11} \times T_1$ (15.66), $L_{11} \times T_2$ (15.40), $L_{11} \times T_3$ (20.92), $L_{12} \times T_3$ (19.98), $L_{13} \times T_3$ (17.13), $L_{15} \times T_1$ (14.54) and $L_{18} \times T_2$ (16.05) across the environments showed higher estimates of heterosis for ear length.

Estimates of relative heterosis ranged from -17.30 to 34.37 in E_1; -21.17 to 28.23 in E_2; -19.78 to 38.67 in E_3; and -3.31 to 22.70 in pooled analysis over environments, respectively. Among the hybrids most heterotic combinations for ear length were $L_2 \times T_3$ (15.49), $L_3 \times T_1$ (23.61), $L_4 \times T_1$ (23.49), $L_4 \times T_2$(21.37), $L_4 \times T_3$ (20.93), $L_5 \times T_2$ (23.18), $L_7 \times T_3$ (21.68), $L_{11} \times T_1$ (15.46), $L_{11} \times T_2$ (17.30), $L_{11} \times T_3$ (25.66), $L_{12} \times T_3$ (34.37), $L_{13} \times T_1$ (12.76), $L_{13} \times T_2$ (31.58), $L_{13} \times T_3$ (29.9) (30.09), $L_{15} \times T_1$ (17.92), $L_{15} \times T_3$ (13.54), $L_{18} \times T_2$ (31.50), $L_{18} \times T_3$ (16.37), $L_{19} \times T_1$

(17.58), $L_{19} \times T_2$ (24.84), $L_{19} \times T_3$ (15.20) and $L_{21} \times T_2$ (17.77) in **E_1**; $L_1 \times T_1$ (22.09), $L_1 \times T_2$ (15.87), $L_3 \times T_1$ (16.24), $L_3 \times T_3$ (16.24), $L_4 \times T_1$ (24.78), $L_4 \times T_3$ (26.30), $L_5 \times T_2$ (20.04), $L_7 \times T_3$ (15.50), $L_9 \times T_3$ (13.60), $L_{10} \times T_2$ (13.51), $L_{11} \times T_3$ (25.72), $L_{12} \times T_3$ (23.28), $L_{13} \times T_1$ (14.38), $L_{13} \times T_3$ (19.12), $L_{14} \times T_3$ (12.6), $L_{18} \times T_1$ (11.31) and $L_{21} \times T_3$ (25.72) in **E_2**; $L_3 \times T_1$ (23.83), $L_5 \times T_1$ (30.68), $L_5 \times T_2$ (20.99), $L_8 \times T_1$ (14.69), $L_{11} \times T_1$ (23.50), $L_{12} \times T_2$ (21.95), $L_{13} \times T_1$ (21.84), $L_{13} \times T_2$ (32.41), $L_{13} \times T_3$ (17.84), $L_{14} \times T_1$ (28.52), $L_{14} \times T_2$ (19.64), $L_{14} \times T_3$ (23.61), $L_{15} \times T_3$ (14.95), $L_{17} \times T_1$ (22.16), $L_{17} \times T_2$ (14.61), $L_{20} \times T_1$ (38.67), and $L_{21} \times T_1$ (23.50) in **E_3**; and $L_3 \times T_1$ (14.09), $L_4 \times T_1$ (14.65), $L_4 \times T_3$ (18.12), $L_{11} \times T_1$ (17.13), $L_{11} \times T_3$ (20.70), $L_{12} \times T_3$ (22.29), $L_{13} \times T_2$ (15.43), $L_{13} \times T_3$ (17.49), $L_{14} \times T_3$ (14.33), $L_{15} \times T_1$ (17.67), $L_{15} \times T_3$ (16.57) and $L_{18} \times T_2$ (16.43) in pooled analysis, respectively.

Standard heterosis ranged from -28.51 to 36.02, -20.99 to 28.42, -27.96 to 36.30 and -19.28 to 28.18 in E_1, E_2, E_3 and in pooled analysis, respectively. Cross combinations, $L_3 \times T_1$ (15.30), $L_5 \times T_2$ (20.34), $L_6 \times T_2$ (30.96), $L_8 \times T_3$ (30.11), $L_9 \times T_3$ (31.83) and $L_{11} \times T_2$ (36.02) in **E_1**; $L_5 \times T_2$ (28.42), $L_{11} \times T_3$ (13.61), $L_{12} \times T_3$ (17.96) and $L_{21} \times T_3$ (13.61) in **E_2**; $L_1 \times T_2$ (36.30), $L_5 \times T_2$ (18.47), $L_6 \times T_1$ (25.82), $L_6 \times T_2$ (25.82), $L_9 \times T_2$ (32.79), $L_{16} \times T_1$ (29.68), $L_{17} \times T_3$ (27.90), $L_{19} \times T_2$ (29.68) and $L_{19} \times T_3$ (27.90) in **E_3**; $L_6 \times T_2$ (26.34), $L_8 \times T_3$ (23.87), $L_{11} \times T_2$ (28.18), $L_{17} \times T_1$ (24.55) and $L_{20} \times T_2$ (23.94) in the pooled analysis exhibited maximum positive heterosis over check.

On the basis of study for all environments, 5 crosses, $L_3 \times T_1$, $L_5 \times T_2$, $L_{11} \times T_3$, $L_{13} \times T_1$ and $L_{13} \times T_3$ for BP, 4 crosses, $L_3 \times T_1$, $L_5 \times T_2$, $L_{13} \times T_1$

and $L_{13} \times T_3$ for MP and $L_5 \times T_2$ for CP showed positive and significant heterosis for this trait. However, cross $L_5 \times T_2$ exhibited significantly positive heterosis (BP, CP and MP) in all the environments.

4.2.5 Ear diameter (cm)

The estimates of per cent heterobeltiosis, relative heterosis and standard heterosis for ear diameter are given in Table 4.2.5. The estimates of heterobeltiosis ranged from –36.75 to 69.91, -27.90 to 36.08, -13.38 to 29.63 and -17.22 to 27.15 in E_1, E_2, E_3 and in pooled analysis across environments, respectively. Some of the most promising hybrids with significant higher estimates of heterosis for ear diameter were $L_1 \times T_1$ (30.43), $L_3 \times T_1$ (30.43), $L_{11} \times T_1$ (29.01) and $L_{21} \times T_3$ (69.91) in **E_1**; $L_1 \times T_1$ (17.85), $L_3 \times T_1$ (34.21), $L_3 \times T_2$ (15.78), $L_4 \times T_1$ (36.08), $L_4 \times T_2$ (26.80) $L_4 \times T_3$ (26.80), $L_5 \times T_2$ (19.82), $L_5 \times T_3$ (16.37), $L_{10} \times T_1$ (17.92), $L_{10} \times T_3$ (32.07) $L_{11} \times T_1$ (25.00), $L_{11} \times T_3$(19.64), $L_{12} \times T_1$ (28.86), $L_{12} \times T_2$ (28.86), $L_{12} \times T_3$ (28.86) $L_{14} \times T_2$ (22.54), $L_{15} \times T_1$ (18.69), $L_{18} \times T_1$ (34.40), $L_{18} \times T_2$ (24.73), $L_{18} \times T_3$ (32.25) and $L_{21} \times T_1$ (25.00) in **E_2**; $L_5 \times T_1$ (27.27), $L_5 \times T_2$ (20.00), $L_9 \times T_1$ (21.29), $L_9 \times T_2$ (22.33), $L_{10} \times T_1$ (14.90), $L_{11} \times T_1$ (21.19), $L_{14} \times T_1$ (21.29), $L_{16} \times T_3$ (18.69), $L_{17} \times T_2$ (16.66), $L_{21} \times T_1$ (29.63) and $L_{20} \times T_2$ (22.63) in **E_3**; and $L_{17} \times T_1$ (27.15) and $L_{21} \times T_3$ (17.69) across the environments.

The magnitude of mid-parent heterosis for ear diameter ranged from -25.59 to 69.99, -26.19 to 29.11, -16.61 to 21.21 and -13.21 to 24.90 in E_1, E_2, E_3 and over environments, respectively.

Table 4.2.5: Estimation of heterosis (%) over better-, mid- and check- parent in three environments 11 (E_1, E_2, E_3)

Cross	Ear width (cm)											
	Normal			Low nitrogen			Excess soil moisture			Pooled		
	BP	MP	CP	BP	MP	CP	BP	MP	CP	BP	MP	CP
$L_1 \times T_1$	30.43**	-13.77	4.34	17.85*	12.34	7.31	-7.51	-3.90	.78	-11.92	-3.27	3.91
$L_1 \times T_2$	-9.42	-5.66	-9.42	3.57	5.45	-5.69	-1.50	-8.39	6.50	-6.77	-3.50	-3.13
$L_1 \times T_3$	26.01	24.00	12.31	-7.14	-13.69*	-15.47 *	.75	-1.10	8.94	0.77	3.15	2.34
$L_2 \times T_1$	2.51	31.8**	-13.76	-6.01	-2.34	1.62	-7.74	-1.13	6.50	-17.22 *	-13.79 *	-2.34
$L_2 \times T_2$	-6.52	-7.85	-6.52	-7.51	2.07	.45	-13.38*	-16.61**	.97	-10.07	-8.09	-2.34
$L_2 \times T_3$	12.19	4.15	.67	-0.75	.76	7.31	-2.81	-1.42	12.19	-2.16	1.12	6.25
$L_3 \times T_1$	30.43**	-14.28	4.34	34.21**	29.11**	24.39**	-10.87	-5.74	.56	-7.28	0.72	19.45**
$L_3 \times T_2$	.56	3.37	.87	15.78*	18.91**	7.31	-4.34	-9.27	7.31	0.75	3.08	4.69
$L_3 \times T_3$	4.87	2.38	-6.52	7.89	1.23	.67	10.87	10.87	24.39**	3.85	5.06	5.47
$L_4 \times T_1$	3.33	-17.36	.89	36.08**	28.00**	7.56	-7.04	-0.37	7.31	-11.26	-1.83	4.69
$L_4 \times T_2$	-4.34	-0.37	-4.34	26.80**	20.00**	.56	-13.38*	-16.61**	.78	-5.26	-1.18	-1.56
$L_4 \times T_3$	.77	-1.60	-10.87	26.80**	8.85	.98	-2.81	-1.42	12.19	-1.54	1.59	0.67
$L_5 \times T_1$	9.64	-24.69*	-9.42	7.75	4.60	1.62	27.27**	20.12**	13.82	-13.91	-2.99	1.56
$L_5 \times T_2$	-6.52	-1.90	-6.52	19.82*	16.96*	24.39**	20.00*	.38	7.31	-11.28	-5.60	-7.81
$L_5 \times T_3$	4.87	4.03	-6.52	16.37*	10.20	9.75	17.27*	4.03	4.87	0.77	6.07	2.34
$L_6 \times T_1$	-9.61	-24.24*	-9.42	1.62	1.62	1.62	8.94	8.94	8.94	-15.23 *	-6.57	0.89
$L_6 \times T_2$	-24.63	-20.30	-24.63	-10.56	-4.76	-10.56	1.62	-9.42	1.62	-15.04 *	-11.72	-11.72
$L_6 \times T_3$	1.62	1.62	-9.42	-10.56	-12.69*	-10.59	-3.25	-8.81	-3.25	-9.23	-6.72	-7.81
$L_7 \times T_1$	-35.26**	-19.7*	-2.89	-1.57	.87	1.62	-11.97	-5.66	1.62	-15.23 *	-9.54	0.56
$L_7 \times T_2$	-9.42	-5.66	-9.42	-18.11 *	-11.48	-15.44 *	-7.74	-11.16 *	6.50	-9.77	-9.43	-6.25
$L_7 \times T_3$	6.50	4.80	-5.07	-1.57	-2.34	1.62	-3.09	-2.13	-2.74	-11.36	-10.69	-8.59
$L_8 \times T_1$	-9.46	-15.85	5.79	-4.58	-1.57	1.62	7.20	8.06	8.94	-10.60	-4.59	5.47
$L_8 \times T_2$	-9.42	-10.07	-9.42	-27.48**	-20.50**	-22.76**	.89	-10.07	1.62	-13.53	-13.21 *	-10.16
$L_8 \times T_3$	1.62	-4.94	-9.42	-20.61**	-20.00**	-15.44 *	-7.20	-11.78	-5.69	-12.88	-12.21	-10.16
$L_9 \times T_1$	-8.01	-9.69	7.97	1.62	1.62	1.62	21.29**	13.42	6.50	-10.60	0.37	5.47
$L_9 \times T_2$	5.79	11.87	5.79	8.94	16.01 *	8.94	22.33**	7.28	13.82	5.26	11.55	19.38**
$L_9 \times T_3$	1.62	1.62	-9.4	1.62	-0.79	1.62	15.74	1.62	1.62	-3.85	0.81	-2.34
$L_{10} \times T_1$	-29.46**	-16.3	5.79	17.92 *	9.17	1.62	14.9*	16.80**	18.69 *	-7.95	0.72	8.59
$L_{10} \times T_2$	1.44	.65	1.44	12.26	11.21	-3.25	-1.57	-10.71	1.62	-3.76	-0.78	0.78
$L_{10} \times T_3$	13.82	5.66	1.44	32.07**	19.14**	13.82	10.23	5.66	13.82	7.69	9.80	9.38

Table 4.2.5: Contd....

$L_{11} \times T_1$	29.01*	-10.77	7.97	25.00**	19.14**	13.82	21.19**	-4.80	-3.25	-10.60	-1.82	5.47
$L_{11} \times T_2$	-9.42	-5.66	-9.42	11.60	13.63	1.62	-1.57	-10.71	1.62	-7.52	-4.28	-3.91
$L_{11} \times T_3$	-3.25	-4.80	-13.76	19.64*	11.20	8.94	3.15	-1.13	6.50	-5.38	-3.15	-3.91
$L_{12} \times T_1$	-9.61	-25.15*	-9.42	28.86**	13.63	1.62	-1.57	0.76	1.62	-15.23 *	-6.23	0.89
$L_{12} \times T_2$	-9.42	-5.66	-9.420	28.86**	21.95**	1.62	5.51	-4.28	8.94	-6.02	-1.96	-2.37
$L_{12} \times T_3$	26.01	24.00	12.31	28.86**	10.61	1.62	-8.6	-12.45*	-5.69	7.69	11.11	9.38
$L_{13} \times T_1$	-3.36	-13.84	1.44	-6.71	-2.72	1.62	2.29	5.51	8.94	-13.91	-1.89	1.56
$L_{13} \times T_2$	-5.07	2.34	-5.07	-6.71	3.30	1.62	-4.58	-11.97*	1.62	-2.26	5.26	1.56
$L_{13} \times T_3$	13.82	16.18	1.44	-6.71	-4.94	1.62	-4.58	-7.06	1.62	-2.31	4.10	-0.78
$L_{14} \times T_1$	-2.3	-19.30 *	1.44	13.72	3.11	-5.69	21.29**	13.4	6.50	-11.92	-6.99	3.91
$L_{14} \times T_2$	1.44	19.71*	1.44	22.54*	19.04*	1.62	13.70	20.30**	-15.44*	-3.70	-2.99	1.56
$L_{14} \times T_3$	26.01	17.87	12.31	11.76	-1.29	-7.31	13.88	0.95	0.86	0.78	1.89	5.47
$L_{15} \times T_1$	-6.7	-20.66 *	-5.07	18.69*	18.69**	18.69*	-5.69	-5.69	-5.69	-16.56 *	-3.82	-1.56
$L_{15} \times T_2$	-9.42	-4.21	-9.42	8.94	16.01*	8.94	1.62	-9.42	1.62	-11.28	-3.28	-7.81
$L_{15} \times T_3$	-4.878	-4.87	-15.21	1.62	-0.79	1.62	8.94	2.68	8.94	-9.23	-2.07	-7.81
$L_{16} \times T_1$	-35.26**	-18.78	-2.89	-27.90**	-26.19**	-18.39*	0.87	0.68	0.57	-12.58	-3.65	3.13
$L_{16} \times T_2$	12.31	18.77	12.31	-14.72*	-7.17	-10.56	1.62	-9.42	1.62	3.76	7.81	7.81
$L_{16} \times T_3$	1.62	1.62	-9.42	1.55	1.55	6.50	18.69*	11.87	18.69*	-1.54	1.19	0.45
$L_{17} \times T_1$	4.92	33.91**	27.39*	-5.69	-5.69	-5.69	-5.07	.38	6.50	27.15 **	21.71 **	14.06
$L_{17} \times T_2$	-9.42	-9.42	-9.42	-3.25	3.03	-3.25	16.66*	10.65	30.89**	-9.77	-8.75	-6.25
$L_{17} \times T_3$	1.62	-4.21	-9.42	-7.31	-9.52	-7.31	-6.52	-6.52	4.87	3.08	3.08	4.69
$L_{18} \times T_1$	-9.61	-25.59*	-9.42	34.40**	15.74*	1.62	1.62	1.62	1.62	-17.88 *	-11.74	-3.13
$L_{18} \times T_2$	-5.07	-1.87	-5.07	24.73*	15.42*	-5.69	13.8	1.44	13.82	3.01	4.18	7.03
$L_{18} \times T_3$	0.56	-2.38	-10.87	32.25**	10.81	0.98	-4.87	-10.34	-4.87	-6.15	-6.15	-4.69
$L_{19} \times T_1$	-9.61	-19.09	-9.42	-4.65	-2.38	0.56	4.87	4.87	4.87	-17.22 *	-2.72	-2.34
$L_{19} \times T_2$	-2.8	11.66	-2.89	-4.65	3.79	0.87	4.87	-6.52	4.87	-2.26	8.79	1.56
$L_{19} \times T_3$	-4.87	4.0	-15.21	-4.65	-4.65	0.89	0.96	-5.74	0.84	-8.46	0.85	-7.03
$L_{20} \times T_1$	-4.58	-25.45 *	-10.87	14.91	10.54	6.50	29.63**	21.21**	13.82	-17.22 *	-9.42	-2.34
$L_{20} \times T_2$	-6.52	-1.14	-6.52	1.75	4.50	-5.69	22.63**	7.28	13.82	-4.51	-1.55	-0.78
$L_{20} \times T_3$	0.67	0.87	-10.87	9.64	2.88	1.62	15.74	1.62	1.62	-5.38	-3.53	-3.91
$L_{21} \times T_1$	-36.75**	-20.66 *	-5.07	25.00**	19.14**	13.82	-6.29	-4.80	-3.25	-11.26	0.75	4.69
$L_{21} \times T_2$	-9.42	-4.21	-9.42	11.60	13.63	1.62	-1.57	-10.71	1.62	-4.51	2.42	-0.78
$L_{21} \times T_3$	69.91**	69.99**	51.44**	-3.50	-7.56	-10.56	-1.63	-4.00	8.10	17.69 *	24.90 **	19.53

*,** Significant at 5% and 1 % probability levels , respectively.

The most heterotic cross combinations for positive and significant relative heterosis were $L_2 \times T_1$ (31.80) $L_{14} \times T_2$ (19.71, $L_{17} \times T_1$ (33.91) and $L_{21} \times T_3$ (69.99) in **E_1**; $L_3 \times T_1$ (29.11), $L_3 \times T_2$ (18.91), $L_4 \times T_1$ (28.00), $L_4 \times T_2$ (20.00), $L_5 \times T_2$ (16.96), $L_9 \times T_2$ (16.01), $L_{10} \times T_3$ (19.14) $L_{11} \times T_1$ (19.14), $L_{12} \times T_2$ (21.95), $L_{14} \times T_2$ (19.04), $L_{15} \times T_1$ (18.69), $L_{15} \times T_2$ (16.01), $L_{18} \times T_1$ (15.74), $L_{18} \times T_2$ (15.42) and $L_{21} \times T_1$ (19.14) in **E_2**; $L_5 \times T_1$ (20.12), $L_{10} \times T_1$ (16.80), $L_{14} \times T_2$ (20.30) and $L_{20} \times T_1$ (21.21) in **E_3**; and $L_{17} \times T_1$ (21.71) and $L_{21} \times T_3$ (24.90) in the pooled analysis.

The magnitudes of standard heterosis ranged from -24.63 to 51.44 in E_1; -18.39 to 24.39 in E_2; -15.44 to 30.89 in E_3; and -11.72 to 19.45 in the pooled analysis. The highest check parent heterosis was observed in cross, $L_{21} \times T_3$ (51.44) followed by $L_{17} \times T_1$ (27.39) in **E_1**; $L_3 \times T_1$ (24.39), $L_5 \times T_2$ (24.39) followed by $L_{15} \times T_1$ (18.69) in **E_2**; and $L_{17} \times T_2$ (30.89) followed by $L_3 \times T_3$ (24.39), $L_{10} \times T_1$ (18.69) and $L_{16} \times T_3$ (18.69) in **E_3** and $L_3 \times T_1$ (19.45) followed by $L_9 \times T_2$ (19.38) in the pooled analysis.

On the basis of study for all environments, the cross $L_{11} \times T_1$ for BP showed positive and significant heterosis. However, none of the hybrid exhibited significantly positive heterosis (BP, CP and MP) in all the environments.

4.2.6 Number of kernel-rows per ear

The nature and per cent magnitude of heterobeltiosis, relative heterosis and standard heterosis for number of kernel rowsperear are presented in Table 4.2.6. The range of heterobeltiosis in E_1, E_2, E_3 and

Table 4.2.6: Estimation of heterosis (%) over better-, mid- and check- parent in three environments 15 (E_1, E_2, E_3)

Cross	Number of kernel rows/ ear											
	Normal			Low nitrogen			Excess soil moisture			Pooled		
	BP	MP	CP	BP	MP	CP	BP	MP	CP	BP	MP	CP
$L_1 \times T_1$	9.78	0.09	-4.75	15.25**	9.88	5.22	-14.98*	-14.58*	-18.24**	-5.93	-1.94	-6.31
$L_1 \times T_2$	15.80*	7.59	0.47	-0.545	-5.1	-9.20	-0.46	-1.73	-4.27	-3.8	0.21	-4.26
$L_1 \times T_3$	15.80*	10.4	0.47	15.80**	10.40	5.72	-0.46	0.49	-4.27	3.7	6.70	0.47
$L_2 \times T_1$	14.52*	15.67**	13.71*	-8.06	8.73	11.20*	19.22**	18.84**	22.32**	14.15	14.52 **	15.30 **
$L_2 \times T_2$	-0.93	-0.47	1.78	-3.50	-4.21	-4.70	-14.98*	-16.06**	-18.24**	-7.5	-7.03	-7.87
$L_2 \times T_3$	-0.93	1.94	1.34	-3.50	-4.21	-4.70	-10.2	-9.85	-13.71*	-4.9	-4.09	-6.29
$L_3 \times T_1$	4.98	0.60	2.21	1.34	-1.88	-4.70	24.84**	19.86**	-18.24**	-7.5	-7.50	-7.87
$L_3 \times T_2$	-2.45	-4.83	-7.09	6.58	3.18	.22	29.00**	25.53**	22.77**	-9.9	-9.90	-10.26
$L_3 \times T_3$	4.98	4.98	0.67	6.58	3.18	.22	-12.42*	-6.62	-4.73	-1.1	0.20	-1.58
$L_4 \times T_1$	7.08	-2.36	-7.09	8.89*	9.43	10.22*	-5.64	-5.20	-9.25	-1.9	0.54	-2.36
$L_4 \times T_2$	15.25*	7.08	1.45	-15.79**	-15.31**	-14.7**	-0.93	-2.19	-4.73	-5.9	-3.53	-6.31
$L_4 \times T_3$	16.89*	11.44	1.41	-7.47	-7.01	-6.34	-8.87	-8.44	-12.36	-2.7	-1.67	-5.86
$L_5 \times T_1$	-3.40	-3.18	0.47	0.56	.248	.72	0.86	-7.36	-17.79**	-5.46	-3.40	-5.84
$L_5 \times T_2$	17.50**	15.87**	14.18*	25.17**	24.98**	24.62**	14.95*	-4.58	13.7*	-17.00 **	15.18 **	17.33 **
$L_5 \times T_3$	-1.13	3.21	2.83	-2.42	-2.17	-1.71	46.54**	35.76**	20.47**	11.08	11.94	-15.30**
$L_6 \times T_1$	14.85*	7.17	4.01	40.24**	20.41**	5.72	.47	0.47	-4.27	2.07	8.72	1.65
$L_6 \times T_2$	10.93	5.44	0.47	13.88 *	-2.28	-14.20**	-13.71	-15.21 *	-17.79**	-10.21	-14.52**	-15.57**
$L_6 \times T_3$	0.52	-2.01	-8.96	25.41**	7.66	-5.47	-13.71	-13.71 *	-17.7**	-8.03	-3.32	-10.95
$L_7 \times T_1$	-3.84	-3.40	0.47	-0.49	0.56	.72	-14.52*	-14.11 *	-17.79**	-6.35	-5.91	-5.84
$L_7 \times T_2$	-10.63	-8.67	-6.61	.76	1.26	1.99	-23.8**	-24.83**	-26.77**	-11.43	-11.01	-10.95
$L_7 \times T_3$	-8.39	-4.15	-4.27	-15.27**	-14.81**	-14.20**	-5.17	-4.72	-8.80	-9.50	-7.80	-9.01
$L_8 \times T_1$	-9.38	-10.75	-8.96	4.11	-1.02	-5.47	-16.51**	-10.81	-8.80	-8.24	-7.83	-7.80
$L_8 \times T_2$	-4.72	-4.50	-4.27	.56	-4.93	-9.20	-20.59**	-16.55**	-13.26	-9.41	-9.02	-8.98
$L_8 \times T_3$	-4.72	-2.18	-4.27	.78	-4.93	-9.20	-24.74**	-19.60**	-17.79**	-10.99	-9.35	-10.57
$L_9 \times T_1$	0.49	-3.69	-4.27	-0.80	-3.30	-5.47	17.08*	8.14	-4.27	-4.27	0.29	-4.66
$L_9 \times T_2$	20.37**	17.44**	14.65*	10.93*	8.14	5.72	0.55	-8.86	-17.79**	0.88	5.68	0.47
$L_9 \times T_3$	-4.41	-4.41	-8.96	-4.72	-7.12	-9.20	17.08*	8.14	-4.27	-4.37	-1.16	-7.40
$L_{10} \times T_1$	-5.17	-6.38	-4.27	8.61	3.54	-0.84	27.63**	28.23**	22.74**	6.69	8.54	6.26
$L_{10} \times T_2$	-7.49	-7.05	-6.61	4.93	0.03	-4.20	-14.52*	-15.60 *	-17.79**	-9.40	-7.84	-9.76
$L_{10} \times T_3$	-5.17	-2.42	-4.27	2.15	-2.61	-6.74	-0.46	3.78	-4.27	-1.95	-1.64	-5.06

Table 4.2.6: Contd....

$L_{11} \times T_1$	-0.46	-1.73	.47	15.80**	10.40	5.72	8.87	7.49	4.70	-3.87	0.21	-4.26
$L_{11} \times T_2$	-3.98	-3.52	-3.07	10.32*	5.18	.72	-9.81	-9.38	-13.26	-0.7	3.50	-1.1
$L_{11} \times T_3$	-0.46	2.42	.47	10.32*	5.18	.72	-9.81	-9.38	-13.26	-10.89	-8.3	-13.71
$L_{12} \times T_1$	-0.54	-9.31	-13.71*	21.28**	15.62**	10.72*	-5.17	-6.38	-8.80	-7.03	-3.08	-7.40
$L_{12} \times T_2$	4.93	-2.50	-8.96	-0.54	-5.18	-9.20	-0.46	.1.34	-4.27	0.88	5.16	0.47
$L_{12} \times T_3$	15.80*	10.40	.47	3.94	.90	-1.74	-13.71	-7.36	-17.79**	-1.12	1.68	-4.26
$L_{13} \times T_1$	11.71	1.86	-3.07	-7.89	-10.58	-12.93**	-16.66*	-9.09	-17.79**	-5.06	-1.03	-5.44
$L_{13} \times T_2$	15.80*	7.59	.47	6.55	3.43	.72	10.93	2.76	-8.80	0.88	5.16	0.47
$L_{13} \times T_3$	4.93	.03	-8.96	-10.53*	-9.97	-9.20	22.67**	13.25*	.24	-4.37	-1.66	-7.40
$L_{14} \times T_1$	.67	-1.50	.47	-3.18	-2.57	-1.74	33.69**	21.09**	9.23	-6.24	-2.63	-6.62
$L_{14} \times T_2$	-9.38	-9.17	-8.96	-11.02*	-10.47	-9.70	-5.53	-12.74	-22.77**	-12.96	-9.60	-13.31
$L_{14} \times T_3$	14.11*	17.16**	14.65*	17.75**	13.99**	10.72*	25.55**	27.12**	17.79**	15.37*	16.95**	17.03**
$L_{15} \times T_1$	-31.61**	-23.06**	-8.96	1.87	-1.37	-4.20	6.08	-3.84	-13.26	-10.41	-7.99	-5.82
$L_{15} \times T_2$	-24.52**	-13.80**	.47	-8.75	-11.66**	-14.20**	11.54	3.02	-8.80	-2.18	0.46	2.84
$L_{15} \times T_3$	-24.88**	-12.42*	.87	5.86	-2.65	-9.70	-9.43	-9.43	-13.71 *	-15.38 *	-11.90	-11.04
$L_{16} \times T_1$	55.67**	41.09**	33.59**	6.44	-2.11	9.25	40.68**	38.23**	34.03**	8.81	16.15 **	8.37
$L_{16} \times T_2$	11.54	3.028	-4.27	6.44	-2.11	9.23	9.90	9.90	4.70	-7.03	-0.75	-7.40
$L_{16} \times T_3$	28.07**	21.40**	9.90	.55	-4.68	9.28	-4.27	-4.27	-8.80	-1.15	4.14	-4.28
$L_{17} \times T_1$	.98	-1.74	.79	6.08	.56	-4.20	5.22	3.39	.24	-7.50	-4.67	-7.87
$L_{17} \times T_2$	-13.71*	-13.71*	-13.71*	.78	-5.21	-9.7	-4.75	-4.75	-9.25	4.84	8.05	24.42**
$L_{17} \times T_3$	-4.27	-1.94	-4.27	6.44	-2.11	-9.20	-4.27	-4.27	-8.80	0.49	2.15	-2.70
$L_{18} \times T_1$	.49	-3.69	-4.27	6.44	-2.11	-9.20	-8.96	-10.54	-13.2	-7.05	-4.21	-7.42
$L_{18} \times T_2$	5.48	2.91	.47	11.72*	2.73	-4.70	-14.18*	-14.18*	-18.24**	-0.69	2.35	-1.09
$L_{18} \times T_3$	-4.91	-4.91	-9.43	.45	-2.51	-4.70	22.06**	12.74	-0.20	-6.49	-4.95	-9.4
$L_{19} \times T_1$	17.08*	6.11	.47	.67	-2.51	-4.70	10.99	.59	-9.25	-5.4	-0.13	-5.84
$L_{19} \times T_2$	11.54	3.02	-4.27	-5.24	-7.63	-9.70	10.99	2.51	-9.25	-8.62	-3.46	-8.98
$L_{19} \times T_3$	10.99	5.21	-4.75	.55	-4.68	-9.20	6.08	-2.01	-13.26	-6.49	-2.53	-9.46
$L_{20} \times T_1$	23.97**	23.97**	28.36**	-10.44*	-15.10**	-19.12**	17.08*	6.11	-4.27	28.33**	18.86**	27.90**
$L_{20} \times T_2$	-8.01	-6.41	-4.75	.55	-4.68	-9.20	17.0*	8.14	-4.27	-5.93	-2.87	-6.31
$L_{20} \times T_3$	-3.42	.60	1.34	15.80**	10.40	5.72	8.87	7.49	4.70	-3.25	-1.45	-6.31
$L_{21} \times T_1$	16.18*	8.41	5.22	10.32*	5.18	.72	-9.81	-9.38	-13.26	-5.44	0.73	-5.82
$L_{21} \times T_2$	10.93	5.44	.47	10.32*	5.18	.72	-9.81	-9.38	-13.26	-7.03	-0.96	-7.40
$L_{21} \times T_3$	5.69	3.02	-4.27	21.28**	15.62**	10.72*	-5.17	-6.38	-8.80	-2.76	2.22	-5.84

*,** Significant at 5% and 1 % probability levels , respectively.

across environments was -31.61 to 55.67, -15.79 to 40.24, -24.74 to 46.54 and -17.00 to 28.33, respectively. Hybrids with the maximum heterotic expression were $L_1 \times T_2$ (15.80), $L_1 \times T_3$ (15.80), $L_2 \times T_1$ (14.53), $L_4 \times T_2$ (15.25), $L_4 \times T_3$ (16.89) $L_5 \times T_2$ (17.50), $L_6 \times T_1$ (14.85), $L_9 \times T_2$ (20.37), $L_{12} \times T_3$ (15.80) $L_{13} \times T_2$ (15.80), $L_{14} \times T_3$(14.11), $L_{16} \times T_1$ (55.67), $L_{16} \times T_3$ (28.07), $L_{19} \times T_1$ (17.08) $L_{20} \times T_1$(23.97) and $L_{21} \times T_1$ (16.18) in **E_1**; $L_1 \times T_1$ (15.25), $L_1 \times T_3$ (15.80), $L_5 \times T_2$ (25.17), $L_6 \times T_1$ (40.24), $L_6 \times T_2$ (13.88), $L_6 \times T_3$ (25.41), $L_9 \times T_2$ (10.93), $L_{11} \times T_1$ (15.80) $L_{11} \times T_2$ (10.32), $L_{11} \times T_3$(10.32), $L_{12} \times T_1$ (21.28), $L_{14} \times T_3$ (17.75), $L_{18} \times T_2$ (11.72) $L_{20} \times T_3$(15.80), $L_{21} \times T_1$ (10.32), $L_{21} \times T_2$ (10.32) and $L_{21} \times T_3$ (21.28) in **E_2**; $L_2 \times T_1$ (19.82), $L_3 \times T_1$ (24.84) $L_3 \times T_2$ (29.00), $L_5 \times T_2$(14.95), $L_5 \times T_3$ (46.54), $L_9 \times T_1$ (17.08), $L_9 \times T_3$ (17.08) $L_{10} \times T_1$(27.63), $L_{13} \times T_3$ (22.67), $L_{14} \times T_1$ (33.69) $L_{14} \times T_3$ (25.55), $L_{16} \times T_1$(40.68), $L_{18} \times T_3$ (22.06), $L_{20} \times T_1$ (17.08) and $L_{20} \times T_2$ (17.0) in **E_3**; $L_{14} \times T_3$ (15.37) and $L_{20} \times T_1$ (28.33) over environments.

As regards the magnitude of relative heterosis, it ranged from -23.06 to 41.09, -15.31 to 24.98, -24.83 to 38.23 and –14.52 to 18.86 E_1, E_2, E_3 and across the environments, respectively. In individual environments, crosses, $L_2 \times T_1$ (15.67), $L_5 \times T_2$ (15.87), $L_9 \times T_2$ (17.44), $L_{14} \times T_3$(17.16), $L_{16} \times T_1$ (41.09), $L_{16} \times T_3$ (21.40) and $L_{20} \times T_1$(23.97) in **E_1**; $L_5 \times T_2$ (24.98), $L_6 \times T_1$ (20.41), $L_{12} \times T_1$ (15.62), $L_{14} \times T_3$ (13.99), and $L_{21} \times T_3$ (15.62) in **E_2**; $L_2 \times T_1$ (18.84), $L_3 \times T_1$ (19.86) $L_3 \times T_2$ (25.53), $L_5 \times T_3$ (35.76), $L_{10} \times T_1$(28.23), $L_{13} \times T_3$ (13.25), $L_{14} \times T_1$ (21.09) $L_{14} \times T_3$ (27.12) and $L_{16} \times T_1$(38.23) in **E_3** and $L_2 \times T_1$ (14.52), $L_5 \times T_2$(15.18), L_{14}

× T_3 (16.95), L_{16} × T_1(16.15) and L_{20} × T_1 (18.86) had maximum relative heterosis for number of kernel rows per ear.

Standard heterosis ranged from -13.71 to 33.59, -14.70 to 24.62, -22.32 to 34.03 and -15.30 to 27.90 in E_1, E_2, E_3 and in pooled analysis, respectively. In cross combinations, hybrids which exhibited maximum heterosis over check were L_2 × T_1 (13.71), L_5 × T_2 (14.18), L_9 × T_2 (14.65), L_{14} × T_3(14.65), L_{16} × T_1 (33.59), and L_{21} × T_1 (28.36) in **E_1**; L_2 × T_1 (11.20), L_4 × T_1 (10.22), L_5 × T_2 (24.62), L_{12} × T_1 (10.72), L_{14} × T_3 (10.72) and L_{21} × T_3 (10.72) in **E_2**; L_2 × T_1 (22.32), L_3 × T_2 (22.77), L_5 × T_3 (20.47), L_{10} × T_1(22.74), L_{14} × T_3 (17.79) and L_{16} × T_1 (34.03) in **E_3**; and L_2 × T_1 (15.30), L_5 × T_2(17.33), L_{14} × T_3 (17.03), L_{17} × T_2 (24.42) and L_{20} × T_1 (27.90) in the pooled analysis for number of kernel rows per ear.

On the basis of study for all the environments, L_5 × T_2 and L_{14} × T_3 for BP and L_2 × T_1, L_5 × T_2 and L_{14} × T_3 for MP, L_2 × T_1, L_5 × T_2, L_{14} × T_3 and L_{16} × T_1 showed positive and significant heterosis. However, only one cross, L_{14} × T_3 showed significantly positive heterosis (BP, CP and MP) in all the environments.

4.2.7 Number of kernels per row

The estimates of per cent heterobeltiosis, relative heterosis and standard heterosis for number of kernels per row are presented in the Table 4.2.7 for E_1, E_2, E_3 and across the environments. The estimates of heterobeltiosis ranged from -22.51 to 33.91, -27.97 to 46.60, -26.89 to 50.32 and -18.00 to 26.40 in E_1, E_2, E_3 and pooled analysis, respectively. The most heterotic cross combinations were L_1 × T_1 (24.92), L_2 × T_3

Table 4.2.7: Estimation of heterosis (%) over better-, mid- and check- parent in three environments (E_1, E_2, E_3)

Cross	Number of kernels/ Row											
	Normal			Low nitrogen			Excess soil moisture			Pooled		
	BP	MP	CP	BP	MP	CP	BP	MP	CP	BP	MP	CP
$L_1 \times T_1$	24.92**	7.69	-0.98	44.33**	44.32**	20.27*	-1.24	-5.05	-10.51	5.41	12.36	1.48
$L_1 \times T_2$	1.60	-4.11	-19.47**	46.60**	42.50**	22.17*	16.72*	35.08**	38.13**	-7.64	-3.40	-14.58 *
$L_1 \times T_3$	5.71	8.02	25.24**	10.59	-1.08	-7.84	8.28	1.25	-1.88	-8.29	-2.49	-12.19
$L_2 \times T_1$	-15.58 *	-12.16	-11.68	20.90	26.69**	10.89	-1.01	-4.32	-9.38	-0.95	0.57	-4.65
$L_2 \times T_2$	6.58	11.05	2.81	30.06**	32.66**	19.30	1.03	-3.42	-7.50	11.06	11.57	3.67
$L_2 \times T_3$	19.16*	10.39	-0.80	15.69	9.00	6.12	14.3*	7.51	4.68	7.58	8.94	3.01
$L_3 \times T_1$	10.96	3.25	1.00	-3.00	14.20	15.71	0.97	0.12	-2.81	2.99	5.29	3.67
$L_3 \times T_2$	-1.38	-0.10	-10.23	-6.43	7.63	11.63	-15.99*	-17.59**	-19.14**	-7.99	-4.10	-7.38
$L_3 \times T_3$	-2.97	1.35	-11.68	-1.01	6.24	18.09	2.93	-0.65	-0.93	-0.33	2.17	0.34
$L_4 \times T_1$	16.56*	22.24**	22.79**	36.91**	45.23**	28.88**	15.13*	21.62**	19.74**	16.83**	18.15**	27.66**
$L_4 \times T_2$	16.93*	12.02	3.71	29.29**	33.55**	21.71*	4.11	-0.48	-4.68	12.39	13.31	5.67
$L_4 \times T_3$	-3.75	3.32	-7.15	34.37**	28.33**	26.49*	8.20	1.73	-0.93	8.97	9.96	4.33
$L_5 \times T_1$	-8.18	-10.42	-8.51	-19.46*	-1.12	6.71	26.51**	17.58**	7.51	-2.09	1.45	1.34
$L_5 \times T_2$	-16.81*	-11.98	-17.12*	-9.05	9.23	20.50*	5.51	-3.05	-10.33	-7.56	-2.37	-4.32
$L_5 \times T_3$	19.15*	8.47	-0.81	-23.52**	-13.94	1.33	24.3**	12.27*	5.63	-1.45	2.39	2.01
$L_6 \times T_1$	-14.93*	-5.98	-11.00	-18.66*	0.54	9.71	-3.65	-7.62	-13.15*	-6.55	-4.53	-6.07
$L_6 \times T_2$	0.79	-1.53	14.62	35.55**	22.04**	-13.07	3.64	-1.72	-6.57	-11.84	-8.18	-11.39
$L_6 \times T_3$	1.45	1.92	-14.41	-22.22**	-11.79	4.91	13.02	5.39	1.87	-3.81	-1.48	-3.32
$L_7 \times T_1$	-10.20	-9.43	-4.42	30.33**	16.00	-11.87	13.06	10.42	5.63	-9.61	-4.70	-2.99
$L_7 \times T_2$	-12.75	-4.82	-7.14	33.17**	21.22*	-15.46	4.02	0.48	-2.81	-14.26	-7.89	-7.98
$L_7 \times T_3$	-12.75	-2.09	-7.14	-18.01*	-9.62	3.70	-13.11 *	-8.79	-10.33	-11.79	-6.76	-5.32
$L_8 \times T_1$	-22.51**	-16.13*	-18.94*	8.93	9.98	-7.44	-10.33	-9.38	-10.33	-9.37	-7.12	22.75 **
$L_8 \times T_2$	-13.50	-13.50	-23.27**	24.27*	22.00*	5.58	5.81	5.81	5.81	2.71	3.20	-5.00
$L_8 \times T_3$	9.77	13.25	-2.63	3.72	-6.22	-11.87	-1.88	-3.42	-1.88	-0.77	1.42	-4.99
$L_9 \times T_1$	14.42	1.15	-5.16	12.83	20.39*	7.55	1.23	-2.15	-7.32	1.33	5.10	-2.46
$L_9 \times T_2$	16.38	12.43	-3.54	15.08	19.59*	9.70	-17.84**	-14.21*	-17.84**	2.72	4.49	-4.99
$L_9 \times T_3$	-5.47	-5.68	-21.65**	26.41*	21.52*	20.50*	-15.38*	-20.44**	-22.53**	-6.33	-3.10	20.31 **
$L_{10} \times T_1$	-4.57	-7.12	-5.35	-4.88	13.35	16.90	-7.29	-9.83	-14.08*	-5.54	-2.17	-2.33
$L_{10} \times T_2$	-10.54	-5.55	-11.27	-7.81	7.38	13.30	0.82	-3.01	-6.56	-6.03	-0.80	-2.84
$L_{10} \times T_3$	22.41 *	11.71	1.90	-0.99	7.73	21.69*	-2.73	-7.95	-9.85	-0.23	3.60	3.16

Table 4.2.7: Contd...

$L_{11} \times T_1$	-4.54	-6.87	-4.89	-15.62	-1.71	3.70	-26.89**	-25.22**	-23.46**	-1.13	0.62	-4.82
$L_{11} \times T_2$	-12.67	-7.59	-12.98	-2.91	5.63	19.31	-18.82**	-18.23**	-15.01*	-5.63	-5.42	-12.32
$L_{11} \times T_3$	22.09**	33.03**	21.64**	-3.34	4.77	-4.67	-16.09*	-18.04**	-21.60**	26.40**	28.15 **	23.45**
$L_{12} \times T_1$	-20.10*	-25.74**	-27.44**	9.31	15.45	7.80	8.45	4.76	1.32	-18.00 *	-14.61 *	-14.25 *
$L_{12} \times T_2$	1.23	2.42	-8.07	26.55*	23.80**	24.80*	-9.43	-13.93*	-15.39*	-14.24	-8.98	-10.31
$L_{12} \times T_3$	17.21*	22.31**	6.44	15.25	30.15**	24.58*	15.44*	6.97	-2.44	-2.14	2.18	22.35 **
$L_{13} \times T_1$	-0.54	-11.80	-17.12*	-9.58	-0.38	-2.26	2.06	-6.50	-13.74*	-12.02	-9.60	-15.31*
$L_{13} \times T_2$	-4.45	-7.43	-20.38**	-17.37	-15.37	-10.68	19.43*	7.54	0.93	2.81	3.58	-4.91
$L_{13} \times T_3$	22.92*	22.99**	2.43	-8.95	7.64	9.71	36.49**	18.10**	1.88	6.81	9.46	2.27
$L_{14} \times T_1$	4.86	5.20	10.41	-3.98	10.92	15.70	50.32**	28.50**	12.2	11.23	12.59	9.72
$L_{14} \times T_2$	-16.12*	-8.95	-11.68	-4.96	2.47	14.52	45.27**	21.95**	8.44	-8.61	-5.67	-9.85
$L_{14} \times T_3$	32.90**	25.05**	29.34**	1.18	14.28	9.41	16.31	-3.80	-19.72**	-12.29	-10.98	-13.48
$L_{15} \times T_1$	3.27	18.69*	-14.40	21.14*	33.49**	30.99**	20.39*	-1.67	-16.91**	1.81	5.04	-1.99
$L_{15} \times T_2$	9.56	5.84	-9.19	22.52*	25.50**	32.48**	32.65**	6.32	-8.45	13.80	15.13	5.25
$L_{15} \times T_3$	-4.37	-4.58	-20.74**	-4.15	11.42	10.89	-28.42**	-28.00**	-29.0**	3.75	6.76	-0.66
$L_{16} \times T_1$	-26.84**	-15.92*	-23.46**	-27.97**	-18.23*	-16.66	-5.68	-6.13	-6.57	-9.69	-2.96	-13.06
$L_{16} \times T_2$	33.91**	24.85**	3.71	-10.35	-5.14	3.72	0.93	-1.12	-0.009	12.35	18.47 **	3.91
$L_{16} \times T_3$	23.40*	18.95*	-4.42	-19.61*	-7.60	-9.47	0.88	4.27	5.62	8.97	16.79 **	4.33
$L_{17} \times T_1$	-4.60	-7.58	-6.25	1.69	14.09	14.52	-5.38	-3.21	-0.93	-12.56	-9.46	-9.64
$L_{17} \times T_2$	-8.29	-3.59	-9.87	-0.44	3.99	12.11	-20.63**	-20.06**	-16.11**	-13.53	-8.74	-10.64
$L_{17} \times T_3$	-6.44	1.30	-8.05	9.00	14.52	0.54	-6.94	-5.30	-5.63	-5.15	-1.53	-1.99
$L_{18} \times T_1$	-22.86**	-28.22**	-29.79**	5.30	7.69	-2.87	2.30	3.02	3.74	-13.21	-10.78	-11.64
$L_{18} \times T_2$	-6.95	-5.75	-15.30*	-0.54	-6.03	-8.27	-10.63	-11.41*	-9.38	-3.73	0.89	-1.99
$L_{18} \times T_3$	11.94	16.94*	1.89	5.82	20.09*	15.69	-8.49	-10.39	-14.07*	-3.74	-0.78	-2.00
$L_{19} \times T_1$	-19.71*	-22.9**	-22.55**	-0.75	9.89	8.50	-11.49	-14.27*	-16.89**	-7.40	-7.06	30.19
$L_{19} \times T_2$	-11.26	-7.54	-14.40	-15.00	-12.46	-7.07	-2.49	-7.08	-8.44	-1.86	0.46	-4.82
$L_{19} \times T_3$	-1.88	5.33	-5.35	12.60	24.55*	16.12	28.14**	16.59**	4.68	-4.78	-4.16	-7.65
$L_{20} \times T_1$	17.89*	14.47*	16.39*	9.88	18.50*	13.32	6.32	-4.39	-13.14*	5.44	7.39	5.33
$L_{20} \times T_2$	-16.98*	-12.53	-18.03*	4.05	4.12	7.31	14.94	1.57	-6.10	-10.22	-6.77	-10.31
$L_{20} \times T_3$	-3.22	5.01	-4.44	-15.62	-1.71	3.70	-26.89**	-25.22**	-23.46**	-6.56	-4.57	-6.65
$L_{21} \times T_1$	16.30	4.98	0.09	-2.91	5.63	19.31	-18.82**	-18.23**	-15.01*	10.23	14.43 *	6.11
$L_{21} \times T_2$	13.14	11.43	-2.62	-3.34	4.7	-4.6	-16.09*	-18.04**	-21.60**	5.97	7.89	-1.99
$L_{21} \times T_3$	-7.91	-6.38	-20.75**	9.31	15.45	7.80	8.45	4.76	1.32	-3.72	-0.31	-7.82

*,** Significant at 5 and 1 % probability levels , respectively.

(19.16), $L_4 \times T_1$ (16.56), $L_4 \times T_2$ (16.93), $L_5 \times T_3$ (19.15) $L_{10} \times T_3$ (22.41), $L_{11} \times T_3$ (22.09), $L_{12} \times T_3$ (17.21) $L_{13} \times T_3$ (22.92), $L_{14} \times T_3$(32.90), $L_{16} \times T_2$ (33.91), $L_{16} \times T_3$ (23.40) and $L_{20} \times T_1$(17.89) in **E_1**; $L_1 \times T_1$ (44.33), $L_1 \times T_2$ (46.60), $L_2 \times T_2$ (30.06), $L_4 \times T_1$ (36.91), $L_4 \times T_2$ (29.29) $L_4 \times T_3$ (34.37), $L_6 \times T_2$ (35.55), $L_7 \times T_1$ (30.33), $L_7 \times T_2$ (33.17) $L_8 \times T_2$ (24.27), $L_9 \times T_3$(26.41), $L_{12} \times T_2$ (26.55), $L_{15} \times T_1$ (21.14) and $L_{15} \times T_2$ (22.52) in **E_2**; $L_1 \times T_2$ (16.72), $L_2 \times T_3$ (14.30), $L_4 \times T_1$ (15.13), $L_5 \times T_1$ (26.51) $L_5 \times T_3$ (24.3), $L_{12} \times T_3$ (15.44), $L_{13} \times T_2$ (19.43), $L_{13} \times T_3$ (36.49) $L_{14} \times T_1$ (50.32), $L_{14} \times T_2$ (45.27), $L_{15} \times T_1$ (20.39), $L_{15} \times T_2$ (32.65) and $L_{19} \times T_3$ (28.14) in **E_3**; and $L_4 \times T_1$ (16.83) and $L_{11} \times T_3$ (26.40) in the pooled analysis.

As regards the magnitude of relative heterosis, it ranged from -25.74 to 33.03, -18.23 to 45.23, -28.00 to 35.08 and -14.61 to 28.15 in E_1, E_2, E_3 and in pooled analysis, respectively. The most heterotic cross combinations for number of kernels per row were $L_4 \times T_1$ (22.24), $L_{11} \times T_3$ (33.03), $L_{12} \times T_3$ (22.31) $L_{13} \times T_3$ (22.99), $L_{14} \times T_3$(25.05), $L_{15} \times T_1$ (18.69), $L_{16} \times T_2$ (24.85), $L_{16} \times T_3$ (18.95) and $L_{20} \times T_1$(14.47) in **E_1**; $L_1 \times T_1$ (44.32), $L_1 \times T_2$ (42.50), $L_2 \times T_1$ (26.69), $L_2 \times T_2$ (32.66), $L_4 \times T_1$ (45.23), $L_4 \times T_2$ (33.55) $L_4 \times T_3$ (28.33), $L_6 \times T_2$ (20.04), $L_7 \times T_2$ (21.22) $L_8 \times T_2$ (20.00), $L_9 \times T_1$ (20.39), $L_9 \times T_2$ (19.59), $L_9 \times T_3$(21.52), $L_{12} \times T_2$ (23.80), $L_{12} \times T_3$ (30.15), $L_{15} \times T_1$ (33.49), $L_{15} \times T_2$ (25.50), $L_{18} \times T_3$ (20.09), $L_{19} \times T_3$ (24.55) and $L_{20} \times T_1$ (18.50) in **E_2**; $L_1 \times T_2$ (35.08), $L_4 \times T_1$ (21.62), $L_5 \times T_1$ (17.58) $L_5 \times T_3$ (12.27), $L_{13} \times T_3$ (18.10) $L_{14} \times T_1$ (28.50), $L_{14} \times T_2$ (21.95) and $L_{19} \times T_3$ (16.59) in **E_3**; $L_4 \times T_1$ (18.15), $L_{11} \times T_3$ (28.15), $L_{16} \times T_2$ (18.47), $L_{16} \times T_3$ (16.79) and $L_{21} \times T_1$ (14.43) across the environments.

Estimates of standard heterosis ranged from -23.27 to 29.34, -15.46 to 32.48, -23.46 to 38.13 and 14.58 to 27.66 in E_1, E_2, E_3 and across the environments for number of kernels per row. Among hybrids, most heterotic cross combinations were $L_1 \times T_3$ (25.24), $L_4 \times T_1$ (22.79), $L_{11} \times T_3$ (21.64), $L_{14} \times T_3$ (39.34) and $L_{21} \times T_1$ (16.39) in **E_1**; $L_1 \times T_1$ (20.27), $L_1 \times T_2$ (22.17), $L_4 \times T_1$ (28.88), $L_4 \times T_2$ (21.71) $L_4 \times T_3$ (26.49), $L_5 \times T_2$ (20.50), $L_9 \times T_3$ (20.50), $L_{10} \times T_3$ (21.69), $L_{12} \times T_2$ (24.80), $L_{12} \times T_3$ (24.58), $L_{15} \times T_1$ (30.99) and $L_{15} \times T_2$ (32.48) in **E_2**; $L_1 \times T_2$ (38.13) and $L_4 \times T_1$ (19.74) in **E_3**. However, hybrid, $L_4 \times T_1$ (27.66), $L_8 \times T_1$ (22.75), $L_9 \times T_3$ (20.31), $L_{11} \times T_3$ (23.45) and $L_{12} \times T_3$ (22.35 in the pooled analysis exhibited maximum standard heterosis.

On the basis of study for all environments, the cross combination, $L_4 \times T_1$ exhibited significantly positive heterosis (BP, CP, MP and pooled) in all the environments.

4.2.8 Number of nodes bearing brace or brace roots

The nature and per cent magnitude of heterobeltiosis, relative heterosis and standard heterosis among the hybrids for brace roots are presented in Table 4.2.8. The range of heterobeltiosis in E_1, E_2, E_3 and across environments was -47.76 to 72.72, -38.59 to 59.45, -33.89 to 53.33 and -27.45 to 34.15, respectively. Hybrids with the maximum heterotic expression were $L_2 \times T_2$ (70.27) and $L_3 \times T_3$ (72.72) in **E_1**; $L_{13} \times T_1$ (59.45) and $L_{16} \times T_1$ (31.11) in **E_2**; $L_3 \times T_3$ (53.33) and $L_{20} \times T_3$ (46.15) in **E_3**; and $L_3 \times T_3$ (34.15) and $L_2 \times T_1$ (29.79) in the pooled analysis. However, most of the crosses in E_2, E_3 and pooled analysis exhibited significant positive heterosis for brace roots.

Table 4.2.8: Estimation of heterosis (%) over better-, mid- and check- parent in three environments (E_1, E_2, E_3)

Cross	Number of nodes bearing brace roots											
	Normal			Low nitrogen			Excess soil moisture			Pooled		
	BP	MP	CP	BP	MP	CP	BP	MP	CP	BP	MP	CP
$L_1 \times T_1$	54.05**	14.00	11.76	16.32	29.54**	46.15**	-20.40	-11.36	-23.52 *	8.51	10.87	8.51
$L_1 \times T_2$	2.02	4.28	-7.84	8.16	12.76	35.89**	8.16	12.76	3.92	13.33	18.60 *	8.51
$L_1 \times T_3$	38.10**	20.00*	34.98**	-4.08	14.63	20.51	-4.08	-11.32	-7.84	26.67 **	32.56 **	21.28 *
$L_2 \times T_1$	30.54**	28.00**	24.51**	-5.40	-7.89	-10.25	7.27	25.53**	15.68	29.79 **	35.56 **	29.79 **
$L_2 \times T_2$	70.27**	80.00**	23.52*	5.40	-4.87	2.67	-7.27	2.00	3.45	18.60	21.43 **	8.51
$L_2 \times T_3$	4.05	2.85	11.76	21.62	28.57*	15.38	3.63	1.78	11.76	23.26 *	26.19 **	12.77
$L_3 \times T_1$	30.99**	31.25**	23.52*	-13.33	-7.14	0.56	26.66*	35.71**	11.76	12.77	20.45 *	12.77
$L_3 \times T_2$	54.54**	44.54**	1.44	0.67	0.78	15.34	2.34	2.78	-11.76	14.63	14.63	4.78
$L_3 \times T_3$	72.72**	72.72**	11.76	-13.33	2.56	1.56	53.33**	35.29**	35.29**	34.15 **	34.15 **	17.02
$L_4 \times T_1$	21.35*	16.00*	22.35*	-23.25*	-19.51*	-15.38	-7.2	8.51	0.78	25.53 **	28.26 **	25.53 **
$L_4 \times T_2$	5.40	11.42	-3.52	11.62	9.09	23.07*	-18.18	-10.0ns	-11.76	-2.22	2.33	-6.38
$L_4 \times T_3$	5.40	11.42	-3.52	18.60	34.21**	30.76**	3.63	1.78	11.76	8.89	13.95	4.26
$L_5 \times T_1$	4.28	-4.08	-7.84	12.76	23.25*	35.89**	2.78	20.40*	15.68	12.77	12.77	12.77
$L_5 \times T_2$	-5.71	-2.94	-5.29	-4.25	-2.17	15.38	-33.89**	-25.00**	-23.52*	-17.02	-11.36	-17.02
$L_5 \times T_3$	22.85*	27.64**	11.76	8.51	27.50**	30.76**	6.78	28.62**	23.52*	21.28 *	29.55 **	21.28 *
$L_6 \times T_1$	3.17	3.17	7.45	20.51	20.51*	20.51	15.68	31.11**	15.68	11.76	16.33 *	21.28 *
$L_6 \times T_2$	3.17	5.41	7.45	-10.25	-16.66	-10.25	3.92	10.41	3.92	0.67	10.87	8.51
$L_6 \times T_3$	-44.44**	-27.08**	-31.30**	-10.25	-2.77	-10.25	-19.60	-24.07**	-19.60	-27.45 **	-19.57 *	-21.28 *
$L_7 \times T_1$	-5.40	-5.00	-1.37	10.81	7.89	5.12	-4.08	6.81	-7.84	-12.77	-6.82	-12.77
$L_7 \times T_2$	43.24**	51.42**	3.92	27.02*	14.63	20.51	20.40	25.53**	15.68	29.27 **	29.27 **	12.77
$L_7 \times T_3$	6.06	-5.40	-1.37	10.81	17.14	5.12	8.16	2.34	3.92	4.88	4.88	-8.51
$L_8 \times T_1$	-44.44**	-28.57**	-5.37	-25.53**	-18.60*	-10.25	11.32	28.26**	15.68	-8.51	-6.52	-8.51
$L_8 \times T_2$	6.06	2.94	-1.37	-12.76	-10.87	5.12	17.77	8.16	3.92	-4.44	3.89	-8.51
$L_8 \times T_3$	4.06	2.94	-3.37	1.45	17.50	20.51	-7.01	-3.63	3.92	0.78	4.65	-4.26
$L_9 \times T_1$	5.06	-27.08**	-3.37	-28.08**	-14.58	5.12	4.44	11.90	-7.84	-12.77	-10.87	-12.77
$L_9 \times T_2$	6.06	6.06	-2.37	-17.54*	-7.84	20.51	17.77	17.77	3.92	0.78	4.65	-4.26
$L_9 \times T_3$	7.06	6.06	-2.37	-38.59**	-22.2*	-10.25	4.44	-7.84	-7.84	-13.33	-9.30	-17.02
$L_{10} \times T_1$	10.81	-18.00*	-1.60	-4.08	6.81	20.51	-3.63	12.76	3.92	4.67	4.78	3.23
$L_{10} \times T_2$	4.06	-5.40	-3.37	20.40*	25.53**	51.28**	-14.54	-6.00	-7.84	3.67	6.82	2.45
$L_{10} \times T_3$	5.06	-5.40	-4.37	-16.32	2.45	5.12	7.27	5.35	15.68	-4.26	2.27	-4.26

Table 4.2.8: Contd...

$L_{11} \times T_1$	-9.85	-7.69	-7.84	8.163	20.45*	35.89**	23.25	29.26**	3.92	-3.77	2.00	8.51
$L_{11} \times T_2$	27.76*	23.00*	31.37**	20.40 *	25.53**	51.28**	37.20**	34.09**	25.68*	23.77*	18.51*	28.51**
$L_{11} \times T_3$	-2.98	3.0	7.45	8.16	29.26**	35.89**	9.30	-6.00	-7.84	3.77	17.02 *	17.02
$L_{12} \times T_1$	10.81	-8.00	-1.60	8.16	20.45 *	35.89**	-16.32	-6.81	-19.60	-4.26	-2.17	-4.26
$L_{12} \times T_2$	6.06	-5.40	-1.37	-4.08	1.98	20.51	-4.08	5.67	-7.84	-4.44	3.25	-8.51
$L_{12} \times T_3$	6.06	-5.40	-1.37	-16.32	1.78	5.12	-16.32	-22.6**	-19.60	-13.33	-9.30	-17.02
$L_{13} \times T_1$	3.17	-2.98	7.45	59.45**	55.26**	51.28**	-4.08	6.81	-7.84	11.76	16.33 *	21.28 *
$L_{13} \times T_2$	-47.76**	-30.00**	-31.37**	10.81	2.56	5.12	8.16	12.76	3.92	-15.69	-6.52	-8.51
$L_{13} \times T_3$	-2.98	3.00	7.45	27.02*	34.28**	20.51	-4.08	-11.32	-7.84	3.92	15.22	12.77
$L_{14} \times T_1$	-5.44	-8.57	-1.37	14.63	17.50	20.51	34.28*	27.02*	-7.84	-8.51	2.38	-8.51
$L_{14} \times T_2$	6.06	2.94	-3.37	0.67	-4.65	5.12	34.28*	17.50	-7.84	4.78	5.13	-12.77
$L_{14} \times T_3$	6.06	2.94	-1.37	14.63	27.02*	20.51	17.14	-10.87	-19.60	3.67	5.13	-12.77
$L_{15} \times T_1$	4.4	4.44	-3.37	5.12	5.12	5.12	4.44	11.90	-7.84	-16.33	-14.58	-12.77
$L_{15} \times T_2$	4.44	-7.08	-3.37	-10.25	-16.6	-10.25	-8.88	-8.88	-19.60	-24.49 **	-17.78 *	-21.28 *
$L_{15} \times T_3$	7.6	-3.25	-5.29	15.38	25.00*	15.38	13.33	3.67	5.45	-12.24	-4.44	-8.51
$L_{16} \times T_1$	6.06	-2.08	-1.37	31.11**	40.47**	51.28**	20.51	20.51	-7.84	2.56	9.30	4.56
$L_{16} \times T_2$	6.06	6.06	-3.37	4.44	4.44	20.51	35.89**	26.19 *	3.92	9.76	12.50	-4.26
$L_{16} \times T_3$	6.06	6.06	-3.37	4.44	20.5*	20.51	20.51	-2.08	-7.84	4.88	7.50	-8.51
$L_{17} \times T_1$	2.45	-1.25	-5.29	1.78	7.14	15.38	-11.76	4.65	-11.76	-12.77	-8.89	-12.77
$L_{17} \times T_2$	6.06	6.06	-2.37	-22.2*	-22.22*	-10.25	-31.37**	-27.08**	-31.37**	-18.60	-16.67 *	-25.53 **
$L_{17} \times T_3$	6.06	6.06	-1.3	-8.88	5.12	5.12	-7.84	-12.96	-7.84	-4.65	-2.38	-12.77
$L_{18} \times T_1$	5.44	4.44	-1.37	5.12	5.12	5.12	-8.88	-2.38	-19.60	-20.41	-18.75 *	-17.02
$L_{18} \times T_2$	4.44	-2.08	-3.37	20.51	11.90	20.51	4.44	4.44	-7.84	-12.24	-4.44	-8.51
$L_{18} \times T_3$	2.67	1.25	3.52	15.38	25.00*	15.38	13.33	4.56	5.78	8.16	17.78 *	12.77
$L_{19} \times T_1$	6.60	10.41	3.92	4.44	11.90	20.51	-7.84	4.44	-7.84	4.26	8.89	4.26
$L_{19} \times T_2$	6.97	2.97	2.45	4.44	4.44	20.5	3.92	10.41	3.92	27.91 **	30.95 **	17.02
$L_{19} \times T_3$	3.90	0.90	2.52	13.33	30.76**	30.76**	-11.76	-16.66 *	-11.76	23.26 *	26.19 **	12.77
$L_{20} \times T_1$	0.78	1.45	3.52	-23.52**	-13.33	3.67	3.56	2.67	-23.52*	-7.84	-4.08	2.34
$L_{20} \times T_2$	-3.09	-8.75	-2.52	-23.54**	-18.75*	6.98	15.38	7.14	-11.76	-19.61	-10.87	-12.77
$L_{20} \times T_3$	7.61	-1.25	-5.29	-11.76	7.14	15.38	46.15**	18.75*	11.76	-11.76	-2.17	-4.26
$L_{21} \times T_1$	6.97	5.41	7.45	20.51	20.51*	20.51	3.92	17.77	3.92	17.02	25.00 **	17.02
$L_{21} \times T_2$	6.06	6.06	-1.37	-10.25	-16.66	-10.25	3.92	10.41	3.92	5.78	3.27	-12.77
$L_{21} \times T_3$	6.06	6.06	-1.37	20.51	30.55**	20.5	-7.84	-12.96	-7.84	4.88	4.88	-8.51

*,** Significant at 5% and 1 % probability levels , respectively.

The estimates of relative heterosis for grain yield ranged from -30.00 to 80.00, -22.22 to 55.26, -27.08 to 35.71 and -19.57 to 35.56 in the E_1, E_2, E_3 and across the environments, respectively. The two most heterotic cross combinations were $L_2 \times T_2$ (80.00) and $L_3 \times T_3$ (72.72) in **E_1**; $L_{13} \times T_1$ (55.26) and $L_{16} \times T_1$ (40.47) in **E_2**; $L_3 \times T_1$ (35.71) and $L_3 \times T_3$ (35.29) in **E_3**; and $L_2 \times T_1$ (35.56) and $L_3 \times T_3$ (34.15) in pooled analysis which exhibited maximum and significant mid-parent heterosis for brace roots.

The estimates of standard heterosis ranged from -31.37 to 34.98, -15.38 to 51.28, -31.37 to 35.29 and -25.53 to 29.79 in E_1, E_2, E_3 and across environments, respectively. Some of the most heterotic hybrid combinations were $L_1 \times T_3$ (34.98) and $L_{11} \times T_2$ (31.37) in **E_1**; $L_1 \times T_1$ (46.15), $L_{10} \times T_2$ (51.28), $L_{11} \times T_2$ (51.28), $L_{13} \times T_1$ (51.28) and $L_{16} \times T_1$ (51.28) in **E_2**; $L_3 \times T_3$ (35.29) and $L_{11} \times T_2$ (25.68) in **E_3**; and $L_2 \times T_1$ (29.79), $L_4 \times T_1$ (25.53) and $L_{11} \times T_2$ (28.51) in the pooled analysis.

On the basis of study for all environments, the cross $L_{11} \times T_2$ for BP and CP, $L_5 \times T_3$ and $L_{11} \times T_2$ for MP showed positive and significant heterosis. However, $L_{11} \times T_2$ revealed significantly positive heterosis (BP, CP and MP) in all the environments.

4.2.9 Days to 50 per cent tasselling

The nature and magnitude of per cent heterobeltiosis, relative heterosis and standard heterosis among hybrids for days to 50 per cent tasselling are presented in Table 4.2.9. This Table indicated range of per cent heterobeltiosis from -8.21 to 10.34, -10.34 to 11.72, -5.36 to 8.36

Table 4.2.9: Estimation of heterosis (%) over better-, mid- and check- parent in three environments (E_1, E_2, E_3)

Cross	Days to 50 % tasselling											
	Normal			Low nitrogen			Excess soil moisture			Pooled		
	BP	MP	CP	BP	MP	CP	BP	MP	CP	BP	MP	CP
$L_1 \times T_1$	-3.94	-2.01	-7.37**	-2.05	-4.02**	-9.88**	2.05	2.05	4.12**	-4.67*	-1.35	-6.41 **
$L_1 \times T_2$	3.23	1.32	9.37**	-2.05	-2.05	-8.88**	2.05	1.01	4.12**	-0.68	-0.34	-6.32 **
$L_1 \times T_3$	2.09	1.03	7.37**	2.05	1.01	9.20**	2.11	1.06	2.02	0.68	0.68	8.77 **
$L_2 \times T_1$	-2.01	-2.99	-6.37**	0.76	-2.01	-8.00**	2.11	1.06	2.02	-2.67	-1.68	5.41 **
$L_2 \times T_2$	-0.67	2.33	-8.13**	-2.68	-0.68	-9.69**	-0.68	-1.69	1.32	-0.68	-0.68	-4.41 **
$L_2 \times T_3$	1.34	3.42	6.26**	-2.74	-3.72*	-7.47**	-1.68	-1.68	1.32	-0.68	-0.34	-5.46 **
$L_3 \times T_1$	1.34	1.33	6.26**	-4.69**	-5.64**	-13.47**	-2.68	-2.68	1.32	2.67	2.01	7.56 **
$L_3 \times T_2$	1.34	2.37	6.26**	-2.68	-1.69	-11.69**	-1.68	-1.69	1.32	-0.68	-0.34	-5.77 **
$L_3 \times T_3$	2.01	4.110 *	5.64**	-4.02*	-4.02**	-12.88**	2.11	1.06	2.02	-0.68	0.76	-5.77 **
$L_4 \times T_1$	2.05	1.56	7.51**	1.78	-0.99	-9.20**	2.05	1.01	4.12**	-0.67	0.00	-4.49 *
$L_4 \times T_2$	4.11	4.11 *	5.64**	-2.01	-1.01	-11.00**	-2.0s	-2.01	2.02	0.45	0.34	-5.13 **
$L_4 \times T_3$	4.11	5.19**	5.64**	-2.01	-2.01	-11.03**	-2.01	-3.05**	-6.21**	1.35	2.04	-3.85 *
$L_5 \times T_1$	-8.21**	-6.04**	-1.92	8.21**	6.04**	-3.71*	2.05	2.05	4.12**	3.33	4.73 **	-0.64
$L_5 \times T_2$	-5.47**	-5.47**	-4.40 *	1.37	1.37	-9.81**	1.37	2.33	3.42**	2.04	2.39	-3.85 *
$L_5 \times T_3$	-5.47**	-6.54**	-4.40*	1.37	1.33	-9.81**	1.37	1.37	3.42**	2.74	2.74	-3.85 *
$L_6 \times T_1$	2.67	-1.33	-6.89**	2.79	-2.33	-10.40**	-1.34	-1.33	2.72*	-1.33	-0.34	-5.13 **
$L_6 \times T_2$	4.02	5.08**	-3.78*	2.09	1.03	-11.00**	1.37	2.33	4.12**	2.04	2.04	-3.85 *
$L_6 \times T_3$	2.68	4.79**	-5.02**	0.69	-1.37	-12.29**	-5.36**	-4.40**	-1.46	-0.68	-0.34	-6.41 **
$L_7 \times T_1$	-6.99**	3.72 *	-5.02**	-3.35	-4.31**	-12.29**	-3.42**	-3.42**	-1.46	-2.67	-1.35	-6.41 **
$L_7 \times T_2$	-7.69**	-6.57**	-4.40*	-2.68	-1.69	-11.69**	-2.74 *	-3.72**	-2.76	0.45	0.34	-5.77 **
$L_7 \times T_3$	-7.69**	-7.69**	-4.40*	-0.67	-0.67	-9.81**	-2.74 *	-2.74 *	-1.76	1.37	1.37	-5.13 **
$L_8 \times T_1$	1.31	1.31	-4.40*	7.53**	5.36**	-4.32**	-4.69**	-3.72**	-0.76	0.67	1.00	-3.21 **
$L_8 \times T_2$	1.31	3.35	-4.40*	3.42	3.42*	-7.98**	-4.69**	-4.69**	-1.76	0.67	0.68	-4.49 *
$L_8 \times T_3$	-1.97	1.01	-6.51**	2.05	1.01	-9.20**	-4.02**	-3.05**	-1.07	-1.34	-0.34	-5.77 **
$L_9 \times T_1$	4.02	2.99	-3.78*	2.05	1.98	-9.20**	-2.05	-2.05	-2.07	-0.67	0.34	-4.49 *
$L_9 \times T_2$	10.06**	11.18**	1.80	2.05	2.05	-9.20**	1.23	-1.01	2.02	4.08	4.08 *	-1.92
$L_9 \times T_3$	6.04**	8.21**	-1.92	2.05	1.01	-9.20**	1.32	1.45	2.02	2.72	3.07 *	-3.21 *
$L_{10} \times T_1$	8.78**	7.33**	-0.06	0.67	-0.66	-9.20**	-1.3	-2.68	2.02	1.33	2.01	-2.56
$L_{10} \times T_2$	6.08**	6.80**	-2.54	2.02	2.72	-7.98**	2.02	1.68	5.52**	3.38	3.73 *	-1.92
$L_{10} \times T_3$	-8.10**	9.96**	-0.68	-2.02	-2.35	-11.63**	0.67	0.68	3.44**	2.03	2.72	-3.21 *

Table 4.2.9: Contd...

$L_{11} \times T_1$	5.96**	5.61**	-0.68	-10.34**	-7.74**	-2.49	2.06	1.71	3.43**	4.00	5.05 **	0.67
$L_{11} \times T_2$	7.25**	9.09**	0.55	11.72**	11.34**	-1.28	1.37	0.78	2.72*	6.80 **	6.80 **	0.64
$L_{11} \times T_3$	5.29**	8.16**	-1.30	-2.75	-4.08**	-14.77**	-2.75*	-3.03**	-1.46	0.78	0.34	-5.77 **
$L_{12} \times T_1$	10.34**	7.74**	-0.68	2.06	-2.33	-9.81**	-4.05**	-3.41**	-0.76	0.89	1.35	-3.85 *
$L_{12} \times T_2$	8.27**	7.90**	-2.54	4.13*	3.78*	-7.98**	-4.05**	-4.37**	-0.76	2.04	2.39	-3.85*
$L_{12} \times T_3$	6.89**	7.63**	-3.78*	4.82**	3.40*	-7.37**	-1.35	-1.68	2.02	3.42	3.42 *	-3.21*
$L_{13} \times T_1$	-2.56	-1.29	-5.64**	-1.68	-2.34	-11.00**	-2.72*	-2.38*	-1.07	-2.00	-2.00	-5.77 **
$L_{13} \times T_2$	1.28	4.63**	-1.92	5.44**	5.80**	-5.54**	-2.72*	-3.37**	-1.07	1.33	2.36	-2.56
$L_{13} \times T_3$	1.28	5.68**	-1.92	3.40	2.70	-7.37**	-3.40**	-3.75**	-6.21**	2.67	4.05 *	-1.28
$L_{14} \times T_1$	2.01	0.99	-5.64**	1.45	-2.01	-11.3**	-2.01	-1.01	2.02	-1.33	-0.67	-5.13 **
$L_{14} \times T_2$	7.38**	8.47**	-1.68	1.37	1.37	-9.81**	-2.68*	-2.65*	1.32	2.03	2.37	-3.21 *
$L_{14} \times T_3$	-7.38**	-9.58**	-0.68	1.37	1.33	-9.81**	8.36**	6.44**	9.71**	-4.73*	-5.44 **	-0.64
$L_{15} \times T_1$	5.26**	5.26**	-1.68	-0.67	-1.66	-9.81**	3.42**	3.42**	5.52**	2.00	2.34	-1.92
$L_{15} \times T_2$	6.57**	8.72**	0.55	0.67	1.69	-8.59**	-4.79**	-3.72**	-6.91**	-4.03	-4.73 *	-0.64
$L_{15} \times T_3$	5.26**	8.47**	-0.68	1.34	1.34	-7.98**	-1.68	-0.68	1.32	2.01	3.05 *	-2.56
$L_{16} \times T_1$	5.96**	5.61**	-0.68	-1.98	-2.31	-9.81**	-3.97**	-2.35*	1.32	0.89	0.33	-3.21 *
$L_{16} \times T_2$	2.64	4.37*	-3.78*	-1.32	1.33	-9.20**	-3.31**	-2.66*	2.027	-0.66	0.67	-3.85 *
$L_{16} \times T_3$	2.64	5.44**	-3.78*	-3.31	-2.66	-11.3**	-5.29**	-3.70**	-2.07	-1.99	-0.34	-5.13 **
$L_{17} \times T_1$	1.98	1.65	-4.40*	-1.98	-2.31	-9.81**	-2.02	-1.36	1.32	-0.67	-0.67	-4.49 **
$L_{17} \times T_2$	-5.96**	-7.74**	-5.68**	0.56	1.68	-7.98**	-2.02	-1.68	-5.52**	2.67	3.70 *	-5.28**
$L_{17} \times T_3$	-5.96**	-8.84**	-1.68	-3.97*	-3.33*	-11.6**	-2.02	-1.36	1.32	0.78	1.35	-3.85 *
$L_{18} \times T_1$	4.05	2.66	-4.40*	-2.0	-3.33*	-11.6**	-3.97**	-2.35*	1.32	-1.33	-1.00	-5.13 **
$L_{18} \times T_2$	5.40**	6.12**	-3.16	-1.67	0.89	-10.4**	-2.64 *	-2.00	2.72*	0.67	1.35	-3.85 *
$L_{18} \times T_3$	3.37	-5.15**	-5.02**	-0.67	-1.01	-10.4**	-2.64 *	-1.01	2.72*	0.56	1.02	-4.49 *
$L_{19} \times T_1$	2.35	1.16	-5.64**	2.40	1.16	-9.20**	1.34	1.17	2.02	-0.67	0.51	-4.49 *
$L_{19} \times T_2$	3.70	4.58*	-4.40*	1.71	1.54	-9.81**	-2.34	-1.52	1.32	1.36	1.53	-4.49 *
$L_{19} \times T_3$	1.68	3.60*	-6.26**	1.71	0.50	-9.81**	-0.34	-1.51	1.32	1.0	1.20	-5.13 **
$L_{20} \times T_1$	2.02	0.83	-5.95**	0.67	-1.13	-9.50**	0.78	-0.17	1.67	-1.0	-0.17	-4.81 *
$L_{20} \times T_2$	1.71	0.84	-6.82**	0.89	1.84	-9.50**	0.89	-1.18	1.67	0.78	0.17	-5.45 **
$L_{20} \times T_3$	3.84	1.88	-6.82**	-2.02	-2.18	-11.35**	0.77	-0.17	1.67	-0.68	-0.17	-6.09 **
$L_{21} \times T_1$	-0.34	-2.17	-4.37**	-4.26*	-4.10**	-11.00**	-2.34	-1.18	2.27	-2.67	-2.50	-5.41 **
$L_{21} \times T_2$	-1.34	-0.17	-5.37**	-6.23**	-4.18**	-12.88**	-1.33	-1.16	-4.13**	-2.3	-1.52	-5.41 **
$L_{21} \times T_3$	1.70	2.93	-6.51**	-6.23**	-5.14**	-12.88**	-2.34	-1.18	2.07	-2.34	-1.18	-5.45 **

*,** Significant at 5 and 1 % probability levels , respectively.

and -4.73 to 6.80 in E_1, E_2, E_3 and across environments, respectively. Hybrids with maximum per cent heterotic expression for early flowering were $L_5 \times T_1$ (-8.21), $L_7 \times T_2$ (-7.69), $L_7 \times T_3$ (-7.69), $L_{10} \times T_3$ (-8.10) and $L_{14} \times T_3$ (-7.38) in **E_1**; crosses $L_3 \times T_1$ (-4.69), $L_{11} \times T_1$ (-10.34), $L_{21} \times T_2$ (-6.23) and $L_{21} \times T_3$ (-6.23) in **E_2**; and crosses $L_6 \times T_3$ (-5.36), $L_8 \times T_2$ (-4.69), $L_8 \times T_3$ (-4.69), $L_8 \times T_3$ (-4.02), $L_{12} \times T_1$ (-4.05), $L_{12} \times T_2$ (-4.05), $L_{15} \times T_2$ (-4.79) and $L_{16} \times T_3$ (-5.29) in **E_3**, however, in the pooled analysis over environments, maximum heterobeltiosis was shown by the crosses $L_{14} \times T_3$ (-4.73) and $L_1 \times T_1$ (-4.67).

The estimates of per cent relative heterosis ranged from -7.69 to 11.18, -7.74 to 11.34, -4.69 to 6.44 and -5.44 to 6.80 in E_1, E_2, E_3 and pooled analysis, respectively. The most promising heterotic hybrids for early flowering in three environments were $L_7 \times T_3$ (-7.69), $L_{14} \times T_3$ (-9.58), $L_{17} \times T_2$ (-7.74) and $L_{17} \times T_3$ (-8.84) in **E_1**; crosses, $L_3 \times T_1$ (-5.64), $L_{11} \times T_1$ (-7.74) and $L_{21} \times T_3$ (-5.14) in **E_2** and $L_6 \times T_3$ (-4.40), $L_8 \times T_2$ (-4.69) and $L_{12} \times T_2$ (-4.37) in **E_3**. Similarly in pooled analysis, highly significant heterotic hybrids were $L_{14} \times T_3$ (-5.44) and $L_{15} \times T_2$ (-4.73).

The estimates of per cent heterosis over check parent ranged from -7.37 to 9.37 in E_1, -13.47 to 9.20 in E_2, -6.91 to 9.71 in E_3 and –6.41 to 8.77 across environments. Among hybrids, $L_2 \times T_2$ (-8.13) followed by $L_1 \times T_1$ (-7.37) and $L_6 \times T_1$ (-6.89) in **E_1**; $L_{11} \times T_3$ (-14.77) followed by $L_3 \times T_1$ (-13.47), $L_3 \times T_3$ (-12.88), $L_{21} \times T_2$ (-12.88) and $L_{21} \times T_3$ (-12.88) in **E_2** and $L_{15} \times T_2$ (-6.91) followed by $L_4 \times T_3$ (-6.21) and $L_{13} \times T_3$ (-6.21) in **E_3** showed significant maximum negative standard heterosis for early

flowering. In the pooled analysis, significant negative heterotic cross combinations for days to 50 per cent tasselling were $L_1 \times T_1$ (-6.41), $L_1 \times T_2$ (-6.32), $L_6 \times T_3$ (-6.41), $L_7 \times T_1$ (-6.41) and $L_{20} \times T_3$ (-6.09). However, most of the crosses in E_1, E_2, E_3 and pooled environment showed significant negative standard heterosis for day to 50 per cent tasselling.

None of the crosses showed significant heterosis for earliness in all the environments except $L_{17} \times T_2$ and $L_{21} \times T_2$ which exhibited check parent heterosis.

4.2.10 Days to 50 per cent silking

The estimates of per cent heterobeltiosis, relative heterosis and standard heterosis in 63 hybrids for days to 50 per cent silking are presented in Table 4.2.10. The range of estimates for heterobeltiosis varied from -8.98 to 11.61 in E_1, -6.21 to 12.93 in E_2, -6.87 to 7.36 in E_3 and –5.23 to 8.77 in the pooled analysis. The hybrids $L_1 \times T_1$ (-8.98) followed by $L_{21} \times T_2$ (-7.59) and $L_{21} \times T_1$ (-5.77) in **E_1**; $L_3 \times T_1$ (-6.21) followed by $L_3 \times T_2$ (-6.21) and $L_{21} \times T_1$ (-4.02) in **E_2**; $L_{16} \times T_3$ (-6.87) followed by $L_{11} \times T_3$ (-6.25) and $L_{14} \times T_2$ (-6.02) in **E_3** showed maximum and significant negative heterosis over better parent for days to 50 per cent silking. In pooled analysis, crosses, $L_{21} \times T_1$ (-5.23) and $L_{16} \times T_3$ (5.09) observed maximum negative heterosis for early 50 per cent silking.

Results on the estimates of per cent relative heterosis ranged from -6.60 to 9.49, -5.32 to 12.62, -5.06 to 6.79 and -7.79 to 9.73 in E_1, E_2, E_3 and pooled analysis, respectively. The most promising heterotic hybrids for early flowering were $L_1 \times T_1$ (-5.59), $L_{21} \times T_1$ (-6.46) and $L_{21} \times$

Table 4.2.10: Estimation of heterosis (%) over better-, mid- and check- parent in three environments (E_1, E_2, E_3)

Cross	Days to 50 % silking											
	Normal			Low nitrogen			Excess soil moisture			Pooled		
	BP	MP	CP	BP	MP	CP	BP	MP	CP	BP	MP	CP
$L_1 \times T_1$	-8.98**	-5.59*	-10.64**	1.93	0.95	-10.78**	3.87 *	2.87*	-0.06	-2.48	-0.63	-7.10 **
$L_1 \times T_2$	-5.59*	-3.79	-9.34**	1.93	1.93	-9.78**	5.80**	3.79**	1.80	-0.63	0.64	-6.51 *
$L_1 \times T_3$	-1.93	-0.97	-8.54**	1.93	0.77	-10.68**	1.22	-0.95	-3.78*	-1.27	-0.64	-8.28 **
$L_2 \times T_1$	7.98**	6.46**	9.64**	1.93	0.95	9.78**	1.12	0.99	-1.92	3.11	1.89	7.69 **
$L_2 \times T_2$	-0.63	-1.56	-7.70**	7.09**	7.09**	-5.75**	-1.63	-1.56	-2.54	7.63**	7.27 **	-5.33 *
$L_2 \times T_3$	5.06	7.09**	-2.41	-0.64	-2.53	-12.50**	-0.63	-0.63	-2.54	1.27	8.27 **	-5.92 *
$L_3 \times T_1$	3.22	-0.62	-5.93*	-6.21**	-5.32**	-14.53**	-0.63	-0.63	-2.54	-3.11	-2.19	-7.69 **
$L_3 \times T_2$	3.22	1.26	-5.93*	-6.21**	-4.43*	-14.53**	1.26	0.31	-0.68	-1.26	-0.95	-7.10 **
$L_3 \times T_3$	1.93	2.93	-7.11**	-3.72	-3.72*	-11.82**	1.10	1.12	-1.92	-0.63	-0.32	-7.10 **
$L_4 \times T_1$	1.93	-1.86	-7.11**	0.87	1.94	-8.55**	1.11	0.94	-0.06	-0.62	0.00	-5.33 *
$L_4 \times T_2$	5.80*	3.79	-3.58	1.34	1.89	-8.55**	1.23	0.56	-1.06	1.89	1.89	-4.14
$L_4 \times T_3$	3.87	4.88	-5.35*	0.98	0.65	-8.55**	1.86	2.82*	1.80	1.89	2.53	-4.14
$L_5 \times T_1$	7.74**	3.72	-1.82	11.61**	10.53**	-1.70ns	-5.48**	-3.72**	-3.78 *	8.48**	9.45 **	-2.37
$L_5 \times T_2$	7.09*	5.06*	-2.41	1.29	1.29	-10.46**	-2.43	-1.53	-0.68	1.26	1.58	-4.73
$L_5 \times T_3$	7.09*	8.14**	-2.41	7.09**	5.06**	-5.75**	-2.43	-0.62	-0.68	3.80	4.13	-2.96
$L_6 \times T_1$	2.58	-1.24	-6.52*	4.43*	4.43*	-6.33**	-3.16*	-3.16*	-5.02**	-1.24	0.76	-5.92 *
$L_6 \times T_2$	3.87	1.89	-5.35*	-1.89	-1.95	-11.82**	3.7*	2.82*	1.80	0.63	1.27	-5.33 *
$L_6 \times T_3$	6.45*	7.49**	-2.99	-1.26	-2.19	-11.14**	-5.06**	-5.06**	-6.89**	0.88	0.87	-7.10 **
$L_7 \times T_1$	6.45*	2.48	-2.99	-1.24	-0.31	-9.70**	-5.06**	-5.06**	-6.89**	-1.86	-0.94	-6.51 *
$L_7 \times T_2$	7.09*	5.06*	-2.41	-2.48	-0.63	-10.46**	-4.43**	-5.32**	-6.26**	-0.63	-0.32	-6.51 *
$L_7 \times T_3$	7.09*	8.14**	-2.41	3.10	3.10	-5.75**	-4.43**	-4.43**	-6.26**	1.90	2.22	-4.73
$L_8 \times T_1$	1.26	-1.53	-5.93*	7.09**	6.07**	-5.75**	-2.58	-3.51*	-6.26**	-1.24	0.32	-5.92 *
$L_8 \times T_2$	5.06	4.07	-2.41	5.16*	5.16**	-7.49**	-2.58	-4.43**	-6.26**	0.63	1.59	-5.33 *
$L_8 \times T_3$	0.87	1.93	-7.11**	7.74**	5.69**	-5.18**	-1.93	-2.84*	-5.64**	1.27	1.60	-5.92 *
$L_9 \times T_1$	3.87	0.89	-5.35*	3.8	2.87	-8.55**	0.99	0.94	-0.06	0.78	1.26	-4.73
$L_9 \times T_2$	11.61**	9.49**	1.70	7.74**	7.74**	-5.18**	-3.73*	-3.72**	-3.78*	8.77**	7.43 **	-2.37
$L_9 \times T_3$	7.74**	8.79**	-1.82	3.87	1.89	-8.55**	-5.59**	-4.70**	-5.64**	1.91	1.91	-5.33 *
$L_{10} \times T_1$	8.44**	4.05	-1.82	4.37*	5.03**	-5.18**	-5.00**	-4.40**	-5.64**	0.62	1.57	-4.14
$L_{10} \times T_2$	9.74**	7.30**	-0.64	3.7	5.39**	-5.73**	1.87	1.55	1.17	8.40 **	9.73 **	-1.78
$L_{10} \times T_3$	7.79**	8.49**	-2.41	-1.87	-2.18	-10.84**	0.87	0.62	-0.68	1.90	2.22	-4.73

Table 4.2.10: Contd...

$L_{11} \times T_1$	3.68	2.42	-0.64	9.74**	8.33**	-4.03*	0.87	0.62	-0.68	3.11	3.75	-1.78
$L_{11} \times T_2$	3.06	3.70	-1.23	12.93**	12.62**	-1.19	-2.50	-2.80*	-3.16 *	4.40	4.40	-1.78
$L_{11} \times T_3$	3.06	6.66**	-1.23	-0.64	-2.85	-13.1**	-6.25**	-5.66**	-6.89**	-1.26	-0.63	-7.10 **
$L_{12} \times T_1$	5.73*	2.46	-2.41	1.87	2.51	-7.43**	-5.36**	-5.91**	-6.26**	-0.62	-0.31	-5.33 *
$L_{12} \times T_2$	5.73*	4.40	-2.41	5.62**	7.30**	4.03 *	7.36**	6.79**	6.26**	1.25	1.57	-4.14
$L_{12} \times T_3$	4.45	6.14*	-3.58	2.50	2.18	-6.87**	-3.06*	-1.55	-1.92	1.25	2.21	-4.14
$L_{13} \times T_1$	-2.42	-3.01	-5.35*	-2.51	-2.20	-11.9**	-0.62	-0.31	-1.92	-1.86	-1.86	-6.51 *
$L_{13} \times T_2$	1.21	2.45	-1.82	5.03*	6.36**	-5.16**	-2.51	-3.12*	-3.78*	1.24	1.88	-3.55
$L_{13} \times T_3$	3.03	7.25**	-0.05	5.03*	4.3*	-5.16**	3.14*	3.47*	1.80	3.73	5.03 *	-1.18
$L_{14} \times T_1$	-3.59	-3.59	-5.35*	1.93	.95	-10.27**	-3.65 *	-1.86	-1.92	-1.85	-1.55	-5.92 *
$L_{14} \times T_2$	-0.59	1.22	-2.41	7.09**	7.09**	-5.75**	-6.09**	-5.23**	-4.40**	0.74	0.93	-4.14
$L_{14} \times T_3$	9.21**	4.07	-2.41	7.09**	5.06**	-5.35**	3.04*	4.96**	4.90**	3.09	4.70	-1.18
$L_{15} \times T_1$	-2.35	-1.48	-2.41	3.10	4.07 *	-5.35**	3.16*	3.16*	1.17	1.2	1.85	-2.37
$L_{15} \times T_2$	-1.17	1.51	-1.23	4.34*	6.32**	-4.00 *	4.43**	3.44*	2.42	2.45	3.73	-1.18
$L_{15} \times T_3$	9.21**	3.10	-2.41	3.10	3.10	-5.35**	-4.43**	-4.43**	-6.26**	-1.23	0.63	-4.73
$L_{16} \times T_1$	0.87	-1.30	-2.43	3.75	4.40*	-5.35**	-1.87	-1.25	-2.54	0.62	0.93	-3.55
$L_{16} \times T_2$	.60	2.14	-1.82	4.37*	6.03**	-5.18**	-1.25	-1.55	-1.92	1.23	2.18	-2.96
$L_{16} \times T_3$	.60	5.0*	-1.82	-3.12	-3.42	-11.92**	-6.87**	-6.28**	-7.51**	-5.09*	-7.57**	-7.10 **
$L_{17} \times T_1$	3.75	1.52	-2.41	-1.87	-1.25	-10.86**	-5.62**	-5.03**	-6.2**	-1.86	-1.56	-6.51 *
$L_{17} \times T_2$	5.62*	5.29*	-0.64	1.11	1.58	-9.14**	1.87	1.55	1.17	2.50	2.82	-2.96
$L_{17} \times T_3$	9.21**	6.41*	-2.41	-1.87	-2.18	-10.86**	-3.7*	-3.15*	-4.40**	-0.63	0.32	-5.92 *
$L_{18} \times T_1$	5.73*	2.46	-2.41	-1.91	-2.22	-12.50**	-3.75*	-3.14*	-4.40**	-1.86	-0.94	-6.51 *
$L_{18} \times T_2$	7.00*	5.66*	-1.23	1.27	1.92	-9.71**	-0.62	-0.93	-1.30	1.89	2.21	-4.14
$L_{18} \times T_3$	7.0 *	8.73**	-1.23	1.27	0.87	-9.71**	-0.62	0.56	-1.30	2.53	2.86	-4.14
$L_{19} \times T_1$	2.14	1.05	-1.82	8.09**	6.88**	-5.18**	4.12*	3.96**	1.80	3.11	3.91	-1.78
$L_{19} \times T_2$	1.52	2.31	-2.41	1.61	1.45	-10.46**	-0.31	-1.41	-2.54	0.63	0.79	-5.33 *
$L_{19} \times T_3$	1.52	5.23*	-2.41	7.44**	5.23**	-5.75**	-0.31	-0.47	-2.54	2.84	3.33	-3.55
$L_{20} \times T_1$	0.97	-1.98	-5.64*	0.88	-0.15	-10.62**	-1.86	-1.09	-2.23	-1.55	-1.09	-6.21 *
$L_{20} \times T_2$	-1.86	-2.02	-7.40**	5.71**	6.56**	-5.41**	-1.86	-2.02	-2.23	0.63	0.78	-5.03 *
$L_{20} \times T_3$	-1.86	1.80	-7.40**	0.98	-1.09	-10.62**	-1.86	-1.09	-2.23	-1.25	-0.47	-6.80 **
$L_{21} \times T_1$	-5.77*	-6.46**	-8.87**	-4.02 *	-5.97**	-11.82**	-5.88**	-4.85**	-5.64**	-5.23 *	-7.79 **	-8.88 **
$L_{21} \times T_2$	-7.59**	-6.60**	-10.61**	-2.16	-1.15	-10.28**	1.54	1.70	1.80	-2.77	-1.71	-6.51 *
$L_{21} \times T_3$	-3.95	-1.15	-7.11**	-2.16	-2.01	-10.278**	-5.88**	-4.85**	-5.64**	-4.00	-2.35	-7.69 **

*,** Significant at 5% and 1 % probability levels , respectively.

T_2 (-6.60) in **E_1**; $L_3 \times T_1$ (-5.32), $L_3 \times T_2$ (-4.43) and $L_3 \times T_3$ (-3.72) in **E_2**; $L_6 \times T_3$ (-5.06), $L_7 \times T_1$ (-5.06), $L_7 \times T_2$ (-5.32), $L_{11} \times T_3$ (-5.66), $L_{12} \times T_1$ (-5.91), $L_{14} \times T_2$ (5.23), $L_{16} \times T_3$ (6.28)and $L_{17} \times T_1$ (-5.03) in **E_3**; $L_{21} \times T_1$ (-7.79) and $L_{16} \times T_3$ (-7.57) in the pooled analysis.

The range of standard heterosis for all the environments was -10.64 to 9.64 in E_1, -14.53 to 9.78 in E_2, -7.51 to 6.26 in E_3 and -8.88 to 7.69 for pooled analysis across the environments. The most heterotic hybrids were $L_1 \times T_1$ (-10.64), $L_1 \times T_2$ (-9.34), $L_2 \times T_1$ (-9.64) and $L_{21} \times T_2$ (-10.61) in **E_1**; $L_2 \times T_3$ (-12.50), $L_3 \times T_1$ (-14.53), $L_3 \times T_2$ (-14.53), $L_{11} \times T_3$ (-13.1) and $L_{18} \times T_1$ (-12.50) in **E_2**; $L_6 \times T_3$ (-6.89), $L_7 \times T_1$ (-6.89), $L_{11} \times T_3$ (-6.89) and $L_{16} \times T_3$ (-7.51) in **E_3**; and $L_1 \times T_3$ (-8.28), $L_2 \times T_1$ (-7.69), $L_3 \times T_1$ (-7.69), $L_{21} \times T_1$ (8.88) and $L_{21} \times T_3$ (-7.69) in across the environments which showed significant negative heterosis for check parent value. Crosses which showed significant heterosis for earliness in all the environments were, $L_{21} \times T_1$ for BP, $L_{21} \times T_1$ for MP and $L_6 \times T_1$, $L_8 \times T_1$, $L_8 \times T_3$, $L_{21} \times T_1$ and $L_{21} \times T_3$ for CP. However, one hybrid $L_{21} \times T_1$ exhibited significant negative heterosis (BP, MP and CP) in all the environments. In pooled analysis, 4 crosses showed significant positive better parent heterosis and 5 hybrids mid-parent heterosis.

4.2.11 Anthesis – silking interval

The estimates of per cent heterobeltiosis, relative heterosis and standard heterosis in 63 test hybrids for anthesis-silking interval are presented in Table 4.2.11. The range of estimates for heterobeltiosis varied from -65.00 to 85.71 in E_1, -50.00 to 90.47 in E_2, -60.00 to 54.54

Table 4.2.11: Estimation of heterosis (%) over better-, mid- and check- parent in three environments (E_1, E_2, E_3)

Cross	Anthesis-silking interval											
	Normal			Low nitrogen			Excess soil moisture			Pooled		
	BP	MP	CP	BP	MP	CP	BP	MP	CP	BP	MP	CP
$L_1 \times T_1$	-52.94**	-42.85*	-27.92	54.45**	78.94**	20.56	27.27	12.00	-30.34**	8.67	8.33	-13.33 **
$L_1 \times T_2$	-52.94**	-42.85*	-27.92	-54.55**	-54.54**	20.56	-51.54**	-36.00**	-15.42	9.56	12.00	-6.67
$L_1 \times T_3$	-27.27	-27.27	-27.92	5.67	-12.0	-21.98	6.45	-12.00	-45.27**	-23.08	-16.67	-33.33 **
$L_2 \times T_1$	-52.94**	-42.85*	-27.92	27.27	47.36*	-0.70	5.43	5.97	-30.34**	-7.69	-4.00	-20.00 **
$L_2 \times T_2$	-41.17 *	-28.5	-9.91	20.00**	10.0**	56.02**	-7.14	-7.43	-35.32**	7.14	15.38	8.67
$L_2 \times T_3$	45.45	45.45*	44.144	18.18	4.00	-7.80	-7.14	-7.13	-35.32**	7.69	12.00	-6.67
$L_3 \times T_1$	-41.17*	-20.00	-9.91	-28.57	-9.09	-29.07	-7.14	-7.14	-35.33**	-35.38 *	-12.00	-26.67 **
$L_3 \times T_2$	-41.17*	-20.00	-9.91	-50.00**	-44.00**	-50.35**	14.28	14.28	-20.98 *	-41.43 **	-15.38	-26.67 **
$L_3 \times T_3$	-27.27	-15.78	-27.92	4.34	3.99	-0.79	5.43	3.45	-30.48**	-7.69	-4.00	-20.00 **
$L_4 \times T_1$	-35.29*	-21.42	-0.90	3.78	27.27	-0.70	6.45	2.67	-30.48**	7.90	7.78	-13.33 **
$L_4 \times T_2$	27.27	8.98	26.12	21.42	36.00*	20.56	21.42	21.42	-15.43ns	14.29	18.52	6.67
$L_4 \times T_3$	5.67	9.67	-0.90	21.42	21.42	20.56	7.45	6.45	-30.38**	7.69	7.69	-6.67
$L_5 \times T_1$	-35.29*	-21.42	-0.90	54.54**	78.94**	20.56	-60.00**	-52.91**	-60.99**	-14.29	-11.11	-20.00 **
$L_5 \times T_2$	18.18	-7.14	17.11	-9.09	-9.09	-29.07	-35.00**	-23.59 *	-35.33**	-14.29	-14.29	-20.00 **
$L_5 \times T_3$	18.18	18.18	17.11	72.72**	52.00**	34.75*	-35.00**	-23.29 *	-35.33**	7.14	11.11	5.78
$L_6 \times T_1$	-47.05**	-28.00	-18.91	5.88	44.00**	27.66	-45.45 *	-52.00**	-70.19**	-35.38 *	-12.00	-26.67 **
$L_6 \times T_2$	-52.94**	-36.00	-27.92	-35.29**	-21.42	-21.98	54.54**	36.00**	-15.43	-44.29 **	-7.69	-20.00 **
$L_6 \times T_3$	50.00	26.31	8.10	-29.41 *	-22.58	-14.89	-18.18	-28.00 *	-55.22**	-15.38	-12.00	-26.67 **
$L_7 \times T_1$	-14.2	-22.58	8.10	7.14	36.36*	6.38	-35.71*	-35.74**	-55.24**	-14.29	-11.11	-20.00 **
$L_7 \times T_2$	-7.14	-16.12	17.11	-7.14	4.00	-7.80	-28.57*	-28.57 *	-50.49**	-14.29	-14.29	-20.00 **
$L_7 \times T_3$	-7.14	4.000	17.11	35.71*	35.71 *	34.75*	-28.57*	-28.51 *	-50.29**	0.00	3.70	-6.67
$L_8 \times T_1$	-58.82**	-44.00*	-36.93	-9.09	5.26	-29.07	25.00	-9.09	-50.24**	-40.77 **	-18.18	-40.00 **
$L_8 \times T_2$	62.50	4.00	17.11	18.18	18.18	-7.80	25.00	-9.09	-50.29**	-14.29	4.35	-20.00 **
$L_8 \times T_3$	37.50	15.78	-0.90	81.81**	60.00**	41.84**	37.50	4.89	-45.74**	7.69	27.27 **	-6.67
$L_9 \times T_1$	8.65	-36.00	-27.92	27.27	47.36*	-0.70	17.64	29.03**	-0.49	7.69	12.00	-6.67
$L_9 \times T_2$	37.50	-12.00	-0.90	81.81**	81.81**	41.84**	-35.29**	-29.02**	-45.74**	4.56	7.69	-6.67
$L_9 \times T_3$	37.50	15.78	-0.90	27.27	12.00	-0.70	-52.94**	-48.37**	-60.99**	-15.38	-12.00	-26.67 **
$L_{10} \times T_1$	-52.94**	-33.33	-27.92	53.84**	90.47**	41.84**	-38.46*	-40.71**	-60.19**	-47.69	35.00	-40.00 **
$L_{10} \times T_2$	85.71*	8.33	17.1	23.07	33.33*	13.47	3.78	-3.70	-35.33**	5.34	12.00	-6.67
$L_{10} \times T_3$	10.56	-22.22	-36.93	6.45	-3.70	-7.80	2.67	-3.70	-35.23**	-15.38	-8.33	-26.67 **

Table 4.2.11: Contd....

$L_{11} \times T_1$	-23.07	-33.33 *	-9.91	5.32	11.11	-29.07	-18.75	-13.33ns	-35.32**	-15.38	-15.38	-26.67 **
$L_{11} \times T_2$	-53.84 *	-60.00**	-45.94	20.00	14.28	-14.89	-43.75**	-40.00**	-55.22**	-35.71 *	-33.33 **	-39.34**
$L_{11} \times T_3$	-30.76	-25.00	-18.91	20.00	8.66	-14.89	-43.75**	-40.00**	-55.2**	-23.08	-23.08 **	-33.33 **
$L_{12} \times T_1$	-46.15*	-53.33**	-32.93	4.65	33.33**	13.47	-37.50**	-33.33**	-50.29**	-26.67	-21.43 **	-26.67 **
$L_{12} \times T_2$	-23.07	-33.33*	-9.91	18.75	40.73**	34.75*	-37.50**	-33.33**	-50.29**	-13.33	-10.34	-13.33 **
$L_{12} \times T_3$	-15.38	-8.33	-0.90	-12.50	-6.66	-0.70	-12.50	-6.67	-30.38**	-13.33	-7.14	-13.33 **
$L_{13} \times T_1$	-35.29*	-15.38	-0.91	-8.33	10.00	-21.98	41.66*	30.76*	-15.43	3.67	8.33	-13.33 **
$L_{13} \times T_2$	-35.29*	-15.38	-0.90	16.66	21.73	-0.70	16.66	7.69	-30.34**	-7.14	4.00	-13.33 **
$L_{13} \times T_3$	55.55	40.00	26.12	41.66*	30.76*	20.56	16.6	7.69	-30.34**	15.38	25.00 **	12.89
$L_{14} \times T_1$	-45.0**	-40.54**	-0.90	27.27	47.36*	-0.74	-17.64	-9.67	-30.38**	-18.75	-10.34	-13.33 **
$L_{14} \times T_2$	-65.00**	-62.16**	-38.93	72.72**	72.72**	34.52 *	-41.17**	-35.44**	-50.29**	-45.00 **	-20.00	-20.00 **
$L_{14} \times T_3$	-65.00**	-54.83**	-38.82	72.72**	52.00**	34.52 *	-23.52*	-16.29	-35.33**	-58.75 **	-10.34	-13.33 **
$L_{15} \times T_1$	-65.00**	-62.16**	-33.93	35.71 *	72.72**	34.52 *	-7.14	-7.14	-35.32**	-38.75 **	-10.34	-13.33 **
$L_{15} \times T_2$	-55.00**	-51.35**	-18.91	50.00**	68.00**	48.96**	7.14	7.14	-25.37*	-6.25	5.87	4.57
$L_{15} \times T_3$	-65.00**	-54.83**	-34.93	14.28	14.28	13.45	-50.0**	-50.00**	-55.17**	-37.50 **	-31.03 **	-33.33 **
$L_{16} \times T_1$	-56.25**	-57.57**	-34.45	90.00**	91.11**	34.75*	30.00	8.333	-35.32**	8.89	4.00	-13.33 **
$L_{16} \times T_2$	-12.50	-15.15	26.12	10.00**	90.47**	41.84**	40.00*	16.66	-30.34**	14.29	23.08 **	6.67
$L_{16} \times T_3$	-12.50	3.70	26.12	10.00	-8.33	-21.98	-20.00	-33.33 *	-50.19**	-15.38	-12.00	-26.67 **
$L_{17} \times T_1$	30.00	-3.70	17.11	3.67	11.11	-29.07	-46.15**	-48.14**	-55.17**	-23.08	-16.67	-33.33 **
$L_{17} \times T_2$	-41.17*	-25.92	-9.91	4.53	-4.76	-29.07	10.88	-3.70	-35.32**	-21.43	-12.00	-26.67 **
$L_{17} \times T_3$	-30.00	-33.33	-36.93	30.0	8.33	-7.80	-23.07	-25.92*	-50.24**	-23.08	-16.67	-33.33 **
$L_{18} \times T_1$	30.00	-3.70	17.11	3.88	11.11	-29.78	18.56	-16.66	-50.24**	-15.38	-4.35	-26.67 **
$L_{18} \times T_2$	40.00	3.70	26.12	40.00	33.33	-0.70	40.00*	16.66	-30.34**	7.89	16.67	-6.67
$L_{18} \times T_3$	70.00*	61.90**	53.15*	40.00	16.67	-0.709	40.00*	16.6	-30.34**	15.38	30.43 **	12.45
$L_{19} \times T_1$	3.03	1.49	53.15*	90.47**	96.16**	41.84**	48.14**	45.45**	-0.49	40.74 **	43.40 **	26.67 **
$L_{19} \times T_2$	-21.21	-22.38	17.11	-4.76	-6.97	-29.07	-3.70	-5.45	-35.33**	-14.29	-12.73	-20.00 **
$L_{19} \times T_3$	-3.03	16.36	44.14	80.95**	55.12**	34.75*	-3.70	-5.45	-35.33**	18.52	20.75	6.67
$L_{20} \times T_1$	-38.23*	-31.14*	-5.40	3.88	13.51	-25.32	-18.18	-11.47	-32.83**	-14.81	-13.21	-23.33 **
$L_{20} \times T_2$	-38.25 *	-31.14*	-5.40	85.71**	81.39**	38.28 *	-18.82	-11.47	-32.36**	3.57	5.45	-3.33
$L_{20} \times T_3$	-22.22	-14.28	-5.40	28.57	10.20	-4.255	-18.12	-11.47	-32.86**	-7.41	-5.66	-16.67 **
$L_{21} \times T_1$	-46.34**	-41.33**	-0.90	-4.34	12.82	-21.86	-44.82**	-43.80**	-50.19**	-35.48 *	-29.82 **	-33.33 **
$L_{21} \times T_2$	-60.97**	-57.33**	-27.92	47.82*	51.11**	20.57	17.24	19.29	-15.23	-9.68	-5.08	-6.67
$L_{21} \times T_3$	-46.34**	-30.15*	-0.90	47.82*	33.33 *	20.56	-44.82**	-43.86**	-52.19**	-22.58	-15.79	-20.00 **

*,** Significant at 5% and 1 % probability levels , respectively.

in E_3 and –58.75 to 40.74 in the pooled analysis. The hybrids $L_{14} \times T_2$ (-65.00), $L_{14} \times T_3$ (-65.00), $L_{15} \times T_1$ (-65.00), $L_{15} \times T_2$ (-65.00), $L_{15} \times T_3$ (-65.00) and $L_{21} \times T_2$ (-60.97) in **E_1**; $L_3 \times T_2$ (-50.00), $L_6 \times T_2$ (-35.29) and $L_6 \times T_3$ (-29.41) in **E_2**; $L_5 \times T_1$ (-60.00), $L_9 \times T_3$ (-52.94) and $L_{15} \times T_3$ (-50.00) in **E_3** showed maximum and significant negative heterosis over better parent for days to 50 per cent silking. In pooled analysis, crosses $L_6 \times T_2$ (-44.29), $L_{14} \times T_2$ (-45.00) and $L_{14} \times T_3$ (-58.75) observed maximum negative heterosis for short anthesis-silking interval.

Results on the estimates of per cent relative heterosis ranged from -62.16 to 61.90, -44.00 to 96.16, -52.91 to 45.45 and -33.33 to 43.40 in E_1, E_2, E_3 and pooled analysis, respectively. The most promising heterotic hybrids for early flowering were $L_{11} \times T_2$ (-60.00), $L_{14} \times T_2$ (-62.16) and $L_{15} \times T_1$ (-62.16) in **E_1**; $L_1 \times T_2$ (-54.54) and $L_3 \times T_2$ (-44.00) in **E_2**; $L_5 \times T_1$ (-52.91), $L_6 \times T_1$ (-52.00) and $L_{15} \times T_3$ (-50.00) in **E_3**; and $L_{11} \times T_2$ (-33.33) and $L_{15} \times T_3$ (-31.03) in the pooled analysis.

The range of standard heterosis for all the environments was -45.94 to 53.15 in E_1, -50.35 to 56.02 in E_2, -70.19 to 0.00 in E_3 and -40.00 to 12.89 for pooled across the environments. The most heterotic hybrids were $L_{11} \times T_2$ (-45.94), $L_{14} \times T_2$ (-38.93) and $L_{14} \times T_3$ (-38.82) in E_1; $L_1 \times T_2$ (-54.54) and $L_3 \times T_2$ (-50.35) in E_2; $L_5 \times T_1$ (-60.99), $L_6 \times T_1$ (-70.19), $L_9 \times T_3$ (-60.99) and $L_{10} \times T_1$ (-60.19) in E_3; and $L_8 \times T_1$ (-40.00), $L_{10} \times T_1$ (-40.00) and $L_{11} \times T_2$ (-39.34) in across the environments which showed significant negative heterosis for check parent value. Crosses which showed significant heterosis for earliness in all the environments were $L_1 \times T_2$ for

BP and $L_1 \times T_2$ for MP. However, none of the crosses exhibited significant negative heterosis (BP, MP and CP) in all the environments

4.2.12 Protein percentage

The estimates of per cent heterobeltiosis, relative heterosis and standard heterosis for protein percentage are given in Table 4.2.12. In pooled analysis, 14 crosses exhibited significant negative better parent heterosis along with 11 mid-parent and19 standard heterosis. Better-parent heterosis in E_1, E_2, E_3 and pooled analysis ranged from -32.22 to 48.32, -32.42 to 48.92, -32.43 to 48.81 and -32.39 to 43.39 per cent, respectively. The most promising hybrids with significant higher estimates of heterosis for protein percentage were $L_3 \times T_1$, $L_3 \times T_3$, $L_{10} \times T_1$, $L_{10} \times T_2$, $L_{17} \times T_1$, $L_{17} \times T_3$, $L_{18} \times T_2$ and $L_{18} \times T_3$ in E_1, E_2 and E_3. However, $L_3 \times T_3$, $L_{14} \times T_3$, $L_{17} \times T_3$ and $L_{18} \times T_3$ (37.59) showed higher estimates of heterosis for protein percentage across the environments.

The estimates of relative heterosis for protein percentage ranged from -26.01 to 43.30, -24.79 to 43.86, -26.19 to 43.73 and -26.15 to 43.62 in E_1, E_2, E_3 and across environments, respectively. Maximum mid-parent heterosis in hybrids were observed in $L_1 \times T_3$, $L_2 \times T_1$, $L_3 \times T_1$, $L_{10} \times T_1$, $L_{12} \times T_3$, $L_{13} \times T_3$, $L_{14} \times T_3$, $L_{17} \times T_3$, $L_{18} \times T_3$ and $L_{20} \times T_3$ in E_1, E_2 , E_3 and pooled over environments.

The estimates of standard heterosis for protein percentage ranged from -30.05 to 23.74, -27.37 to 22.77, -27.18 to 21.95 and -30.26 to 34.67 in E_1, E_2, E_3 and pooled analysis, respectively.

Table 4.2.12: Estimation of heterosis (%) over better-, mid- and check- parent in three environments (E_1, E_2, E_3)

Cross	Protein (%)											
	Normal			Low nitrogen			Excess soil moisture			Pooled		
	BP	MP	CP	BP	MP	CP	BP	MP	CP	BP	MP	CP
$L_1 \times T_1$	-29.76**	-24.56**	-27.13**	-30.01**	-24.79**	-27.37**	-29.96**	-24.75**	-27.18**	-29.92 **	-24.70 **	-27.32 **
$L_1 \times T_2$	7.54	3.63	3.74	1.56	3.66	3.77	3.77	3.66	3.95	2.66	3.66	3.70
$L_1 \times T_3$	3.63	21.7 *	7.51	3.66	21.97*	7.58	3.66	21.92*	7.75	3.65	21.89 **	7.49
$L_2 \times T_1$	11.22	17.45*	11.28	11.32	17.61*	11.38	11.30	17.58*	11.56	11.28	19.55*	11.28
$L_2 \times T_2$	-6.51	-4.80	-6.46	-6.57	-4.84	-6.51	-6.56	-4.84	-6.34	-6.55	-4.83 **	-6.55
$L_2 \times T_3$	-13.53	.06	-13.48	-13.65	.06	-13.59	-13.62	.06	-13.42	-13.60	0.07	-13.60
$L_3 \times T_1$	26.61*	21.84 *	4.59	26.90*	21.80*	4.63	26.84*	21.71 *	4.80	17.03	21.72 **	4.55
$L_3 \times T_2$	8.99	.55	-9.97	9.08	.56	-10.05	9.06	.56	-9.88	-6.71	0.56	-10.08
$L_3 \times T_3$	25.59*	33.49**	3.74	25.86*	33.84**	3.77	25.81*	33.76**	3.95	25.76 *	33.69 **	3.70
$L_4 \times T_1$	7.54	11.60	3.74	7.617	11.71	3.77	7.60	11.69	3.95	7.59	11.67	3.70
$L_4 \times T_2$	3.72	3.72	.05	3.76	3.76	.05	3.75	3.75	.23	3.75	3.75	4.78
$L_4 \times T_3$	0.78	13.93	-3.53	2.89	14.08	-3.56	4.78	14.05	-3.39	5.67	14.02	-3.61
$L_5 \times T_1$	11.86	11.86	.05	11.98	11.98	.05	11.96	11.96	.23	11.94	11.94	6.89
$L_5 \times T_2$	14.54	17.77*	23.56 *	14.69	17.94*	23.77*	14.66	17.9 *	23.59 *	20.88 *	17.87	23.74 *
$L_5 \times T_3$	.65	10.93	-9.97	.66	11.05	-10.05	.65	11.03	-9.88	0.66	11.01	-10.08
$L_6 \times T_1$	-1.93	7.06	5.43	-1.94	7.13	5.48	-1.94	7.11	5.66	-1.94	7.10	5.41
$L_6 \times T_2$	-13.54	-8.85	-7.04	-13.65	-8.93	-7.10	-13.63	-8.92	-6.93	-13.61	-8.90	-7.14
$L_6 \times T_3$	-28.61**	-14.87	-23.24*	-28.46**	-15.04	-23.45*	-28.79**	-15.01	-23.27*	-28.75 **	-14.98	-23.41 *
$L_7 \times T_1$	5.31	7.34	-2.10	5.36	7.41	-2.12	5.35	7.39	-1.94	5.35	7.38	-2.17
$L_7 \times T_2$	-17.7	-19.29*	-23.56*	-17.94	-19.47*	-23.77*	-17.90	-19.44*	-23.59*	-20.88 *	-19.40 *	-23.74 *
$L_7 \times T_3$	-16.07	-5.90	-21.98*	-16.22	-5.97	-22.18*	-16.19	-5.95	-22.00*	-16.17	-5.94	-22.15 *
$L_8 \times T_1$	-17.39	-14.28	-20.32*	-17.55	-14.41	-20.50*	-17.52	-14.39	-20.32*	-17.49	-14.36	-20.48 *
$L_8 \times T_2$	-6.66	-6.66	-9.97	-6.73	-6.73	-10.05	-6.71	-6.71	-9.88	-6.71	-6.71	-10.08
$L_8 \times T_3$	-7.27	5.64	-10.55	-7.34	5.70	-10.64	-7.32	5.69	-10.47	-7.31	5.68	-10.66
$L_9 \times T_1$	-32.22**	-26.01**	-27.13**	-32.42**	-26.2**	-27.37**	-32.43**	-26.19**	-27.1**	-32.39 **	-26.15 **	-27.32 **
$L_9 \times T_2$	-26.19**	-22.19**	-20.64*	-26.45**	-22.38**	-20.82*	-26.36**	-22.34**	-20.6 *	-26.32 *	-22.31 **	-20.80 *
$L_9 \times T_3$	-6.93	10.94	.05	-6.99	11.04	.05	-6.98	11.02	.23	-6.97	11.01	7.78
$L_{10} \times T_1$	48.32**	30.17**	23.74**	48.92**	30.51**	22.77**	48.81**	30.44**	21.95**	16.08	30.38 **	3.70
$L_{10} \times T_2$	38.88**	16.74	-2.86	39.33**	16.92	-2.89	39.27**	16.88	-2.71	0.70	16.85	-2.94
$L_{10} \times T_3$	13.9	11.58	-20.32*	14.09	11.73	-20.50*	14.02	11.70	-20.32*	9.42	11.67	-20.48 *

Table 4.2.12: Contd...

$L_{11} \times T_1$	-10.56	-3.586ns	-6.46	-10.65	-3.61	-6.51	-10.63	-3.61	-6.34	-10.62	-3.61	-6.55
$L_{11} \times T_2$	-20.07*	-16.81 *	-16.40	-20.24 *	-16.98*	-16.54	-20.20*	-16.96 *	-16.37	-20.17 *	-16.93	-16.54
$L_{11} \times T_3$	-2.79	14.58	1.66	-2.81	14.72	1.68	-2.81	14.69	1.85	-2.81	14.67	1.62
$L_{12} \times T_1$	-10.70	-5.36	-9.97	-10.79	-5.41	-10.05	-10.77	-5.40	-9.88	-10.76	-5.39	-10.08
$L_{12} \times T_2$	-7.22	-5.17	-6.46	-7.28	-5.21	-6.51	-7.27	-5.21	-6.34	-7.26	-5.20	-6.55
$L_{12} \times T_3$	6.64	23.80*	7.51	6.70	24.04*	7.58	6.68	23.99*	7.75	6.68	23.95 **	7.49
$L_{13} \times T_1$	-22.65*	-20.65*	-27.1**	-22.70*	-20.84*	-27.37**	-22.82*	-20.80*	-27.19**	-22.78 *	-20.77 **	-27.32 **
$L_{13} \times T_2$	14.12	12.77	7.51	14.25	12.89	7.58	14.22	12.86	7.75	11.52	12.85	7.49
$L_{13} \times T_3$	10.11	24.18*	3.74	10.21	24.44*	3.77	10.19	24.39*	3.95	10.17	24.34 **	3.70
$L_{14} \times T_1$	5.89	-5.97	-20.64*	5.99	-6.03	-20.82*	6.89	-6.026	-20.6 *	-11.34	-6.01	-20.80 *
$L_{14} \times T_2$	9.02	-1.58	-13.48	9.12	-1.59	-13.59	9.10	-1.59	-13.42	-10.36	-1.59	-13.60
$L_{14} \times T_3$	22.40	27.62*	-2.86	22.65	27.94*	-2.89	22.60	27.87*	-2.71	22.55 *	27.81**	-2.94
$L_{15} \times T_1$	-18.27	-18.27*	-26.90**	-18.45	-18.45*	-27.13**	-18.41	-18.41*	-26.9**	-18.38	-18.38 *	-27.09 **
$L_{15} \times T_2$	-15.26	-18.46*	-24.21*	-15.41	-18.64*	-24.42*	-15.38	-18.60*	-24.2 *	-21.55 *	-18.57 *	-24.38 **
$L_{15} \times T_3$	4.57	15.25	-6.46	4.62	15.42	-6.51	4.61	15.39	-6.34	4.60	15.36	-6.55
$L_{16} \times T_1$	-21.31*	-18.06*	-23.56*	-21.50*	-18.24*	-23.76 *	-21.46*	-18.20*	-23.59*	-21.43 *	-18.17 *	-23.74 *
$L_{16} \times T_2$	3.01	3.36	.05	3.03	3.39	.059	3.03	3.39	.23	3.03	3.39	5.67
$L_{16} \times T_3$	-7.91	5.22	-10.55	-7.98	5.28	-10.64	-7.97	5.27	-10.47	-7.96	5.26	-10.66
$L_{17} \times T_1$	27.96*	15.09	-6.46	28.30*	15.25	-6.51	28.23*	15.22	-6.34	4.60	15.19	-6.55
$L_{17} \times T_2$	-4.32	-17.50	-30.05**	-4.37	-17.68	-30.34**	-4.36	-17.64	-30.14**	-27.64 **	-17.61	-30.26 **
$L_{17} \times T_3$	43.08**	43.30**	4.59	43.6**	43.86**	4.63	43.4**	43.73**	4.80	43.39 **	43.62 **	4.55
$L_{18} \times T_1$	2.67	-12.2	-30.05**	5.78	-12.37	-30.32**	8.76	-12.34	-30.1**	-21.93 *	-12.32	-30.26 **
$L_{18} \times T_2$	32.91*	11.72	-7.04	33.31*	11.84	-7.10	33.25*	11.82	-6.93	-3.66	11.79	-7.14
$L_{18} \times T_3$	43.06**	40.13**	.058	43.60**	40.63**	.059	43.49**	40.52**	.23	37.59 **	40.43 **	34.67**
$L_{19} \times T_1$	1.53	4.59	-3.53	1.55	4.64	-3.56	1.55	4.63	-3.39	1.55	4.62	-3.61
$L_{19} \times T_2$	-8.92	-9.62	-13.48	-9.00	-9.71	-13.59	-8.99	-9.69	-13.42	-10.36	-9.67	-13.60
$L_{19} \times T_3$	-5.23	7.26	-9.97	-5.28	7.34	-10.05	-5.27	7.32	-9.88	-5.26	7.31	-10.08
$L_{20} \times T_1$	2.02	-5.01	-20.52*	2.05	-5.068	-20.70*	2.04	-5.05	-20.53*	-11.21	-5.05	-20.68 *
$L_{20} \times T_2$	4.16	-6.92	-18.86*	4.21	-6.99	-19.02*	4.20	-6.98	-18.85*	-15.97	-6.97	-19.01
$L_{20} \times T_3$	17.45	21.37*	-8.50	17.65	21.62*	-8.58	17.61	21.57*	-8.40	17.57	21.52 *	-8.61
$L_{21} \times T_1$	-28.22**	-23.68**	-27.13**	-28.47**	-23.9**	-27.35**	-28.42**	-23.86**	-27.1**	-28.37 **	-23.82 **	-27.32 **
$L_{21} \times T_2$	-21.83*	-19.83*	-20.64*	-22.0 *	-20.01 *	-20.86 *	-21.94 *	-19.97*	-20.64 *	-21.95 *	-19.94 *	-20.80 *
$L_{21} \times T_3$	-1.44	14.75	.05	-1.45	14.90	.05	-1.45	14.87	.236	-1.45	14.84	3.56

*,** Significant at 5% and 1 % probability levels , respectively.

The cross cross combinations, $L_{10} \times T_1$ and $L_5 \times L_2$ exhibited higher and significant heterosis over check in all E_1, E_2 and E_3 environments and hybrids, $L_5 \times L_2$ and $L_{18} \times T_3$ exhibited higher and significant heterosis in pooled environment.

The cross combination $L_{10} \times T_1$ exhibited higher and significant positive heterosis (BP, MP and CP) in all the environments.

4.2.13 Lysine (%)

The nature and magnitude of per cent heterobeltiosis, relative heterosis and standard heterosis for lysine content are presented in Table 4.2.13. The heterobeltiosis ranged from -39.23 to 31.95, -39.01 to 34.75, -38.57 to 34.25 and -40.91 to 33.61 in E_1, E_2, E_3 and across environments, respectively. The crosses, $L_1 \times T_1$, $L_{11} \times T_3$, $L_{12} \times T_1$, $L_{16} \times T_2$ and $L_{18} \times T_3$ expressed maximum heterobeltiosis for lysine in all the environments as well as in pooled environment.

As regards the magnitude of relative heterosis, it ranged from -30.00 to 40.06 in E_1; -32.38 to 44.01 in E_2; -35.01 to 43.30 in E_3; and -34.41 to 42.39 in the pooled analysis. Among all 63 crosses, hybrid, $L_1 \times T_1$, $L_8 \times T_2$, $L_9 \times T_1$, $L_{10} \times T_2$ $L_{11} \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_1$, $L_{12} \times T_3$, $L_{14} \times T_1$, $L_{16} \times T_1$, $L_{16} \times T_2$, $L_{18} \times T_3$, $L_{19} \times T_1$, $L_{19} \times T_2$, $L_{19} \times T_3$, $L_{20} \times T_2$ and $L_{21} \times T_1$ showed maximum relative heterosis in all the environments.

Estimates of standard heterosis for lysine ranged from -43.72 to 45.40, -45.71 to 47.19, -45.18 to 45.48 and -33.44 to 26.76 in E_1, E_2, E_3 and pooled analysis, respectively. Maximum heterosis over check was exhibited by $L_1 \times T_1$, $L_{16} \times T_2$ and $L_{18} \times T_2$ in E_1, E_2, E_3 and across

Table 4.2.13: Estimation of heterosis (%) over better-, mid- and check- parent in three environments (E_1, E_2, E_3)

Cross	Lysine (%)											
	Normal			Low nitrogen			Excess soil moisture			Pooled		
	BP	MP	CP	BP	MP	CP	BP	MP	CP	BP	MP	CP
$L_1 \times T_1$	29.78**	20.86**	29.03**	32.73**	22.77 *	28.09**	32.20**	22.43*	29.53**	23.75**	21.99 **	22.70**
$L_1 \times T_2$	4.25	8.53	-26.93**	4.67	9.41	-27.52**	4.60	9.25	-28.46**	4.50	9.05	-12.04
$L_1 \times T_3$	7.25	2.75	-24.82**	7.97	3.01	-25.23**	7.84	2.97	-26.24**	-1.45	2.91	-9.36
$L_2 \times T_1$	-36.5**	-30.0**	-37.45**	-39.01**	-32.38**	-38.95**	-38.57**	-31.97**	-39.57**	-38.00 **	-31.45 **	-25.42 **
$L_2 \times T_2$	-31.25**	-16.94*	-32.21**	-33.39**	-18.36*	-33.33**	-33.02**	-18.11*	-34.04**	-32.53 **	-17.79 *	-18.84 **
$L_2 \times T_3$	-7.65	4.11	-9.03	-8.18	4.43	-8.09	-8.09	4.38	-9.53	-7.97	4.31	10.70
$L_3 \times T_1$	-31.16**	-28.15**	-39.56**	-33.58**	-30.44**	-41.28**	-33.15**	-30.03**	-41.79**	-32.60 **	-29.51 **	-28.09 **
$L_3 \times T_2$	-7.19	6.96	-18.50 *	-7.75	7.59	-18.31 *	-7.65	7.48	-19.57 *	-7.52	7.34	-1.34
$L_3 \times T_3$	-12.08	-5.88	-22.80**	-13.02	-6.37	-23.08**	-12.85	-6.28	-24.04**	-12.64	-6.17	-6.80
$L_4 \times T_1$	-3.98	-0.84	-17.54 *	-4.30	-0.91	-17.33 *	-4.24	-0.90	-18.59 *	-4.17	-0.88	-0.11
$L_4 \times T_2$	-19.81*	-8.45	-31.14**	-21.38*	-9.23	-32.05**	-21.11*	-9.09	-32.80**	-20.75 **	-8.91	-17.39 *
$L_4 \times T_3$	-8.37	-2.92	-21.31**	-9.04	-3.16	-21.49**	-8.92	-3.12	-22.50**	-8.77	-3.07	-4.91
$L_5 \times T_1$	-8.70	-6.89	-23.59**	-9.41	-7.47	-23.90**	-9.28	-7.36	-24.97**	-9.12	-7.23	-7.80
$L_5 \times T_2$	-12.78	-1.53	-27.01**	-13.83	-1.68	-27.61**	-13.64	-1.65	-28.59**	-13.41	-1.62	-12.15
$L_5 \times T_3$	-19.49*	-15.74*	-32.63**	-21.08*	-17.09*	-33.71**	-20.80*	-16.85*	-34.44**	-20.44 **	-16.54 *	-19.29 **
$L_6 \times T_1$	-5.19	-5.81	-24.73**	-5.64	-6.31	-25.14**	-5.56	-6.22	-26.11**	-6.76	-6.11	-9.25
$L_6 \times T_2$	-1.32	8.83	-21.66**	-1.44	9.68	-21.81**	-1.42	9.53	-22.80**	-1.39	9.34	-5.35
$L_6 \times T_3$	8.17	10.37	-14.12 *	8.88	11.28	-13.61	8.75	11.12	-14.90	8.59	10.91	4.24
$L_7 \times T_1$	1.08	6.21	-10.00	1.16	6.71	-9.14	1.15	6.62	-10.55	1.13	6.51	9.48
$L_7 \times T_2$	-10.83	3.36	-20.61**	-11.66	3.67	-20.66**	-11.51	3.61	-21.79**	-11.33	3.55	-4.01
$L_7 \times T_3$	-9.45	-2.44	-19.38**	-10.18	-2.64	-19.33 *	-10.05	-2.60	-20.43**	-9.89	-2.56	-2.45
$L_8 \times T_1$	-14.93	-9.66	-22.54**	-16.04	-10.43	-22.76**	-15.84	-10.30	-23.76**	-15.59	-10.12	-6.47
$L_8 \times T_2$	-1.06	15.78*	-9.91	-1.13	17.17*	-9.04	-1.12	16.92*	-10.46	-1.11	16.61 *	9.59
$L_8 \times T_3$	-4.52	3.93	-13.07	-4.86	4.25	-12.47	-4.80	4.19	-13.79	-4.73	4.12	5.57
$L_9 \times T_1$	11.02	15.21 *	-3.68	11.88	16.45*	-2.28	11.73	16.23*	-3.88	11.53	15.95 *	17.50 *
$L_9 \times T_2$	-15.77	-3.42	-26.90**	-17.01	-3.73	-27.54**	-16.79	-3.67	-28.46**	-16.51	-3.60	-12.04
$L_9 \times T_3$	4.85	11.62	-9.03	5.23	12.60	-8.09	5.16	12.42	-9.53	5.08	12.20	10.70
$L_{10} \times T_1$	3.74	3.18	-17.45*	4.07	3.45	-17.23 *	4.014	3.40	-18.42*	2.75	3.34	4.67
$L_{10} \times T_2$	16.97	29.15**	-6.93	18.44	31.95**	-5.810	18.18	31.45**	-7.31	17.84	30.80 **	13.38
$L_{10} \times T_3$	-9.48	-7.54	-27.98**	-10.29	-8.21	-28.6**	-10.15	-8.09	-29.53**	-9.97	-7.94	-13.38

Table 4.2.13: Contd...

$L_{11} \times T_1$	-28.38**	-29.29**	-43.72**	-30.83**	-31.77**	-45.81**	-30.41**	-31.34**	-43.20**	-31.62 **	-30.74 **	-33.44 **
$L_{11} \times T_2$	17.20	28.63**	-7.98	18.71	31.40**	-6.95	18.44	30.90**	-8.42	18.10 *	30.27 **	12.04
$L_{11} \times T_3$	31.95**	33.90**	3.59	34.75**	36.91**	5.61	34.25**	36.37**	3.79	33.61 **	35.68 **	26.76 **
$L_{12} \times T_1$	19.36 *	19.49*	-3.77	21.01*	21.15 *	-2.38	20.72*	20.86*	-3.98	20.34 **	20.48 **	17.39 *
$L_{12} \times T_2$	-8.05	2.11	-25.77**	-8.73	2.31	-26.31**	-8.61	2.28	-27.31**	-8.46	2.23	-10.70
$L_{12} \times T_3$	14.14	17.33*	-7.98	15.34	18.85*	-6.95	15.13	18.58*	-8.426	14.86	18.24 *	12.04
$L_{13} \times T_1$	-3.03	-8.27	-30.00**	-3.32	-9.02	-30.87**	-3.27	-8.88	-31.66**	-13.63	-8.72	-15.94 *
$L_{13} \times T_2$	-14.70	-9.94	-38.41**	-16.11	-10.95	-40.00**	-15.85	-10.77	-40.55**	-15.53	-10.54	-26.64 **
$L_{13} \times T_3$	-4.49	-7.09	-31.03**	-4.92	-7.75	-32.00**	-4.84	-7.63	-32.77**	-10.06	-7.48	-17.28 *
$L_{14} \times T_1$	14.21	19.89**	1.49	15.30	21.50**	3.33	15.11	21.21**	1.57	14.86	20.85 **	24.08 **
$L_{14} \times T_2$	-13.03	.74	-22.71**	-14.02	.81	-22.95**	-13.85	.79	-23.98**	-13.62	0.78	-6.69
$L_{14} \times T_3$	-3.55	3.82	-14.29*	-3.82	4.14	-13.81	-3.77	4.08	-15.09*	-3.72	4.01	4.01
$L_{15} \times T_1$	-15.65*	-9.04	-20.61**	-16.78*	-9.75	-20.67**	-16.58*	-9.62	-21.75**	-16.33	-9.46	-4.01
$L_{15} \times T_2$	-16.77*	-1.27	-21.66**	-17.98*	-1.38	-21.10**	-17.76*	-1.36	-22.87**	-17.49	-1.34	-5.35
$L_{15} \times T_3$	-39.23**	-32.85**	-42.80**	-42.05**	-35.4**	-44.72**	-41.56**	-35.01**	-45.18**	-40.91 **	-34.41 **	-32.22 **
$L_{16} \times T_1$	23.47*	20.15**	-5.87	25.59*	21.92*	-4.66	25.21*	21.60*	-6.20	17.87	21.20 **	14.72 *
$L_{16} \times T_2$	29.34**	40.06**	45.40**	31.99**	44.01**	47.19**	31.52**	43.30**	45.48**	30.91 **	42.39 **	26.76 **
$L_{16} \times T_3$	-26.1**	-26.12**	-43.68**	-28.48**	-28.42**	-45.71**	-28.05**	-28.0**	-46.11**	-27.52 **	-27.52 **	-33.33 **
$L_{17} \times T_1$	-1.49	-4.14	-24.91**	-1.63	-4.50	-25.33**	-1.60	-4.44	-26.29**	-6.99	-4.36	-9.48
$L_{17} \times T_2$	-18.64*	-11.90	-37.98**	-20.32*	-13.07	-39.52**	-20.02*	-12.86	-40.09**	-19.64 *	-12.59	-26.09 **
$L_{17} \times T_3$	-1.26	-1.26	-24.73**	-1.38	-1.38	-25.14**	-1.36	-1.36	-26.11**	-1.33	-1.33	-9.25
$L_{18} \times T_1$	-2.57	-5.92	-26.84**	-2.80	-6.44	-27.42**	-2.76	-6.35	-28.33**	-9.51	-6.23	-11.93
$L_{18} \times T_2$	7.24	15.32	19.47**	7.90	16.85	19.42*	7.78	16.5	20.55**	7.64	16.22 *	22.56**
$L_{18} \times T_3$	28.15**	27.18**	-3.77	30.74**	29.66**	-2.38	30.27**	29.22**	-3.98	27.64 **	28.65 **	17.39 *
$L_{19} \times T_1$	13.61	17.21*	-2.63	14.69	18.62*	-1.14	14.50	18.37*	-2.77	14.26	18.05 **	18.84 **
$L_{19} \times T_2$	6.24	21.19*	-8.94	6.74	23.13*	-8.00	6.65	22.78*	-9.44	6.54	22.34 **	10.81
$L_{19} \times T_3$	12.28	18.852*	-3.77	13.26	20.44*	-2.38	13.08	20.16*	-3.98	12.86	19.80 *	17.39 *
$L_{20} \times T_1$	-15.22	-10.50	-23.77**	-16.36	-11.34	-24.05**	-16.16	-11.19	-25.09**	-15.90	-11.00	-8.03
$L_{20} \times T_2$	5.85	23.22**	-4.82	6.29	25.29**	-3.52	6.21	24.92**	-5.09	6.12	24.45 **	16.05 *
$L_{20} \times T_3$	-15.22	-8.23	-23.72**	-16.36	-8.91	-24.05**	-16.16	-8.79	-25.03**	-15.90	-8.64	-8.03
$L_{21} \times T_1$	10.88	15.74*	-2.63	11.73	17.02*	-1.13	11.58	16.79*	-2.77	11.39	16.50 *	18.84 **
$L_{21} \times T_2$	-16.68*	-3.97	-26.84**	-17.97*	-4.33	-27.29**	-17.74 *	-4.26	-28.33**	-17.45	-4.18	-11.93
$L_{21} \times T_3$	-13.08	-6.95	-23.68**	-14.10	-7.53	-24.00**	-13.92	-7.42	-25.00**	-13.69	-7.30	-7.92

*,** Significant at 5% and 1 % probability levels , respectively.

the environments. However, hybrids, $L_9 \times T_1$, $L_{11} \times T_3$, $L_{12} \times T_1$, $L_{14} \times T_1$, $L_{16} \times T_1$, $L_{16} \times T_2$, $L_{18} \times T_2$, $L_{18} \times T_3$, $L_{19} \times T_1$, $L_{19} \times T_3$, $L_{20} \times T_2$ and $L_{21} \times T_1$ across the environments also exhibited positive and significant standard heterosis for lysine . However, 9 crosses exhibited significant negative better parent heterosis alongwith 7 mid-parent and 8 standard heterosis in pooled analysis,.

On the basis of study for all environments, hybrids, $L_1 \times T_1$ and $L_{16} \times T_2$ exhibited significantly positive heterosis (BP, CP and MP) in all the environments and across the environments.

4.2.14 Tryptophan (%)

The estimates of per cent heterobeltiosis, relative heterosis and standard heterosis for tryptophan contents in the E_1, E_2, E_3 and across environments are presented in Table 4.2.14. In pooled analysis, 15 out of 63 crosses exhibited significantly negative better parent heterosis alongwith 6 mid-parent and 8 standard heterosis. The estimates of heterobeltiosis ranged from -38.97 to 30.56, -41.70 to 33.17, -41.24 to 32.71 and -40.61 to 32.11 in E_1, E_2, E_3 and pooled analysis, respectively. The most promising hybrids with significant higher estimates of heterobeltiosis for tryptophan percentage were $L_1 \times T_1$, $L_{11} \times T_3$, $L_{12} \times T_1$, $L_{16} \times T_1$, $L_{16} \times T_2$ and $L_{18} \times T_3$ in E_1, E_2, E_3 and pooled environment

The magnitude of relative heterosis for tryptophan showed that the estimates ranged from -32.10 to 41.72, -35.65 to 42.32, -34.94 to 42.40 and -34.18 to 42.15 in E_1, E_2, E_3 and pooled analysis,

Table 4.2.14: Estimation of heterosis (%) over better-, mid- and check- parent in three environments (E_1, E_2, E_3)

Cross	Tryptophan (%)											
	Normal			Low nitrogen			Excess soil moisture			Pooled		
	BP	MP	CP	BP	MP	CP	BP	MP	CP	BP	MP	CP
$L_1 \times T_1$	28.29**	19.54 *	9.58	31.0**	23.42**	16.66	30.52**	23.69**	18.09	15.24 *	22.13 **	10.53
$L_1 \times T_2$	3.41	8.99	-11.66	3.74	7.18	-7.61	3.68	7.65	-6.19	3.61	7.9	-11.84
$L_1 \times T_3$	6.34	3.31	-9.16	6.95	1.78	-4.76	6.84	2.26	-3.33	-1.43	2.48	-9.21
$L_2 \times T_1$	-36.3**	-30.13**	-24.16**	-38.8**	-31.3**	-21.90*	-38.37**	-30.70**	-20.47*	-37.82 **	-30.72 **	-25.00 **
$L_2 \times T_2$	-31.46**	-16.59*	-18.33*	-33.5**	-19.63*	-15.23	-33.21**	-19.06 *	-13.81	-32.73 **	-18.38 *	-18.86 *
$L_2 \times T_3$	-8.04	4.57	9.58	-8.58	3.37	16.66	-8.48	3.76	18.09	-8.36	3.92	10.53
$L_3 \times T_1$	-30.70**	-28.01**	-26.66**	-33.0**	-29.14**	-24.76**	-32.63**	-28.44**	-23.33*	-32.10 **	-28.52 **	-27.63 **
$L_3 \times T_2$	-7.08	7.76	-1.66	-7.6	6.08	3.81	-7.53	6.5	5.23	-7.41	6.80	-1.32
$L_3 \times T_3$	-12.20	-5.30	-7.08	-13.1	-7.24	-2.38	-12.97	-6.72	-0.95	-12.76	-6.40	-7.02
$L_4 \times T_1$	-4.80	-1.85	-0.83	-5.17	-0.45	4.76	-5.106	3.88	6.19	-5.02	-0.80	-0.44
$L_4 \times T_2$	-20.00*	-7.83	-16.66	-21.55*	-10.56	-13.3	-21.27*	-9.97	-11.90	-20.92 *	-9.42	-17.11 *
$L_4 \times T_3$	-7.60	-1.07	-3.75	-8.1	-2.74	1.42	-8.08	-2.26	2.85	-7.95	-2.00	-3.51
$L_5 \times T_1$	-8.23	-6.69	-7.08	-8.88	-5.74	-2.38	-8.77	-5.23	-0.95	-8.62	-5.92	-7.02
$L_5 \times T_2$	-13.16	-1.17	-12.08	-14.2	-3.50	-8.09	-14.03	-2.97	-6.66	-13.79	-2.52	-12.28
$L_5 \times T_3$	-17.28*	-12.60	-16.25	-18.66*	-15.08	-12.85	-18.42*	-14.48	-11.42	-18.10 *	-14.03 *	-16.67
$L_6 \times T_1$	-4.78	-5.80	-8.75	-5.18	-4.73	-4.28	-5.11	-4.22	-2.85	-5.02	-4.95	-8.77
$L_6 \times T_2$	-1.30	9.66	-5.41	-1.41	8.01	-0.47	-1.39	8.44	.95	-1.37	8.72	-5.26
$L_6 \times T_3$	8.69	11.85	4.16	9.43	11.00	10.47	9.30	11.37	11.90	9.13	11.42	4.82
$L_7 \times T_1$	.77	5.66	8.75	.83	7.76	15.71	.820	8.13	17.14	0.81	7.14	9.65
$L_7 \times T_2$	-11.19	3.83	-4.16	-12.03	1.92	.95	-11.88	2.38	2.381	-11.69	2.74	-3.95
$L_7 \times T_3$	-9.26	-1.26	-2.08	-9.95	-2.90	3.33	-9.83	-2.43	4.76	-9.68	-2.18	-1.75
$L_8 \times T_1$	-14.39	-9.41	-5.83	-15.44	-8.77	-0.95	-15.26	-8.26	.476	-15.02 *	-8.83	-5.70
$L_8 \times T_2$	-0.75	16.96*	9.16	-0.81	16.91*	16.19	-0.803	16.23*	17.61	-0.79	16.38 *	10.09
$L_8 \times T_3$	-4.16	5.19	5.41	-4.47	3.98	11.90	-4.41	4.38	13.33	-4.35	4.54	6.14
$L_9 \times T_1$	11.15	14.81*	16.25	12.01	17.83*	24.28*	11.86	18.12*	25.71**	11.67	16.86 *	17.54 *
$L_9 \times T_2$	-15.53	-2.52	-11.66	-16.73	-4.90	-7.61	-16.52	-4.36	-6.19	-16.25 *	-3.90	-11.84
$L_9 \times T_3$	4.78	12.39	9.58	5.15	11.61	16.66	5.08	11.96	18.09	5.00	12.00	10.5
$L_{10} \times T_1$	3.01	2.35	-0.41	3.271	4.24	5.23	3.22	4.67	6.66	3.17	3.71	5.78
$L_{10} \times T_2$	15.94	29.32**	12.08	17.290	29.04**	19.52*	17.05	29.26**	20.95*	16.74 *	29.22 **	13.16
$L_{10} \times T_3$	-9.91	-6.90	-12.91	-10.748	-9.04	-9.04	-10.59	-8.49	-7.61	-10.41	-8.12	-13.16

Table 4.2.14: Contd...

$L_{11} \times T_1$	-28.38**	-29.30**	-31.67**	-30.80**	-30.64**	-30.47**	-30.37**	-29.82**	-29.04**	-30.03 **	-29.92 **	-32.89 **
$L_{11} \times T_2$	16.15	28.81**	10.83	17.53	28.49**	18.09	17.29	28.71**	19.52*	16.97 *	28.68 **	11.84
$L_{11} \times T_3$	30.56**	34.08**	24.58**	33.17**	34.77**	33.81**	32.71**	34.91**	35.23**	32.11 **	34.58 **	26.32 **
$L_{12} \times T_1$	18.29*	18.29*	15.83	19.81*	21.78**	23.81*	19.54*	22.04**	25.23**	19.20 *	20.63 **	17.11 *
$L_{12} \times T_2$	-8.51	2.62	-10.41	-9.21	.510	-6.19	-9.09	1.01	-4.76	-8.93	1.41	-10.53
$L_{12} \times T_3$	13.19	17.69*	10.83	14.28	17.25*	18.09	14.09	17.56*	19.52*	13.84	17.51 *	11.84
$L_{13} \times T_1$	-3.31	-8.52	-15.00	-3.62	-7.69	-11.42	-3.57	-7.12	-10.00	-11.74	-7.80	-15.35
$L_{13} \times T_2$	-14.69	-8.86	-25.00**	-16.06	-11.95	-22.85*	-15.81	-11.29	-21.42*	-15.50 *	-10.66	-25.88 **
$L_{13} \times T_3$	-4.73	-6.07	-16.25	-5.18	-8.27	-12.85	-5.10	-7.69	-11.42	-9.52	-7.32	-16.67
$L_{14} \times T_1$	14.00	19.10*	22.08*	15.06	22.49**	30.95**	14.87	22.77**	32.38**	14.63	21.38 **	23.68 **
$L_{14} \times T_2$	-12.84	1.58	-6.66	-13.80	-0.48	-1.90	-13.63	4.88	-0.476	-13.41	0.39	-6.58
$L_{14} \times T_3$	-3.50	4.64	3.33	-3.76	3.37	9.52	-3.71	3.78	10.95	-3.66	3.95	3.95
$L_{15} \times T_1$	-15.44*	-9.27	-4.16	-16.53 *	-8.62	.95	-16.34*	-8.12	2.38	-16.09 *	-8.69	-3.95
$L_{15} \times T_2$	-16.54*	-0.43	-5.41	-17.7 *	-2.56	-0.47	-17.51*	-2.07	.952	-17.24 *	-1.67	-5.26
$L_{15} \times T_3$	-38.97**	-32.10**	-30.83**	-41.7**	-35.65**	-29.52**	-41.24**	-34.94**	-28.09**	-40.61 **	-34.18 **	-32.02 **
$L_{16} \times T_1$	23.07*	19.29*	13.33	25.12*	23.00**	20.95*	24.75*	23.26**	22.38*	19.36 *	21.77 **	24.47
$L_{16} \times T_2$	29.86**	41.72**	19.58*	32.51**	42.32**	28.09**	32.03**	42.40**	29.52**	31.43 **	42.15 **	21.05 **
$L_{16} \times T_3$	-25.33**	-24.65**	-31.25**	-27.58**	-28.17**	-30.00**	-27.18**	-27.36**	-28.57**	-26.67 **	-26.67 **	-32.46 **
$L_{17} \times T_1$	-1.81	-4.82	-9.58	-1.97	-3.63	-5.23	-1.94	-3.11	-3.81	-5.79	-3.89	-9.65
$L_{17} \times T_2$	-16.29	-8.64	-22.91**	-17.73	-11.64	-20.47*	-17.47	-10.99	-19.04*	-17.14 *	-10.39	-23.68 **
$L_{17} \times T_3$	-0.90	3.89	-8.75	-0.985	-1.71	-4.28	-0.971	-1.2	-2.85	-0.95	-0.95	-8.77
$L_{18} \times T_1$	-1.84	-5.75	-11.25	-2.01	-4.64	-7.14	-1.98	-4.11	-5.71	-7.62	-4.87	-11.40
$L_{18} \times T_2$	7.83	16.70	-2.50	8.54	15.50	2.85	8.41	15.87	4.28	8.25	16.05 *	-2.19
$L_{18} \times T_3$	28.11**	28.11**	18.83*	30.65**	28.39**	23.81*	30.18**	28.60**	25.23**	27.14 **	28.37 **	17.11 *
$L_{19} \times T_1$	13.71	16.77*	17.50*	14.78	20.0 *	25.71**	14.59	20.27*	27.14**	14.35	18.95 *	18.86 *
$L_{19} \times T_2$	6.45	22.22**	10.00	6.95	21.48*	17.14	6.86	21.76*	18.57	6.75	21.83 **	10.96
$L_{19} \times T_3$	12.09	19.57*	15.83	13.04	19.26*	23.81*	12.87	19.54*	25.23**	12.66	19.46 *	17.11 *
$L_{20} \times T_1$	-15.00	-10.70	-7.91	-16.11	-10.17	-3.33	-15.91	-9.64	-1.90	-15.66 *	-10.19	-7.89
$L_{20} \times T_2$	5.769	23.87**	14.58	6.19	23.26**	22.38*	6.12	23.51**	23.81*	6.02	23.56 **	15.79
$L_{20} \times T_3$	-15.00	-7.33	-7.91	-16.11	-9.37	-3.33	-15.91	-8.85	-1.90	-15.66 *	-8.50	-7.89
$L_{21} \times T_1$	11.02	15.33*	17.50*	11.86	18.38*	25.71**	11.71	18.66*	27.14**	11.52	17.40 *	18.86 *
$L_{21} \times T_2$	-16.14	-2.74	-11.25	-17.37*	-5.10	-7.14	-17.15*	-4.57	-5.71	-16.87	-4.11	-11.40
$L_{21} \times T_3$	-12.59	-5.73	-7.50	-13.55	-7.69	-2.85	-13.38	-7.17	-1.42	-13.17	-6.84	-7.46

*,** Significant at 5% and 1 % probability levels , respectively.

respectively. Among the hybrids, most heterotic cross combination for this trait were $L_1 \times T_1$, $L_8 \times T_2$, $L_9 \times T_1$, $L_{10} \times T_2$, $L_{11} \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_1$, $L_{12} \times T_3$, $L_{14} \times T_1$, $L_{16} \times T_1$, $L_{16} \times T_2$, $L_{18} \times T_3$, $L_{19} \times T_1$, $L_{19} \times T_2$, $L_{19} \times T_3$, $L_{20} \times T_2$ and $L_{21} \times T_1$ in E_1, E_2, E_3 and across the environments.

Estimates of the standard heterosis ranged from -31.67 to 24.58, -30.47 to 33.81, -29.4 to 35.23 and -32.89 to 26.32 in E_1, E_2, E_3 and pooled analysis, respectively. The significant standard heterosis was revealed by the crosses, $L_{11} \times T_3$, $L_{14} \times T_1$, $L_{16} \times T_2$, $L_{18} \times T_3$ and $L_{21} \times T_1$ in E_1; $L_9 \times T_1$, $L_{10} \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_1$, $L_{14} \times T_1$, $L_{16} \times T_1$, $L_{16} \times T_2$, $L_{18} \times T_3$, $L_{19} \times T_1$, $L_{19} \times T_3$, , $L_{20} \times T_2$ and $L_{21} \times T_1$ in E2, E3 and across the environments, respectively.

On the basis of study for all environments, 3 crosses, $L_{11} \times T_3$, $L_{16} \times T_2$ and $L_{18} \times T_3$ observed significantly positive heterosis (BP, CP and MP) in all the environments and across the environments.

4.2.15 Grain yield (kg per ha)

The nature and magnitude of heterobeltiosis, relative heterosis and standard heterosis among the hybrids for grain yield are presented in Table 4.2.15. The range of heterobeltiosis in E_1, E_2, E_3 and across environments was -66.19 to 193.31, -59.97 to 166.59, -72.17 to 130.53 and -68.81 to 56.31, respectively. Hybrids with the maximum percentage of heterotic expression were $L_1 \times T_1$ (112.42), $L_1 \times T_2$ (115.77), $L_1 \times T_3$ (66.48), $L_2 \times T_1$ (101.12), $L_2 \times T_2$ (98.30), $L_2 \times T_3$ (103.02) $L_3 \times T_1$ (193.31), $L_4 \times T_1$ (108.71), $L_4 \times T_2$ (102.24) $L_5 \times T_1$ (185.55), $L_5 \times T_3$ (175.05), $L_9 \times T_1$ (101.93), $L_9 \times T_2$(69.11), $L_{10} \times T_1$ (153.50), $L_{11} \times T_3$

Table 4.2.15: Estimation of heterosis (%) over better-, mid- and check- parent in three environments (E_1, E_2, E_3)

Cross	Grain yield (kg/ha)											
	Normal			Low nitrogen			Excess soil moisture			Pooled		
	BP	MP	CP	BP	MP	CP	BP	MP	CP	BP	MP	CP
$L_1 \times T_1$	112.42**	84.86**	94.52**	149.99**	117.26**	199.52**	81.78**	45.41*	99.55**	56.31 **	80.53 **	151.85 **
$L_1 \times T_2$	115.77**	71.24**	97.53**	56.25**	-16.70	99.65*	-54.54 *	-62.27**	-50.02	-15.12	0.33	44.62 *
$L_1 \times T_3$	66.48 *	30.41	52.45*	54.67**	59.98**	99.70**	-9.08	-21.55	-0.050	-17.30	-1.90	42.11 *
$L_2 \times T_1$	101.12**	59.99*	57.88*	61.07**	59.10**	99.75**	99.87**	50.88**	99.87**	52.20**	36.04 *	80.78 **
$L_2 \times T_2$	98.30**	63.04**	55.62*	61.04**	53.08**	99.70**	49.90	17.58	49.90	-5.13	17.55	61.65 **
$L_2 \times T_3$	103.02**	64.42**	59.37*	11.07	-16.64	99.75**	49.92	22.44	49.92	-4.92	18.18	63.37 **
$L_3 \times T_1$	193.31**	147.28**	154.09**	-20.00	-21.56	99.80**	-14.29	-11.76	49.95	58.26**	38.62 *	106.66 **
$L_3 \times T_2$	25.43	-3.73	8.66	-20.00	-24.52	99.80**	-71.39**	-69.66**	-49.95	-38.98 *	-34.73	3.97
$L_3 \times T_3$	-8.97	-31.08	-21.14	19.92	9.06	199.51**	-71.42**	-68.74**	-50.00	-36.89 *	-32.22	8.4
$L_4 \times T_1$	108.69**	166.77**	135.39**	11.10	-9.09	99.75**	78.50**	20.45	49.92	52.96**	58.23 **	98.13 **
$L_4 \times T_2$	102.24*	18.43	16.48	11.13	-13.03	99.80**	19.06	-16.30	45.00	-26.26	-3.24	25.65
$L_4 \times T_3$	96.91	13.51	13.41	11.13	-16.61	99.80**	78.53**	31.03	49.95	-17.16	9.01	42.34 *
$L_5 \times T_1$	185.55**	131.53**	83.17**	66.59**	47.29*	.050	66.60*	-11.07	.025	-14.34	24.05	38.02
$L_5 \times T_2$	45.10	-36.01	-42.90	16.64	49.95*	54.00*	66.55*	-6.98	26.00	-52.82 **	-30.64	-19.61
$L_5 \times T_3$	175.05*	19.20	8.22	-16.68	-52.33**	-0.05	-16.68	-51.17 *	-49.97	-50.14 **	-26.53	-14.33
$L_6 \times T_1$	-65.33*	-67.65**	-64.00*	-37.53	-52.38**	-0.10	-55.36*	-63.83**	-50.00	-67.32 **	-62.13 **	-47.35 *
$L_6 \times T_2$	-39.4	-48.2*	-37.11	-25.02	-45.44*	19.91	-55.34*	-62.57**	-49.97	-59.77 **	-52.28 **	-31.45
$L_6 \times T_3$	-25.92	-37.47	-23.06	-37.47	-56.46**	35.88	-10.72	-22.14	45.99	-47.94 **	-38.04 *	-10.54
$L_7 \times T_1$	66.56*	21.59	13.8	66.51**	5.23	99.75**	130.53**	30.38	49.92	-11.54	19.98	42.53 *
$L_7 \times T_2$	75.53	15.63	19.94	-0.08	-40.01*	19.86	72.12**	1.76	11.93	-31.28 *	-5.13	17.09
$L_7 \times T_3$	64.86	7.00	12.65	-16.76	-52.38**	-0.150	130.45**	42.79	49.87	-27.89	-0.19	23.91
$L_8 \times T_1$	-43.09	-54.22*	-54.48	-44.46	-54.56**	-0.150	-70.23**	-69.97**	-50.02	-64.61 **	-60.82 **	-42.98 *
$L_8 \times T_2$	-1.18	-27.85	-20.95	-33.33	-47.82**	19.86	19.02	23.79	99.45**	-23.56	-13.27	30.25
$L_8 \times T_3$	-52.43	-65.75**	-61.95*	-44.43	-58.31**	-0.100	-70.2**	-68.03**	-50.00	-68.81 **	-64.49 **	-46.41 *
$L_9 \times T_1$	101.93**	96.54**	127.5**	49.96*	30.40	199.11**	-16.65	-29.81	-0.025	50.74**	33.12	94.54 **
$L_9 \times T_2$	69.11**	51.36 *	90.58**	49.96*	-58.30**	-0.050	-16.65	-27.27	-0.025	-17.00	-6.20	41.43 *
$L_9 \times T_3$	-66.19*	-70.1**	-61.90*	-15.01	31.98*	69.76**	-58.31*	-62.24**	-50.00	-61.42 **	-56.24 **	-33.71
$L_{10} \times T_1$	153.50**	97.59**	92.44**	66.56**	36.30*	199.5**	88.72**	83.05**	80.25**	60.77**	41.69 **	78.48 **
$L_{10} \times T_2$	-20.88	-44.14	-39.94	-33.32	-47.8**	19.91	-23.08	-54.55 *	-49.976	-60.52 **	-48.49 **	-32.74
$L_{10} \times T_3$	51.73	5.61	15.19	-80.04	-66.66	-99.70*	53.68*	-4.77	-0.050	-27.21	-4.75	25.07

Table 4.2.15: Contd...

$L_{11} \times T_1$	-39.41	-40.50	-30.53	-58.33**	-59.99**	-0.100	-58.33 *	-64.96**	-50.00	-57.82 **	-54.76 **	-32.04
$L_{11} \times T_2$	-19.13	-26.92	-7.28	-58.33**	-61.53**	-0.100	-58.33*	-63.64**	-50.00	-53.87 **	-49.24 **	-21.41
$L_{11} \times T_3$	73.94**	70.56**	63.57*	66.53**	48.10**	199.21**	66.53**	50.19**	99.35**	55.14**	38.23 *	115.02 **
$L_{12} \times T_1$	-32.51	-34.31	-23.93	-20.02	-21.59	99.70**	-16.69	-29.839	-0.050	-33.48 *	-28.86	7.19
$L_{12} \times T_2$	-32.33	-39.43*	-23.73	-59.97**	-62.24**	-0.05	-16.67	-27.27	-0.025	-47.67 **	-42.59 **	-10.84
$L_{12} \times T_3$	26.51	11.87	42.60	59.96**	9.09	199.16**	-58.30*	-62.22**	-49.97	-19.93	-11.81	37.58
$L_{13} \times T_1$	78.09	20.48	8.22	-28.59	-49.98*	-0.050	-25.40	-56.87**	-49.97	-46.83 **	-28.15	-14.33
$L_{13} \times T_2$	136.81**	43.98	43.90	42.71	-4.80	99.75**	49.0	-9.94	-0.025	-18.89	11.57	38.20
$L_{13} \times T_3$	93.96*	16.12	17.86	42.71	-9.08	99.75**	49.08	-5.65	-0.025	-26.51	1.36	26.28
$L_{14} \times T_1$	139.7**	91.57**	89.63**	66.47**	35.20*	99.70**	63.22**	56.69**	70.50**	81.25**	59.30**	79.11 **
$L_{14} \times T_2$	-19.08	-41.35	-36.01	-0.083	-40.01*	19.86	-33.35	-56.52**	-50.00	-59.46 **	-45.91 **	-30.93
$L_{14} \times T_3$	-23.98	-45.67*	-39.88	-16.72	-52.36**	-0.100	33.22	-9.09	-0.05	-52.40 **	-36.31 *	-18.22
$L_{15} \times T_1$	53.40	39.34	51.73	41.07	29.10	99.75**	-16.67	-29.82	-0.025	-12.01	0.42	41.77 *
$L_{15} \times T_2$	-36.00	-46.84*	-36.73	-33.32	-47.81**	19.91	-58.30*	-63.61**	-49.97	-59.67 **	-52.87 **	-31.28
$L_{15} \times T_3$	15.35	-5.37	14.09	-44.42	-58.29**	-0.05	24.95	13.21	49.92	-27.52	-15.00	24.54
$L_{16} \times T_1$	99.95**	55.82*	51.75	-37.43	-52.32**	34.00	36.36	9.09	49.95	-12.02	7.15	41.75 *
$L_{16} \times T_2$	100.93**	41.84	52.49	25.00	-9.08	99.80**	36.36	13.19	49.95	-5.98	17.00	60.20 **
$L_{16} \times T_3$	90.65*	32.67	44.70	-37.43	-56.45**	45.99	36.36	17.68	49.95	-19.38	0.65	38.54
$L_{17} \times T_1$	-36.82	-57.13*	-61.44*	-24.94	-42.81*	19.96	-41.11	-59.94**	-49.95s	-64.37 **	-53.83 **	-42.58 *
$L_{17} \times T_2$	22.99	-24.99	-24.94	13.66	-27.27	59.83	29.38	-8.34	9.965	-39.51 *	-20.10	3.07
$L_{17} \times T_3$	69.88	2.017	3.67	149.8**	73.88**	99.31**	76.37**	30.42	49.901	18.32	38.21 *	74.10 **
$L_{18} \times T_1$	125.04**	64.66*	54.34	24.93	-4.78	99.75**	36.30	9.06	49.92	-0.04	23.30	61.06 **
$L_{18} \times T_2$	125.31**	48.79*	54.52	24.93	-9.11	99.75**	36.30	13.16	49.92	-5.43	19.14	61.14 **
$L_{18} \times T_3$	-7.75	-39.98	-36.73	-12.51	-39.09*	39.87	-9.10	-21.54	-0.025	-47.36 **	-33.48 *	-9.55
$L_{19} \times T_1$	76.83*	48.68*	52.47	99.97**	46.30*	199.26**	-54.49*	-63.6**	-49.97	-11.81	6.24	42.09 *
$L_{19} \times T_2$	37.34	5.10	18.42	33.34	-6.98	99.75**	81.80**	50.90**	99.88**	-4.49	17.60	62.74 **
$L_{19} \times T_3$	35.39	2.20	16.74	166.59**	77.78**	99.36**	-9.06	-21.53	-0.025	-5.73	16.44	61.98 **
$L_{20} \times T_1$	6.22	18.53	59.37*	-46.63**	-42.8**	59.83**	-16.64	-13.03	49.92	-16.99	-10.58	56.11 **
$L_{20} \times T_2$	-27.38	-24.64	8.94	-33.28*	-31.00*	99.80**	-72.17**	-70.10**	-49.95	-44.65 **	-41.92 **	4.09
$L_{20} \times T_3$	-3.46	-0.885	44.83	-33.30 *	-33.30*	99.75**	-44.41**	-38.43*	-0.02	-26.29	-22.97	38.62
$L_{21} \times T_1$	-38.05	-36.07	-21.49	-59.96**	-60.75**	-0.050	25.56	-4.76	49.92	-32.79 *	-32.03 *	8.29
$L_{21} \times T_2$	-63.19**	-64.91**	-53.35	-59.95**	-62.21**	12.00	-66.61**	-67.17**	-49.95	-66.25 **	-64.93 **	-42.50 *
$L_{21} \times T_3$	-10.52	-15.67	13.39	-35.97	-41.78**	59.83**	34.98	1.71	49.92	-21.38	-17.96 *	35.09

*,** Significant at 5% and 1 % probability levels , respectively.

(73.94), L_{13} × T_2 (136.81), L_{13} × T_3 (93.96), L_{14} × T_1 (139.7), L_{16} × T_1 (99.95), L_{16} × T_2 (100.93), L_{16} × T_3 (90.65), L_{18} × T_1 (125.04), L_{18} × T_2 (125.31) and L_{19} × T_1 (76.83) in **E_1**, ; L_1 × T_1 (149.99), L_1 × T_2 (56.25), L_1 × T_3 (54.67), L_2 × T_1 (61.07), L_2 × T_2 (61.04), L_5 × T_1 (66.59), L_7 × T_1 (65.51), L_9 × T_1 (49.96), L_9 × T_2 (49.96), L_{10} × T_1 (66.56), L_{11} × T_3 (66.53), L_{12} × T_3 (59.96), L_{14} × T_1 (66.47), L_{17} × T_3 (149.8), L_{19} × T_1 (99.97) and L_{19} × T_3 (166.59) in **E_2**, L_1 × T_1 (81.78), L_2 × T_1 (99.87), L_4 × T_1 (78.50), L_4 × T_3 (78.53), L_5 × T_1 (66.60), L_5 × T_2 (66.55), L_7 × T_1 (130.53), L_7 × T_2 (72.12), L_7 × T_3 (130.45), L_{10} × T_1 (88.72), L_{10} × T_3 (53.68), L_{11} × T_3 (66.53), L_{14} × T_1 (63.22), L_{17} × T_3 (76.37) and L_{19} × T_2 (81.80) in **E_3** and L_1 × T_1 (56.31), L_2 × T_1 (52.20), L_3 × T_1 (58.26), L_4 × T_1 (52.96), L_9 × T_1 (50.74), L_{10} × T_1 (50.77), L_{11} × T_3 (45.14) and L_{14} × T_1 (50.50) across the environments.

The estimates of relative heterosis for grain yield ranged from -70.10 to 166.77, -62.24 to 117.26, -70.10 to 50.90 and -64.93 to 80.53 in the E_1, E_2, E_3 and across the environments, respectively. The most heterotic cross combinations were L_1 × T_1 (84.86), L_1 × T_2 (71.24), L_2 × T_1 (59.99), L_2 × T_2 (63.04), L_2 × T_3 (64.42) L_3 × T_1 (147.28), L_4 × T_1 (166.77), L_5 × T_1 (131.53), L_9 × T_1 (96.54), L_9 × T_2(51.36), L_{10} × T_1 (97.59), L_{11} × T_3 (70.56), L_{14} × T_1 (91.57), L_{16} × T_1 (55.82), L_{18} × T_1 (64.66), L_{18} × T_2 (48.79) and L_{19} × T_1 (48.68) in **E_1**, ; L_1 × T_1 (117.26), L_1 × T_3 (59.98), L_2 × T_1 (59.10), L_2 × T_2 (53.08), L_5 × T_1 (47.29), L_5 × T_2 (49.95), L_9 × T_3 (31.98), L_{10} × T_1 (36.30), L_{11} × T_3 (48.10), L_{14} × T_1 (35.20), L_{17} × T_3 (73.88), L_{19} × T_1 (46.30) and L_{19} × T_3 (77.78) in **E_2**, L_1 × T_1 (81.78), L_2 × T_1 (50.88), L_{10} × T_1

(83.05), $L_{11} \times T_3$ (50.19), $L_{14} \times T_1$ (56.69) and $L_{19} \times T_2$ (50.90) in **E_3** and $L_1 \times T_1$ (80.53), $L_2 \times T_1$ (36.04), $L_3 \times T_1$ (38.62), $L_4 \times T_1$ (58.23), $L_{10} \times T_1$ (41.69), $L_{11} \times T_3$ (38.23), $L_{14} \times T_1$ (59.30) and $L_{17} \times T_3$ (38.21) across the environments.

In case of standard heterosis, the estimates ranged from -64.00 to 154.09, -99.70 to 199.52, -50.00 to 99.88 and -42.98 to 151.85 in E_1, E_2, E_3 and across environments, respectively. Some of the most heterotic hybrid combinations were $L_1 \times T_1$ (94.52), $L_1 \times T_2$ (97.53), $L_1 \times T_3$ (52.45), $L_2 \times T_1$ (57.88), $L_2 \times T_2$ (55.62), $L_2 \times T_3$ (59.37), $L_3 \times T_1$ (154.09), $L_4 \times T_1$ (135.39), $L_5 \times T_1$ (83.17), $L_9 \times T_1$ (127.5), $L_9 \times T_2$ (90.58), $L_{10} \times T_1$ (92.44), $L_{11} \times T_3$ (63.57), $L_{14} \times T_1$ (89.63) and $L_{20} \times T_1$ (59.37) in **E_1**; $L_1 \times T_1$ (199.52), $L_1 \times T_2$ (99.65), $L_1 \times T_3$ (99.70), $L_2 \times T_1$ (99.75), $L_2 \times T_2$ (99.70), $L_2 \times T_3$ (99.75) $L_3 \times T_1$ (99.80), $L_3 \times T_2$ (99.80), $L_3 \times T_3$ (199.51), $L_4 \times T_1$ (99.75), $L_4 \times T_2$ (99.80) $L_4 \times T_3$ (99.80), $L_5 \times T_2$ (54.00), $L_7 \times T_1$ (99.75), $L_9 \times T_1$ (199.11), $L_9 \times T_3$ (69.76), $L_{10} \times T_1$ (199.5), $L_{11} \times T_3$ (199.21), $L_{12} \times T_1$ (99.70), $L_{12} \times T_3$ (199.16), $L_{13} \times T_2$ (99.75), $L_{13} \times T_3$ (99.75), $L_{14} \times T_1$ (99.70), $L_{15} \times T_1$ (99.75), $L_{16} \times T_2$ (99.80), $L_{17} \times T_3$ (99.31), $L_{18} \times T_1$ (99.75), $L_{18} \times T_2$ (99.75), $L_{19} \times T_1$ (199.26) $L_{19} \times T_2$ (99.75), $L_{19} \times T_3$ (99.36), $L_{20} \times T_1$ (59.83), $L_{20} \times T_2$ (99.80), $L_{20} \times T_3$ (99.75) and $L_{21} \times T_3$ (59.83) in **E_2**; $L_1 \times T_1$ (99.55), $L_2 \times T_1$ (99.87), $L_8 \times T_2$ (99.45), $L_{10} \times T_1$ (80.25), $L_{11} \times T_3$ (99.35), $L_{14} \times T_1$ (70.50) and $L_{19} \times T_2$ (99.88) in **E_3**; and $L_1 \times T_1$ (151.85), $L_1 \times T_2$ (44.62), $L_1 \times T_3$ (42.11), $L_2 \times T_1$ (80.78), $L_2 \times T_2$ (61.65), $L_2 \times T_3$ (63.37), $L_3 \times T_1$ (106.66), $L_4 \times T_1$ (98.13), $L_4 \times T_3$ (42.34), $L_7 \times T_1$ (42.53), $L_9 \times T_1$ (94.54), $L_9 \times T_2$ (41.43), $L_{10} \times T_1$ (78.48), $L_{11} \times T_3$

(115.02), $L_{14} \times T_1$ (79.11), $L_{15} \times T_1$ (41.77), $L_{16} \times T_1$ (41.75), $L_{16} \times T_2$ (60.20), $L_{17} \times T_3$ (74.10), $L_{18} \times T_1$ (61.06), $L_{18} \times T_2$ (61.14), $L_{19} \times T_1$ (42.09) $L_{19} \times T_2$ (62.74), $L_{19} \times T_3$ (61.98) and $L_{20} \times T_1$ (56.11) in the pooled analysis.

On the basis of study for all environments, 7 crosses for BP, 5 for MP and 5 for CP showed positive and significant heterosis. However, $L_1 \times T_1$, $L_{10} \times T_1$, $L_{11} \times T_3$ and $L_{14} \times T_1$ revealed significantly positive heterosis (BP, CP and MP) in all the environments.

4.3 Variability Parameters

The estimates and magnitude of heritability (broad sense) , expected genetic advance, genetic advance as per cent of mean, GCV, PCV and ECV for 15 characters in E_1, E_2 and E_3 are presented in Table 4.3.1.

4.3.1 Heritability

Heritability estimates per cent in broad sense were high for protein percentage (97.90), lysine (93.93), tryptophan (93.93), 100-kernel weight (60.03), grain yield (53.85) ear length (51.10), ear diameter (43.75) and number of kernels per row (42.04), whereas, moderate heritability estimates were recorded for number of kernel rows per ear (38.15) and anthesis-silking interval (23.65) and Low heritability values were recorded for days to 50 per cent tasselling (20.94), days to 50 per cent silking (19.50), plant height (19.49), ear height (19.90), number of nodes bearing brace roots (18.15) in E_1.

In E_2, heritability estimates (per cent) were high for protein percentage (97.88), lysine (96.75), tryptophan (96.75), 100-kernel weight (64.50) and ear height (42.42), whereas, moderate heritability estimates were recorded for days to 50 per cent tasselling (31.90), days to 50 per cent silking (36.53), grain yield (27.83), ear length (28.35), plant height (25.18) and number of kernel rows per ear (21.12). Low heritability values were recorded for ear diameter (16.70), number of kernels per row (19.62), number of nodes bearing brace roots (20.20), anthesis-silking interval (10.12).

In E_3, high estimates of heritability in the broad sense were observed for the characters like protein percentage (97.88), lysine (96.75), tryptophan (96.75), 100-kernel weight (64.50), ear height (61.17), grain yield (51.73) and ear length (40.62), whereas, moderate heritability estimates were recorded for the traits like plant height (34.32), and number of nodes bearing brace roots (36.48). Low heritability estimates were observed for days to 50per cent tasselling (12.05), days to 50per cent silking (21.32), ear diameter (14.79), number of kernel rows per ear (17.21) number of kernels per row (14.12) and anthesis-silking interval (17.04).

The estimates of heritability in the broad sense were observed high for the characters like protein percentage, lysine, tryptophan and 100-kernel weight in all the three environments.

4.3.2 Expected genetic advance

The highest genetic advance as per cent of mean was recorded for grain yield (49.92), tryptophan (28.53), lysine (28.43), protein (27.02),

Table 4.3.1: Heritability (h^2_b), Expected genetic advance, Genotypic coefficient of variation, Phenotypic coefficient of variation and Environmental coefficient of variation for important economic characters a in Quality Protein Maize (QPM) under E_1, E_2 and E_3 environments

Characters	E_1						E_2						E_3					
	Herita-bility (%)	Genetic Advance	Genetic advance in % of mean	GCV (%)	PCV (%)	ECV (%)	Herita-bility (%)	Genetic Advance	Genetic advance in % of mean	GCV (%)	PCV (%)	ECV (%)	Herita-bility (%)	Genetic Advance	Genetic advance in % of mean	GCV (%)	PCV (%)	ECV (%)
Plant height (cm)	19.49	6.87	3.69	4.067	9.212	8.265	25.18	9.13	5.23	5.06	10.08	8.72	34.32	13.60	7.28	6.03	10.29	8.34
Ear height (cm)	19.90	3.77	5.08	5.538	12.41	11.10	42.42	9.26	14.34	10.69	16.42	12.46	61.17	12.28	20.08	12.47	15.94	9.93
100 kernel weight	60.03	1.12	3.03	3.293	7.357	6.578	64.50	1.07	3.39	4.33	11.38	10.52	62.69	2.40	6.62	5.63	9.85	8.08
Ear length (cm)	51.10	1.69	10.57	7.198	10.06	7.041	28.35	0.936	6.48	5.90	11.08	9.38	40.62	1.34	8.87	6.78	10.65	8.20
Ear diameter (cm)	43.75	0 .488	11.40	8.367	12.64	9.486	16.70	0.122	3.10	3.68	9.02	8.23	14.79	0.128	3.09	3.91	10.17	9.39
No. of kernel rows/ear	38.15	0 .922	6.86	5.394	8.733	6.868	21.12	0.437	3.47	3.67	7.99	7.10	17.21	0.528	3.96	4.63	11.16	10.16
Number of kernels/row	42.04	3.02	9.19	6.886	10.62	8.085	19.62	1.48	5.20	5.72	12.93	11.59	14.12	1.01	3.21	4.15	11.06	10.25
No. of nodes bearing brace roots	18.15	0 .161	11.83	13.47	31.62	28.60	20.20	0.087	6.64	7.19	16.01	14.30	36.48	0.154	10.34	8.33	13.79	10.99
Days to 50% tasselling	20.94	0 .689	1.38	1.471	3.216	2.859	31.90	1.08	2.18	1.91	3.45	2.86	12.05	0.284	0.58	0.817	2.35	2.20
Days to 50% silking	19.50	0 .728	1.37	1.513	3.427	3.075	36.53	1.41	2.64	2.13	3.52	2.80	21.32	0.829	1.57	1.65	3.58	3.18
Anthesis-Silking Interval	23.65	0 .486	15.18	4.14	11.13	27.20	10.12	0.252	6.27	5.54	10.00	28.44	17.04	0.729	18.23	7.00	3.69	27.92
Protein (%)	97.90	2.654	27.02	13.25	13.39	1.94	97.88	2.65	27.32	13.42	13.56	1.97	97.88	2.65	27.26	13.39	13.53	1.96
Lysine (%)	93.93	0 .856	28.43	14.19	14.65	3.60	96.75	0.218	31.59	15.45	15.71	2.82	93.93	0.214	30.14	15.06	15.54	3.82
Tryptophan (%)	93.93	0 .214	28.53	14.19	14.65	3.60	96.75	0.875	31.36	15.45	15.71	2.82	93.93	0.856	30.14	15.06	15.54	3.82
Grain yield (kg/ha)	53.85	1914.32	49.92	33.02	45.00	30.56	27.83	731.6	27.37	25.18	47.74	40.55	51.73	1320.6	44.88	30.28	42.10	29.25

E_1 : Normal (recommended dose of nitrogen**), E_2 :** Low-nitrogen, **E_3 :** Excess soil moisture
GCV: Genotypic coefficient of variation, **PCV:** Phenotypic coefficient of variation, **ECV:** Environmental coefficient of variation

while, genetic advance in per cent of mean was moderate for anthesis-silking interval (15.18), brace roots (11.83), ear diameter (11.40) and ear length (10.57). However, characters like number of kernels per row (9.19), number of kernel rows per ear (6.86), ear height (5.08), plant height (3.69), 100-kernel weight (3.03) days to 50per cent tasselling (1.38) and days to 50per cent silking (1.37) showed low genetic advance in per cent of mean in the E_1.

In the E_2, highest genetic advance in per cent of mean was observed for lysine (31.59) followed by tryptophan (31.36), grain yield (27.37) and protein content (27.32), whereas, characters like ear height (14.34) showed moderately higher genetic advance in per cent of mean. While, number of nodes bearing brace roots (6.64), anthesis-silking interval (6.27), ear length (6.48), plant height (5.23), number of kernels per row (5.20), number of kernel rows per ear (3.47), 100-kernel weight (3.39), ear diameter (3.10), days to 50per cent tasselling and silking (2.18 and 2.64, respectively) showed low genetic advance in per cent of mean.

The high expected genetic advance in per cent of mean was estimated in E_3 for characters like grain yield (44.88) followed by lysine and tryptophan contents (30.14 each) and protein (27.26). While, genetic advance in per cent of mean was moderate for ear height (20.08), anthesis-silking interval (18.23) and brace roots (10.34). The low value of genetic advance in per cent of mean was observed for ear length (8.87), plant height (7.28), 100-kernel weight (6.62), number of

kernel rows per ear (3.96), number of kernels per ear (3.21), ear diameter (3.09), days to 50 per cent tasselling (0.58) and silking (1.57).

The expected genetic advance in per cent of mean was high for grain yield, protein content, lysine and tryptophan in all the three environments.

4.3.3 Coefficient of variation

Estimates of phenotypic (PCV), genotypic (GCV), and environmental (ECV) coefficients of variation are presented in Table 4.3.1. In general, phenotypic coefficient of variation was higher than the genotypic coefficient of variation in the same direction. The results obtained for various characters are described below:

4.3.3.1 Plant height (cm)

Genotypic, phenotypic and environmental coefficients of variation were 4.067, 9.212 and 8.265 per cent in E_1; 5.06, 10.08 and 8.72 in E_2; and 6.03, 10.29 and 8.34 per cent in E_3, respectively.

4.3.3.2 Ear height (cm)

The genotypic, phenotypic and environmental coefficients of variation were 5.538, 12.41 and 11.10 per cent in E_1; 10.69, 16.42 and 12.46 per cent in E_2; 12.47, 15.94 and 9.93 per cent in E_3, respectively.

4.3.3.3 100-kernel weight (g)

The GCV, PCV and ECV were 3.293, 7.357 and 6.578 per cent in E_1; 4.33, 11.38 and 10.52 per cent in E_2; and 5.63, 9.85 and 8.08 per cent in E_3, respectively.

4.3.3.4 Ear length (cm)

The genotypic, phenotypic and environmental coefficients of variation were 7.198, 10.06 and 7.041 per cent in E_1; 5.90, 11.08 and 9.38 in E_2; and 6.78, 10.65 and 8.20 per cent in E_3, respectively.

4.3.3.5 Ear diameter (cm)

The GCV, PCV and ECV were 8.367, 12.64 and 9.486 in E_1; 3.68, 9.02 and 8.23 in E_2; and 3.91, 10.17 and 9.39 per cent in E_3, respectively.

4.3.3.6 Number of kernel rows per ear

The genotypic coefficients of variation were 5.394 in E_1, 3.67 in E_2; and 4.63 in E_3, phenotypic coefficients of variation were 8.733 in E_1; 7.99 in E_2; and 11.16 in E_3. Similarly, ECV estimates were 6.868 in E_1; 7.10 in E_2; and 10.16 per cent in E_3.

4.3.3.7 Number of kernels per row

The genotypic, phenotypic and environmental coefficients of variation were 6.886, 10.62 and 8.085 per cent in E_1; 5.72, 12.93 and 11.59 per cent in E_2; and 4.15, 11.06 and 10.25 per cent in E_3, respectively.

4.3.3.8 Number of nodes bearing brace roots

The GCV, PCV and ECV estimates were 13.47, 31.62 and 28.60 per cent in E_1; 7.19, 16.01 and 14.30 in E_2; 8.33, 13.79 and 10.99 per cent in E_3, respectively.

4.3.3.9 Days to 50 per cent tasselling

The genotypic, phenotypic and environmental coefficients of variation were 1.471, 3.216 and 2.859 per cent in E_1; 1.91, 3.45 and 2.86 in E_2; and 0.816, 2.35 and 2.20 per cent in E_3, respectively.

4.3.3.10 Days to 50 per cent silking

The genotypic, phenotypic and environmental coefficients of variation were 1.513, 3.427 and 3.075 in E_1; 2.13, 3.52 and 2.80 in E_2; and 1.65, 3.58 and 3.18 per cent in E_3, respectively.

4.3.3.11 Anthesis-silking interval

The GCV, PCV and ECV were 4.14, 11.13 and 27.20 per cent in E_1; 5.54, 10.00 and 28.44 in E_2; 7.00, 3.69 and 27.92 per cent in E_3, respectively.

4.3.3.12 Protein per cent

The GCV, PCV and ECV estimates were 13.25, 13.39 and 1.94 per cent in E_1; 13.42, 13.56 and 1.97 per cent in E_2; and 13.39, 13.53 and 1.96 per cent in E_3, respectively.

4.3.3.13 Lysine per cent

The genotypic coefficients of variation were 14.19 in E_1; 15.45 in E_2; and 15.06 in E_3, phenotypic coefficients of variation were 14.65 in E_1; 15.71 in E_2 and 15.54 in E_3. Similarly ECV estimates were 3.60 in E_1; 2.82 in E_2; and 3.82 per cent in E_3.

4.3.3.14 Tryptophan per cent

The GCV, PCV and ECV estimates were 14.19, 14.65 and 3.60 per cent in E_1; 15.45, 15.71 and 2.82 per cent in E_2; and 15.06, 15.54 and 3.82 per cent in E_3, respectively.

4.3.3.15 Grain Yield (kg per ha)

The genotypic coefficients of variation were 33.02 in E_1; 25.18 in E_2; and 30.28 in E_3, phenotypic coefficients of variation were 45.00 in E_1; 47.74 in E_2 and 42.10 in E_3. Similarly ECV estimates were 30.56 in E_1; 40.55 in E_2; and 29.25 per cent in E_3.

4.4 Combining Ability

4.4.2 Analysis of variance for line x tester

The ANOVA for combining ability with respect to various characters is presented in the Table 4.4.1 for E_1, E_2 and E_3 environments and in the Table 4.4.2 for pooled over environments. Variance due to lines was significant for most of the characters except 100-kernels weight and brace roots in $E_1$and E_3, number of kernels per row in E3; days to 50 per cent silking and anthesis-silking interval in E_2 and E_3 environments. Variance due to tester was significant for all the characters except brace roots in E_1 and E_2 environment and days to 50 per cent tasselling in E_1 environment. All the characters showed significant differences in all the three environments for line x tester component.

Pooled analysis of variance over environments for combining ability indicated that variance due to lines was significant for all the

Table 4.4.1: Analysis of variance of line x tester for different characters in Quality Protein Maize (QPM) under E_1, E_2 and E_3 environments

Source of variation	Degree of freedom	Environment	Mean Sum of Squares														
			Plant height (cm)	Ear height (cm)	100 kernels weight (g)	Ear length (cm)	Ear diameter (cm)	kernel rows/ ear	No. of kernel/ row	No. of nodes bearing brace roots	Days to 50% tasselling	Days to 50% silking	Anthesis-Silking interval	Protein (%)	Lysine (%)	Tryptophan (%)	Grain yield (kg/ha)
Lines	20	E1	819.38**	288.45**	32.44	9.92**	0.77**	3.97**	29.68**	1.16	18.85**	20.80**	4.21**	3.56**	0.625*	0.387*	11495922**
		E2	578.87**	457.34**	43.55**	6.509**	0.53*	1.897*	53.46*	0.220*	8.202*	13.100	4.562	3.564**	0.624*	0.0387**	5129838**
		E3	651.04**	192.54**	27.551	6.062**	0.321**	7.914**	43.612	0.168	4.724*	8.31	3.09	3.56**	0.629**	0.0387*	4389945**
Tester	2	E1	728.69**	50.23**	33.53**	14.68**	0.35**	3.46**	22.88**	1.47	3.34	8.88*	2.37**	11.18**	0.126*	0.758**	27557990**
		E2	215.46**	68.40**	49.73**	7.614**	1.08*	6.094**	1.045*	0.30	7.54**	7.44**	2.18**	11.18**	0.125*	0.71**	7001589**
		E3	165.82**	48.844**	93.26**	0.924**	0.557**	0.908**	40.792	2.59**	4.14**	10.1**	6.48**	11.18**	0.125*	0.75*	3168386**
Line x tester	40	E1	740.53**	248.76**	20.31**	8.18**	0.685**	4.17**	55.54**	0.50**	1.99**	2.48**	1.64**	5.65**	0.643**	0.401**	7267835**
		E2	410.03**	217.35**	54.71**	5.18**	0.31**	3.04**	28.08**	0.116**	4.134**	8.35**	4.48**	5.65**	0.643**	0.0402**	3459082**
		E3	705.99**	273.36**	50.67**	7.009**	0.37**	8.42**	33.22**	0.143**	2.737**	7.156**	3.120**	5.655**	0.644**	0.0411**	5136878**
Error	172	E1	0.89	0.65	0.71	0.02	0.02	0.02	0.07	0.03	0.21	0.21	0.20	0.20	0.004	0.005	4.598
		E2	0.08	0.67	0.07	0.240	0.246	0.246	0.700	0.247	0.208	0.208	0.198	0.198	0.0004	0.00005	-0.91526
		E3	0.80	0.069	0.069	0.002	0.246	0.002	0.698	0.002	0.208	0.21	0.20	0.20	0.0023	0.00054	-1.52

****,***significant at 1% and 5% levels of probability, respectively
E_1 : Normal (recommended dose of nitrogen**), E_2 :** Low-nitrogen, **E_3 :** Excess soil moisture

Table 4.4.2: Pooled analysis of variance of line x tester for different characters of Quality Protein Maize (QPM) over three (E_1, E_2 and E_3) environments

Source of variation	Degree of freedom	Mean Squares														
		Plant height (cm)	Ear height (cm)	100 kernels weight (g)	Ear length (cm)	Ear diameter (cm)	kernel rows/ ear	No. of kernel/ row	No. of nodes bearing brace roots	Days to 50% tasselling	Days to 50% silking	Anthesis-Silking interval	Protein (%)	Lysine (%)	Tryptophan (%)	Grain yield (kg/ha)
Line (L)	20	2844.95**	452.58**	38.47**	15.47**	0.87**	3.18*	42.01**	0.64**	16.13**	17.87**	4.90**	10.69	1.87	0.116	1220.46**
Tester (T)	2	4123.16**	65.75**	64.27**	12.61**	0.79**	3.26**	48.94**	0.67	5.92	19.19	5.28	33.54	0.37	0.022	2290.10**
Line x tester	40	2955.95**	293.51**	29.07**	8.54**	0.49**	6.47**	45.72**	0.25**	4.40**	6.64**	3.01**	16.96**	1.93**	0.121**	944.07**
Line x Env.	40	3147.26**	242.83**	32.53**	3.50*	0.37*	5.30**	42.37	0.45*	7.82**	12.16**	3.48**	0.004	0.0004	0.000004	440.40**
Tester x Env.	4	3336.27**	400.68**	41.10**	5.30**	0.34*	3.59**	7.83	0.44	3.06	3.61	2.87	0.004	0.0006	0.00054	741.55**
(Line x tester) x Env.	80	3503.13**	222.99**	48.31**	5.91**	0.44**	4.58**	35.56**	0.25**	2.23**	5.67**	3.11**	0.045*	0.054**	0.0055**	321.04**
Error	372	0.068	0.068	0.0681	0.002	0.002	0.002	0.068	0.002	0.198	0.198	0.186	0.186	0.00005	0.00005	0.00003

**,*significant at 1% and 5% levels of probability, respectively
E_1 : Normal (recommended dose of nitrogen**), E_2 :** Low-nitrogen, **E_3 :** Excess soil moisture,

characters except quality parameters. Whereas, variance due to testers was significant for plant height, ear height, 100-kernels weight ear length, ear diameter, number of kernel rows per ear, number of kernels per row and grain yield. For line x tester interaction component, the variance was significant for all the characters. Component for line x environment interaction was non significant for number of kernels per row, protein, lysine and tryptophan contents. While, tester x environment component of variance was significant for plant height, ear height, 100-kernel weight, ear length, ear diameter, number of kernel rows per ear and grain yield. Higher order interaction i.e., (line x tester) x environment was significant for all fifteen characters.

4.4.3 Estimates of combining ability effects

The estimates of GCA effects of the parental lines and SCA effects of crosses for different characters under three environments as well as pooled over environments are given in Tables 4.4.3 and 4.4.4, respectively. The results for each of the individual characters are presented below.

4.4.3.1 Plant height (cm)

The estimates of GCA and SCA effects for plant height are presented in the Tables 4.4.3 and 4.4.4, respectively. The range of GCA effects among lines was -18.98 to 17.46, -9.22 to 16.22, -14.13 to 16.31 and -13.93 to 35.34 in E1, E2, E3 and pooled analysis, respectively. Perusal of these Tables revealed that L_4 (17.46), L_{10} (12.35) and L_{11}

Table 4.4.3: Estimates of general combining ability effects of lines and testers for important economic characters under normal (recommended dose of nitrogen, E_1), low – nitrogen (E_2), excess soil moisture (E_3) and pooled over environments in Quality Protein Maize (QPM).

Character	Plant height (cm)				Ear height (cm)				100-kernel weight (g)			
Environment	**E_1**	**E_2**	**E_3**	**Pooled**	**E_1**	**E_2**	**E_3**	**Pooled**	**E_1**	**E_2**	**E_3**	**Pooled**
LINE												
L_1	0.49	-3.09	-14.84**	-7.931	11.33**	-8.36**	-7.38**	-1.467	0.21	1.12	-1.32	0.005
L_2	7.35	8.45*	6.09	5.180	4.87	-7.83*	-0.18	-1.045	-0.05	-1.40	-3.11**	1.523
L_3	5.86	8.96*	-2.80	1.892	6.71	2.35	1.34	3.466	2.48**	-3.09**	1.62	0.335
L_4	17.46**	16.22**	5.70	11.014 *	6.31	3.29	4.60	4.733	3.18**	-1.95*	-0.54	0.230
L_5	1.24	-2.83	16.31**	2.792	-4.91	2.73	2.55	0.122	-1.10	0.94	1.77	0.538
L_6	-13.87**	-7.44	-14.13**	-13.931**	-8.36**	-14.38**	-4.63	-9.123 **	-0.51	-1.12	0.99	0.214
L_7	-10.31**	-7.55	3.26	-6.986	-4.80	4.84	-3.51	-1.156	-2.40**	-0.83	-3.89**	2.372 **
L_8	5.10	-6.64	9.17**	0.425	3.11	-9.15**	7.74**	0.566	-1.41	0.28	0.19	0.315
L_9	-4.29	7.14	-11.05**	-4.853	-7.11**	2.53	-7.15**	-3.912	1.80	3.32**	-1.23	1.297
L_{10}	12.35**	-2.89	6.26	3.125	6.53**	12.17**	2.99	7.233 *	0.08	1.16	-0.69	0.183
L_{11}	16.74**	1.10	10.81**	17.43**	3.32	1.40	4.38	3.033	-1.94	-1.75	-1.22	-1.636
L_{12}	4.42	-9.05**	-9.01**	-6.664	-6.73**	1.24	-3.11	-2.867	0.60	3.96**	-0.25	1.440
L_{13}	-9.92**	1.67	8.15	-2.153	-2.91	8.06**	0.38	1.844	0.73	2.08**	0.37	1.060
L_{14}	3.06	15.82**	1.63	4.725	-0.42	11.55**	2.54	4.555	-3.36**	-1.23	-0.72	-1.766
L_{15}	1.80	0.89	5.53	0.625	2.64	7.95*	5.27	5.288	2.73**	1.03	1.76	2.839 **
L_{16}	-1.54	-5.44	-0.30	-4.542	0.31	-3.31	-7.06**	-3.356	2.69**	-1.49	-1.40	0.068
L_{17}	-4.54	-2.44	0.70	-4.208	-7.69**	-7.98*	-5.73	-7.134 *	-1.44	-0.40	1.11	0.245
L_{18}	3.35	5.78	-8.08	-1.764	3.37	-5.16	-0.84	-0.878	-1.09	3.36**	1.28	3.183 **
L_{19}	-18.98**	2.45	-4.41	35.347**	-4.13	2.17	6.49	1.511	-0.95	-1.43	3.52**	0.377
L_{20}	-8.15	-11.9**	-3.08	-9.820	2.70	0.51	1.16	1.455	-2.18**	-4.46**	1.77	1.623
L_{21}	-7.65	-9.22**	-5.91	-9.708	-4.13	-4.63	0.16	8.567**	1.94	1.90*	-0.02	1.273
S.E.(gi)	0.099	0.094	0.099	0.3145	0.085	0.086	0.085	0.2687	0.088	0.088	0.088	0.2809
SE(gi-gj)	0.141	0.133	0.133	0.4447	0.121	0.121	0.123	0.3801	0.125	0.125	0.123	0.3972
TESTER												
T_1	0.89	0.06	1.88**	5.177 **	0.24	-0.18	0.18	0.080	0.49	-0.65**	0.43	0.089
T_2	-3.76**	-0.56**	-1.02**	-3.897 *	-0.99**	3.58**	-0.96**	0.546	-0.84**	0.34	-1.37**	-0.623 *
T_3	2.88**	0.49**	-0.86	-1.280	0.75*	-3.40**	0.78**	-0.626 *	0.35	0.30	0.95*	0.534
S.E.(gj)	0.037	0.035	0.037	0.0356	0.032	0.032	0.032	0.1031	0.033	0.033	0.033	0.0333
SE(gi-gj)	0.053	0.05	0.05	0.0504	0.045	0.045	0.046	0.1458	0.047	0.047	0.046	0.0471

*, ** Significant at 5% and 1 % probability levels, respectively.

(16.74) in E_1; L_2 (8.45), L_3 (8.96), L_4 (16.22) and L_{14} (15.82) in E_2; L_5 (16.31) and L_{11} (10.81) in E_3; and L_4 (11.01), L_{11} (17.43) and L_{19} (35.34) in pooled environment exhibited higher significant positive GCA effects. Among the testers, T_3 (2.88) in E_1; T_3 (0.49) in E_2; T_1 (1.88) in E_3 and T_3 (0.75) in pooled analysis had positive and significant GCA effects. This indicated that these parents were good general combiners for plant height. However, line L_6 showed significant negative effect of GCA in E_1, E_3 and pooled environment.

Estimates of SCA effects in crosses ranged from -25.11 to 30.27, -31.31 to 22.34, -34.99 to 26.41 and -7.43 to 28.60 in E_1, E_2, E_3 and pooled environment, respectively. Hybrids, L_1 X T_1 (13.25), L_1 X T_2 (11.76), L_2 X T_1 (10.11), L_3 X T_2 (10.78), L_5 X T_1 (24.89), L_9 X T_1 (28.16), L_{12} X T_3 (13.06), L_{13} X T_3 (30.27), L_{15} X T_3 (24.35), L_{16} X T_1 (17.67), L_{17} X T_3 (12.68), L_{18} X T_3 (14.79) and L_{19} X T_3 (12.46), in E_1; L_5 X T_1 (20.21), L_6 X T_2 (14.45), L_8 X T_2 (10.71), L_{12} X T_3 (22.34), L_{15} X T_1 (10.82), L_{16} X T_3 (10.73), L_{17} X T_3 (16.40), L_{18} X T_1 (11.60) and L_{19} X T_3 (10.84) in E_2; L_2 X T_1 (15.62), L_3 X T_2 (11.95), L_5 X T_1 (19.06), L_6 X T_3 (16.25), L_8 X T_2 (9.18), L_{10} X T_3 (14.19), L_{15} X T_1 (16.17), L_{16} X T_1 (10.67), L_{17} X T_3 (26.41) and L_{18} X T_2 (20.36) in E_3; and L_5 X T_1 (17.15), L_5 X T_3 (13.05), L_6 X T_1 (10.62), L_8 X T_2 (11.99), L_{12} X T_3 (15.06), L_{13} X T_3 (12.09), L_{14} X T_1 (13.31), L_{17} X T_1 (25.51), L_{17} X T_3 (20.61), L_{19} X T_1 (28.60), L_{19} X T_2 (23.65) and L_{19} X T_3 (14.92) in the pooled environment exhibited maximum and significant SCA effects for plant height. So these were the best combiners for this trait. Two crosses, L_5 X T_1 and L_{17} X T_3 exhibited significant SCA effects in E_1, E_2, E_3 and pooled environment.

Table 4.4.4: Estimates of specific combining ability effects of crosses for important economic characters under normal (recommended dose of nitrogen, E_1), low – nitrogen (E_2), excess soil moisture (E_3) and pooled over environments in Quality Protein Maize (QPM).

Character	Plant height (cm)				Ear height (cm)				100-kernel weight (g)			
Environment	**E1**	**E2**	**E3**	**Pooled**	**E1**	**E2**	**E3**	**Pooled**	**E1**	**E2**	**E3**	**Pooled**
CROSSES												
L_1 X T_1	13.25**	-0.93	6.82	5.478	-11.44*	-2.35	3.95	0.053	0.99	0.04	-0.42	0.203
L_1 X T_2	11.76**	5.56	1.41	2.580	13.65**	11.75*	-19.04**	-1.212	1.07	-2.68**	0.84	0.255
L_1 X T_3	-25.01**	-4.63	4.59	2.898	-12.21*	-9.40	15.09**	1.159	-2.06**	2.64**	-0.42	0.052
L_2 X T_1	10.11*	-7.73	15.62**	1.767	16.76**	-3.15	2.49	5.364	-4.01	-3.98**	-0.69	2.894 **
L_2 X T_2	-4.57	4.56	-9.31*	0.992	-7.35	7.75	-0.71	-0.101	5.58	1.28*	-0.13	2.241 **
L_2 X T_3	-5.54	3.17	-6.31	0.776	-9.41	-4.60	-1.78	-5.263	-1.57**	2.70**	0.82	0.653
L_3 X T_1	-14.40**	3.76	3.51	6.611	-9.09	0.67	4.98	-1.147	4.05**	-0.50	-2.13**	0.533
L_3 X T_2	10.78*	-1.09	11.95**	9.331	-5.32	7.44	5.64	2.588	-1.82**	3.34**	1.20*	0.907
L_3 X T_3	3.61	-2.67	5.45	2.720	14.41**	-8.11	-10.62*	-1.441	-2.23**	0.17	0.93	0.376
L_4 X T_1	8.00	-3.51	-3.99	4.066	1.31	-4.26	-4.29	-2.414	1.75**	-0.63	-3.08**	1.655 **
L_4 X T_2	9.32	5.78	-0.42	7.008	7.21	2.64	2.51	4.121	-1.78**	-0.66	0.70	1.914 **
L_4 X T_3	-17.32**	-2.27	4.41	2.942	-8.52	1.62	1.78	-1.707	0.03	8.29**	2.38**	3.569 **
L_5 X T_1	24.89**	20.21**	19.06**	17.156 **	17.20**	14.96**	18.43**	16.864 **	1.69**	3.02**	1.89**	2.198 **
L_5 X T_2	-19.13**	-5.83	6.30	4.103	-5.24	-5.47	0.90	-3.268	-2.76**	0.67	-0.87	0.98
L_5 X T_3	-5.76	-14.38**	-25.36**	13.053**	-11.97*	-9.49	-19.33**	13.96 **	1.07	-3.69**	-1.01	1.211
L_6 X T_1	1.34	-7.84	-12.66**	10.622 *	-0.02	-1.60	-2.76	-1.458	-2.67**	1.12	-2.41**	1.318 *
L_6 X T_2	-5.35	14.45**	-3.59	3.953	3.88	-9.69	-10.26*	-5.357	3.93**	-3.18**	-1.34*	0.198
L_6 X T_3	4.01	-6.60	16.25**	6.669	-3.86	11.29*	13.01**	6.815	-1.26*	2.06**	0.74	1.516 *
L_7 X T_1	1.78	3.27	7.45	0.066	-9.57	-1.82	6.82	-1.525	-0.19	-0.46	0.38	1.573 *
L_7 X T_2	4.43	3.89	-0.64	4.675	7.65	6.42	-1.04	4.343	1.25*	1.46*	-0.14	2.144 **
L_7 X T_3	-6.21	-7.16	-6.81	4.609	1.92	-4.60	-5.78	-2.819	-1.06	-1.00	3.77**	0.572
L_8 X T_1	-7.63	2.36	-1.46	6.477	-3.44	11.47*	5.58	4.520	1.84**	0.83	-0.30	0.122
L_8 X T_2	9.75	10.71*	9.18*	11.997 *	-1.52	-12.86*	6.44	-2.646	-1.01	-0.31	0.04	0.571
L_8 X T_3	-2.12	-13.07**	-7.72	5.520	5.01	1.39	-12.02**	-1.874	-0.83	-0.51	-0.73	0.693
L_9 X T_1	28.16**	4.98	-10.84**	3.201	7.14	2.89	-2.14	2.631	-1.07	0.29	-0.98	0.077
L_9 X T_2	-5.43	4.87	5.34	6.909	2.63	-11.60*	-1.73	-3.568	-3.88**	-2.93**	2.29**	1.508 *
L_9 X T_3	-22.73**	-9.85	5.50	3.708	-19.77**	8.71	3.87	0.937	4.95**	0.64	-1.30*	1.430 *
L_{10} X T_1	5.11	4.60	-20.55**	7.844	13.09**	-5.15	-14.18**	-2.080	1.45**	-0.86	2.79**	1.126
L_{10} X T_2	3.76	-0.78	6.36	5.231	-1.68	3.09	12.46**	4.621	-2.03**	1.35*	-1.53*	-0.739
L_{10}X T_3	-8.88	-3.83	14.19**	2.613	-11.41*	2.07	1.72	-2.541	0.58	-0.49	-1.25*	-0.387

Contd.....

L_{11} X T_1	-3.27	-12.09**	1.89	8.722	-3.00	1.62	-0.07	-0.480	-0.63	10.45**	-2.69**	2.376 **
L_{11} X T_2	8.27	5.64	-2.80	5.820	0.93	-0.73	-2.53	-0.779	0.09	0.54	3.42**	-1.677 *
L_{11} X T_3	-5.00	6.45	0.90	2.902	2.07	-0.89	2.60	1.259	0.54	-1.91**	-0.73	-0.700
L_{12} X T_1	-17.75**	8.97	-6.08	9.188	4.56	-6.02	-5.3	-2.280	-1.38*	0.76	4.14**	0.337
L_{12} X T_2	4.69	-31.31**	2.62	5.880	-8.41	10.02*	6.56	2.721	3.13**	-1.53*	0.03	0.544
L_{12} X T_3	13.06**	22.34**	3.46	15.069 **	13.85**	-4.00	-1.18	-0.441	-1.75**	3.29**	-4.18**	-0.881
L_{13} X T_1	-25.11**	5.05	3.56	9.733	-13.46**	-1.04	0.93	-14.525**	-1.30*	-0.78	-2.38**	-1.489 *
L_{13} X T_2	-5.16	-9.53	1.27	2.358	6.56	-2.00	-0.13	1.477	-3.59**	0.93	3.91**	0.417
L_{13} X T_3	30.27**	4.48	-4.83	12.091 **	6.90	3.04	-0.80	3.048	4.89**	-0.15	-1.52*	1.073
L_{14} X T_1	-1.46	-7.98	-17.79**	13.311 **	-3.82	-0.40	-2.09	-2.103	-0.90	0.45	8.82**	2.790 **
L_{14} X T_2	-0.95	2.51	8.98	5.631	0.28	-2.29	-1.09	-1.034	-1.91**	1.65*	-4.61**	-1.626 *
L_{14} X T_3	2.41	5.46	8.81	.680	3.54	2.69	3.18	3.137	2.81**	-2.10**	-4.21**	-1.164
L_{15} X T_1	-0.33	10.82*	16.17**	4.656	4.98	13.07**	1.04	6.364	0.31	2.17**	0.02	0.833
L_{15} X T_2	-24.02**	-0.89	-3.75	-7.436	-12.12**	-4.02	-2.16	-16.101**	1.20*	-3.35**	3.69**	0.514
L_{15} X T_3	24.35**	-9.94	-12.42**	2.780	7.14	-9.05	1.11	-0.263	-1.51**	1.18	-3.72**	-1.347 *
L_{16} X T_1	17.67**	0.82	10.67**	5.489	3.98	11.00*	2.04	5.675	-0.20	4.36**	2.16**	2.108 **
L_{16} X T_2	-7.68	-11.55**	-10.42**	7.769	-6.79	-9.56	-6.82	-7.723	1.14*	1.49*	1.07	1.233
L_{16} X T_3	-9.99	10.73*	-0.25	2.280	2.81	-1.45	4.78	2.048	-0.94	-5.85**	-0.23	3.340 **
L_{17} X T_1	-13.00**	-15.84**	-34.99**	25.511 **	-8.69	-2.00	-17.96**	-9.547	0.37	-0.49	-0.74	0.622
L_{17} X T_2	0.32	-0.55	8.58	4.897	3.21	-8.89	8.84	1.054	0.96	-0.52	0.73	1.388 *
L_{17} X T_3	12.68**	16.40**	26.41**	20.613 **	5.48	10.89*	9.11	8.493	-1.33*	1.02	-1.99**	0.766
L_{18} X T_1	-9.22	11.60**	1.45	2.955	-1.07	-5.15	7.82	0.51	-1.82**	0.48	-0.62	2.308 **
L_{18} X T_2	-5.57	-1.78	20.36**	6.453	-5.35	3.09	6.96	1.56	1.41*	4.72**	-0.33	1.268
L_{18} X T_3	14.79**	-9.83	-21.81**	3.498	6.42	2.07	-14.78**	2.096	0.40	-2.24**	0.95	1.040
L_{19} X T_1	-19.55**	-6.73	8.12	28.601 **	-12.24	-11.15*	1.82	-7.192	2.19**	0.85	-0.52	0.174
L_{19} X T_2	7.09	-4.11	-6.98	23.658 **	4.99	5.09	-3.04	2.343	-0.69	5.85**	-0.73	0.478
L_{19} X T_3	12.46**	10.84*	-1.14	14.942 **	7.25	6.07	1.22	4.848	-1.51**	0.70	0.25	0.652
L_{20} X T_1	5.95	-9.06	8.12	2.566	-1.24	-7.15	-3.51	-3.969	0.84	-5.99**	-3.17**	2.771 **
L_{20} X T_2	2.59	-0.44	-13.98**	1.825	8.49	7.59	-5.38	3.566	-0.12	5.72**	-0.46	1.045
L_{20} X T_3	-8.54	9.51	5.86	4.391	-7.25	-0.43	8.89	0.404	-0.72	0.26	0.63	1.726 *
L_{21} X T_1	-4.55	-4.73	-4.05	8.677	-1.91	-4.42	-3.51	-3.280	-1.28*	-2.64**	0.94	.329
L_{21} X T_2	5.09	9.89	2.36	7.897	4.32	2.22	3.62	3.388	-0.17	-0.74	0.24	00.444
L_{21} X T_3	-0.54	-5.16	1.69	0.780	-2.41	2.20	-0.11	-2.107	1.45*	3.38	-0.18	0.115
S.E.	0.172	0.163	0.172	0.5164	0.147	0.149	0.147	0.1517	0.153	0.153	0.153	0.1517
SE(sij-skl)	0.244	0.230	0.231	0.7303	0.208	0.211	0.214	0.2145	0.217	0.217	0.214	0.2145

*, ** Significant at 5% and 1 % probability levels, respectively.

E_1: Normal (recommended dose of nitrogen**), E_2:** Low-nitrogen, **E_3:** Excess soil moisture, **Env.** : Environment

4.4.3.2 Ear height (cm)

Estimates of GCA effects of parents and SCA effects of crosses for ear height are given in Tables 4.4.3 and 4.4.4, respectively. These Tables indicated that significant positive GCA effects were observed for L_1 (11.33) and L_{10} (6.53) in E_1' L_{10} (12.17), L_{13} (8.06), L_{14} (11.55) and L_{15} (7.95) in E_2; L_8 (7.74) in E_3, and L_{10} (7.23) and L_{21} (8.57) in the pooled environment, however, L_{10} showed positive GCA effect in E_1, E_3 and pooled environment indicating its good combining ability for this trait. While, maximum GCA effect was observed in T_3 (0.75), T_2 (3.58) and T_3 (0.78) for E_1; E_2 and E_3 environment, respectively.

The estimates of SCA effects of crosses for ear height ranged from -19.77 to 17.20 in E_1; -12.86 to 14.96 in E_2; -19.33 to 18.83 in E_3; and -16.10 to 16.86 in pooled environment. In E_1, maximum SCA effects was observed for L_5 X T_1 (17.20) followed by L_2 X T_1 (16.76), L_3 X T_3 (14.41), L_{12} X T_3 (13.85) L_1 X T_2 (13.65) and L_{10} X T_1 (13.09), while, cross, L_5 X T_1 (14.96) followed by L_{15} X T_1 (13.07), L_1 X T_2 (11.75), L_8 X T_1 (11.47), L_6 X T_3 (11.29), L_{16} X T_1 (11.00), L_{17} X T_3 (10.89) andL_{12} X T_2 (10.02) in E2; cross, L_{15} X T_1 (18.43) followed by L_1 X T_3 (15.09), L_6 X T_3 (13.01) and L_{10} X T_2 (12.46) in E_3 and L_5 X T_1 (16.86) exhibited maximum SCA effect for ear height. However, L_5 X T_1 showed positive and significant SCA effect for ear height in all environments indicating its average combining ability for this trait.

4.4.3.3 100-kernel weight (g)

Estimates of GCA effects of parents and SCA effects of crosses for 100-kernel weight are presented in Tables 4.4.3 and 4.4.4, respectively.

Perusal of results on GCA effects of lines indicated significant positive effects of L_3 (2.48), L_4 (3.18), L_{15} (2.73) and L_{16} (2.69) in E_1, L_9 (3.32), L_{12} (3.96), L_{13} (2.08) and L_{18} (3.36) in E_2, L_{19} (3.52) in E_3 and L_7 (2.37), L_{15} (2.83) and L_{18} (3.18) in the pooled environment. While, among the testers, T_2 (0.95) showed positively significant GCA effect in E3 environment. So these were considered as the best general combiners for 100-kernel weight in their respective environment.

SCA effects of crosses ranged from -4.01 to 5.58, -1.00 to 3.38, -1.01 to 1.07 and -1.164 to 1.268 in E_1, E_2, E_3 and pooled environment. Results of crosses revealed that crosses with significant and positive SCA effects were L_2 X T_2 (5.58) followed by L_9 X T_3 (4.95), L_{13} X T_3 (4.89), L_3 X T_1 (4.05), L_6 X T_2 (3.93), L_{12} X T_2 (3.13), L_{14} X T_3 (2.81), L_{19} X T_1 (2.19), L_8 X T_1 (1.84), L_4 X T_1 (1.75), L_5 X T_1 (1.69), L_{10} X T_1 (1.45), L_{21} X T_3 (1.45), L_{18} X T_2 (1.41), L_7 X T_2 (1.25) and L_{16} X T_2 (1.14) in E_1, L_{11} X T_1 (10.45) followed by L_4 X T_3 (8.29), L_{19} X T_2 (5.85), L_{20} X T_2 (5.72), L_{18} X T_2 (4.72), L_{16} X T_1 (4.36), L_3 X T_2 (3.34), L_{12} X T_3 (3.29), L_5 X T_1 (3.02), L_2 X T_3 (2.70), L_1 X T_3 (2.64), L_{15} X T_1 (2.17), L_6 X T_3 (2.06), L_{14} X T_2 (1.65), L_{16} X T_2 (1.49), L_7 X T_2 (1.46), L_{10} X T_2 (1.35) and L_2 X T_2 (1.28) in E_2, L_{14} X T_1 (8.82) followed by L_{12} X T_1 (4.14), L_{13} X T_2 (3.91), L_7 X T_3 (3.77), L_{15} X T_2 (3.69), L_{11} X T_2 (3.42), L_{10} X T_1 (2.79), L_4 X T_3 (2.38), L_9 X T_2 (2.29), L_{16} X T_1 (2.16) and L_5 X T_1 (1.89) in E_3. However, in the pooled analysis, maximum SCA effects were revealed by L_2 X T_1 (2.89), L_4 X T_3 (3.57), L_{14} X T_1 (2.79), L_{16} X T_3 (3.34) and L_{20} X T_1 (2.77) for 100-kernel weight.

4.4.3.4 Ear length (cm)

The range of GCA effects for lines was -2.34 to 2.27, -1.58 to 1.45, -1.62 to 1.53 and -1.17to 1.12in E_1, E_2, E_3 and pooled analysis, respectively. Estimates of GCA effects of parents for ear length are given in Table 4.4.3. Results of pooled analysis revealed that the best combiner for maximum ear length was L_{14} (1.127) followed by L_{13} (1.053). While, the best general combining lines were L_{13} (2.27), L_{12} (1.27) and L_2 (1.17) in E_1, L_{14} (1.45), L_{12} (1.22) and L_3 (0.82) in E_2 and L_{15} (1.53) and L_{14} (1.11) in E_3 environment. However, among the testers, T_3 (0.42) in E1; T_3 (0.37) in E2; T_2 (0.12) in E3 and T_3 (0.23) in pooled environment showed positive and significant GCA effects which means these are best combiners for particular environment.

Estimates of SCA effects of crosses for ear length are presented in Table 4.4.4. Perusal of the results of hybrids revealed that the range of this character varied from -3.64 to 3.33, -2.46 to 2.43, -2.42 to 2.12 and -0.61 to 2.59 in E_1, E_2, E_3 and across environments, respectively. The most promising crosses for higher ear length were L_{18} X T_2 (3.33) L_{12} X T_3 (2.97), L_7 X T_3 (2.36), L_{11} X T_3 (1.91), L_1 X T_1 (1.85), L_{11} X T_1 (1.73) and L_{15} X T_1 (1.74) in E_1; L_{10} X T_2 (2.43), L_{13} X T_3 (2.40) and L_{21} X T_2 (1.87) in E_2; L_{11} X T_3 (2.12), L_1 X T_3 (2.03), L_3 X T_1(1.99), L_{21} X T_1 (1.71), L_4 X T_3 (1.58), L_{18} X T_2 (1.58), L_{12} X T_1 (1.54), L_{16} X T_3 (1.45), L_{17} X T_3 (1.25), L_{18} X T_1 (1.12), L_5 X T_2 (1.07) and L_9 X T_3 (1.01) in E_3 environment. However, L_{11} X T_2 (2.59), L_{18} X T_2 (1.95), L_2 X T_3 (1.83) and L_{11} X T_3 (1.629) had maximum SCA effects in the pooled environment.

Table 4.4.3 : Contd.....

Character	Ear length (cm)				Ear diameter (cm)				Number of kernel rows / ear			
Environment	**E_1**	**E_2**	**E_3**	**Pooled**	**E_1**	**E_2**	**E_3**	**Pooled**	**E_1**	**E_2**	**E_3**	**Pooled**
LINE												
L_1	-0.69	0.31	-1.03**	-0.468	0.28	-0.18	0.01	0.039	0.05	0.77	-0.01	0.270
L_2	1.17**	0.40	0.62	0.732	-0.14	0.13	0.06	0.016	-0.42	-0.14	-1.36**	-0.640 **
L_3	0.27	0.82*	0.08	0.377	0.14	0.44**	0.43**	0.272 **	-0.11	0.50	-0.94	-0.182
L_4	0.66	0.78	0.55	0.664	-0.06	0.11	0.07	0.039	-0.04	2.21**	0.01	0.061
L_5	-0.53	-1.35**	0.42	-0.486	-0.17	-0.17	0.16	-0.061	-0.28	-0.45	0.77	0.011
L_6	-1.28**	-1.14**	-1.11**	-1.178 *	-0.50**	-0.26*	0.10	-0.284 **	0.02	2.07**	-0.65	-0.189
L_7	-0.11	0.44	-0.45	-0.040	-0.10	-0.16	0.40**	-0.217 **	-0.26	2.18**	-1.32**	-0.468
L_8	-2.34**	-1.05**	0.02	-1.132 *	-0.03	-0.49**	0.53**	-0.217 **	-0.60	-0.37	-0.65	-0.541 **
L_9	-1.45**	-0.44	-1.33**	-1.075 *	0.24	0.18	0.50**	0.172	0.29	0.29	0.01	0.200
L_{10}	-0.34	0.11	0.02	-0.076	0.30	0.18	0.27	0.250 **	-0.49	0.17	1.35**	0.342
L_{11}	0.33	0.33	0.22	0.294	-0.06	0.21*	0.07	-0.039	0.13	-0.34	-0.21	-0.152
L_{12}	1.27**	1.22**	0.22	0.905	0.07	0.34**	0.13	0.094	-0.82	1.57**	0.90	0.219
L_{13}	2.27**	0.78	0.11	1.053 *	0.14	0.08	0.13	0.028	-0.32	0.79	0.01	0.163
L_{14}	0.83	1.45**	1.11**	1.127 *	0.40	0.08	0.03	0.150	0.52	1.07**	-0.88	-0.097
L_{15}	0.14	0.42	1.53**	0.698	-0.29	-0.14	0.32*	-0.250 **	-0.17	-0.23	0.66	0.085
L_{16}	-0.56	-0.11	-0.45	-0.373	0.17	0.41**	0.13	0.150 *	2.07**	1.35**	-0.65	0.589 **
L_{17}	-0.91	-1.58**	-0.58	-1.024 *	-0.39**	-0.38**	0.08	-0.228 **	-0.62	-0.56	2.55**	0.455
L_{18}	0.86	-0.08	0.98	0.588	-0.22	-0.21*	0.38**	-0.017	-0.40	-0.34	0.44	-0.100
L_{19}	0.20	0.17	0.09	0.153	-0.25	-0.04	0.05	-0.117	-0.18	-0.34	-0.67	-0.397
L_{20}	-0.40	-0.51	-1.62**	-0.845	-0.26	0.01	0.07	-0.106 *	1.34**	-0.16	0.39	0.522 **
L_{21}	0.61	-1.00**	0.72	0.108	0.74**	0.04	0.20	0.328 **	0.29	-0.98*	0.24	-0.151
S.E.(gi)	0.016	0.016	0.016	0.0471	0.016	0.016	0.016	0.0471	0.015	0.015	0.015	0.0471
SE(gi-gj)	0.023	0.023	0.023	0.0667	0.023	0.023	0.023	0.0667	0.023	0.023	0.023	0.0667
TESTER												
T_1	0.11	-0.06	0.12**	0.058	0.03	0.13**	0.02	0.059*	0.23*	0.35**	-0.13**	0.152 **
T_2	-0.53*	-0.32**	0.01	-0.282 **	-0.08*	-0.13**	0.01	-0.069 **	-0.24*	-0.12	0.11**	-0.083
T_3	0.42*	0.37**	-0.12**	0.225 **	0.06	0.02	0.05**	0.010	0.01	-0.23*	0.02	-0.069
S.E.(gj)	0.006	0.006	0.006	0.0617	0.006	0.006	0.006	0.0625	0.006	0.005	0.006	0.0625
SE(gi-gj)	0.008	0.008	0.008	0.0873	0.008	0.008	0.008	0.0884	0.008	0.008	0.008	0.0884

*, ** Significant at 5% and 1 % probability levels, respectively.

4.4.3.5 Ear diameter (cm)

Combining ability effects of parents and crosses for ear diameter are given in Table 4.4.3 and 4.4.4, respectively. The range of GCA effect for lines was -0.50 to 0.74, -0.49 to 044, 0.01to 0.50 and -0.28 to 0.33 in E1, E2, E3 and pooled analysis, respectively. Results indicated highly significant and positive GCA effects of line, L_3 in each of the E_2, E_3 and pooled environment. Lines with maximum GCA effect for higher ear diameter were L_{21} (0.74) in E_1; L_3 (0.44) followed by L_{16} (0.41), L_{12} (0.34) and L_{11} (0.21) in E_2; L_8 (0.53) followed by L_9 (0.50), L_3 (0.43), L_{18} (0.40), L_{18} (0.38) and L_{15} (0.32) in E_3 and L_{21} (0.33) followed by L_3 (0.27) and L_{10} (0.25) across environment. Testers with maximum GCA effect for higher ear diameter were T_1 (0.13) in E_1; T_3 (0.05) in E_3 and T_1 (0.059) across environment. While, T_2 (-0.08) showed negative and significant GCA effect in E_1 environment.

In crosses, the range of SCA effects was -0.92 to 1.74, -0.74 to 0.65, -0.87 to 0.89 and 0.008 to 0.988 in E_1, E_2, E_3 and pooled environment, respectively. The SCA effects in pooled analysis revealed that L_9 X T_3 had significant positive effect in all the three environments as well as pooled analysis, so it may be considered as best combiner for ear diameter. However, L_{21} X T_3 (1.74), L_{21} X T_3 (0.72), L_{16} X T_2 (0.65) and L_{12} X T_3 (0.61) in E_1; L_{21} X T_3 (0.65) and L_{17} X T_3 (0.65) in E_2; L_{13} X T_2 (0.89), L_8 X T_1 (0.88), L_{15} X T_3 (0.86), L_{20} X T_2 (0.86) L_1 X T_2 (0.85), L_{16} X T_3 (0.83), L_{18} X T_2 (0.68), L_9 X T_3 (0.68) and L_3 X T_3 (0.60) in E_3 and L_1 X T_3 (0.85), L_5 X T_3 (0.85), L_6 X T_1 (0.82), L_9 X T_3 (0.99) and L_{10} X T_3

Table 4.4.4 : *Contd.....*

Character	Ear length (cm)				Ear diameter (cm)				Number of kernel rows / ear			
Environment	**E1**	**E2**	**E3**	**Pooled**	**E1**	**E2**	**E3**	**Pooled**	**E1**	**E2**	**E3**	**Pooled**
CROSSES												
L_1 X T_1	1.85**	0.90	0.39	1.048	0.06	0.36	-0.23	0.063	-0.72	0.27	-1.25	0.567
L_1 X T_2	-0.12	1.23	-2.42**	-0.435	-0.46	0.09	0.85**	0.108	0.48	1.69*	0.58	0.043
L_1 X T_3	-1.73*	-2.13**	2.03**	-0.612	0.40	-0.45	0.19	0.846 **	0.24	0.92	0.67	0.610
L_2 X T_1	-1.29	0.21	-0.52	0.532	-0.35	-0.18	-0.01	0.181	-1.52*	-0.76	-0.50	0.924
L_2 X T_2	0.62	0.07	0.20	0.298	0.10	0.01	-0.27	0.053	0.88	0.32	-0.13	0.357
L_2 X T_3	0.67	-0.29	0.32	1.834 **	0.25	0.17	0.28	0.234	0.63	0.43	0.63	0.566
L_3 X T_1	-0.11	0.72	1.99**	0.869	0.21	0.44	-0.46	0.063	0.10	-0.79	-0.32	0.335
L_3 X T_2	-0.47	-1.03	-0.22	0.571	0.12	0.00	-0.14	0.008	-0.43	0.34	-1.22	0.437
L_3 X T_3	0.58	0.29	-1.77**	0.298	-0.33	-0.44	0.60*	0.054	0.32	0.45	1.54**	0.772
L_4 X T_1	0.83	1.10	-1.52**	0.135	0.21	0.07	0.01	0.096	-0.96	1.50*	0.06	0.198
L_4 X T_2	0.13	-1.97**	-0.06	0.634	0.12	0.03	-0.28	0.042	0.51	-1.37	0.49	0.124
L_4 X T_3	-0.96	0.87	1.58**	0.499	-0.33	-0.10	0.27	0.854	0.46	-0.13	-0.55	0.075
L_5 X T_1	-0.42	-0.03	0.68	0.075	-0.11	0.12	0.19	0.063	0.35	0.89	-1.96**	0.242
L_5 X T_2	0.32	-0.84	1.07**	0.182	0.13	-0.69*	-0.07	0.208	-1.25	-2.04**	-1.60*	1.627 *
L_5 X T_3	0.10	0.87	-1.75**	0.258	-0.01	0.57	-0.12	0.846 **	0.90	1.15	3.56**	1.869 **
L_6 X T_1	1.17	1.42	-0.46	0.711	0.21	0.20	0.24	0.819 **	0.55	1.04	1.46	1.015
L_6 X T_2	-1.03	-0.99	-0.33	0.782	-0.38	-0.03	-0.04	0.153	0.52	-1.16	-0.78	0.474
L_6 X T_3	-0.14	-0.43	0.79*	0.071	0.17	-0.17	-0.20	0.066	-1.06	0.12	-0.68	0.541
L_7 X T_1	-0.66	-0.83	-0.12	0.538	0.11	0.10	0.24	0.152	0.33	0.26	0.13	0.237
L_7 X T_2	-1.70*	0.76	0.67	0.088	-0.08	-0.33	0.46	0.014	-0.20	0.90	-1.44	0.248
L_7 X T_3	2.36**	0.07	-0.55	0.625	-0.03	0.23	-0.70*	0.666	-0.12	-1.16	1.31	0.011
L_8 X T_1	-0.11	-0.33	0.76	0.108	0.44	0.43	0.88**	0.385	-0.67	-0.02	0.79	0.034
L_8 X T_2	0.86	0.60	0.89*	0.781	-0.15	-0.30	-0.01	0.153	0.46	-0.05	-0.11	0.102
L_8 X T_3	-0.75	-0.26	-1.65**	0.889	-0.29	-0.14	-0.27	0.232	0.21	0.0	-0.68	0.136
L_9 X T_1	0.67	-0.94	0.43	0.054	0.27	-0.23	-0.06	0.004	-0.90	-0.69	0.79	0.264
L_9 X T_2	1.31	0.32	-1.44**	0.061	0.28	0.33	0.26	0.292	2.24**	1.29	-1.44	0.694
L_9 X T_3	-1.98**	0.63	1.01**	0.116	0.72*	0.65*	0.68*	0.988 **	-1.34	-0.60	0.65	0.430
L_{10} X T_1	1.56	-1.50	-0.24	0.058	0.11	-0.23	0.28	0.052	-0.12	0.06	3.46**	1.134
L_{10} X T_2	-0.47	2.43**	-0.11	0.616	0.02	-0.17	-0.41	0.186	0.02	0.08	-2.78**	0.891
L_{10}X T_3	-1.09	-0.93	0.35	0.558	-0.13	0.40	0.13	0.734 *	0.10	-0.14	-0.68	0.242

Contd.....

L_{11} X T_1	1.73*	1.61	-0.46	0.959	0.57	-0.06	0.11	0.207	-0.06	0.81	-0.31	2.145 **
L_{11} X T_2	-3.64**	-2.46**	-1.66**	2.588 **	-0.12	0.20	-0.28	0.064	-0.09	0.45	2.11**	0.823
L_{11} X T_3	1.91**	0.85	2.12**	1.629*	-0.46	-0.14	0.17	0.143	0.16	-1.26	-1.80*	0.968
L_{12} X T_1	-2.22**	-0.61	1.54**	0.429	-0.36	0.10	-0.22	0.159	-1.12	-1.46	0.57	0.669
L_{12} X T_2	-0.75	-0.68	-1.99**	1.142	-0.25	-0.13	-0.01	0.131	0.02	1.01	1.00	0.675
L_{12} X T_3	2.97**	1.29	0.45	1.571	0.61*	0.03	0.23	0.290	1.10	0.45	-1.57	0.006
L_{13} X T_1	-1.22	-1.17	-0.35	1.243	0.07	-0.13	-0.02	0.026	-0.12	-0.36	-0.54	0.337
L_{13} X T_2	1.25	-1.24	0.78	0.930	-0.12	0.13	0.89**	0.103	0.85	1.46	-0.11	0.731
L_{13} X T_3	-0.03	2.40**	-0.43	0.313	0.04	-0.02	-0.87**	0.077	-0.73	-1.10	0.65	0.394
L_{14} X T_1	0.73	0.17	-0.35	0.151	-0.19	-0.13	0.18	0.048	-0.45	0.04	-0.32	0.244
L_{14} X T_2	-0.64	-0.57	0.78	0.189	-0.08	0.13	-0.11	0.020	-1.31	-0.99	-0.55	0.953
L_{14} X T_3	-0.09	0.41	-0.43	0.038	0.27	-0.02	-0.07	0.068	1.77*	0.95	0.87	2.196 **
L_{15} X T_1	1.74*	-0.14	-0.43	0.391	0.20	-0.21	0.37	0.119	-1.09	-0.66	0.82	0.313
L_{15} X T_2	-1.45	-0.05	0.03	0.492	0.11	0.36	-0.82**	0.020	0.70	0.81	1.91**	1.142
L_{15} X T_3	-0.29	0.19	0.40	0.101	-0.30	-0.15	0.86**	0.099	0.39	-0.14	-2.73**	0.829
L_{16} X T_1	-0.88	0.39	-0.45	0.315	-0.16	0.24	-0.32	0.081	2.66	1.83**	-0.54	1.184
L_{16} X T_2	0.08	-0.02	-1.00**	0.311	0.65*	0.10	-0.01	0.247	-2.21**	-0.10	-0.11	2.805 **
L_{16} X T_3	0.80	-0.38	1.45**	0.625	-0.49	-0.34	0.83**	0.166	-0.46	-1.33	0.65	0.379
L_{17} X T_1	-0.93	-0.21	-1.72**	0.953	-0.27	-0.74**	-0.30	0.437	0.62	-0.40	-3.14**	0.973
L_{17} X T_2	1.10	0.95	0.47	0.840	0.21	0.09	-0.22	0.025	-0.85	0.14	3.69**	0.995
L_{17} X T_3	-0.17	-0.74	1.25**	0.113	0.06	0.65*	0.52	0.412	0.23	0.26	-0.55	0.022
L_{18} X T_1	-3.31**	-0.81	1.12**	0.999	-0.07	-0.14	-0.33	0.181	-0.21	-0.55	-0.30	0.354
L_{18} X T_2	3.33**	0.95	1.58**	1.951**	0.24	0.22	0.68*	0.380	0.93	0.59	0.81	0.774
L_{18} X T_3	-0.02	-0.14	-2.70**	0.952	-0.17	-0.08	-0.34	0.199	-0.72	-0.03	-0.51	0.420
L_{19} X T_1	0.36	0.69	-0.66	0.130	-0.04	-0.01	-0.10	0.048	0.24	-0.55	0.81	0.166
L_{19} X T_2	0.99	1.37	0.47	0.944	0.37	-0.04	0.41	0.247	0.04	-0.08	-0.08	0.043
L_{19} X T_3	-1.35	-2.06**	0.19	1.073	-0.34	0.05	-0.31	0.199	-0.28	0.64	-0.73	0.124
L_{20} X T_1	0.56	0.73	0.66	0.648	-0.09	-0.13	0.04	0.059	2.66**	-0.13	1.02	1.184
L_{20} X T_2	-0.81	-0.68	-0.56	0.682	0.22	0.13	0.86**	0.136	-1.54*	0.34	-0.56	0.585
L_{20} X T_3	0.25	-0.04	-0.10	0.034	-0.13	-0.02	-0.10	0.077	-1.12	-0.21	-0.46	0.599
L_{21} X T_1	-0.05	-1.39	1.71**	0.091	-0.83**	0.10	0.14	0.193	0.44	0.09	-0.76	0.076
L_{21} X T_2	1.08	1.87**	-0.16	0.931	-0.92**	-0.13	0.16	0.297	0.24	1.77**	0.33	0.065
L_{21} X T_3	-1.03	-0.49	-1.55**	1.022	1.74**	0.03	-0.30	0.490	-0.68	0.68	0.43	0.141
S.E.	0.028	0.028	0.028	0.0258	0.027	0.028	0.027	0.2864	0.028	0.027	0.028	0.0258
SE(sij-skl)	0.039	0.40	0.40	0.0365	0.040	0.40	0.40	0.4050	0.040	0.40	0.40	0.0365

*, ** Significant at 5% and 1 % probability levels, respectively.

E_1: Normal (recommended dose of nitrogen**), E_2:** Low-nitrogen, **E_3:** excess soil moisture

(0.73) across environments had significantly higher estimates of SCA effect for this trait.

4.4.3.6 Number of kernel rows per ear

Estimates of GCA effects of parents and SCA effects of crosses for number of kernel-rows per ear are presented in Tables 4.4.3 and 4.4.4, respectively. GCA effects of lines ranged from -0.42 to 2.07in E_1, -0.98 to 2.21 in E_2, -1.32 to 2.55 in E_3 and -0.64 to 0.59 in pooled environment. Study of the results on GCA effects of the lines indicated significant positive effects of L_{16} for number of kernel rows per ear in E_1, E_2 and pooled environments. However, lines with significant positive GCA effect for higher number of kernel-rows per ear were L_{20} (1.34) in E_1; L_4 (2.21), L_7 (2.18), L_6 (2.07), L_{12} (1.57) and L_{14} (1.07) in E_2; L_{17} (2.55) and L_{10} (1.35) in E_3. Results across environments indicated that best general combiners identified for this trait were L_{16} (0.59) and L_{20} (0.52). Testers with maximum GCA effect for higher number of kernel-rows per ear were T_1 (0.23) in E1; T_1 (0.35) in E2, T_2 (0.11) in E3 and T_1 (0.152) across environments, which indicated that these were best combiners for particular environment.

SCA effects of crosses ranged from -2.21 to 2.66 in E_1, -2.04 to 1.83 in E_2, -3.14 to 3.69 in E_3 and 0.006 to 2.805 in pooled environment. The most promising crosses for higher number of kernel-rows per ear were L_{20} X T_1 (2.66), L_9 X T_2 (2.24) and L_{14} X T_3 (1.77) in E_1, L_{16} X T_1 (1.83), L_{21} X T_2 (1.77), L_1 X T_2 (1.69) and L_4 X T_1 (1.50) in E_2 and L_{17} X T_2 (3.69), L_5 X T_3 (3.56), L_{10} X T_1 (3.46), L_{11} X T_2 (2.11), L_{15} X T_2

(1.91) and L_3 X T_3 (1.54) in E_3 environment. In the pooled analysis, most promising cross combinations with significant higher positive effects were L_{16} X T_2 (2.805), L_{14} X T_3 (2.196), L_{11} X T_1 (2.145), L_5 X T_3 (1.869) and L_5 X T_2 (1.627) for number of kernel rows per ear.

4.4.3.7 Number of kernels per row

Tables 4.4.3 and 4.4.4 presented the estimates of GCA effects of the parents and SCA effects of crosses for number of kernels per row, respectively. GCA effects of lines ranged from -2.39 to 3.68 in E_1, -4.47 to 4.86 in E_2, -3.36 to 5.28 in E_3 and -1.61to 3.17 in pooled environment. Results on GCA effects indicated high and significant positive effects for L_{11} (3.68), L_4 (3.14), L_{20} (2.47) and L_2 (2.03) in E_1, L_4 (4.86), L_{16} (4.47) and L_{10} (2.53) in E_2, L_{15} (5.28) and L_5 (2.95) in E_3. However, on the basis of pooled analysis, best parents were L_4 (3.169), L_{15} (1.493), L_2 (1.429) and L_{20} (0.668) for maximum number of kernels per row. Among the testers, T_3 in E_1, E_2, E_3 and pooled analysis had positive and significant GCA effects, indicating good general combining ability for number of kernels per row in all the environment

The estimates of SCA effects of crosses ranged from -7.63 to 7.55, -5.53 to 5.80, -6.78 to 4.48 and 0.03 to 4.779 in E_1, E_2, E_3 and across environments, respectively. The overall results indicated that only one cross, L_{14} X T_1 had high significant positive effect for this trait in all the environments. However, L_{14}X T_1 (7.55), L_{11} X T_3 (6.92), L_{20} X T_1 (6.74), L_{18} X T_3 (5.42), L_{12} X T_3 (5.36), L_1 X T_1 (5.21), L_{16} X T_2 (4.95), L_{13} X T_3 (4.62), L_{13} X T_3 (4.16), L_8 X T_3 (3.95) and L_9 X T_2(3.04) in **E_1**, L_{14} X T_1

Table 4.4.3 : Contd.....

Character	Number of kernel / row				Number of nodes bearing brace roots				Days to 50 % tasselling			
Environment	**E_1**	**E_2**	**E_3**	**Pooled**	**E_1**	**E_2**	**E_3**	**Pooled**	**E_1**	**E_2**	**E_3**	**Pooled**
LINE												
L_1	-2.39**	0.92	-3.36**	-1.611 **	0.48**	0.45**	-0.11	0.203*	-2.74**	-2.98**	0.63	-1.029
L_2	2.03**	1.08	1.17	1.429 *	0.79**	-0.18**	0.20	0.269**	-1.96*	-1.20	-0.26	-1.140
L_3	0.65	1.93*	-0.09	0.829	0.37	-0.13*	0.54**	0.158	-0.96	-1.53	-0.26	-0.918
L_4	3.14**	4.86**	1.51	3.169 **	0.37	-0.03	0.54**	0.125	-1.07	-0.31	-2.96**	-0.140
L_5	-0.03	0.36	2.95**	1.094	-0.01	0.16**	0.13	0.092	0.37	1.93*	2.74**	0.749
L_6	-1.70	-2.14**	0.50	-1.110	0.30	-0.20**	0.04	0.047	-0.52	-0.75	-0.15	-0.474
L_7	0.92	-4.47**	1.73	-0.609	-0.17	-0.07	0.11	-0.042	-0.18	-0.75	-1.48	-0.807
L_8	-2.29**	-3.55**	1.86	-1.328	-0.37	-0.13*	0.39*	-0.108	-0.63	1.47	-1.26	-0.140
L_9	-0.51	1.22	-3.03**	-0.773	-0.37	-0.13*	-0.03	-0.175	1.60	0.36	-0.37	0.526
L_{10}	1.41	2.53**	-0.99	0.981	-0.30	0.13*	0.11	-0.020	1.71*	0.13	0.74	0.860
L_{11}	3.68**	-0.58	-1.38	0.570	0.10	0.33**	0.11	0.180	-2.04**	-2.13**	-2.26**	-2.304 **
L_{12}	-0.35	-1.14	-2.31**	-1.26	-0.30	0.07	-0.43**	-0.153	1.04	0.80	-0.93	0.304
L_{13}	-1.08	0.31	-1.60	-0.794	0.30	0.13*	-0.03	0.136	0.60	1.02	-0.04	0.526
L_{14}	-0.54	-1.20	0.81	-0.311	-0.37	0.02	-0.16	-0.175	1.04	-0.20	1.77*	0.638
L_{15}	-2.22**	1.42	5.28**	1.493 *	-0.39*	-0.03	-0.11	-0.220**	2.15**	0.58	1.78*	1.304
L_{16}	0.25	4.47**	-2.72**	0.668 *	-0.37	0.20**	-0.03	-0.064	0.82	-0.09	-0.48	0.082
L_{17}	0.25	-2.47**	-1.61	-1.276	-0.39*	-0.15*	-0.25	-0.264**	1.26	0.02	0.29	2.526 **
L_{18}	-2.08**	-0.69	1.17	-0.536	-0.06	-0.22**	-0.11	-0.064	0.04	-0.53	0.07	-0.140
L_{19}	-1.97	-3.27**	1.28	-1.319	0.48**	0.02	-0.05	0.180	-0.63	0.13	-0.26	-0.251
L_{20}	2.47**	-0.70	-2.05**	-0.091	-0.03	-0.13	-0.09	-0.086	-1.57	-0.14	-0.21	-0.640
L_{21}	0.36	1.12	0.89	0.792	-0.03	-0.07	0.44**	-0.020	-2.40**	-1.31	0.29	-1.140
S.E.(gi)	0.088	0.088	0.088	0.0882	0.016	0.016	0.016	0.0577	0.152	0.152	0.152	0.1528
SE(gi-gj)	0.0124	0.124	0.124	0.1247	0.023	0.023	0.023	0.0816	0.215	0.214	0.214	0.2160
TESTER												
T_1	0.04	-0.04	-0.05	-0.018	0.16**	0.22**	-0.01	0.057	-0.22**	0.16	-0.14**	-0.069
T_2	-0.62**	-0.09*	-0.78**	-0.500 *	-0.15**	-0.22**	-0.02	-0.062	0.24**	0.24*	0.10	0.201 **
T_3	0.58**	0.14**	0.83**	0.518 **	-0.01	0.02	0.03*	0.006	-0.02	-0.40**	0.02	-0.132*
S.E.(gj)	0.033	0.033	0.033	0.1054	0.006	0.006	0.006	0.0626	0.057	0.057	0.057	0.0575
SE(gi-gj)	0.047	0.047	0.047	0.1491	0.008	0.008	0.008	0.0886	0.081	0.081	0.081	0.0813

*, ** Significant at 5% and 1 % probability levels, respectively.

(5.80), L_{12} X T_3 (4.09), L_5 X T_2 (3.15), L_7 X T_3 (3.08) and L_2 X T_2 (2.45) in **E_2** and L_1 X T_3 (4.48), L_{14} X T_1 (3.99), L_{12} X T_1 (3.85), L_{18} X T_1 (3.49), L_{11} X T_3 (3.44), L_{19} X T_2 (3.44), L_{21} X T_1 (3.44), L_{17} X T_3 (3.39), L_8 X T_2 (3.60) and L_9 X T_1 (3.10) in **E_3** and L_{14} X T_1 (4.779), L_{20} X T_1 (6.74), L_{11} X T_3 (3.939), L_1 X T_1 (3.326), L_{16} X T_1 (3.806), L_{14} X T_3 (3.503), L_{13} X T_1 (3.094) and L_{20} X T_1 (3.092) in across the environment had significant and high SCA effects for number of kernels per row.

4.4.3.8 Number of nodes bearing brace roots

Estimates of GCA effects of parents and SCA effects of crosses for brace roots are presented in Tables 4.4.3 and 4.4.4, respectively. GCA effects of lines ranged from -0.39 to 0.79 in E_1, -0.22 to 0.45 in E_2, -0.43 to 0.54 in E_3 and -0.264 to 0.269 in pooled environment. Based on the results, in lines having significant positive GCA effects were L_2 (0.79), L_1 (0.48) and L_{19} (0.48) in E_1; L_1 (0.45), L_{11} (0.33)and L_5 (0.16) in E_2; L_3 (0.54), L_4 (0.54) and L_{21} (0.44) in E_3 environment. Results across the environments indicated that best general combiners identified for this trait were L_2 (0.269) and L_1 (203). Testers with maximum GCA effects for brace roots were T_1 (0.16) in E1 and T_1 (0.22) in E2 which indicated that these were best combiners for particular environment.

SCA effects of crosses ranged from -0.52 to 1.04 in E_1, -0.25 to 0.85 in E_2, -0.65 to 0.88 in E_3 and -0.257 to 1.239 in pooled environment. The most promising crosses for brace roots were L_4 X T_1 (1.04), L_1 X T_3 (0.57), L_7 X T_2 (0.55), L_{11} X T_3 (0.55) and L_{21} X T_1 (0.51) in E_1, L_3 X T_2 (0.85), L_4 X T_2 (0.85), L_{17} X T_1 (0.83) and L_{15} X T_3 (0.76) L_{10} X

Table 4.4.4 : Contd....

Character	Number of kernels / row				Number of nodes bearing brace roots				Days to 50 % tasselling			
Environment	**E1**	**E2**	**E3**	**Pooled**	**E1**	**E2**	**E3**	**Pooled**	**E1**	**E2**	**E3**	**Pooled**
CROSSES												
L_1 X T_1	5.21**	2.47	2.30	3.326 *	-0.27	0.13	-0.23	0.123	0.22	-0.83*	0.48	0.042
L_1 X T_2	-0.94	3.06	-6.78**	1.553	-0.30	0.04	0.84**	0.004	-0.24	-0.90*	0.21	0.312
L_1 X T_3	-4.27**	-5.53**	4.48**	1.773	0.57*	-0.17	-0.01	0.128	0.02	1.73**	-0.68*	1.354 *
L_2 X T_1	-3.15*	-0.29	-1.84	1.761	0.49	-0.18	0.12	0.143	-0.56	0.40	0.37	0.069
L_2 X T_2	2.84	2.45**	-0.44	1.501	-0.08	-0.03	-0.13	0.071	-0.35	-0.02	-0.24	0.201
L_2 X T_3	0.31	-1.81	2.28	0.260	-0.41	0.18	0.01	0.072	0.90*	-0.38	-0.13	0.132
L_3 X T_1	2.90	0.20	1.76	1.619	0.04	-0.09	0.01	0.012	0.11	-0.60*	0.03	0.153
L_3 X T_2	-0.58	-0.88	-3.31*	.589	-0.05	0.85**	-0.38	0.693 *	-0.35	0.32	-0.24	0.090
L_3 X T_3	-2.32	0.68	1.55	0.030	0.01	-0.06	0.37	0.105	0.24	0.29	0.21	0.243
L_4 X T_1	1.07	0.93	-0.17	0.609	1.04**	-0.39	0.01	0.221	-0.44	0.51	0.14	0.069
L_4 X T_2	2.07	-1.01	0.22	0.427	-0.45	0.85**	-0.18	0.160	0.10	-0.57	-1.13	0.534
L_4 X T_3	-3.14*	0.08	-0.05	1.037	-0.59*	0.74**	0.17	0.061	0.35	0.06	0.98**	0.466
L_5 X T_1	0.07	-0.74	2.39	0.574	-0.11	0.09	0.19	0.054	1.11**	2.06**	0.37	1.180 **
L_5 X T_2	-2.43	3.15*	-3.22*	0.835	-0.28	-0.14	-0.77*	0.293	-0.68	-1.35**	-0.24	0.757 *
L_5 X T_3	2.36	-2.42	0.84	0.261	0.39	0.05	0.28	1.239 **	-0.43	-0.71*	-0.13	0.423
L_6 X T_1	0.82	2.60	-2.51	0.305	0.17	0.24	0.28	0.232	-0.67*	0.29	0.59	0.069
L_6 X T_2	0.15	-3.68*	0.56	0.990	0.48	-0.11	0.09	0.151	0.54	-0.13	0.98**	0.466
L_6 X T_3	-0.97	1.08	1.95	0.686	-0.65*	-0.13	-0.37	0.584 *	0.13	-0.16	-1.57**	0.534
L_7 X T_1	0.63	-1.07	2.94	0.834	-0.36	-0.09	-0.19	0.212	0.00	-0.71*	-0.08*	0.265
L_7 X T_2	0.29	-2.01	0.67	0.351	0.55*	0.15	0.82**	0.307	-0.13	-0.46	-0.02	0.201
L_7 X T_3	-0.91	3.08*	-3.61*	0.482	-0.19	-0.06	-0.03	0.095	0.13	1.17**	0.10	0.466
L_8 X T_1	-1.51	-0.75	-2.86	1.708	-0.16	-0.22	0.85**	0.579 *	0.78*	1.40**	0.03	0.735 *
L_8 X T_2	-2.44	2.93	3.60*	1.361	0.15	0.02	-0.04	0.040	0.32	-0.68*	-0.24	0.201
L_8 X T_3	3.95*	-2.17	-0.74	0.347	0.01	0.70**	-0.10	0.039	-1.10**	-0.71*	0.21	0.534
L_9 X T_1	1.78	-1.36	3.10*	1.175	-0.16	-0.02	-0.05	0.079	-1.11**	-0.16	-0.52	0.598
L_9 X T_2	3.04*	-0.70	0.09	0.810	0.15	0.22	0.16	0.174	1.43**	-0.24	0.21	0.466
L_9 X T_3	-4.83**	2.06	-3.18*	1.984	0.01	-0.20	-0.10	0.095	-0.32	0.40	0.32	0.132
L_{10} X T_1	-0.20	-0.07	-1.34	0.536	-0.03	-0.09	0.01	0.034	0.78*	0.06	-0.63*	0.069
L_{10} X T_2	-1.72	-1.01	2.06	0.225	0.08	0.75**	-0.18	0.085	-1.02**	0.65*	0.76*	0.132
L_{10}X T_3	1.93	1.08	-0.72	0.761	-0.05	-0.26	0.17	0.050	0.24	-0.71*	-0.13	0.201

Contd.....

L_{11} X T_1	-2.30	1.04	-1.62	0.959	-0.23	-0.09	0.01	0.101	0.11	1.73**	1.03**	0.958 *
L_{11} X T_2	-4.62**	-2.50	-1.82	2.980	-0.32	0.15	0.22	0.018	0.32	2.32**	0.43	1.021 **
L_{11} X T_3	6.92**	1.45	3.44*	3.939 *	0.55*	-0.06	-0.23	0.083	-0.43	-4.05**	-1.46**	-1.979 **
L_{12} X T_1	-6.57**	-4.08**	3.85*	2.266	-0.03	0.18	-0.05	0.632*	1.11**	-0.94*	-0.30	0.042
L_{12} X T_2	1.22	-0.01	-2.62	0.471	0.08	0.02	0.66*	0.085	-0.35	-0.02	-0.57	0.312
L_{12} X T_3	5.36**	4.09**	-1.23	2.738	-0.05	-0.20	-0.10	0.117	-0.76*	0.95*	0.87*	0.354
L_{13} X T_1	-2.04	-3.85*	-3.40*	3.094 *	0.17	0.61*	-0.05	0.143	-1.11**	-1.83**	-0.86*	-1.265 **
L_{13} X T_2	-2.58	-0.32*	5.47	0.857	-0.52*	-0.25	0.16	0.204	0.43	1.10**	-1.13**	0.132
L_{13} X T_3	4.62**	4.16**	-2.07	2.237	0.35	-0.06	-0.10	0.061	0.68*	0.73*	1.98**	1.132 **
L_{14} X T_1	7.55**	5.80**	3.99*	4.779 **	-0.16	0.04	0.88**	0.012	-1.56**	-0.60*	-0.97*	-1.042 **
L_{14} X T_2	0.08	-1.61	-2.30	1.276	0.15	-0.11	0.69*	0.040	0.65*	-0.02	-1.57**	0.312
L_{14} X T_3	-7.63**	-4.19**	1.31	3.503 *	0.01	0.07	-0.67*	0.028	0.90*	0.62*	2.54**	1.354 **
L_{15} X T_1	0.10	-0.96	-1.95	0.935	-0.14	-0.02	0.03	0.034	0.20	-0.71*	0.59	0.042
L_{15} X T_2	2.68	0.77	2.45	1.963	0.17	-0.16	-0.16	0.049	0.21	-0.13	0.98*	0.354
L_{15} X T_3	-2.78	0.19	-0.50	1.028	-0.03	0.76**	0.82**	0.683 *	-0.21	0.84*	-1.57**	0.312
L_{16} X T_1	-5.71**	-4.09**	-1.62	3.806 *	-0.16	0.24	-0.05	0.010	1.33**	-0.05	0.25	0.513
L_{16} X T_2	4.95**	1.96	0.11	2.342	0.15	-0.11	0.76*	0.062	-0.79*	0.21	0.32	0.090
L_{16} X T_3	0.75	2.13	1.51	1.465	0.01	-0.13	-0.10	0.072	-0.54*	-0.16	-0.57	0.423
L_{17} X T_1	0.63	3.26*	-6.06**	0.723	-0.20	0.83**	0.70*	0.010	-1.11**	-0.16	-0.52	0.598
L_{17} X T_2	-0.05	-4.34**	2.67	0.575	0.17	-0.16	-0.22	0.071	0.43	0.76*	1.21**	0.799 *
L_{17} X T_3	-0.58	1.08	3.39*	1.298	0.03	0.03	0.12	0.061	0.68*	-0.60*	-0.68*	0.201
L_{18} X T_1	-5.70**	-4.18**	3.49*	2.130	-0.47	-0.13	-0.77*	-0.257	0.11	-0.60*	-0.30	0.265
L_{18} X T_2	0.29	2.55	1.89	1.575	-0.17	0.61*	0.84**	-0.004	0.32	-0.02	0.10	0.132
L_{18} X T_3	5.42**	1.63	-5.39**	0.555	0.63	0.03	0.12	0.561 *	-0.43	0.62*	0.21	0.132
L_{19} X T_1	-3.15*	1.18	-0.62	0.863	-0.40	-0.07	-0.03	0.168	0.11	0.06	0.37	0.180
L_{19} X T_2	0.51	0.28	3.44*	1.412	0.30	-0.03	0.18	0.151	0.32	-0.35	-0.24	0.090
L_{19} X T_3	2.64	-1.46	-2.83	0.549	0.10	0.09	-0.15	0.016	-0.43	0.29	-0.13	0.090
L_{20} X T_1	6.74**	2.82	-0.28	3.092 *	0.44	-0.09	-0.65*	0.032	0.89*	0.17	0.14	0.402
L_{20} X T_2	-5.27**	0.88	-0.56	1.649	-0.05	-0.05	-0.04	0.049	-0.57	0.10	-0.13	0.201
L_{20} X T_3	-1.47	-3.70*	0.84	1.443	-0.39	0.14	0.30	0.016	-0.32	-0.27	-0.02	0.201
L_{21} X T_1	2.85	1.12	3.44*	2.469	0.51*	0.11	0.08	0.232	-0.11	0.51	-0.19	0.069
L_{21} X T_2	2.51	0.40	-2.17	0.247	-0.19	-0.25	0.09	0.115	-0.57	-0.57	0.54	0.201
L_{21} X T_3	-5.36**	-1.52	-1.27	2.717	-0.32	0.14	-0.17	0.117	0.68*	0.06	-0.35	0.132
S.E.	0.152	0.152	0.152	0.4824	0.028	0.028	0.028	0.0258	0.263	0.263	0.263	0.2633
SE(sij-skl)	0.216	0.215	0.215	0.6822	0.040	0.040	0.040	0.0365	0.372	0.372	0.372	0.3724

*, ** Significant at 5% and 1 % probability levels, respectively.

E_1: Normal (recommended dose of nitrogen**), E_2:** Low-nitrogen, **E_3:** excess soil moisture

T_2 (0.75), L_4 X T_3 (0.74), L_8 X T_3 (0.70), L_{13} X T_1 (0.61) and L_{18} X T_1 (0.61) in E_2 , L_{14} X T_1 (0.88), L_8 X T_1 (0.85), L_{18} X T_2 (0.84), L_1 X T_2 (0.84) and L_{15} X T_3 (0.82), L_7 X $T2_1$ (0.82), L_{16} X T_2 (0.76), L_{17} X T_1 (0.70), L_{14} X T_2 (0.69) and L_{12} X T_2 (0.66) in E_3 environment. In the pooled analysis, most promising cross combinations with significant higher positive effects were L_5 X T_3 (1.239), L_3 X T_2 (0.693) and L_{15} X T_3 (0.683) L_6 X T_3 (0.584), L_8 X T_1 (0.579) and L_{18} X T_3 (0.561) for brace roots.

4.4.3.9 Days to 50 per cent tasselling

Estimates of GCA and SCA effects of parents and crosses are presented in Tables 4.4.3 and 4.4.4, respectively. GCA effects of lines ranged from -2.74 to 2.15 in E_1, -2.98 to 1.93 in E_2, -2.96 to 2.74 in E_3 and -2.304 to 2.526 in pooled environment.

Results indicated significant negative GCA effect for L_1 (-2.74), L_{21} (-2.40), L_{11} (-2.04) and L_2 (-1.96) in E_1; L_1 (-2.98) and P_{11} (-2.13) in E_2; L_4 (2.96) and L_{11} (-2.26) in E3 and L_{11} (-2.304) in the pooled analysis. Among the testers, T_1 (-0.22) in E1, T_3 (-0.40) in E2, T_1 (-0.14) in E3 and T_3 (-0.132) in pooled environment had negative and significant GCA effects. This indicated that these parental lines were good general combiners for earliness.

Specific combining ability effects of crosses indicated the range for this character from -1.56 to 1.43, -4.05 to 2.06, -1.57 to 2.54 and -1.979 to 1.354 in the E_1, E_2, E_3 and across environments, respectively. The best specific combiner for early pollen shedding was L_{14} X T_1(-1.56) followed by L_9 X T_1 (-1.11), L_{13} X T_1 (-1.11) and L_{17} X T_1 (-1.11), in **E_1**; L_{11}

X T_3 (-4.05), followed by L_{13} X T_1 (-1.83) in **E_2**; L_6 X T_3 (-1.57), L_{14} X T_2 (-1.57), L_{15} X T_3 (-1.57) followed by L_{11} X T_3 (-1.46) in **E_3**; and L_{11} X T_3 (-1.979) followed by L_{13} X T_1 (1.265) and L_5 X T_3 (-1.042) in the pooled environment. However, cross L_{13} X T_1 exhibited negative and significant SCA effect in overall environments.

4.4.3.10 Days to 50 per cent silking

Combining ability effects of parents and crosses for days to 50 per cent silking are given in Table 4.4.3 and 4.4.4, respectively. GCA effects of lines ranged from -3.80 to 1.64 in E_1, -3.02 to 1.25 in E_2, -2.10 to 1.67 in E_3 and -1.534 to 3.246 in pooled environment. Significant negative GCA effects were exhibited for L_1 (-3.80) , L_{21} (-2.80), L_2 (-1.69) and L_{20} (-1.63) in E_1; L_3 (-3.02) and L_{21} (-1.47) in E_2; L_7 (-2.10), L_8 (-1.88) and L_{21} (-1.65) in E_3; and L_{21} (-0.19), L_1 (-1.310) and L_3 (-1.310) in the pooled analysis. Among the testers, T_1 (-0.43) in E1, T_3 (-0.32) in E2 and T_1 (-0.222) and T_3 (-0.143) in pooled environment had negative and significant GCA effect. However L_{21} and T_2 had negative GCA effects for all the environments. Results in pooled environment revealed that L_1, L_3 and L_{21} were the best combiners for early 50 per cent silking. GCA effects were observed significantly positive in L_4 and L_{10} across the environments.

The range of SCA effects in crosses was -1.68 to 1.73, -3.79 to 2.60, -2.62 to 2.32 and –1.587 to 1.365 in E_1, E_2, E_3 and pooled analysis, respectively. In E_1, best specific combinations were L_2 X T_1 (-1.68), L_9 X T_1 (-1.57), L_8 X T_3 (-1.27) , L_{21} X T_2 (-1.27), L_{13} X T_1 (-1.24)

Table 4.4.3 : Contd.....

Character	Days to 50 % silking				Anthesis-silking interval				Protein (%)			
Environment	**E_1**	**E_2**	**E_3**	**Pooled**	**E_1**	**E_2**	**E_3**	**Pooled**	**E_1**	**E_2**	**E_3**	**Pooled**
LINE												
L_1	-3.80**	-1.13	1.01	-1.310*	-0.87**	0.03	0.57	-0.087	0.49	0.49	0.49	0.493
L_2	-1.69*	-0.69	0.12	-0.754	0.24	0.48	0.35	0.357	0.77*	0.77*	0.77*	0.768 *
L_3	-1.36	-3.02**	0.45	-1.310*	-0.43	-1.52**	0.69	-0.421	1.03**	1.03**	1.03**	1.035 **
L_4	-0.80	-0.13	1.67*	3.246 **	0.46	0.37	0.91**	0.579	1.11**	1.11**	1.11**	1.107 **
L_5	0.98	1.31	0.45	0.913	0.57	0.15	-0.31	0.135	-0.18	-0.18	-0.18	-0.175
L_6	-0.58	-0.91	-0.44	-0.643	-0.31	-0.41	-0.54	-0.421	0.15	0.15	0.15	0.152
L_7	0.75	-0.25	-2.10**	-0.532	0.69	0.26	-0.87**	0.024	-0.71*	-0.71*	-0.71*	-0.714 *
L_8	-0.69	1.31	-1.88**	-0.421	-0.09	-0.19	-0.65	-0.310	-0.46	-0.46	-0.46	-0.455
L_9	1.20	0.53	-0.33	0.468	-0.20	0.37	0.24	0.135	-0.72*	-0.72*	-0.72*	-0.717 *
L_{10}	1.31	0.64	0.45	2.802 **	-0.43	0.48	-0.31	-0.087	0.36	0.36	0.36	0.358
L_{11}	1.64*	1.31	-0.55	0.802	-0.76*	-1.19**	-0.65	-0.865 **	0.29	0.29	0.29	0.291
L_{12}	0.64	1.31	-1.21	0.246	-0.43	0.48	-0.31	-0.087	0.76*	0.76*	0.76*	0.758 *
L_{13}	0.87	0.53	1.67*	0.690	0.46	-0.30	0.91**	0.357	0.49	0.49	0.49	0.493
L_{14}	0.31	0.64	1.12	0.690	-0.76*	0.81*	0.02	0.024	-0.31	-0.31	-0.31	-0.309
L_{15}	1.09	1.75**	0.90	1.246*	-0.98**	1.26**	-0.20	0.024	-1.09**	-1.09**	-1.09**	-1.091 **
L_{16}	1.09	0.42	-0.77	0.246	0.35	0.59	-0.20	0.246	-0.20	-0.20	-0.20	-0.198
L_{17}	1.20	-1.13	-0.33	-0.087	-0.20	-1.30**	-0.76*	-0.754 *	-0.12	-0.12	-0.12	-0.117
L_{18}	1.31	-1.36	0.12	0.024	1.35**	-0.74*	0.13	0.246	-0.31	-0.31	-0.31	-0.311
L_{19}	0.98	0.64	0.79	0.802	1.57**	0.48	1.02**	1.024 **	0.07	0.07	0.07	0.071
L_{20}	-1.63*	-0.30	0.17	-0.587	-0.04	-0.13	0.41	0.079	-0.72*	-0.72*	-0.72*	-0.723 *
L_{21}	-2.80**	-1.47*	-1.65*	-1.534**	-0.20	0.03	-0.43	-0.198	-0.72*	-0.72*	-0.72*	-0.717 *
S.E.(gi)	0.153	0.152	0.153	0.1528	0.148	0.148	0.148	0.1491	0.148	0.148	0.148	0.1491
SE(gi-gj)	0.214	0.214	0.214	0.2160	0.209	0.209	0.209	0.2108	0.209	0.209	0.209	0.2108
TESTER												
T_1	-0.43**	-0.05	-0.19	-0.222 **	-0.21**	-0.21**	-0.05	-0.159	-0.26*	-0.26*	-0.26	-0.262 *
T_2	0.27*	0.37**	0.46**	0.365 **	0.04	0.14*	0.34**	0.175 *	-0.22	-0.22	-0.22	-0.224
T_3	0.16	-0.32**	-0.27	-0.143 **	0.17*	0.07	-0.19	-0.016	0.49**	0.49**	0.49**	0.486 **
S.E.(gj)	0.058	0.056	0.058	0.0575	0.056	0.056	0.056	0.0561	0.056	0.056	0.056	0.0561
SE(gi-gj)	0.081	0.081	0.081	0.0813	0.079	0.079	0.079	0.0793	0.079	0.079	0.079	0.0793

*, ** Significant at 5% and 1 % probability levels, respectively.

L_2 X T_2 (-0.71) L_3 X T_3 (-0.60) and L_{12} X T_3 (-0.60) in **E_1**; L_{11} X T_3 (-3.79), L_{19} X T_2 (-2.48), L_{16} X T_3 (-2.24), L_{10} X T_3 (-1.79), L_{14} X T_1 (-1.73) L_6 X T_2 (-1.59), L_7 X T_2 (-1.59), L_3 X T_2 (-0.81) and L_9 X T_2 (-0.62) in **E_2**; and L_{15} X T_3 (-2.62) , L_{13} X T_2 (-1.79), L_6 X T_3 (-1.62), L_{17} X T_1 (-1.48) and L_1 X T_3 (-1.40), L_{21} X T_2 (-1.27), L_9 X T_3 (-1.06), L_{10} X T_1 (-1.92), L_{10} X T_3 (-0.83), L_{11} X T_3 (-1.51), L_{12} X T_2 (-1.24), L_{14} X T_2 (-2.57), L_{19} X T_2 (-1.24), L_4 X T_2 (-0.79), L_5 X T_1 (-0.92), L_6 X T_1 (-0.70) and L_9 X T_2 (-0.79) in **E_3**. In the pooled environment, L_{13} X T_2 (-1.587), L_{14} X T_2 (-1.587) and L_{10} X T_3 (-1.222) were the best combiners for days to 50 per cent silking. However, combination L_{10} X T_3 had negative and significant SCA effect in all three and across the environments.

4.4.3.11 Anthesis – silking interval

Estimates of GCA and SCA effects of parents and crosses are presented in Table 4.4.3 and 4.4.4, respectively. GCA effects of lines ranged from -0.98 to 1.57 in E_1, -1.52 to 1.26 in E_2, -0.87 to 1.02 in E_3 and -0.865 to 1.024 in pooled environment. Results indicated significant negative GCA effect for L_{15} (-0.98) and L_1 (-0.87) in E_1; L_3 (-1.52), L_{17} (-1.30) and L_{11} (-1.19) in E_2; L_7 (-0.87) and L_{17} (-0.76) in E3 and L_{11} (-0.865) and L_{17} (-0.754) in the pooled analysis. This indicated that these lines were good general combiners for earliness. In case of testers, T_1 (-0.21) in E1, T_1 (-0.21) in E2 had negative and significant GCA effects. However, T_2 in E2, E3 and pooled environment had positive and significant GCA effects.

Table 4.4.4 : Contd....

Character	Days to 50 % silking				Anthesis – silking interval				Protein (%)			
Environment	**E1**	**E2**	**E3**	**Pooled**	**E1**	**E2**	**E3**	**Pooled**	**E1**	**E2**	**E3**	**Pooled**
CROSSES												
L_1 X T_1	0.43	0.05	0.52	0.333	0.21	0.88**	0.05	0.381	2.23**	2.23**	2.23**	2.228 **
L_1 X T_2	-0.27	-0.37	0.87*	0.079	-0.04	0.53	0.66*	0.381	1.25	1.25	1.25	1.254
L_1 X T_3	-0.16	0.32	-1.40**	0.413	-0.17	-1.41**	-0.71*	0.762 *	0.97	0.97	0.97	0.974
L_2 X T_1	-1.68**	-0.40	0.41	0.556 *	-0.90**	-0.5	0.28	0.397	1.88*	1.88*	1.88*	1.877 *
L_2 X T_2	-0.71*	1.86**	-0.57	0.190	-0.49	1.75**	-0.46	0.270	-0.18	-0.18	-0.18	0.183
L_2 X T_3	2.40**	0.46	0.16	0.365	1.39**	-1.19**	0.18	0.127	-1.69	-1.69	-1.69	1.694
L_3 X T_1	0.65*	-0.40	-0.25	0.012	0.43	0.10	-0.39	0.048	0.85	1.85*	0.85	0.847
L_3 X T_2	-0.05	-0.81**	0.10	0.254	0.18	-1.25**	0.21	0.286	-0.85	-0.85	-0.85	0.850
L_3 X T_3	-0.60*	0.21	0.16	0.254	-0.61*	1.15**	0.18	0.238	0.00	0.17	0.12	0.003
L_4 X T_1	-0.5*	0.05	-0.14	0.222	-0.12	-0.46	-0.28	0.286	0.68	0.68	0.68	0.678
L_4 X T_2	0.73*	-0.37	-0.79*	0.143	0.62*	0.20	0.32	0.381	0.22	2.22**	0.22	0.221
L_4 X T_3	-0.16	0.32	0.94*	0.365	-0.50	0.26	-0.04	0.095	-0.90	-0.90	-0.90	0.899
L_5 X T_1	0.65*	2.60**	-0.92*	0.778 *	-0.23	0.77	-1.06**	0.175	1.54	1.54	1.54	1.541
L_5 X T_2	-0.38	0.14	0.10	1.143 **	0.18	-1.92**	0.21	0.508	-1.19	-1.19	-1.19	1.190
L_5 X T_3	-0.27	0.54	0.83*	0.365	0.05	0.15	0.85	0.683 *	-0.35	-0.35	-0.35	0.350
L_6 X T_1	-0.46	2.16**	-0.70*	0.333	-0.01	0.66	-1.50**	0.048	1.83*	1.83*	1.83	1.826 *
L_6 X T_2	-0.49	-1.59**	2.32**	0.079	-0.60*	0.03	1.77**	0.048	0.37	0.37	0.37	0.365
L_6 X T_3	0.95**	-0.57	-1.62**	0.413	0.61*	-0.63*	-0.26	0.095	-2.19**	-2.19**	-2.19	2.192 **
L_7 X T_1	0.21	-0.51	-0.03	0.111	-0.01	-0.01	-0.17	0.063	1.83*	1.83*	1.83*	1.833 *
L_7 X T_2	-0.16	-1.59**	-0.35	0.698 *	0.07	-1.03**	-0.23	0.397	-0.65	-0.65	-0.65	0.651
L_7 X T_3	-0.05	2.10**	0.38	0.810 *	-0.06	0.04	0.40	0.460	-1.18	-1.18	-1.18	1.182
L_8 X T_1	-0.02	0.27	0.08	0.111	-0.90**	0.23	-0.06	0.730 *	-0.50	-0.50	-0.50	0.503
L_8 X T_2	1.29**	0.14	-0.57	0.143	0.85**	-0.58	-0.46	0.063	0.64	0.64	0.64	0.640
L_8 X T_3	-1.27**	0.87**	0.49	0.032	0.05	1.81**	0.51	0.794 *	-0.14	-0.14	-0.14	0.137
L_9 X T_1	-1.57**	-0.62*	1.86**	0.111	-0.46	-0.46	2.39**	0.492	-1.02	-1.02	-1.02	1.018
L_9 X T_2	1.73**	0.37	-0.79*	0.635 *	0.29	1.20**	-1.01**	0.159	-0.32	-0.32	-0.32	0.316
L_9 X T_3	-0.16	-0.35	-1.06**	0.524 *	0.16	-0.74	-1.38**	0.651 *	1.33	1.33	1.33	1.334
L_{10} X T_1	0.32	1.27**	-1.92**	0.111	-0.23	1.43**	-1.06**	0.048	1.43	1.43	1.43	1.427
L_{10} X T_2	0.29	0.52	1.10**	0.635 *	1.18**	-0.25	0.21	0.381	0.64	0.64	0.64	0.637
L_{10}X T_3	-0.60*	-1.79**	-0.83*	-1.222 **	-0.95**	-1.19**	0.85*	0.429	-2.06**	-2.06**	-2.06	2.064 **

Contd.....

L_{11} X T_1	0.65*	1.27**	1.75**	0.635 *	0.77*	-0.23	0.94*	0.492	0.33	0.33	0.33	0.331
L_{11} X T_2	-0.38	2.52**	-0.24	1.857 **	-0.82**	0.08	-0.79*	0.508	-0.84	-1.84*	-0.84	0.840
L_{11} X T_3	-0.27	-3.79**	-1.51**	0.222	0.05	0.15	-0.15	0.016	0.51	0.51	0.51	0.510
L_{12} X T_1	0.65*	-0.33	-0.59	0.143	-0.57	0.10	-0.39	0.286	-0.54	-0.54	-0.54	0.536
L_{12} X T_2	-0.05	0.36	-1.24**	0.365	0.18	0.75*	-0.79*	0.048	-0.17	-0.17	-0.17	0.173
L_{12} X T_3	-0.60*	-0.13	1.83**	1.333 **	0.39	-0.85*	1.18**	0.238	0.71	0.71	0.71	0.710 **
L_{13} X T_1	-1.24**	.32	-0.14	0.254	-0.12	-0.79*	0.72*	0.063	2.23**	2.23**	2.23**	2.228 **
L_{13} X T_2	0.06	0.97**	-1.79**	-1.587 **	-0.38	-0.14	-0.68*	0.397	1.68	1.68	1.68	1.684
L_{13} X T_3	1.17**	1.65**	1.94**	1.000 **	0.50	0.93**	-0.04	0.460	0.54	0.54	0.54	0.544
L_{14} X T_1	-0.68*	-1.73**	-0.59	0.587 *	1.10**	0.40	0.61*	0.270	-0.69	-0.69	-0.69	0.686
L_{14} X T_2	0.29	0.52	-2.57**	-1.587 **	-0.49	0.42	-1.12**	0.397	0.09	0.09	0.09	0.093
L_{14} X T_3	0.40	1.21**	3.16**	0.444	-0.61*	0.48	0.51	0.127	0.59	0.59	0.59	0.593
L_{15} X T_1	0.21	-0.17	0.30	0.324	-0.01	0.32	0.50	0.270	-0.62	-0.62	-0.62	0.617
L_{15} X T_2	0.17	0.08	1.32**	0.968 **	0.40	0.64*	0.77	0.603 *	-0.35	-0.35	-0.35	0.348
L_{15} X T_3	-0.38	0.10	-2.62**	0.278	-0.39	-0.96**	-1.26**	-0.873 **	0.97	0.97	0.97	0.965
L_{16} X T_1	0.21	0.16	0.47	0.324	-1.34**	0.99**	0.50	0.048	-1.13	-1.13	-1.13	1.131
L_{16} X T_2	-0.16	0.08	0.45	1.302 **	0.74**	0.97**	0.43	0.714 *	1.53	1.53	1.53	1.525
L_{16} X T_3	-0.05	-2.24**	-0.62	0.556 *	0.61*	-1.96**	-0.93*	0.762 *	-0.39	-0.39	-0.39	0.395
L_{17} X T_1	0.10	-0.29	-1.48**	0.857 **	1.21**	-0.12	-0.95*	0.048	0.74	0.74	0.74	0.738
L_{17} X T_2	0.40	0.30	1.87**	0.302	-0.04	-0.43	0.66*	0.048	-1.99*	-1.99*	-1.99**	1.989
L_{17} X T_3	-0.49	-0.02	-0.40	0.667 *	-1.17**	0.59	0.29	0.095	1.25	1.25	1.25	1.251
L_{18} X T_1	-0.02	-1.06**	-0.92*	0.079	-0.34	-0.68	-0.84*	0.619 *	-1.76	-1.76	-1.76	1.757 *
L_{18} X T_2	-0.05	0.19	0.10	0.587 **	-0.26	0.31	0.10	0.048	0.83	0.83	0.83	0.829
L_{18} X T_3	0.06	0.37	0.83*	1.222 **	0.61*	0.37	0.74*	0.571	0.93	0.93	0.93	0.928
L_{19} X T_1	0.65*	1.27**	1.75**	1.365 **	0.77*	1.43**	1.61**	1.270 **	0.88	0.88	0.88	0.884
L_{19} X T_2	-0.38	-2.48**	-1.24**	0.143	-0.82**	0.25	-1.12**	-1.397 **	-0.29	-0.29	-0.29	0.287
L_{19} X T_3	-0.27	0.21	-0.51	0.111	0.05	0.81**	-0.49	0.127	-0.60	-0.60	-0.60	0.597
L_{20} X T_1	1.10**	-0.45	0.19	0.190	0.21	-1.12**	0.05	0.286	-0.26	-0.26	-0.26	0.258
L_{20} X T_2	-0.60	1.63**	-0.46	0.302	-0.04	0.53	-0.34	0.381	-0.11	-0.11	-0.11	0.106
L_{20} X T_3	-0.49	-0.68*	0.27	0.321	-0.17	-0.41	0.29	0.095	0.36	0.36	0.36	0.364
L_{21} X T_1	0.43	-0.62*	-0.14	0.444	0.54	0.12	-0.95	0.508	-1.02	-1.02	-1.02	1.018
L_{21} X T_2	-1.27**	-0.03	0.21	0.302	-0.71*	0.53	1.66**	0.492	-0.32	-0.32	-0.32	0.316
L_{21} X T_3	0.84**	0.65*	-0.06	0.143	0.16	0.59	-0.71*	0.016	1.33	1.33	1.33	1.334
S.E.	0.264	0.263	0.264	0.2646	0.257	0.257	0.257	0.2582	0.257	0.257	0.257	0.2582
SE(sij-skl)	0.372	0.372	0.372	0.3742	0.363	0.363	0.363	0.3651	0.363	0.363	0.363	0.3651

*, ** Significant at 5% and 1 % probability levels, respectively.

E_1: Normal (recommended dose of nitrogen**), E_2:** Low-nitrogen, **E_3:** excess soil moisture

Specific combining ability effects of crosses indicated the range for this character from -1.34 to 1.39, -1.96 to 1.75, -1.50 to 2.39 and -1.397 to 1.270 in the E_1, E_2, E_3 and across environments, respectively. The best specific combiners for less anthesis-silking interval were L_{16} X T_1(-1.34) followed by L_{17} X T_1 (-1.17), and L_{10} X T_3 (-0.95) in E_1; L_{16} X T_3 (-1.96), followed by L_5 X T_2 (-1.92), L_8 X T_3 (-1.81), L_1 X T_3 (-1.41) and L_3 X T_2(-1.25) in E_2; L_6 X T_1 (-1.50), L_9 X T_3 (-1.38), L_{15} X T_3 (-1.26) and L_{19} X T_2 (-1.12) in E_3; and L_{19} X T_2 (-1.397) followed by L_{15} X T_3 (-0.873) in the pooled environment.

4.4.3.12 Protein percentage

Combining ability effects of the parents and crosses for protein percentage are given in Tables 4.4.3 and 4.4.4, respectively. Results indicated that lines with maximum significant GCA effects for higher protein percentage were L_4, L_3, L_2 and L_{12} in all the three environments along with pooled environment. Therefore, these parents may be used as best combiners for protein percentage. Among the testers, maximum significant GCA effects for higher protein percentage were observed in T_3 for all the three individual and pooled environment.

Estimates of SCA effects in crosses were positive and highly significant for L_1 X T_1, L_2 X T_1, L_7 X T_1 and L_{13} X T_1 in E_1, E_2, E_3 and pooled environment indicating their specific combining ability for protein percentage. However, L_6 X T_3 , L_{10} X T_3, and L_{17} X T_2 crosses exhibited significant negative SCA effects for protein percentage in all the environments as well as in pooled environment.

4.4.3.13 Lysine per cent

Estimates of GCA effects of parents and SCA effects of crosses for lysine content are presented in Tables 4.4.3 and 4.4.4, respectively. Perusal of results on GCA effects of lines indicated significant positive effects of L_{13}, L_{14} and L_{19} in all the three environments and in pooled environment. Among the testers, T3 in E1; T_1 and T_2 in E2 environment showed maximum significant GCA effects for higher protein percentage.

Results revealed that crosses with significant and maximum positive SCA effects were L_{11} X T_3, L_2 X T_3 , L_{16} X T_2 and L_{21} X T_1 in E_1; L_8 X T_2 , L_6 X T_3 , L_7 X T_1, L_{11} X T_3, L_9 X T_1, L_2 X T_3 , L_{16} X T_2 and L_{21} X T_1 in E_2; L_{11} X T_3, L_2 X T_3 , L_{16} X T_2 and L_{21} X T_1 in E_3; and L_2 X T_3, L_3 X T_1, L_{15} X T_3 , L_{20} X T_3, L_{16} X T_2 and L_{21} X T_1 in the pooled environment. On the basis of study of all three individual environments and pooled environment, crosses L_{11} X T_3, L_2 X T_3 , L_{16} X T_2 and L_{21} X T_1 showed significant and maximum positive SCA effects.

4.4.3.14 Tryptophan per cent

Tables 4.4.3 and 4.4.4 presented the estimates of GCA effects of the parents and SCA effects of crosses for tryptophan content, respectively. Results on GCA effects indicated high and significant positive effects for L_9, L_{13}, L_{14} and L_{19} in E_1, E_2, E_3 and in pooled environment for tryptophan content. Among the testers, T_1 in E1, E2, E3 and pooled environment showed maximum significant GCA effects for higher tryptophan percentage.

Table 4.4.3 : Contd.....

Character	Lysine (%)				Tryptophan (%)				Grain yield (kg/ha)			
Environment	**E_1**	**E_2**	**E_3**	**Pooled**	**E_1**	**E_2**	**E_3**	**Pooled**	**E_1**	**E_2**	**E_3**	**Pooled**
LINE												
L_1	-0.02	-0.02	-0.02	-0.024	-0.06**	-0.06**	-0.01	-0.008	2111.47**	1600.69**	1286.09**	13.335 **
L_2	-0.25	-0.25	-0.25	-0.252	-0.07**	-0.07**	-0.07**	-0.065 *	1307.75**	268.56	1619.55**	10.654 **
L_3	-0.28	-0.28	-0.28	-0.278	-0.07**	-0.07**	-0.07**	-0.072 **	1956.97**	713.27	-601.34	3.560
L_4	-0.14	-0.14	-0.14	-0.140	-0.03	-0.03	-0.03	-0.034	1222.70**	269.23	1731.69**	7.407 *
L_5	-0.31*	-0.31*	-0.31*	-0.308 *	-0.07**	-0.07**	-0.07**	-0.072 **	-87.92	-1063.35**	-600.89	-5.847
L_6	-0.02	-0.02	-0.02	-0.020	0.01	0.01	0.07**	-0.004	-2025.17**	-975.17*	-1045.83**	-13.488 **
L_7	0.11	0.11	0.11	0.113	0.03	0.03	0.03	0.029	-111.21	-531.57	837.20	0.652
L_8	0.17	0.17	0.17	0.170	0.05*	0.05*	0.05	0.046	-2173.45**	-976.05*	-158.18	-11.018 **
L_9	0.24	0.24	0.24	0.244	0.06**	0.06**	0.06**	0.060 *	1121.16**	135.28	-601.78	2.184
L_{10}	0.08	0.08	0.08	0.083	0.02	0.02	0.02	0.019	127.57	357.41	-601.78	-0.387
L_{11}	0.14	0.14	0.14	0.136	0.03	0.03	0.03	0.032	-455.12	268.11	-157.96	-1.144
L_{12}	0.27	0.27	0.27	0.270	0.07**	0.07**	0.07**	0.066 *	-688.85	268.56	-601.78	-3.405
L_{13}	0.51**	0.51**	0.51**	0.514 **	0.13**	0.13**	0.13**	0.128 **	153.40	-175.49	-601.56	-2.078
L_{14}	0.30*	0.30*	0.30*	0.396*	0.07**	0.07**	0.07**	0.072 **	-477.91	-531.57	-602.22	-5.365
L_{15}	-0.33*	-0.33*	-0.33*	-0.332 *	-0.09**	-0.09**	-0.09**	-0.085 **	-305.60	-530.90	-157.29	-3.315
L_{16}	0.10	0.10	0.10	0.101	0.03	0.03	0.03	0.027	1039.26	-619.09	1176.18**	5.312
L_{17}	-0.36*	-0.36*	-0.36*	-0.364 *	-0.09**	-0.09**	-0.09**	-0.088 **	-1560.00**	624.19	-68.44	-3.351
L_{18}	0.11	0.11	0.11	0.112	0.03	0.03	0.03	0.028	177.34	2.22	731.24	3.034
L_{19}	0.55**	0.55**	0.55**	0.552 **	0.14**	0.14**	0.14**	0.138 **	351.50	1601.58**	286.98	7.465 *
L_{20}	0.08	0.08	0.08	0.083	0.02	0.02	0.02	0.019	637.62	91.30	-157.07	1.903
L_{21}	0.07	0.07	0.07	0.073	0.02	0.02	0.02	0.019	-1321.55**	-797.24*	287.20	-6.109
S.E.(gi)	0.002	0.002	0.002	0.0211	0.002	0.002	0.002	0.0236	0.714	0.702	0.714	0.7148
SE(gi-gj)	0.002	0.003	0.003	0.0298	0.003	0.003	0.003	0.0333	1.01	1.01	1.01	1.0108
TESTER												
T_1	0.04	0.04**	0.01	0.042	0.12*	0.04**	0.05*	0.010*	763.39**	129.09	159.98*	7.506**
T_2	-0.05*	-0.05**	-0.05**	-0.046*	-0.13*	-0.05**	-0.06**	-0.012 **	-400.91	-378.61**	-256.33	-3.45
T_3	0.05*	0.05**	0.02	0.004	0.01	0.01	0.02	0.002	-362.48	249.52*	96.35	-0.05
S.E.(gj)	0.0007	0.0008	0.0007	0.0025	0.0009	0.0009	0.0009	0.0009	0.270	0.245	0.270	0.1200
SE(gi-gj)	0.001	0.001	0.001	0.0036	0.001	0.001	0.001	0.0013	0.38	0.37	0.36	0.1704

*, ** Significant at 5% and 1 % probability levels, respectively.

Results revealed that crosses with significant and maximum positive SCA effects were L_{11} X T_3 followed by L_2 X T_3, L_{21} X T_1 and L_{18} X T_3 in E_1, E_2 and E_3 and pooled environment, exhibiting best specific combining ability for this trait.

4.4.3.15 Grain yield (kg per ha)

Estimates of GCA and SCA effects of parents (lines + tester) and crosses are presented in Tables 4.4.3 and 4.4.4, respectively. GCA effects of parental lines for grain yield revealed significant and positive effects in case of L_1 (2111.47), L_2 (1307.75), L_3 (1956.97), L_4 (1222.70) and L_9 (1121.16)in E_1, L_1 (1600.69) and L_{19} (1601.18)in E_2, L_1 (1286.09), L_2 (1619.55), L_4 (1731.69) and L_{16} (1176.18)in E_3 and L_1 (13.33), L_2 (10.65), L_4 (7.407) and L_{19} (7.46) in the pooled analysis. Among the testers, T_3 in E2 and T_1 in E1; E3 and pooled environment showed positive and significant GCA effect indicating that these were good general combiners for grain yield in particular environment. However, L_1 exhibited positive and significant GCA effect in over all environment indicating average general combiners for grain yield.

SCA effects of crosses ranged from -1968.03 to 2099.58, -1582.10 to 2536.73, -1937.05 to 2922.15 and -16.78 to 23.24 in the E_1, E_2, E_3 and in pooled analysis, respectively. Results of crosses revealed that crosses with significant and positive SCA effects were L_1 X T_1 (1325.17) L_1 X T_2 (940.38) L_3 X T_1 (2834.57) L_4 X T_1 (1939.31) L_5 X T_1 (1492.07) L_6 X T_3 (979.47) L_8 X T_2 (1236.98) L_9 X T_1 (1777.52) L_9 X T_2 (1696.82) L_{10} X

Table 4.4.4 : Contd.....

Character	Lysine (%)				Tryptophan (%)				Grain yield (kg/ha)			
Environment	**E1**	**E2**	**E3**	**Pooled**	**E1**	**E2**	**E3**	**Pooled**	**E1**	**E2**	**E3**	**Pooled**
CROSSES												
L_1 X T_1	0.38	0.38	0.38	0.384	0.10**	0.10	0.10	0.007	1325.17**	2536.73**	2061.58**	14.240 **
L_1 X T_2	-0.21	-0.21	-0.21	0.207	-0.05*	-0.05*	-0.05*	-0.002	940.38*	-954.63*	-1521.18**	-5.112
L_1 X T_3	-0.18	-0.18	-0.18	0.177	-0.04	-0.04	-0.04	0.045	-615.20	-1582.10**	-540.40	-9.128*
L_2 X T_1	-0.47	-0.47	-0.47	0.468	-0.12**	-0.12**	-0.12**	-0.116 **	-754.80	-128.87	728.78	-0.519
L_2 X T_2	-0.18	-0.18	-0.18	0.182	-0.05*	-0.05*	-0.05*	-0.047	333.56	378.17	-188.38	1.749
L_2 X T_3	0.65**	0.65**	0.65**	0.650 **	0.16**	0.16**	0.16**	0.163 **	421.24	-249.30	-540.40	-1.230
L_3 X T_1	-0.52*	-0.52*	-0.52*	0.521 *	-0.13**	-0.03	-0.13**	-0.129 **	2834.57	-572.91	1617.53	12.925 **
L_3 X T_2	0.37	0.37	0.37	0.368	0.09*	0.04	0.09*	0.093 *	-896.43*	-65.21	-631.76	-5.313
L_3 X T_3	0.15	0.15	0.15	0.154	0.04	0.04	0.04	0.093 *	-1938.14**	638.13	-985.77*	-7.612
L_4 X T_1	0.18	0.18	0.18	0.178	0.04	0.04	0.04	0.040	1939.41**	-129.54	283.84	6.984
L_4 X T_2	-0.25	-0.25	-0.25	0.250	-0.06*	-0.06*	-0.06*	-0.065 *	-898.74*	378.83	-631.98	-3.841
L_4 X T_3	0.07	0.07	0.07	0.073	0.03	0.03	0.03	0.025	-1040.66**	-249.30	348.14	-3.143
L_5 X T_1	0.12	0.12	0.12	0.115	0.03	0.03	0.03	0.028	1492.07**	-128.42	284.95	5.489
L_5 X T_2	0.07	0.07**	0.07	0.074	0.01	0.04	0.06*	0.009	-1587.32**	378.61	700.60	-1.693
L_5 X T_3	-0.19	-0.19	-0.19	0.190	-0.04	-0.04	-0.04	-0.037	95.26	-250.19	-985.55*	-3.796
L_6 X T_1	-0.22	-0.22	-0.22	0.216	-0.05*	-0.05*	-0.05*	-0.013	-1524.43**	-218.61	-604.91	-7.820
L_6 X T_2	-0.01	-0.01	-0.01	0.010	0.01	-0.01	0.01	-0.015	544.95	556.32	-187.94	3.045
L_6 X T_3	0.23	0.83**	0.23	0.226	0.06*	0.06*	0.02	0.018	979.47*	-337.71	792.85	4.775
L_7 X T_1	0.21	0.75**	0.21	0.211	0.05*	0.05*	0.03	0.053 *	-819.16*	671.26	178.33	0.097
L_7 X T_2	-0.10	-0.10	-0.10	0.104	-0.03	-0.03	-0.03	-0.028	551.43	112.05	-418.96	0.815
L_7 X T_3	-0.11	-0.11	-0.11	0.107	-0.02	-0.02	0.03	-0.025	267.73	-783.31*	240.62	-0.911
L_8 X T_1	-0.32	-0.32	-0.32	0.322	-0.08*	-0.08**	-0.08*	-0.080 *	-1055.69**	-218.39	-1493.22**	-9.217 **
L_8 X T_2	0.25	0.85**	0.25	0.246	0.06*	0.06*	0.06*	0.062 *	1236.98**	556.54	2922.15**	15.715 **
L_8 X T_3	0.08	0.08	0.08	0.076	0.02	0.02	0.05*	0.018	-181.29	-338.15	-1428.93**	-6.498
L_9 X T_1	0.32	0.72**	0.32	0.323	0.08*	0.08**	0.04	0.082 *	1777.52**	1337.21**	284.51	11.328 **
L_9 X T_2	-0.47	-0.47	-0.47	0.475	-0.12**	-0.12**	-0.02	-0.119 **	1696.82**	-820.69*	700.82	5.256
L_9 X T_3	0.15	0.15	0.15	0.155	0.04	0.04	0.04	0.037	-3474.33**	-516.52	-985.33*	-16.583 **
L_{10} X T_1	-0.04	-0.04	-0.04	0.042	-0.01	-0.01	0.06*	-0.010	1588.84**	1115.08**	284.51	-10.373 **
L_{10} X T_2	0.45	0.45	0.45	0.446	0.11**	0.01	0.11**	0.112 **	-1703.13**	-776.26*	-631.98	0.414
L_{10}X T_3	-0.40	-0.40	-0.40	0.404	-0.10**	-0.10**	-0.10**	-0.102 **	114.30**	-338.82	347.47	-16.408 **

Contd.....

L_{11} X T_1	-1.10**	-1.10**	-1.10	0.096	-0.27**	-0.27**	-0.27**	-0.273 **	-1968.03**	-1461.89**	-1492.78**	-6.836
L_{11} X T_2	0.35	0.35	0.35	0.353	0.09*	0.09**	0.09*	0.088 *	-20.99	-954.19*	-1076.47**	8.886
L_{11} X T_3	0.74**	0.74**	0.74**	0.743 **	0.19**	0.19**	0.19**	0.185 **	1989.02**	2416.08**	2569.25**	23.244 **
L_{12} X T_1	0.29	0.29	0.29	0.291	0.07*	0.07*	0.07*	0.073 *	-1512.29**	-129.54	283.84	-4.520
L_{12} X T_2	-0.46	-0.46	-0.46	0.460	-0.11**	-0.11**	-0.11**	-0.115 **	-341.06	-953.97*	700.82	-1.982
L_{12} X T_3	0.17	0.17	0.17	0.169	0.04	0.04	0.04	0.042	1853.35**	1083.50**	984.66*	26.502**
L_{13} X T_1	0.08	0.08	0.08	0.078	0.02	0.02	0.04	0.020	-1271.94**	-1017.63**	-1048.51**	-11.127 **
L_{13} X T_2	-0.15	-0.15	-0.15	0.154	-0.04	-0.04	-0.04	-0.038	1093.44**	822.88*	700.60	8.725
L_{13} X T_3	0.08	0.08	0.08	0.076	0.02	0.02	0.06*	0.018	178.50	194.75	347.91	2.402
L_{14} X T_1	0.46	0.46	0.46	0.464	0.12**	0.12**	0.02	0.117 **	2099.58**	670.59	284.29	-4.952
L_{14} X T_2	-0.37	-0.37	-0.37	0.367	-0.09*	-0.09**	-0.09*	-0.092 *	-965.34*	112.05	-632.20	-5.231
L_{14} X T_3	-0.10	-0.10	-0.10	0.097	-0.02	-0.02	0.04	-0.025	-1134.23**	-782.64*	347.91	3.877
L_{15} X T_1	0.25	0.24	0.25	0.252	0.06*	0.06*	0.04	0.064 *	651.58	670.59	-159.98	-7.089
L_{15} X T_2	0.30	0.30	0.30	0.301	0.08*	0.08**	0.08*	0.076 *	-1162.08**	112.05	-1076.47**	3.212
L_{15} X T_3	-0.55*	-0.55*	-0.55*	0.553 *	-0.14**	-0.14**	-0.14**	-0.141 **	510.50	-782.64*	1236.45**	-4.753
L_{16} X T_1	0.38	0.38	0.38	0.380	0.09*	0.04	0.09*	0.092 *	-692.62	-573.36	-159.98	6.735
L_{16} X T_2	0.64*	0.64**	0.64**	0.639 **	0.16**	0.16**	0.16**	0.034	496.77*	1267.14**	256.33	-1.981
L_{16} X T_3	-1.02**	-1.02**	-1.02**	0.018	-0.26**	-0.26**	-0.26**	-0.026	195.85	-693.79*	-96.35	-16.787 **
L_{17} X T_1	0.12	0.12	0.12	0.121	0.02	0.02	0.04	0.023	-1903.60	-1550.08**	-1580.97**	1.378
L_{17} X T_2	-0.29	-0.24	-0.29	0.287	-0.06*	-0.06*	-0.06**	-0.062 *	489.34	-509.92	434.04	15.409 **
L_{17} X T_3	0.17	0.14	0.17	0.166	0.04	0.04	0.04	0.038	1414.26**	2060.00**	1146.93**	22.261**
L_{18} X T_1	-0.43	-0.43	-0.43	0.428	-0.11**	-0.11**	-0.11**	-0.106 **	256.45	137.47	284.29	9.243 *
L_{18} X T_2	-0.06	-0.06	-0.06	0.059	-0.01	-0.01	0.06**	-0.014	1427.01**	1645.17**	1700.60**	11.503 **
L_{18} X T_3	0.49	0.49	0.49	0.487	0.12**	0.12**	0.12**	0.119 **	-1683.45**	-782.64*	-984.89*	-6.823
L_{19} X T_1	0.05	0.05	0.05	0.052	0.01	0.01	0.04	0.014	19.57	-129.09	-1937.05**	5.205
L_{19} X T_2	-0.10	-0.10	-0.10	0.099	-0.02	-0.02	0.04	-0.024	37.65	-954.19*	2477.66**	1.619
L_{19} X T_3	0.05	0.05	0.05	0.047	0.01	0.01	0.08**	0.009	-57.22	1083.28**	-540.62	2.179
L_{20} X T_1	-0.28	-0.28	-0.28	0.282	-0.07*	-0.07*	-0.04	-0.070 *	-34.49	-484.73	1172.60**	-3.626
L_{20} X T_2	0.53*	0.53*	0.53*	0.526	0.13**	0.03	0.03	0.132 **	-567.67	556.76	-1076.03**	1.448
L_{20} X T_3	-0.24	-0.24	-0.24	1.244 **	-0.06*	-0.03	-0.03	-0.062 *	602.16	-72.03	-96.57	2.224
L_{21} X T_1	0.53*	0.53*	0.53*	1.531 **	0.13**	0.13**	0.13**	0.133 **	-797.37	-395.87	728.33	-1.546
L_{21} X T_2	-0.30	-0.30	-0.30	0.300	-0.07*	-0.07*	-0.02	-0.075 *	-705.55	112.49	-1520.29**	-7.047
L_{21} X T_3	-0.23	-0.23	-0.23	0.231	-0.06*	-0.03	-0.02	-0.058 *	1502.93**	283.38	791.96	8.593
S.E.	0.0036	0.003	0.0036	0.0277	0.004	0.004	0.004	0.0134	1.234	1.201	1.234	0.7112
SE(sij-skl)	0.005	0.005	0.005	0.0392	0.005	0.006	0.006	0.0190	1.75	1.74	1.73	1.0060

*, ** Significant at 5% and 1 % probability levels, respectively.

E_1: Normal (recommended dose of nitrogen**), E_2:** Low-nitrogen, **E_3:** excess soil moisture

T_1 (1588.84) L_{11} X T_3 (1989.02) L_{12} X T_3 (1853.35) L_{13} X T_2 (1093.45) L_{14} X T_1 (2099.58) L_{17} X T_3 (1414.26) L_{18} X T_2 (1427.01) and L_{21} X T_3 (1502.93) in E_1, L_1 X T_1 (2536.73) L_9 X T_1 (1337.21) L_{10} X T_1 (1115.08) L_{11} X T_3 (2416.08) L_{12} X T_3 (1083.50) L_{13} X T_2 (822.88) L_{16} X T_2 (1267.14) L_{17} X T_3 (2660.00) L_{18} X T_2 (645.17) and L_{19} X T_3 (1083.28) in E_2, L_1 X T_1 (2061.58), L_8 X T_2 (2922.15), L_{11} X T_3 (2569.25) L_{12} X T_3 (984.66) L_{15} X T_3 (1236.45) L_{17} X T_3 (1146.93) L_{18} X T_2 (1700.60) L_{19} X T_2 (2477.66) and L_{20} X T_1 (1172.60) in E_3 and L_1 X T_1 (14.24) L_3 X T_1 (12.93) L_8 X T_2 (15.72) L_9 X T_1 (11.33) L_{11} X T_3 (23.24) L_{12} X T_3 (26.50) L_{17} X T_3 (22.26) and L_{18} X T_2 (11.50) in pooled environment had significant and higher estimates of SCA, therefore, they may be considered as best combiners for these environments for grain yield. However, cross combination L_1 X T_1, L_{11} X T_3, L_{12} X T_3, L_{17} X T_3 and L_{18} X T_2 had significant and higher estimates of SCA in all three environments individually and pooled environment, considered as best combiner for grain yield.

4.4.4 Variance component of combining ability

Variance component of general combining ability (GCA) and specific combining ability (SCA) are shown in Table 4.4.5. It was noticed that SCA variance was higher than the GCA variance for all the fifteen characters in all three environments.

The GCA variance was negative for the characters like number of kernel row per ear (-0.008), number of kernels per row (-0.086), protein

Table 4.4.5: Component of variance of combining ability in terms of full sibs and half sibs under normal, low-nitrogen and excess soil moisture environments

S. No.	Environment	Component of variance		Plant height (cm)	Ear height (cm)	100 kernels weight (g)	Ear length (cm)	Ear diameter (cm)	kernel rows/ear	Number of kernel / row	No. of nodes bearing brace roots	Days to 50% tasselling	Days to 50% silking	Anthesis-Silking interval	Protein (%)	Lysine (%)	Tryptophan (%)	Grain yield (kg/ha)
1	E_1	Cov H.S. **(σ^2 gca)**		0.231	0.058	0.039	0.007	0.0001	-0.008	-0.086	0.0022	0.051	0.056	0.007	-0.004	-0.0002	-0.0004	189.13
		Cov F.S.		252.87	64.89	9.32	3.6	0.199	1.29	12.5	0.34	2.32	3.17	0.8	2.23	0.16	0.01	5024.5
		Cov (F.S.) - 2 (Cov H.S.) = **σ^2 sca**		252.408	64.77	9.242	3.586	0.1988	1.306	12.672	0.3356	2.218	3.058	0.786	2.238	0.1604	0.0108	4646.24
		σ^2 gca / σ^2 sca		0.00092	0.0009	0.00422	0.0019	0.00050	-0.00613	-0.0067	0.00656	0.02299	0.01831	0.00891	-0.00179	-0.00125	-0.03704	0.04071
2	E_2	Cov H.S.**(σ^2 gca)**		0.384	0.877	-0.043	0.004	0.0008	-0.002	0.067	0.0002	0.013	0.0138	-0.0004	-0.0045	-0.0002	-0.00014	606.06
		Cov F.S.		109.26	155.0	13.34	2.11	0.21	1.24	8.74	0.04	2.06	3.05	1.18	2.22	0.16	0.01	1692.8
		Cov (F.S.) - 2 (Cov H.S.) = **σ^2 sca**		108.492	153.3	13.426	2.102	0.2084	1.244	8.606	0.0396	2.034	3.0224	1.1808	2.229	0.1604	0.01028	680.68
		σ^2 gca / σ^2 sca		0.0035	0.0057	-0.0032	0.0019	0.0038	-0.0016	0.0078	0.0051	0.0064	0.0046	-0.0003	-0.0020	-0.0012	-0.0136	0.8903
3	E_3	Cov H.S.**(σ^2 gca)**		-0.323	-0.306	-0.056	-0.004	-0.0002	-0.003	0.033	0.00004	0.0054	0.0042	0.0009	-0.004	-0.0002	-0.00014	283.86
		Cov F.S.		171.12	59.01	19.36	1.58	0.08	1.93	12.84	0.04	0.85	2.74	1.33	2.22	0.16	0.01	1422.5
		Cov (F.S.) - 2 (Cov H.S.) = **σ^2 sca**		171.766	59.62	19.472	1.588	0.0804	1.936	12.774	0.03992	0.8392	2.7316	1.3282	2.228	0.1604	0.010028	854.78
		σ^2 gca / σ^2 sca		-0.0019	-0.0051	-0.0029	-0.0025	-0.0025	-0.0015	0.0026	0.0010	0.0064	0.0015	0.0007	-0.0018	-0.0012	-0.0140	0.3321
4	E_1	**σ^2A**	F=0	0.924	0.232	0.156	0.028	0.0004	-0.032	-0.344	0.0088	0.204	0.224	0.028	-0.016	-0.0008	-0.0016	756.52
			F=1	0.462	0.116	0.078	0.014	0.0002	-0.016	-0.172	0.0044	0.102	0.112	0.014	-0.008	-0.0004	-0.0008	378.26
		σ^2D	F=0	1009.63	259.09	36.968	14.344	0.7952	5.224	50.688	1.3424	8.872	12.232	3.144	8.952	0.6416	0.0432	18584.96
			F=1	252.408	64.774	9.242	3.586	0.1988	1.306	12.672	0.3356	2.218	3.058	0.786	2.238	0.1604	0.0108	4646.24
5	E_2	**σ^2A**	F=0	1.536	3.508	-0.172	0.016	0.0032	-0.008	0.268	0.0008	0.052	0.0552	-0.0016	-0.018	-0.0008	-0.00056	2424.24
			F=1	0.768	1.754	-0.086	0.008	0.0016	-0.004	0.134	0.0004	0.026	0.0276	-0.0008	-0.009	-0.0004	-0.00028	1212.12
		σ^2D	F=0	433.96	613.22	53.704	8.408	0.8336	4.976	34.424	0.1584	8.136	12.0896	4.7232	8.916	0.6416	0.04112	1922.72
			F=1	108.49	153.30	13.426	2.102	0.2084	1.244	8.606	0.0396	2.034	3.0224	1.1808	2.229	0.1604	0.01028	480.68
6	E_3	**σ^2A**	F=0	-1.292	-1.224	-0.224	-0.016	-0.0008	-0.012	0.132	0.00016	0.0216	0.0168	0.0036	-0.016	-0.0008	-0.00056	1135.44
			F=1	-0.646	-0.612	-0.112	-0.008	-0.0004	-0.006	0.066	0.00008	0.0108	0.0084	0.0018	-0.008	-0.0004	-0.00028	567.72
		σ^2D	F=0	687.0	238.48	77.88	6.35	0.321	7.744	51.09	0.159	3.356	10.92	5.31	8.91	0.641	0.0401	3419.1
			F=1	171.76	59.622	19.47	1.58	0.08	1.93	12.77	0.039	0.83	2.73	1.32	2.22	0.16	0.01	854.78

per cent (-0.004), lysine per cent (-0.0002) and tryptophan per cent (-0.0004) in E1, 100-kernels weight (-0.043), number of kernel row per ear (-0.002), anthesis-silking interval (-0.0004), protein per cent (-0.0045), lysine per cent (-0.0002) and tryptophan per cent (-0.00014) in E2 and plant height (-0.323), ear height (-0.306), 100-kernels weight (-0.056), ear length (-0.004), ear diameter (0.0002), number of kernel row per ear (-0.003), protein per cent (-0.004), lysine per cent (-0.0002) and tryptophan per cent (-0.00014) in E3 environment.

Maximum variance for GCA and SCA was observed for grain yield followed by plant height and ear height in E1, grain yield followed by ear height and plant height in E2, respectively. Whereas, In E3 environment, grain yield followed by number of kernels per row for GCA and grain yield followed by plant height and ear height for SCA.

For all the characters, the ratio of variance of GCA to SCA was lesser than unity in all the environments indicating pre-dominance of non-additive variance.

The non-additive (dominance) variance (σ^2D) was higher than the additive variance (σ^2A) at both F=0 and F=1. Therefore, as the dominance variance is predominant, transgrassive (recombinant) breeding may not be useful. Heterosis breeding is a better choice for these conditions.

4.4.5 Per cent contribution of lines, testers and line x tester interaction to the hybrids sum of squares

Per cent contribution of lines, testers and line x tester interaction to the hybrids sum of squares due to hybrids are given in Table 4.4.6.

Table 4.4.6: Percent contribution of different lines, testers and line x tester component

S. No.	Characters	Due to lines			Due to testers			Due to line x tester		
		Normal* (E_1)	Low-N (E_2)	Excess soil moisture (E_3)	Normal (E_1)	Low-N (E_2)	Excess soil moisture (E_3)	Normal (E_1)	Low-N (E_2)	Excess soil moisture (E_3)
1	**Plant height (cm)**	34.52	41.33	31.30	3.07	0.11	0.79	62.40	58.55	67.89
2	**Ear height (cm)**	36.46	47.20	25.86	0.63	7.93	0.65	62.89	44.86	73.47
3	**100 kernel wt. (g)**	42.44	28.10	19.93	4.38	1.27	6.74	53.16	70.61	73.32
4	**Ear length (cm)**	35.73	36.91	30.04	5.29	4.31	0.45	58.97	58.76	69.49
5	**Ear width (cm)**	35.64	41.88	29.79	1.60	8.45	0.51	62.74	49.66	69.68
6	**No. of kernel rows/ear**	31.35	22.04	31.83	2.72	7.08	0.36	65.91	70.87	67.79
7	**No. of kernels/row**	20.74	48.71	38.21	1.59	0.09	3.57	77.65	51.18	58.21
8	**No. of nodes bearing brace roots**	50.03	48.30	36.39	6.30	0.65	1.27	43.65	51.03	62.32
9	**Days to 50% tasseling**	81.34	47.61	45.81	1.44	4.37	1.11	17.21	48.00	53.07
10	**Days to 50% silking**	78.02	42.87	35.14	3.33	2.43	4.27	18.63	54.69	60.57
11	**Anthesis – Silking Interval**	54.47	33.17	30.98	3.06	1.58	6.49	42.46	65.23	62.52
12	**Protein (%)**	22.28	22.28	22.28	6.98	6.99	6.99	70.72	70.72	70.71
13	**Lysine (%)**	32.46	32.46	32.46	0.65	0.65	0.64	66.88	66.88	66.88
14	**Tryptophan (%)**	32.29	32.29	32.29	0.63	0.63	0.63	67.06	67.06	67.07
15	**Grain Yield (kg/ha)**	39.93	40.23	29.30	9.57	5.49	2.11	50.49	54.26	68.58

*Recommended dose of nitrogen

Per cent contribution due to lines ranged from 20.74 to 81.74, 22.28 to 48.71 and 19.93 to 45.81; due to testers ranged from 0.63 to 9.57, 0.11 to 8.45 and 0.63 to 6.99 and due to line x tester interaction ranged from 17.21 to 77.65, 44.86 to 70.72 and 53.21 to 73.47 in E_1, E_2 and E_3 environment, respectively.

The highest contribution of lines was observed for days to 50 per cent tasselling (81.34) followed by days to 50 per cent silking (78.02), anthesis-silking interval (54.47), brace roots (50.03), 100-kernels weight and grain yield (39.93) in E1; number of kernels per row (48.71) followed by brace roots (48.30), days to 50 per cent tasselling (47.61), ear height (47.20), days to 50 per cent silking (42.47) and plant height (41.33) in E2 and days to 50 per cent tasselling (45.81) followed by number of kernels per row (38.21), brace roots (36.21), lysine per cent (32.46), tryptophan per cent (32.29) and plant height (31.30) in E3 environment.

The contribution of testers was highest for grain yield (9.57) followed by protein per cent (6.98), brace roots (6.30), and ear length (5.29) in E1; ear diameter (8.45) followed by ear height (7.93), number of kernel rows per ear (7.08), and protein (6.99) in E2 and protein per cent (6.99) followed by 100-kernels weight (6.74), anthesis-silking interval (6.49) and days to 50 per cent silking (4.24) in E3 environment.

The contribution of line x tester was highest for number of kernels per row (77.65) followed by protein per cent (70.72), tryptophan per cent (67.06), lysine per cent (66.88) and number of kernel rows per

ear (65.91) in E1; number of kernel rows per ear (70.87), followed by protein per cent (70.72), 100-kernels weight (70.61), tryptophan per cent (67.66), lysine per cent (66.80) in E2 and plant height (73.47) followed by 100-kernels weight (73.32), protein per cent (70.71), ear diameter (69.68) and ear length (69.49) in E3 environment.

It was observed that contribution of line x tester interaction was higher than the contribution of lines and tester separately except for the characters like brace roots, days to 50 per cent tasselling, days to 50 per cent silking and anthesis-silking interval in E_1 and for ear height in E2 where contribution of lines was greater.

4.5 Stability Analysis

4.5.2 Analysis of variance

The pooled analysis of variance is presented in Table 4.5.1 for 15 characters. The mean squares due to genotypes were significant for ear height, ear length, ear diameter, number of kernel rows per ear, days to 50 per cent tasselling, days to 50 per cent silking, protein, lysine, tryptophan contents and grain yield, whereas, mean squares due to environments were also significant for all the characters, indicating sufficient differences among the environments.

Highly significant mean squares due to G × E interaction for all the traits except quality traits as protein, lysine and tryptophan contents, indicated differential response of genotypes in different environments, however, quality traits were unaffected by the changing

Table 4.5.1: Pooled analysis of variance for important economic characters in Quality Protein Maize (QPM) over three environments

Source of variation	Degree of freedom	Mean sum of square														
		Plant height (cm)	Ear height (cm)	100 kernel weight (g)	Ear length (cm)	Ear diameter (cm)	kernel rows/ear	Number of kernel / row	No. of nodes bearing brace roots	Days to 50% tasselling	Days to 50% silking	Anthesis-Silking interval	Protein (%)	Lysine (%)	Tryptophan (%)	Grain yield (kg/ha)
Genotype (G)	89	939.93	173.62**	9.67	3.54**	0.241*	1.63**	14.39	0.112	2.50**	3.42*	1.22	5.0812**	0.5833**	0.03631**	321.18**
Environment (E)	2	3969.42*	3447.19**	806.97**	83.17**	3.160**	34.11**	379.95**	0.700*	105.54**	57.42**	20.60**	0.2623**	1.4877**	0.09217**	3897.81**
G × E	178	871.74**	68.40**	12.80**	1.68**	0.151**	1.51**	12.12**	0.106	1.61	2.53	1.22	0.001	0.001	0.001	100.41**
E + (G × E)	180	906.16*	105.95*	21.62**	2.59	0.185	1.87	16.20	0.113	2.77**	3.14**	1.44*	0.0028	0.0165	0.00103	142.60**
E (Linear)	1	7938.85**	6894.39**	1613.95**	166.34**	6.32**	68.23**	759.90**	1.401**	211.09**	114.84**	41.20**	0.5223**	2.9755**	0.18433**	7795.63**
G × E (Linear)	89	1095.57**	63.80	13.86	1.24	0.136	0.746	10.80	0.055	1.88	3.07*	1.46*	0.002*	0.001**	0.001**	114.01**
Pooled deviation	90	640.72**	72.20**	11.60**	2.11**	0.165**	2.249**	13.29**	0.155**	1.33**	1.982**	0.971**	0.0004	0.0001	0.0001	85.85**
Pooled error	534	0.0329	0.0224	0.0231	0.0008	0.0008	0.0008	0.0229	0.0008	0.067	0.067	0.064	0.0641	0.0002	0.0002	0.00073
Total	269	917.34	128.34	17.67	2.90	0.204	1.795	15.60	0.113	2.683	3.239	1.367	1.6827	0.20408	0.0127	201.69

, * Significant at 5% and 1 % probability levels, respectively

environments. The mean squares due to environment (linear) were highly significant for all the characters, whereas, genotypes × environment (linear) mean squares showed significant differences for plant height, days to 50 per cent silking, anthesis-silking interval, protein, lysine and tryptophan contents. The non-linear (pooled deviation) mean squares due to G × E interaction were also highly significant for all the characters except quality traits i.e., protein, lysine and tryptophan contents.

4.5.3 Mean performance and stability parameters

The stability parameters viz., mean ($\overline{X}i$), linear regression coefficient (bi) and deviation from regression (S^2di) for each character are given in Tables 4.5.2 to 4.5.8.

4.5.3.1 Plant height (cm)

The mean performance computed for all the genotypes (Table 4.5.2) revealed that the values ranged from 148.9 to 311.2 cm with an overall mean of 187.9. The regression coefficients varied from 2.99 to 4.923.

Out of twenty four parents (21 lines + 3 tester) only one line L_{16} showed bi value significantly different from unity. The deviation from regression was non-significant for five lines L_5, L_6, L_{13}, L_{18}, L_{21} and two testers, T_1 and T_2 indicating their stableness i.e. its low fluctuation across the environments. Only line L_5 , L_6 and tester T_1 and T_2 exhibited stable performance ($\overline{X}i > 187.9$, bi = 1, $S^2di = 0$) across the environments. Lines,

Table 4.5.2: Stability parameters for plant height and ear height in different genotypes pooled over environments

Genotype	Plant height (cm)			Ear height (cm)		
	$\bar{X}i$	bi	S^2di	$\bar{X}i$	bi	S^2di
Parent						
L_1	194.80	1.251	205.80**	69.50	1.978	150.72**
L_2	177.70	1.995	842.40**	68.70	1.474	74.17**
L_3	180.00	1.039	140.30**	69.90	0.273	15.03**
L_4	204.20	1.357	50.20**	75.23	1.382	399.73**
L_5	192.40	0.985	1.30	70.23	0.150	11.62**
L_6	195.20	0.970	4.40	63.90	0.712	108.28**
L_7	192.50	0.882	94.90**	73.23	0.939	1.64
L_8	199.40	0.699	45.30**	77.43	0.263	12.75**
L_9	190.00	1.275	331.30**	72.23	1.332	213.77**
L_{10}	204.20	0.119	18.40**	73.23	1.574	20.70**
L_{11}	206.20	0.642	125.40**	80.23	1.541	-0.22
L_{12}	198.90	0.111	13.50**	73.23	1.022	2.14
L_{13}	217.20	1.114	3.30	87.90	0.899	1.64
L_{14}	186.90	1.870	433.60**	68.23	0.024*	18.42**
L_{15}	180.50	1.168	142.00**	56.73	1.069	25.47**
L_{16}	172.70	0.082*	12.40**	60.33	0.879	43.16**
L_{17}	178.20	1.315	113.30**	56.90	1.776	70.84**
L_{18}	183.50	1.737	2.30	67.90	0.678	7.21
L_{19}	190.20	1.859	55.70**	68.23	0.319	14.65**
L_{20}	185.90	1.040	19.00**	74.57	1.766	176.97**
L_{21}	179.20	1.352	1.30	66.23	1.559	2.31
T_1	191.20	1.053	1.50	76.00	0. 918	6.22
T_2	200.60	1.066	7.70	69.30	0.209	13.44**
T_3	185.70	1.155	210.20**	68.90	1.902	139.34*
L_1 X T_1	195.60	1.722	708.70**	69.63	1.866	55.86**
L_1 X T_2	187.00	0.785	99.50**	63.90	1.398	2.75
L_1 X T_3	179.00	0.058*	183.40**	67.23	0.081*	227.96**
L_2 X T_1	192.50	0.381	15.23**	76.07	1.532	-0.20
L_2 X T_2	196.50	1.837	86.00**	83.23	0.157	17.41**
L_2 X T_3	196.50	1.066	2.90	74.90	0.142	13.52**
L_3 X T_1	196.00	1.577	149.20**	73.47	0.914	0.37
L_3 X T_2	201.40	0.724	210.00**	73.63	1.037	3.22
L_3 X T_3	201.10	0.850	44.80**	74.50	0.811	58.11**
L_4 X T_1	181.40	0.383	3.50	65.77	1.541	-0.22
L_4 X T_2	175.60	3.224	671.80**	71.23	0.028*	364.36**
L_4 X T_3	199.20	0.851	274.60**	66.90	1.109	6.29
L_5 X T_1	185.40	1.021	1141.00**	68.23	0.267	17.34**
L_5 X T_2	183.70	1.840	173.70**	74.70	1.374	49.80**
L_5 X T_3	200.70	0.358	19.10**	75.10	1.424	17.09**
L_6 X T_1	188.70	1.030	58.20**	73.37	0.766	117.56**
L_6 X T_2	198.50	0.032*	15.70**	74.90	1.011	122.12**
L_6 X T_3	203.20	0.962	9.90	77.90	0.865	25.08**
L_7 X T_1	202.50	1.473	104.30**	82.57	1.257	126.77**
L_7 X T_2	181.40	0.655	352.10**	70.57	0.113	16.47**
L_7 X T_3	194.20	0.783	1079.70**	75.23	1.182	116.69**
L_8 X T_1	198.20	1.924	167.20**	73.23	1.848	34.15**
L_8 X T_2	175.90	1.066	14.10**	60.30	1.637	1.42
L_8 X T_3	188.50	0.055*	17.50**	68.90	1.378	58.96**
L_9 X T_1	167.50	0.420	98.20**	54.23	1.705	57.86**

Table 4.5.2: Contd...

Genotype	Plant height (cm)			Ear height (cm)		
	$\overline{X}i$	bi	S^2di	$\overline{X}i$	bi	S^2di
L_9 X T_2	188.90	1.486	37.50**	65.30	0.312	75.54**
L_9 X T_3	207.20	1.489	28.20**	71.57	0.895	0.54
L_{10} X T_1	192.50	1.075	38.60**	70.57	0.122	11.63**
L_{10} X T_2	192.90	1.177	72.10**	72.07	0.977	1.06
L_{10}X T_3	185.50	1.321	1174.50**	67.23	1.031	24.27**
L_{11} X T_1	311.20	1.060	4.56	65.23	1.000	5.84
L_{11} X T_2	179.90	0.164	16.10**	75.23	0.960	68.37**
L_{11} X T_3	191.20	0.914	8.80	76.57	0.878	0.07
L_{12} X T_1	184.90	1.732	43.20**	68.40	1.282	28.49**
L_{12} X T_2	176.50	0.025*	58.90**	76.40	2.344	44.47**
L_{12} X T_3	185.40	0.875	77.70**	72.07	0. 029*	18.62**
L_{13} X T_1	178.90	1.061	4.50	64.77	0.775	11.52**
L_{13} X T_2	186.40	0.261	0.30	71.90	1.037	0.18
L_{13} X T_3	181.90	1.299	33.00**	67.23	0.465	3.88
L_{14} X T_1	179.50	0.331	206.80**	68.47	0.167	15.40**
L_{14} X T_2	165.50	0.396	36.00**	60.00	1.285	42.16**
L_{14} X T_3	180.20	0.019*	122.60**	65.67	0.044*	0.13
L_{15} X T_1	181.90	0.367	688.60**	57.80	0.704	7.77
L_{15} X T_2	173.20	0.538	718.30**	51.23	1.141	50.03**
L_{15} X T_3	165.50	0.435	333.10**	52.80	0. 011*	11.94**
L_{16} X T_1	182.90	1.057	517.90**	76.80	1.595	105.74*
L_{16} X T_2	175.20	1.894	181.40**	70.00	1.992	40.05**
L_{16} X T_3	178.90	1.122	5.30	70.00	0.044*	10.13**
L_{17} X T_1	173.90	0.739	18.30**	65.00	0.949	-0.21
L_{17} X T_2	154.50	0.766	14.70**	59.00	0.03*	245.65**
L_{17} X T_3	184.50	1.400	1093.40**	64.67	1.727	9.90
L_{18} X T_1	179.80	1.516	8.80	68.47	1.639	205.94**
L_{18} X T_2	148.90	0.343	106.10**	41.13	0.997	58.57**
L_{18} X T_3	157.20	1.488	89.10**	58.00	1.166	101.83*
L_{19} X T_1	172.20	1.923	77.70**	53.47	1.189	104.19*
L_{19} X T_2	181.20	1.723	177.00**	58.47	0. 016*	228.87**
L_{19} X T_3	186.20	0.753	-0.20	69.00	1.242	111.59*
L_{20} X T_1	183.90	0.778	63.00**	66.67	1.797	10.82**
L_{20} X T_2	187.50	1.914	93.40**	58.13	1.041	12.76**
L_{20} X T_3	187.70	1.270	11.70**	65.53	0.66	1.33
L_{21} X T_1	195.50	1.218	165.80**	73.33	1.373	2.41
L_{21} X T_2	193.90	1.749	26.40**	67.80	1.041	12.76**
L_{21} X T_3	185.70	0.752	-0.10	66.27	1.128	20.28**
HQPM- 1	202.50	1.637	564.40**	81.90	1.322	4.60
Shakti – 1	182.20	0.055*	618.30**	69.90	1.152	15.56**
Pragati	172.10	1.004	6.10	62.10	1.217	56.95**
Mean	187.9	1.00		68.71	1.00	
SE (±)	13.9	2.7		6.01	0.97	

*,** Significant at 5% and 1 % probability levels, respectively.

L_1, L_4, L_9 and L_{19} were suitable for rich environment because of ($\overline{X}i$ > 187.9, bi >1, high S^2di). However, L_{10} and L_{12} were suitable for poor environment because of ($\overline{X}i$ > 187.9, bi much less than 1, low S^2di).

Among the hybrids, the deviation from regression was non-significant for $L_2 \times T_3$, $L_4 \times T_1$, , $L_6 \times T_3$, $L_{11} \times T_1$, $L_{13} \times T_1$, $L_{13} \times T_2$, $L_{16} \times T_3$, $L_{18} \times T_1$, $L_{19} \times T_3$, and $L_{21} \times T_3$, indicating their stable performance across the environments. The hybrids, $L_6 \times T_3$, $L_{11} \times T_1$ and $L_{11} \times T_3$ were detected as most desirable and stable ($\overline{X}i$ > 187.9, bi = 1, S^2di = 0) across the environments. The hybrids $L_1 \times T_1$, $L_2 \times T_2$, $L_3 \times T_1$, $L_8 \times T_1$, $L_9 \times T_3$, $L_{10} \times T_2$, $L_{21} \times T_1$ and $L_{21} \times T_2$ were suitable for rich environment because of ($\overline{X}i$ > 187.9, bi >1, high S^2di). However, $L_2 \times T_1$, $L_5 \times T_3$, $L_6 \times T_2$ and $L_8 \times T_3$ were suitable for poor environment because of ($\overline{X}i$ > 187.9, bi much less than 1, low S^2di).

4.5.3.2 Ear height (cm)

Table 4.5.2 showed the values of three stability parameters, $\overline{X}i$, bi and S^2di for 90 genotypes. The mean performance for ear height varied from 41.13 to 87.90 and bi value from 0.113 to 4.474.

In all the twenty four parents, only one line, (L_{14}) exhibited bi value significantly different from unity, however, lines, L_7, L_{11}, L_{12}, L_{13}, L_{18}, L_{21} and tester, T_1 had S^2di value non-significantly different from zero indicating stable nature of these lines and tester. The desirable and stable parental lines over environments were L_7, L_{12}, L_{13} and T_1 because having

($\overline{X}i > 68.71$, bi = 1, $S^2di = 0$) across the environments. Lines, L_1, L_4, L_9, L_{10}, L_{20} and T_3 were suitable for rich environment because of ($\overline{X}i > 68.71$, bi >1, high S^2di). However, L_3, L_5, L_8, L_{14}, L_{19} and T_2 were suitable for poor environment because of ($\overline{X}i > 68.71$, bi much less than 1, low S^2di).

Among the crosses, $L_1 \times T_3$, $L_4 \times T_2$, $L_{12} \times T_3$, $L_{14} \times T_3$, $L_{15} \times T_3$, $L_{16} \times T_3$, $L_{17} \times T_2$ and $L_{19} \times T_2$ exhibited bi values significantly different from unity. However, S^2di values were non-significant for $L_1 \times T_2$, $L_2 \times T_1$, $L_3 \times T_1$, $L_3 \times T_2$, $L_4 \times T_1$, $L_4 \times T_3$, , $L_8 \times T_2$, $L_9 \times T_3$, , $L_{10} \times T_2$, $L_{11} \times T_1$, $L_{11} \times T_3$, $L_{13} \times T_2$, $L_{13} \times T_3$, $L_{14} \times T_3$, $L_{15} \times T_1$, $L_{17} \times T_1$, $L_{17} \times T_3$, $L_{20} \times T_3$, $L_{21} \times T_1$ and HQPM-1. The most desirable and stable hybrids having high mean ($\overline{X}i > 68.71$, bi = 1 and $S^2di = 0$) were $L_3 \times T_1$, $L_3 \times T_2$, $L_9 \times T_3$, $L_{10} \times T_2$, $L_{11} \times T_3$ and $L_{13} \times T_2$. The hybrids, $L_1 \times T_1$, $L_5 \times T_2$, $L_5 \times T_3$, $L_8 \times T_1$, $L_8 \times T_3$, $L_{12} \times T_2$, $L_{16} \times T_1$, $L_{16} \times T_2$ and Shakti-1 were suitable for rich environment because of ($\overline{X}i > 68.71$, bi >1, high S^2di). However, $L_2 \times T_2$, $L_2 \times T_3$, $L_4 \times T_2$, $L_5 \times T_1$, $L_7 \times T_2$, $L_{10} \times T_1$, $L_{12} \times T_3$, $L_{14} \times T_1$, and $L_{16} \times T_3$ were suitable for poor environment because of ($\overline{X}i > 68.71$, bi much less than 1, low S^2di).

4.5.3.3 100-kernel weight (g)

The mean performance of genotypes ranged from 20.04 to 40.07 with an overall mean of 35.7 and bi values from -1.113 to 16.63 (Table 4.5.3). All the parents showed bi values non-significantly different from unity indicating their average performance, while lines, L_3, L_4, L_6, L_8, L_{11}, L_{12} L_{13}, L_{15} and L_{16} exhibited non-significantly different S^2di values from

Table 4.5.3: Stability parameters for 100-kernel weight and ear length in different genotypes pooled over environments

Genotype	100-kernel weight (g)			Ear length (cm)		
	$\bar{X}i$	bi	S^2di	$\bar{X}i$	bi	S^2di
Parent						
L_1	20.04	1.633	24.40**	16.21	1.091	1.650
L_2	34.86	1.079	22.36**	14.39	-0.243	7.522**
L_3	36.33	1.062	2.19	16.72	0.107	2.931*
L_4	31.41	1.436	4.11	15.83	0.691	-0.005
L_5	35.83	1.945	43.12**	16.32	1.053	0.051
L_6	35.40	0.992	3.13	16.77	0.992	0.069
L_7	35.63	3.106*	18.21**	16.88	0.306	1.232
L_8	36.36	0.936	1.06	15.10	0.852	0.209
L_9	36.23	1.807	25.27**	15.88	0.967	6.337**
L_{10}	34.40	2.479	31.03**	16.43	1.946	10.883**
L_{11}	33.43	2.116	0.54	15.32	1.87	1.172
L_{12}	40.07	1.024	0.46	16.96	-0.031	0.657
L_{13}	38.56	0.105	12.99**	16.22	0.222	2.260*
L_{14}	34.66	1.017	26.79**	14.99	1.807	7.372**
L_{15}	35.60	1.593	1.21	15.06	1.081	1.013
L_{16}	34.29	0.695	1.00	15.17	0.909	1.342
L_{17}	34.70	1.852	27.35**	13.33	0.74	1.148
L_{18}	37.57	1.924	25.20**	14.69	1.058	0.423
L_{19}	35.03	1.247	28.44**	15.06	0.862	0.031
L_{20}	30.60	0.638	88.07**	15.17	-0.722	0.586
L_{21}	34.47	0.969	27.48**	16.39	1.995	14.726**
T_1	35.63	0.523	23.44**	14.61	0.43	5.489**
T_2	35.37	0.684	12.15**	16.94	0.269	2.695*
T_3	35.26	0.761	22.17**	13.78	0.086	-0.002
L_1 X T_1	37.20	1.218	26.02**	14.61	1.376	0.131
L_1 X T_2	34.90	0.462	22.53**	14.28	0.936	2.89*
L_1 X T_3	39.00	0.781	18.86**	16.61	1.024	0.376
L_2 X T_1	37.13	1.045	0.07	15.50	1.426	0.021
L_2 X T_2	34.56	1.202	0.79	14.83	0.852	0.217
L_2 X T_3	36.07	0.792	32.04**	15.17	0.659	0.747
L_3 X T_1	36.57	4.113**	32.87**	16.89	0.193	2.61*
L_3 X T_2	31.80	2.632	9.26*	13.00	0.205	2.08*
L_3 X T_3	33.93	1.398	3.18	17.72	1.553	0.055
L_4 X T_1	37.60	0.973	10.43**	16.11	0.194	2.93*
L_4 X T_2	37.10	0.604	10.83**	15.06	0.92	2.03*
L_4 X T_3	36.83	0.374	12.43**	18.28	1.986	5.969**
L_5 X T_1	35.40	0.682	1.18	15.44	1.863	1.050
L_5 X T_2	36.59	0.535	11.95**	17.28	1.882	2.88*
L_5 X T_3	38.40	2.164	18.52**	17.17	0.661	13.185**
L_6 X T_1	36.85	2.506	79.19**	16.61	1.091	1.650
L_6 X T_2	31.72	0.420	0.66	16.61	0.43	5.489**
L_6 X T_3	33.34	1.183	6.68	16.89	0.465	0.722
L_7 X T_1	38.50	1.027	0.65	16.72	1.896	0.068
L_7 X T_2	37.47	2.005	0.92	15.50	-0.079	4.148**
L_7 X T_3	36.76	0.556	13.78**	16.60	0.569	1.113
L_8 X T_1	37.87	0.996	1.46	14.95	0.177	0.007
L_8 X T_2	36.28	1.073	10.74**	14.61	0.712	0.235
L_8 X T_3	32.86	2.233	13.33**	16.05	1.366	0.403
L_9 X T_1	34.96	1.165	5.09	16.66	1.049	0.034

Table 4.5.3: Contd...

Genotype	100-kernel weight (g)			Ear length (cm)		
	$\bar{X}i$	Bi	S^2di	$\bar{X}i$	bi	S^2di
L_9 X T_2	36.26	3.245*	11.80**	15.11	1.28	0.312
L_9 X T_3	35.26	0.513	22.32**	15.89	0.186	2.81*
L_{10} X T_1	34.70	0.563	0.62	15.22	0.136	10.327**
L_{10} X T_2	37.57	0.524	13.97**	17.83	1.581	0.344
L_{10}X T_3	38.49	3.229*	29.04**	15.44	1.637	3.707**
L_{11} X T_1	36.38	1.218	0.51	15.92	0.944	0.719
L_{11} X T_2	35.97	0.369	4.18	16.39	0.701	0.043
L_{11} X T_3	36.00	3.375*	113.27**	14.88	1.345	1.402
L_{12} X T_1	31.43	2.907	0.16	15.44	1.072	0.542
L_{12} X T_2	34.54	0.125	0.01	13.77	0.883	0.115
L_{12} X T_3	36.37	2.102	65.80**	14.99	1.273	1.968
L_{13} X T_1	36.77	2.617	22.97**	15.83	2.487	9.228**
L_{13} X T_2	36.83	0.956	4.19	16.33	1.306	0.005
L_{13} X T_3	37.43	2.360	36.44**	14.89	1.569	0.017
L_{14} X T_1	34.36	0.584	23.99**	14.40	1.345	-0.006
L_{14} X T_2	38.56	2.913	41.08**	15.73	1.078	0.014
L_{14} X T_3	35.63	0.564	4.07	14.99	0.862	0.031
L_{15} X T_1	34.47	1.117	4.14	14.07	-0.126	10.630**
L_{15} X T_2	35.56	0.227	39.44**	14.33	0.362	6.91**
L_{15} X T_3	36.33	1.016	1.66	15.16	-0.322	0.490
L_{16} X T_1	37.84	2.364	32.03**	15.25	1.792	0.617
L_{16} X T_2	36.47	0.978	1.52	14.99	0.059	0.041
L_{16} X T_3	34.90	1.480	14.77**	13.99	0.862	0.031
L_{17} X T_1	32.90	1.846	1.95	15.68	1.691	1.066
L_{17} X T_2	35.46	0.733	0.36	14.23	1.322	0.262
L_{17} X T_3	35.66	1.153	4.19	15.23	1.322	0.262
L_{18} X T_1	36.83	3.768*	22.95**	14.57	0.016	0.159
L_{18} X T_2	35.20	1.117	7.1**	15.89	1.962	12.987**
L_{18} X T_3	33.23	0.137	16.39**	15.82	0.106	2.15*
L_{19} X T_1	35.50	0.935	35.54**	14.82	1.032	4.154**
L_{19} X T_2	39.42	0.241	12.09**	15.27	1.873	1.675
L_{19} X T_3	37.06	0.976	2.18	15.27	0.68	0.202
L_{20} X T_1	36.33	2.194	33.71**	13.77	-0.818	0.921
L_{20} X T_2	34.12	1.232	59.99**	16.43	1.055	0.104
L_{20} X T_3	34.38	1.683	32.06**	13.43	1.338	0.851
L_{21} X T_1	34.49	1.577	35.61**	14.60	1.605	1.229
L_{21} X T_2	34.00	1.004	2.20	15.37	-0.138	0.784
L_{21} X T_3	35.50	0.269	2.15	14.66	0.563	1.425
HQPM- 1	34.63	1.731	0.56	18.10	1.207	1.907
Shakti – 1	35.49	2.376	39.15**	15.21	1.447	0.129
Pragati	35.43	1.303	1.90	16.00	1.654	-0.001
Mean	35.70	1.00		15.37	1.00	
SE (±)	2.4	0.60		1.02	0.89	

*,** Significant at 5% and 1 % probability levels, respectively.

zero. All the three testers exhibited significantly different S^2di values from zero. The most desirable and stable lines were L_3, L_8 and L_{12} across the environments. Lines, L_5, L_9 and L_{18} were suitable for rich environment because of ($\overline{X}i > 35.7$, bi >1, high S^2di). However, L_{13} was suitable for poor environment because of ($\overline{X}i > 35.70$, bi much less than 1, low S^2di).

All the crosses except $L_3 \times T_1$, $L_9 \times T_2$, $L_{10} \times T_3$, $L_{11} \times T_3$ and $L_{18} \times T_1$ exhibited non-significant bi values from unity indicating average response. Similarly, all the crosses, $L_2 \times T_1$, $L_2 \times T_2$, $L_3 \times T_3$, $L_5 \times T_1$, $L_6 \times T_2$, $L_6 \times T_3$, $L_7 \times T_1$, $L_7 \times T_2$, $L_8 \times T_1$, $L_9 \times T_1$, $L_{10} \times T_1$, $L_{11} \times T_1$, $L_{11} \times T_2$, $L_{12} \times T_1$, $L_{12} \times T_2$, $L_{13} \times T_2$, $L_{14} \times T_3$, $L_{15} \times T_1$, $L_{15} \times T_3$, $L_{16} \times T_2$, $L_{17} \times T_1$, $L_{17} \times T_2$, $L_{17} \times T_3$, $L_{19} \times T_3$, $L_{21} \times T_2$, $L_{21} \times T_3$ and Pragati showed non-significant S^2di values from zero showing their stable performance over environments. The crosses showing desirable stability i.e., high mean (>35.7, bi = 1, $S^2di = 0$) were $L_2 \times T_1$, $L_7 \times T_1$, $L_8 \times T_1$, $L_{13} \times T_2$, $L_{15} \times T_3$, $L_{16} \times T_2$, and $L_{19} \times T_3$ across the environments. The hybrids, $L_3 \times T_1$, $L_5 \times T_3$, $L_6 \times T_1$, $L_9 \times T_2$, $L_{10} \times T_3$, $L_{11} \times T_3$, $L_{12} \times T_3$, $L_{13} \times T_1$, $L_{14} \times T_2$, $L_{16} \times T_1$, $L_{18} \times T_1$, $L_{20} \times T_1$ and Shakti-1 were suitable for rich environment because of ($\overline{X}i > 35.7$, bi >1, high S^2di). However, $L_1 \times T_3$, $L_4 \times T_2$, $L_4 \times T_3$, $L_5 \times T_2$, $L_7 \times T_3$, $L_8 \times T_2$, $L_{10} \times T_2$ and $L_{19} \times T_2$ were suitable for poor environment because of ($\overline{X}i > 35.7$, bi much less than 1, low S^2di).

4.5.3.4 Ear length (cm)

The mean performance of genotypes ranged from 13.00 to 18.28 with an overall mean of 15.37 and bi values from -0.894 to 2.882 (Table 4.5.3).

All parents showed non-significant bi value indicating average performance over environments. All the lines and tester except L_2, L_3, L_9, L_{10}, L_{13}, L_{14} L_{21}, T_1 and T_2 exhibited S^2di values non-significantly deviant from zero indicating stable performance of the lines across the environments. The most desirable and stable lines were L_1, L_5, L_6 and L_{12} across the environments. The Lines suitable for rich environment were L_{10} and L_{21} ($\overline{X}i >$ 15.37, bi >1, high S^2di). However, L_3, L_{13} and T_2 were suitable for poor environment because of ($\overline{X}i >$ 15.37, bi much less than 1, low S^2di).

Among the hybrids none exhibited bi values significantly different from unity, however, all the hybrids except $L_1 \times T_2$, $L_3 \times T_1$, $L_3 \times T_2$, $L_4 \times T_1$, $L_4 \times T_2$, $L_4 \times T_3$, $L_5 \times T_2$, $L_5 \times T_3$, $L_6 \times T_2$, $L_7 \times T_2$, $L_9 \times T_3$, $L_{10} \times T_1$, $L_{10} \times T_3$, $L_{13} \times T_1$, $L_{15} \times T_1$, $L_{15} \times T_2$, $L_{18} \times T_2$, $L_{18} \times T_3$ and $L_{19} \times T_1$ had S^2di value non-significantly different from zero indicating their stable performance. The most desirable and stable crosses having high mean (>15.37, bi = 1 and S^2di = 0 across the environments were $L_1 \times T_3$, $L_6 \times T_1$, $L_9 \times T_1$, $L_{11} \times T_1$, $L_{12} \times T_1$ and $L_{20} \times T_2$. Hybrids, $L_4 \times T_3$, $L_5 \times T_3$, $L_7 \times T_2$, $L_{13} \times T_1$ and $L_{18} \times T_2$ exhibited high mean value, regression coefficient higher than the unity and high deviation from linearity indicating suitableness for rich environment. However, crosses $L_3 \times T_1$, $L_4 \times T_1$, $L_9 \times T_3$ and $L_{18} \times T_3$, $L_{12} \times T_1$ showed high mean value than general mean, much lesser value for regression coefficient and low deviation from linearity indicating good hybrids for poor environment.

4.5.3.5 Ear diameter (cm)

The mean performance of genotypes varied from 3.53 to 5.10 with an overall mean of 4.24 and the range of bi value from -1.516 to 6.791 (Table 4.5.4).

All the twenty four parents except L_3 and L_{14} exhibited bi values non-significantly different from unity indicating average performance of lines over environments. L_1, L_7, L_9, L_{12}, L_{13}, L_{14}, L_{17}, L_{20} and L_{21} had S^2di value significantly different from zero indicating more unstable performance of these lines than the rest. The desirable and stable lines and tester over environments were L_6, L_8, L_{10}, L_{15}, L_{19} T_1 and T_3. However, lines L_9, L_{17} and L_{21} exhibited high mean value, regression coefficient higher than the unity and high deviation from linearity indicating suitableness for rich environment. While, lines L_1, L_7, L_{12} and L_{13} showed high mean value than general mean, much lesser value for regression coefficient and low deviation from linearity indicating good hybrids for poor environment.

However, all the crosses except $L_{15} \times T_1$, $L_{17} \times T_1$, $L_{21} \times T_1$ and $L_{21} \times T_2$ had bi values non-significantly different from unity and all except $L_4 \times T_3$, $L_5 \times T_3$, $L_6 \times T_3$, $L_7 \times T_2$, $L_8 \times T_1$, $L_8 \times T_2$, $L_9 \times T_1$, $L_9 \times T_3$, $L_{10} \times T_2$, $L_{13} \times T_2$, $L_{13} \times T_3$, $L_{16} \times T_1$, $L_{16} \times T_3$, $L_{17} \times T_2$, $L_{18} \times T_1$, $L_{20} \times T_1$, $L_{21} \times T_1$ and $L_{21} \times T_2$ showed S^2di values non-significantly different from zero. These hybrids could be considered stable for this trait. However, according to criteria of desirable stability i.e., high mean (>4.24), bi = 1, $S^2di = 0$, the crosses, $L_1 \times T_2$, $L_5 \times T_2$, $L_{14} \times T_2$, $L_{16} \times T_2$, $L_{18} \times T_2$, $L_{19} \times T_2$

Table 4.5.4: Stability parameters for ear diameter and number of kernel rows per ear in different genotypes pooled over environments

Genotype	Ear diameter (cm)			Number of kernel rows / ear		
	$\bar{X}i$	bi	S^2di	$\bar{X}i$	bi	S^2di
Parent						
L_1	4.43	0.143	0.189*	13.21	-0.964	1.36
L_2	4.13	0.944	0.057	13.50	1.823	0.139
L_3	4.37	4.555**	-0.005	14.17	0.562	-0.008
L_4	4.17	-0.399	0.061	11.94	-0.178	0.268
L_5	4.17	0.485	0.003	12.99	0.682	1.71
L_6	4.53	0.971	-0.004	13.21	0.859	0.612
L_7	4.67	-0.163	0.425**	12.99	0.682	1.71
L_8	4.47	0.985	0.003	12.65	-0.744	1.87
L_9	4.50	1.917	1.493**	13.88	1.011	0.009
L_{10}	4.47	1.021	0.003	13.77	0.985	-0.004
L_{11}	4.20	0.727	0.015	13.21	4.434*	0.254
L_{12}	4.27	0.016	0.156*	13.27	1.242	0.492
L_{13}	4.33	0.116	0.156*	13.28	0.08	2.06
L_{14}	3.93	3.472*	0.192*	11.66	2.001	0.816
L_{15}	4.37	1.012	-0.004	15.17	2.096	8.185**
L_{16}	4.27	0.134	0.051	14.33	0.998	0.080
L_{17}	4.77	0.269	1.247**	12.61	1.903	1.10
L_{18}	3.93	1.342	-0.008	12.56	-0.023	0.235
L_{19}	4.27	0.997	0.015	13.28	1.348	2.06
L_{20}	4.00	2.087	0.133*	15.56	-1.074	3.680*
L_{21}	4.90	0.053	1.819**	12.83	1.823	0.139
T_1	4.50	1.027	0.005	13.00	0.334	0.294
T_2	3.83	2.858	0.086	12.83	1.037	0.061
T_3	3.83	1.041	-0.007	12.61	0.859	0.612
L_1 X T_1	4.50	2.027	0.051	13.44	0.934	0.460
L_1 X T_2	4.67	1.056	-0.006	14.17	0.762	7.55**
L_1 X T_3	4.17	0.002	-0.008	13.06	0.964	1.36
L_2 X T_1	4.63	2.000	0.038	14.98	1.431	13.663**
L_2 X T_2	4.27	1.784	0.029	12.72	0.035	0.511
L_2 X T_3	4.67	0.004	-0.009	13.39	1.089	0.505
L_3 X T_1	4.50	2.027	0.051	13.50	0.958	0.827
L_3 X T_2	4.10	-0.087	0.019	13.94	1.037	2.63
L_3 X T_3	4.10	0.173	0.097	12.17	2.327	2.10
L_4 X T_1	4.27	-1.516	0.091	13.06	0.709	4.364**
L_4 X T_2	4.17	0.002	-0.008	14.17	-0.506	3.336*
L_4 X T_3	4.67	1.654	1.180*	13.50	0.858	0.827
L_5 X T_1	4.33	1.212	0.056	13.33	1.065	0.374
L_5 X T_2	4.33	0.955	0.013	14.17	0.789	0.419
L_5 X T_3	4.43	0.083	0.237**	13.06	0.964	1.36
L_6 X T_1	4.43	1.342	-0.008	13.17	0.381	1.88
L_6 X T_2	4.33	1.212	0.056	12.22	0.889	0.083
L_6 X T_3	4.50	2.425	2.246**	14.39	1.025	2.48
L_7 X T_1	4.20	1.429	0.016	13.28	1.042	2.86
L_7 X T_2	4.93	0.303	0.313**	14.50	0.242	3.082*
L_7 X T_3	3.93	0.372	0.029	12.54	1.115	2.91
L_8 X T_1	4.40	-1.403	0.361**	15.28	1.876	19.863**
L_8 X T_2	4.60	1.568	2.346**	13.06	0.426	0.145

Table 4.5.4: Contd....

Genotype	Ear diameter (cm)			Number of kernel rows / ear		
	$\overline{X}i$	bi	S^2di	$\overline{X}i$	bi	S^2di
L_8 X T_3	4.27	0.13	0.051	13.50	6.116**	0.633
L_9 X T_1	3.67	2.13	0.200**	12.99	1.47	0.426
L_9 X T_2	4.00	1.429	0.016	14.72	2.036	36.070**
L_9 X T_3	4.47	-0.269	0.247**	13.72	1.743	3.308*
L_{10} X T_1	4.13	0.944	0.057	13.05	1.212	0.057
L_{10} X T_2	4.57	1.575	0.858**	13.95	0.899	0.600
L_{10}X T_3	4.07	0.944	0.057	12.77	0.786	0.409
L_{11} X T_1	4.17	0.003	-0.008	13.28	1.645	0.013
L_{11} X T_2	4.33	1.801	0.111	12.83	1.037	0.061
L_{11} X T_3	3.97	-0.572	-0.004	12.77	0.249	0.830
L_{12} X T_1	4.17	0.086	0.019	15.21	8.975**	2.51
L_{12} X T_2	4.23	0.571	-0.004	13.21	0.602	0.008
L_{12} X T_3	4.10	0.004	-0.008	13.21	1.645	0.013
L_{13} X T_1	4.47	0.129	0.051	13.28	1.903	1.10
L_{13} X T_2	4.88	2.973	1.238**	13.06	3.036	0.399
L_{13} X T_3	5.10	6.791**	1.980**	13.28	1.39	0.600
L_{14} X T_1	4.13	1.515	0.091	12.90	0.531	2.44
L_{14} X T_2	4.63	0.857	0.001	13.90	0.952	0.029
L_{14} X T_3	4.23	1.558	0.148*	14.04	1.465	5.054**
L_{15} X T_1	4.07	3.074*	0.495**	13.34	1.082	1.71
L_{15} X T_2	3.90	0.641	0.090	13.44	1.003	2.99
L_{15} X T_3	4.10	0.002	-0.008	12.32	2.787	2.40
L_{16} X T_1	4.40	0.216	0.456**	14.18	0.934	0.021
L_{16} X T_2	4.40	1.041	0.090	14.17	0.154	3.791*
L_{16} X T_3	3.93	-0.216	0.156*	12.77	0.249	0.830
L_{17} X T_1	4.17	3.213*	-0.006	13.57	1.023	0.139
L_{17} X T_2	4.13	-0.788	0.209**	12.90	1.292	1.39
L_{17} X T_3	4.07	1.429	0.016	12.90	0.531	2.44
L_{18} X T_1	4.80	2.13	2.200**	12.90	0.531	2.44
L_{18} X T_2	4.50	1.042	0.025	13.00	0.837	1.62
L_{18} X T_3	3.70	1.784	0.029	14.82	2.943	17.917**
L_{19} X T_1	4.10	0.002	-0.008	12.27	-0.456	0.002
L_{19} X T_2	4.33	0.987	0.090	13.21	2.434	0.254
L_{19} X T_3	4.33	0.991	0.085	13.21	1.39	0.600
L_{20} X T_1	3.53	1.16	0.425**	12.54	1.142	2.86
L_{20} X T_2	4.17	-0.572	-0.004	13.16	1.005	2.57
L_{20} X T_3	3.83	0.641	0.090	12.32	0.433	0.150
L_{21} X T_1	5.03	6.791**	1.980**	14.04	0.934	0.021
L_{21} X T_2	4.43	3.074*	0.495**	14.04	0.943	0.263
L_{21} X T_3	4.33	-0.356	0.110	13.65	0.978	0.268
HQPM- 1	4.27	1.212	0.056	14.10	0.789	0.419
Shakti – 1	3.67	1.143	0.007	12.49	2.58	0.286
Pragati	4.33	1.212	0.056	13.06	1.47	0.426
Mean	4.24	1.00		13.34	1.00	
SE (±)	0.28	1.11		1.o6	1.42	

*,** Significant at 5% and 1 % probability levels, respectively.

and $L_{19} \times T_3$ were identified as most desirable and stable ones. Hybrids, $L_4 \times T_3$, $L_6 \times T_3$, $L_8 \times T_2$, $L_{10} \times T_2$, $L_{13} \times T_2$ and $L_{18} \times T_1$ exhibited high mean value, regression coefficient higher than the unity and high deviation from linearity indicating suitableness for rich environment. However, crosses $L_5 \times T_3$, $L_7 \times T_2$, $L_8 \times T_1$, $L_9 \times T_3$ and $L_{16} \times T_1$ showed high mean value than general mean, much lesser value for regression coefficient and low deviation from linearity indicating good hybrids for poor environment

4.5.3.6 Number of kernel rows per ear

The average performance of genotypes presented in the Table 4.5.4, ranged from 11.66 to 15.28 with an overall mean 13.34 and bi value ranged from –1.435 to 3.975. All the parents (lines and testers), except L_{11} showed non-significantly different value of bi than unity, however, lines L_{15} and L_{20} exhibited significant S^2di value. Thus, these lines indicated an unstable performance over the environments and rest of the lines and testers exhibited non-significant S^2di values from zero showing stable response over environments. The most desirable and stable lines across the environments were L_9, L_{10} and L_{16}. The Lines suitable for rich environment were L_{15} ($\overline{X}i > 15.37$, bi >1, high S^2di). However, L_{13}, L_{19} and L_{20} were suitable for poor environment because of ($\overline{X}i > 15.37$, bi much less than 1, low S^2di). While T_2 exhibited low performance and moderate degree of fluctuation from linearity indicating suitableness for average environment.

Among the crosses, all crosses except $L_8 \times T_3$ and $L_{12} \times T_1$ showed non-significant value for bi, however, S^2di value were significant for hybrids, $L_1 \times T_2$, $L_2 \times T_1$, $L_4 \times T_1$, $L_4 \times T_2$, $L_7 \times T_2$, $L_8 \times T_1$, $L_9 \times T_2$, $L_9 \times T_3$, $L_{14} \times T_3$, $L_{16} \times T_2$ and $L_{18} \times T_3$ indicating unstable performance of these crosses. The hybrids, $L_1 \times T_1$, $L_2 \times T_3$, $L_3 \times T_1$, $L_3 \times T_2$, $L_4 \times T_3$, $L_5 \times T_1$, $L_5 \times T_2$, $L_6 \times T_3$, $L_7 \times T_1$, $L_{10} \times T_2$, $L_{14} \times T_2$, $L_{15} \times T_1$, $L_{15} \times T_2$, $L_{16} \times T_1$, $L_{17} \times T_1$, $L_{21} \times T_1$, $L_{21} \times T_2$, $L_{21} \times T_3$ and HQPM-1 having higher mean (>13.34), bi = 1, $S^2di = 0$ were found to be most desirable and stable across the environments. Hybrids, $L_1 \times T_2$, $L_2 \times T_1$, $L_8 \times T_1$, $L_9 \times T_2$, $L_{14} \times T_3$ and $L_{18} \times T_3$ exhibited high mean value, regression coefficient higher than the unity and high deviation from linearity indicating suitableness for rich environment. However, crosses $L_4 \times T_2$, $L_7 \times T_2$ and $L_{16} \times T_2$ showed high mean value than general mean, much lesser value for regression coefficient and low deviation from linearity indicating good hybrids for poor environment

4.5.3.7 Number of kernels per row

The mean performance of genotypes varied from 27.69 to 37.21 with an overall mean of 32.13. The regression coefficient (bi) values ranged from -1.856 to 3.88 (Table 4.5.5).

All the parents differed non-significantly from unity (bi = 1)except L_{11} indicating their average response over environments. S^2di values non-significantly different from zero exhibited by all lines and testers except L_2, L_3, L_{13} and L_{15} and T_2 indicating their stable performance across the environments. The desirable and stable lines were L_1, L_5, L_6,

Table 4.5.5: Stability parameters for number of kernels per row and brace roots in different genotypes pooled over environments

Genotype	Number of kernels / row			Number of nodes bearing brace roots		
	$\bar{X}i$	bi	S^2di	$\bar{X}i$	bi	S^2di
Parent						
L_1	33.88	0.989	9.52	1.70	3.874	0.997
L_2	38.52	1.856	44.58**	1.70	0.892	0.016
L_3	39.32	1.153	35.94**	1.90	2.261	0.580
L_4	31.83	0.430	-0.19	2.03	1.676	1.601**
L_5	34.61	0.849	9.35	1.70	0.977	0.303
L_6	34.39	1.041	2.70	1.77	1.014	0.055
L_7	34.61	1.042	1.31	1.77	2.061	0.273
L_8	30.92	0.174	8.94	1.57	0.452	0.016
L_9	33.50	0.141	3.88	1.83	5.094	0.995
L_{10}	35.94	0.952	6.07	1.97	3.652	2.092**
L_{11}	35.28	0.014*	6.71	1.47	0.033	0.039
L_{12}	34.83	0.988	0.17	1.63	2.195	0.104
L_{13}	33.83	0.194	17.22*	1.77	1.042	0.025
L_{14}	31.94	0.709	0.08	1.30	0.386	0.070
L_{15}	34.06	0.276	15.61*	1.90	2.128	0.002
L_{16}	31.36	0.452	1.04	1.90	1.024	0.156
L_{17}	29.58	1.145	6.51	1.70	3.609	0.459
L_{18}	32.28	1.043	5.98	1.23	1.297	-0.007
L_{19}	32.39	1.135	12.92	1.37	1.742	0.025
L_{20}	30.72	1.961	4.08	1.77	2.128	0.002
L_{21}	31.61	1.264	0.64	1.43	3.032	0.036
T_1	29.13	1.323	4.87	1.43	5.168*	0.005
T_2	32.72	0.502	49.58**	1.43	3.032	0.036
T_3	31.72	1.027	1.12	1.50	2.195	0.104
L_1 X T_1	32.57	1.001	0.30	1.37	1.742	0.025
L_1 X T_2	31.72	0.825	6.35	1.50	2.195	0.104
L_1 X T_3	29.94	1.399	3.14	1.30	2.58	-0.005
L_2 X T_1	32.61	0.264	8.61	1.57	1.042	0.025
L_2 X T_2	32.44	0.361	0.16	1.57	0.971	0.303
L_2 X T_3	34.44	0.981	13.11	1.50	2.322	0.048
L_3 X T_1	31.78	0.788	10.37	1.70	0.952	0.016
L_3 X T_2	29.27	1.136	2.22	1.70	1.009	0.368
L_3 X T_3	37.21	1.976	21.60**	1.83	2.194	0.104
L_4 X T_1	28.63	1.183	39.18**	1.50	1.675	0.055
L_4 X T_2	29.94	0.796	18.49*	1.43	0.905	0.086
L_4 X T_3	34.17	0.868	35.45**	1.30	0.452	0.016
L_5 X T_1	28.28	0.868	1.75	1.90	3.032	0.936
L_5 X T_2	31.75	0.395	25.47**	1.43	3.032	0.036
L_5 X T_3	34.14	0.159	29.39**	1.77	1.356	0.204
L_6 X T_1	36.63	1.012	13.06	1.43	0.905	0.086
L_6 X T_2	30.10	1.302	0.11	1.37	1.742	0.025
L_6 X T_3	38.89	1.175	61.15**	1.37	0.386	0.070
L_7 X T_1	32.72	0.685	14.22	1.37	1.742	0.025
L_7 X T_2	35.14	0.901	26.82**	1.23	1.29	-0.007
L_7 X T_3	33.17	0.076	45.93**	1.43	2.195	0.104
L_8 X T_1	29.03	-0.590	-0.18	1.57	0.998	0.303
L_8 X T_2	34.69	-0.272	41.22**	1.50	2.195	0.104

Table 4.5.5: Contd...

Genotype	Number of kernels / row			Number of nodes bearing brace roots		
	$\overline{X}i$	bi	S^2di	$\overline{X}i$	bi	S^2di
L_8 X T_3	34.83	1.008	5.35	1.43	0.905	0.086
L_9 X T_1	30.17	0.049*	43.66**	1.37	0.904	0.086
L_9 X T_2	29.83	1.748	2.69	1.87	0.004	-0.008
L_9 X T_3	32.72	1.018	4.38	1.37	1.742	0.025
L_{10} X T_1	33.50	1.197	83.86**	1.30	0.452	0.016
L_{10} X T_2	32.72	0.983	8.76	1.43	0.905	0.086
L_{10}X T_3	32.72	1.045	26.20**	1.77	0.896	0.179
L_{11} X T_1	29.98	0.585	15.62*	1.63	0.452	0.016
L_{11} X T_2	31.78	1.713	23.85**	1.83	1.016	0.179
L_{11} X T_3	30.83	1.333	0.04	1.77	2.194	0.104
L_{12} X T_1	35.17	1.862	60.08**	1.57	1.009	0.368
L_{12} X T_2	29.94	0.057*	0.07	1.37	1.296	-0.007
L_{12} X T_3	31.17	1.333	0.04	1.50	3.485	0.123
L_{13} X T_1	35.43	1.009	0.86	1.83	1.066	0.179
L_{13} X T_2	32.72	0.956	9.71	1.37	3.873	-0.001
L_{13} X T_3	30.78	0.178	9.57	1.43	0.905	0.086
L_{14} X T_1	28.17	1.91	11.02	1.50	0.905	0.086
L_{14} X T_2	31.17	1.488	0.21	1.43	3.873	-0.001
L_{14} X T_3	33.61	0.899	0.14	1.37	0.904	0.086
L_{15} X T_1	31.39	1.304	0.36	1.50	3.032	0.036
L_{15} X T_2	34.56	-0.611	25.57**	1.57	3.485	0.123
L_{15} X T_3	33.56	-1.668	-0.01	1.70	0.977	0.303
L_{16} X T_1	35.83	0.578	15.65*	1.37	2.583	-0.005
L_{16} X T_2	30.59	1.727	13.89	1.50	2.195	0.104
L_{16} X T_3	29.83	1.273	4.79	1.50	0.771	0.303
L_{17} X T_1	34.52	1.021	5.57	1.57	2.195	0.104
L_{17} X T_2	31.02	1.486	7.66	1.77	2.646	0.230
L_{17} X T_3	34.92	1.010	7.56	1.50	0.905	0.086
L_{18} X T_1	30.42	1.113	6.02	1.70	0.889	0.498
L_{18} X T_2	32.93	1.631	28.09**	1.23	0.838	0.008
L_{18} X T_3	30.17	1.172	12.88	1.63	0.959	0.335
L_{19} X T_1	27.69	0.776	11.17	1.30	0.386	0.070
L_{19} X T_2	34.50	1.013	-0.18	1.43	2.195	0.104
L_{19} X T_3	33.99	0.921	10.19	1.63	1.019	0.335
L_{20} X T_1	32.38	1.753	4.06	1.43	2.195	0.104
L_{20} X T_2	33.35	1.002	1.55	1.70	3.484	0.124
L_{20} X T_3	29.78	0.593	2.25	1.37	3.032	0.036
L_{21} X T_1	32.14	0.888	-0.10	1.57	1.012	0.368
L_{21} X T_2	30.88	1.486	12.7	1.37	0.904	0.086
L_{21} X T_3	31.97	1.071	24.79*	1.37	8.16**	0.005
HQPM- 1	33.39	1.028	0.05	1.57	1.676	0.055
Shakti – 1	29.09	1.095	22.51**	1.30	3.87	-0.001
Pragati	32.59	1.788	0.07	1.70	0.838	0.008
Mean	32.13	1.00		1.54	1.00	
SE (±)	2.34	1.14		0.17	1.17	

*,** Significant at 5% and 1 % probability levels, respectively.

L_7, L_{10}, L_{12}, and L_{18} because of bi values close to one and $S^2di = 0$ and high mean value than the population mean. Parents suitable for rich environment were L_2, L_3 and T_2 ($\overline{X}i > 32.13$, bi >1, high S^2di). However, L_{13}, L_{15} and L_{19} were suitable for poor environment because of ($\overline{X}i > 32.13$, bi much less than 1, low S^2di).

All the hybrids except $L_9 \times T_1$ and $L_{12} \times T_2$ exhibited non-significant bi values from unity indicating their average performance, while, $L_3 \times T_3$, $L_4 \times T_1$, $L_4 \times T_3$, $L_5 \times T_2$, $L_5 \times T_3$, $L_6 \times T_3$, $L_7 \times T_2$, $L_7 \times T_3$, $L_8 \times T_2$, $L_9 \times T_1$, $L_{10} \times T_1$, $L_{11} \times T_1$, $L_{11} \times T_2$, $L_{12} \times T_1$, $L_{15} \times T_2$, $L_{18} \times T_2$, $L_{21} \times T_3$ with check, shakti-1 showed significant deviation (S^2di) from zero indicating unstable performance. The desirable and stable crosses having higher mean than overall mean (>32.13), bi = 1 and $S^2di = 0$ were $L_1 \times T_1$, $L_2 \times T_3$, $L_6 \times T_1$, $L_8 \times T_3$, $L_9 \times T_3$, $L_{10} \times T_2$, $L_{13} \times T_1$, $L_{13} \times T_2$, $L_{14} \times T_3$, $L_{17} \times T_1$, $L_{17} \times T_3$, $L_{19} \times T_2$, $L_{19} \times T_3$, $L_{20} \times T_2$ and HQPM-1. The hybrids $L_4 \times T_3$, $L_6 \times T_3$, $L_{10} \times T_1$, $L_{11} \times T_3$ and $L_{12} \times T_1$ are suitable for rich environment because of ($\overline{X}i > 35.7$, bi >1, high S^2di). However, $L_3 \times T_3$, $L_4 \times T_2$, $L_5 \times T_2$, $L_7 \times T_2$, $L_{11} \times T_2$, $L_{15} \times T_2$ and $L_{16} \times T_1$ were suitable for poor environment because of ($\overline{X}i > 35.7$, bi much less than 1, low S^2di).

4.5.4 Number of nodes bearing brace roots

The mean performance of genotypes varied from 1.17 to 2.03 with an overall mean of 1.54. The regression coefficient (bi) values ranged from -3.87 to 8.16 (Table 4.5.5).

All the parents differed non-significantly from unity (bi = 1) except tester T_1 indicating their average response over environments. S^2di values non-significantly different from zero exhibited by all lines and testers except L_4 and L_{10} indicating their stable performance across the environments. The desirable and stable lines were L_2, L_5, L_6, L_{13} and L_{16} because of bi values close to one and $S^2di = 0$ and high mean value than the population mean. Parents suitable for rich environment were L_1, L_9 and L_{10} ($\overline{X}i > 32.13$, bi >1, high S^2di). However, L_4 and L_8 are suitable for poor environment because of ($\overline{X}i > 32.13$, bi much less than 1, low S^2di).

All the hybrids except $L_{21} \times T_3$ exhibited non-significant bi values from unity. While, all the hybrids including checks showed non-significant deviation (S^2di) from zero indicating stable performance. The desirable and stable crosses having higher mean than overall mean (>1.54), bi = 1 and $S^2di = 0$ were $L_2 \times T_1$, $L_2 \times T_2$, $L_3 \times T_1$, $L_3 \times T_2$, $L_8 \times T_1$, $L_{10} \times T_3$, $L_{11} \times T_2$, $L_{12} \times T_1$, $L_{13} \times T_1$, $L_{15} \times T_3$, $L_{18} \times T_1$, $L_{18} \times T_3$, $L_{19} \times T_3$ and $L_{21} \times T_1$. However, $L_9 \times T_2$ and $L_{11} \times T_1$ were suitable for poor environment because of ($\overline{X}i > 32.13$, bi much less than 1, low S^2di).

4.5.4.1 Days to 50 per cent tasselling

The mean performance of genotypes ranged from 48.67 to 52.33 with an overall mean of 49.69 (Table 4.5.6). Among the 24 parents, all except L_{11} showed bi value non-significant by different from unity (bi=1) indicating average response over environments and all the parents

Table 4.5.6: Stability parameters for days to 50% tasselling and days to 50% silking in different genotypes pooled over environments

Genotype	Days to 50% tasselling			Days to 50% silking		
	$\overline{X}i$	bi	S^2di	$\overline{X}i$	bi	S^2di
Parent						
L_1	48.67	0.951	1.721	52.33	0.891	0.429
L_2	48.67	0.951	1.721	52.67	12.467**	0.072
L_3	49.00	0.932	0.495	51.67	0.937	1.624
L_4	48.67	1.001	0.131	52.00	1.014	0.946
L_5	48.67	0.982	0.080	53.33	5.364	15.703**
L_6	48.67	1.026	1.398	53.00	8.54**	5.497**
L_7	48.67	1.036	1.398	52.00	0.108	4.414*
L_8	49.00	1.025	0.069	52.33	5.168	15.696**
L_9	49.00	0.156	14.398**	52.33	13.125**	0.516
L_{10}	49.67	1.011	0.131	53.33	0.959	0.136
L_{11}	49.33	13.025**	0.069	54.00	13.551**	0.147
L_{12}	48.34	4.261	22.375**	54.00	10.68*	-0.057
L_{13}	49.67	2.145	16.791**	52.00	2.945	17.425**
L_{14}	50.00	1.025	0.069	53.67	0.985	3.293*
L_{15}	50.00	1.025	0.069	54.67	1.349	0.204
L_{16}	49.33	0.952	0.080	53.00	1.592	4.622*
L_{17}	48.00	0.156	10.398**	53.33	-0.923	3.444*
L_{18}	48.67	1.965	0.117	52.33	13.015**	0.894
L_{19}	48.67	1.023	0.117	52.67	13.136**	-0.063
L_{20}	49.00	1.024	0.117	52.67	1.015	0.894
L_{21}	49.33	1.009	0.357	53.67	3.379	1.911
T_1	48.33	1.396	19.295**	53.00	12.269**	15.942**
T_2	48.77	1.658	20.083**	53.33	1.014	0.276
T_3	49.00	0.763	1.168	53.00	13.258**	18.774**
L_1 X T_1	49.67	1.009	0.357	53.67	-0.004	-0.131
L_1 X T_2	51.00	2.946	0.168	55.00	13.813**	-0.084
L_1 X T_3	50.33	1.924	0.117	53.33	13.136**	-0.063
L_2 X T_1	50.67	2.433	0.024	54.00	13.379**	1.911
L_2 X T_2	51.00	1.025	0.069	55.33	1.228	-0.062
L_2 X T_3	50.33	2.182	2.694	53.67	0.985	3.293*
L_3 X T_1	52.00	1.527	3.063	55.33	2.026	0.613
L_3 X T_2	52.33	1.909	3.983	55.33	2.945	27.425**
L_3 X T_3	49.00	3.077	1.650	52.33	3.448	5.303*
L_4 X T_1	50.00	2.815	0.061	53.33	1.058	0.276
L_4 X T_2	50.00	2.171	1.474	54.00	3.5	24.841**
L_4 X T_3	50.33	14.276**	0.713	54.00	1.349	0.204
L_5 X T_1	49.00	14.407**	-0.112	52.67	1.043	1.632
L_5 X T_2	50.67	2.044	3.102	54.33	12.702**	1.181
L_5 X T_3	51.33	-13.025**	0.069	55.67	1.228	-0.062
L_6 X T_1	49.33	1.025	0.069	53.00	0.951	0.147
L_6 X T_2	50.33	2.433	-0.024	54.00	2.702	1.181
L_6 X T_3	51.67	0.905	3.612	55.67	9.681**	0.058
L_7 X T_1	51.00	1.669	1.997	55.00	0.673	0.044
L_7 X T_2	51.67	1.669	1.997	55.67	0.673	0.044
L_7 X T_3	50.67	2.302	0.099	53.67	3.379	1.911
L_8 X T_1	50.33	2.433	-0.024	54.33	2.026	0.612
L_8 X T_2	50.00	1.407	-0.112	54.67	2.026	0.613
L_8 X T_3	49.33	0.992	-0.117	52.33	3.57	12.211**

Table 4.5.6: Contd...

Genotype	Days to 50% tasselling			Days to 50% silking		
	$\overline{X}i$	bi	S^2di	$\overline{X}i$	bi	S^2di
L_9 X T_1	49.67	1.007	-0.112	52.67	1.015	0.894
L_9 X T_2	51.33	1.538	0.316	52.67	3.985	13.293**
L_9 X T_3	50.00	2.564	1.107	53.00	1.033	1.533
L_{10} X T_1	49.33	1.038	0.316	54.67	0.217	4.241*
L_{10} X T_2	50.00	1.538	0.316	54.00	1.661	2.333
L_{10}X T_3	49.67	1.025	0.069	54.00	1.661	2.333
L_{11} X T_1	49.67	0.894	-0.008	55.33	0.673	-0.044
L_{11} X T_2	49.67	1.012	-0.112	53.33	1.002	2.333
L_{11} X T_3	49.33	0.894	-0.008	54.33	2.026	0.612
L_{12} X T_1	49.50	15.894**	-0.008	52.83	0.991	0.147
L_{12} X T_2	49.17	-14.381**	0.194	53.50	0.136	5.703*
L_{12} X T_3	48.83	0.912	-0.080	54.50	10.04**	-0.131
L_{13} X T_1	48.67	1.001	-0.131	51.33	0.973	-0.044
L_{13} X T_2	48.67	1.025	1.721	52.67	1.007	0.072
L_{13} X T_3	48.67	0.984	0.898	52.00	11.349**	0.203
L_{14} X T_1	48.67	-0.001	-0.131	51.67	1.004	-0.131
L_{14} X T_2	49.00	0.912	0.080	52.33	1.025	0.516
L_{14} X T_3	49.33	0.981	0.194	52.67	-0.437	1.624
L_{15} X T_1	49.33	0.913	0.083	53.00	1.014	0.946
L_{15} X T_2	48.67	1.001	0.131	52.67	1.033	0.572
L_{15} X T_3	49.00	1.041	2.375	52.33	0.959	0.136
L_{16} X T_1	48.67	-13.644**	0.895	52.67	0.997	1.624
L_{16} X T_2	49.67	0.943	0.898	52.00	0.951	0.146
L_{16} X T_3	49.00	0.912	0.080	52.33	1.007	0.177
L_{17} X T_1	49.33	1.001	0.131	52.67	1.014	0.946
L_{17} X T_2	49.00	1.025	0.069	53.00	0.308	-14.414**
L_{17} X T_3	48.67	1.032	0.193	53.33	0.896	-0.086
L_{18} X T_1	50.00	1.538	0.316	53.67	1.106	0.968
L_{18} X T_2	49.33	0.893	0.496	54.00	0.187	8.491**
L_{18} X T_3	49.67	0.894	0.008	54.33	12.338**	1.534
L_{19} X T_1	50.33	12.001**	0.131	54.00	11.106**	0.968
L_{19} X T_2	50.00	0.381	0.194	53.33	-10.004**	-0.131
L_{19} X T_3	49.67	1.002	0.193	52.67	0.968	-0.057
L_{20} X T_1	48.83	0.912	0.080	52.83	0.985	13.293**
L_{20} X T_2	49.17	0.981	0.194	53.17	1.125	0.516
L_{20} X T_3	49.83	-0.644	0.895	54.17	0.551	0.147
L_{21} X T_1	50.00	0.763	1.168	53.67	1.661	2.333
L_{21} X T_2	49.00	0.982	0.193	53.00	1.047	2.458
L_{21} X T_3	48.67	0.944	0.895	52.33	0.993	13.274**
HQPM- 1	52.00	0.164	4.587*	56.33	2.268	15.944**
Shakti – 1	49.00	1.012	0.080	51.67	0.794	1.061
Pragati	50.67	0.152	5.541*	53.33	2.269	15.943**
Mean	49.69	1.00		53.39	1.00	
SE (±)	0.61	0.55		0.89	0.65	

*,** Significant at 5% and 1 % probability levels, respectively.

except L_9 L_{12} L_{13} L_{17}, T_1 and T_2 had non-significant S^2di value from zero indicating lines to be stable for days to 50 per cent tasselling over environments. The most desirable and stable lines having low mean indicating early flowering than overall mean (<49.69), bi = 1 and S^2di = 0 for early flowering were L_1, L_2, L_3, L_4, L_5, L_6 L_7, L_8, L_{10}, L_{16}, L_{18}, L_{19} L_{20}, L_{21} and T_3. The most desirable parents for rich environment, having low mean indicating early flowering than overall mean (<49.69), bi > 1 and high S^2di value for early flowering were L_{12}, L_{13}, T_1 and T_2. However, lines L_9 and L_{17} showed low mean than overall mean (<49.69), bi much less than 1 and low S^2di value suitable for poor environment.

The crosses $L_4 \times T_3$, $L_5 \times T_1$, $L_5 \times T_3$, $L_{12} \times T_1$, $L_{12} \times T_2$, $L_{16} \times T_1$ and $L_{19} \times T_1$ exhibited significant bi values from unity. All the crosses had non-significant S^2di values except checks, HQPM-1 and Pragati. The most desirable i.e. having mean lower than the population mean and stable (bi = 1 and S^2di = 0) crosses over environments were $L_1 \times T_1$, $L_6 \times T_1$, $L_8 \times T_3$, $L_9 \times T_1$, $L_{10} \times T_1$, $L_{10} \times T_3$, $L_{11} \times T_1$, $L_{11} \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_3$, $L_{13} \times T_1$, $L_{13} \times T_2$, $L_{13} \times T_3$, $L_{14} \times T_1$, $L_{14} \times T_2$, $L_{14} \times T_3$ $L_{15} \times T_1$, $L_{15} \times T_2$, $L_{15} \times T_3$, $L_{16} \times T_2$, $L_{16} \times T_3$, $L_{17} \times T_1$, $L_{17} \times T_2$, $L_{17} \times T_3$, $L_{18} \times T_2$, $L_{18} \times T_3$, $L_{19} \times T_3$, $L_{20} \times T_1$, $L_{20} \times T_2$, $L_{21} \times T_2$, $L_{21} \times T_3$ and check Shakti-1 for this trait. However, checks HQPM-1 and Pragati had high mean than overall mean with bi value much less than unity and low S^2di indicating good for poor environment.

4.5.4.2 Days to 50 per cent silking

The average performance of genotypes for days to 50 per cent silking, along with the regression (bi) and deviation from regression

(S^2di) are presented in the Table 4.5.6. The mean values for this character ranged from 51.53 to 56.33 with overall mean of 53.39. The range of bi values varied from -2.467 to 13.836. Among all the 24 parents, 7 lines, L_2, L_6, L_9, L_{11}, L_{12} L_{18}, L_{19} and two testers, T_1 and T_3 exhibited significant regression coefficient (bi). And all the lines except L_5, L_6, L_7, L_8, L_{13} L_{14}, L_{16}, L_{17} and testers T_1 and T_3 exhibited non-significant deviation from linearity (S^2di) indicating the stable performance of the parental lines across the environments. The most desirable lines were L_1, L_3 L_4, L_{10}, L_{20} and tester T_2, due to low mean (<53.39), bi = 1 and S^2di = 0 exhibiting early silking. The most desirable parents for rich environment, having low mean indicating early silking than overall mean (<53.39), bi > 1 and high S^2di value for early flowering, were L_5, L_6, L_8, L_{13}, T_1 and T_2. However, lines L_{14}, L_{16} and L_{17} showed high mean than overall mean (<49.69), bi much less than 1 and low S^2di value, suitable for poor environment.

All the crosses showed non-significant bi values except $L_1 \times T_2$, $L_2 \times T_1$, $L_5 \times T_2$, $L_6 \times T_3$, $L_{12} \times T_3$, $L_{13} \times T_3$, $L_{18} \times T_3$, $L_{19} \times T_1$ and $L_{19} \times T_2$. The value of S^2di were non-significant for all the crosses except $L_2 \times T_3$, $L_3 \times T_2$, $L_3 \times T_3$, $L_4 \times T_2$, $L_8 \times T_3$, $L_9 \times T_2$, $L_{10} \times T_1$, $L_{12} \times T_2$, $L_{17} \times T_2$, $L_{18} \times T_2$, $L_{20} \times T_1$, $L_{21} \times T_3$, with checks, HQPM-1 and Pragati. The most desirable and stable crosses having lower mean (<53.39), bi = 1 and S^2di = 0 for days to 50 per cent silking were $L_4 \times T_1$, $L_5 \times T_1$, $L_6 \times T_1$, $L_9 \times T_1$, $L_9 \times T_3$, $L_{11} \times T_2$, $L_{12} \times T_1$, $L_{13} \times T_1$, $L_{13} \times T_2$. $L_{14} \times T_1$, $L_{14} \times T_2$, $L_{15} \times T_1$, $L_{15} \times T_2$, $L_{15} \times T_3$, $L_{16} \times T_1$, $L_{16} \times T_2$, $L_{16} \times T_3$, $L_{17} \times T_1$, $L_{17} \times T_3$, $L_{19} \times$

T_3, $L_{20} \times T_2$, $L_{21} \times T_2$, $L_{21} \times T_3$ and Shakti-1. The hybrids, $L_3 \times T_3$, $L_8 \times T_3$ and $L_9 \times T_2$ were suitable for rich environment because of ($\overline{Xi} < 53.39$, bi >1, high S^2di). However, $L_2 \times T_3$, $L_{10} \times T_1$, $L_{12} \times T_2$ and $L_{18} \times T_2$ were suitable for poor environment because of ($\overline{Xi} > 53.39$, bi much less than 1, low S^2di).

4.5.4.3 Anthesis-silking interval

The average performance of genotypes for days to 50 per cent silking, along with the regression (bi) and deviation from regression (S^2di) are presented in the Table 4.5.7. The mean values for this character ranged from 3.00 to 6.33 with overall mean 4.20. The range of bi values varied from -3.163 to 4.109. All the 24 parents except, 3 lines, L_1, L_2, L_5 and one tester T_3 exhibited non-significant regression coefficient (bi) indicating average performance of these parental lines. The non-significant value of deviation from linearity (S^2di) exhibited by all the lines except L_8, L_{13}, L_{16}, L_{17} L_{21} indicating the stable performance of the parental lines across the environments. The most desirable lines and testers were L_3, L_9, L_{14}, L_{18}, L_{19}, L_{20}, T_1 and T_2 due to low mean (<4.20), bi = 1 and $S^2di = 0$ exhibiting short anthesis-silking interval. The most desirable parents for rich environment, having low mean indicating less, anthesis-silking interval (ASI) than overall mean (<4.20), bi > 1 and high S^2di value for less ASI, were L_8 and L_{16}. However, lines L_{13}, L_{17} and L_{21} showed high mean than overall mean (<4.20), bi much less than 1 and low S^2di value, suitable for poor environment.

Table 4.5.7: Stability parameters for Anthesis-Silking Interval and protein (%) in different genotypes pooled over environments

Genotype	Anthesis – silking interval			Protein (%)		
	$\overline{X}i$	bi	S^2di	$\overline{X}i$	bi	S^2di
Parent						
L_1	4.33	3.163**	-0.040	8.25	1.029	-0.1263
L_2	4.67	3.228**	1.104	11.77	1.041	-0.1264
L_3	3.33	1.076	0.01	12.20	1.043	-0.1264
L_4	4.00	2.152	0.421	12.63	1.044	-0.1264
L_5	5.00	4.109**	0.809	10.60	1.037	-0.1263
L_6	4.67	-1.076	0.011	9.80	1.034	-0.1263
L_7	3.67	0.065	0.539	11.86	1.042	-0.1264
L_8	3.67	2.882	4.185**	10.20	1.036	-0.1263
L_9	4.00	1.052	0.421	11.77	1.041	-0.1264
L_{10}	4.33	1.076	0.011	11.77	1.041	-0.1264
L_{11}	5.33	1.076	0.011	11.35	1.04	-0.1264
L_{12}	4.67	2.087	-0.120	10.94	1.038	-0.1264
L_{13}	4.45	1.958	2.786**	11.35	1.04	-0.1264
L_{14}	4.00	1.011	0.073	8.65	1.03	-0.1263
L_{15}	5.00	2.022	0.668	10.20	1.036	-0.1263
L_{16}	3.67	2.969	4.505**	11.96	1.042	-0.1264
L_{17}	4.67	1.205	3.876**	10.54	1.037	-0.1263
L_{18}	3.67	1.065	0.539	8.69	1.03	-0.1263
L_{19}	4.00	0.946	1.464	11.10	1.039	-0.1264
L_{20}	4.00	1.065	0.539	8.65	1.03	-0.1263
L_{21}	4.67	1.958	2.786**	8.83	1.031	-0.1263
T_1	3.00	1.076	0.011	9.02	1.032	-0.1263
T_2	4.00	1.065	0.539	10.20	1.036	-0.1263
T_3	4.67	3.033**	1.661	10.14	1.035	-0.1263
L_1 X T_1	4.67	2.281	5.492**	8.25	1.029	-0.1263
L_1 X T_2	4.67	3.033**	1.661	8.99	1.031	-0.1263
L_1 X T_3	3.67	0.946	1.464	11.35	1.04	-0.1264
L_2 X T_1	4.00	4.045**	3.051**	11.77	1.041	-0.1264
L_2 X T_2	4.67	1.011	0.073	11.01	1.039	-0.1264
L_2 X T_3	3.67	1.152	0.421	9.02	1.032	-0.1263
L_3 X T_1	3.67	1.065	0.539	10.60	1.037	-0.1263
L_3 X T_2	3.00	1.087	-0.120	9.47	1.033	-0.1263
L_3 X T_3	3.33	1.011	0.073	11.53	1.04	-0.1264
L_4 X T_1	3.67	3.098**	0.146	10.20	1.036	-0.1263
L_4 X T_2	4.33	3.033**	1.661	10.60	1.037	-0.1263
L_4 X T_3	4.33	1.076	0.011	12.20	1.043	-0.1264
L_5 X T_1	4.33	0.129	2.533**	8.25	1.029	-0.1263
L_5 X T_2	4.33	1.076	0.011	12.20	1.043	-0.1264
L_5 X T_3	5.00	1.011	0.073	11.77	1.041	-0.1264
L_6 X T_1	4.33	1.076	0.011	8.99	1.031	-0.1263
L_6 X T_2	4.00	4.109	0.809	9.80	1.034	-0.1263
L_6 X T_3	4.33	4.174*	-0.103	11.01	1.039	-0.1264
L_7 X T_1	4.33	4.174*	-0.103	8.27	1.029	-0.1263
L_7 X T_2	5.00	4.174*	-0.103	8.58	1.03	-0.1263
L_7 X T_3	3.33	3.033	1.661	10.60	1.037	-0.1263
L_8 X T_1	4.33	4.174*	-0.103	8.65	1.03	-0.1263
L_8 X T_2	5.33	2.022	0.668	11.35	1.04	-0.1264
L_8 X T_3	3.67	1.141	1.279	10.14	1.035	-0.1263

Table 4.5.7: Contd...

Genotype	Anthesis – silking interval			Protein (%)		
	$\overline{X}i$	bi	S^2di	$\overline{X}i$	bi	S^2di
L_9 X T_1	3.33	1.141	1.279	10.60	1.037	-0.1263
L_9 X T_2	3.67	1.065	0.539	7.91	1.028	-0.1262
L_9 X T_3	3.33	1.087	-0.120	11.86	1.042	-0.1264
L_{10} X T_1	3.67	1.076	0.011	7.91	1.028	-0.1262
L_{10} X T_2	4.67	1.233	-0.126	10.54	1.037	-0.1263
L_{10}X T_3	5.00	-1.076	0.011	11.35	1.04	-0.1264
L_{11} X T_1	6.33	1.076	0.011	10.94	1.038	-0.1264
L_{11} X T_2	4.00	-1.011	0.073	9.80	1.034	-0.1263
L_{11} X T_3	5.33	0.946	1.464	10.20	1.036	-0.1263
L_{12} X T_1	3.83	1.065	0.539	9.00	1.031	-0.1263
L_{12} X T_2	4.83	3.098	0.146	9.19	1.032	-0.1263
L_{12} X T_3	4.17	2.076	0.011	10.37	1.036	-0.1263
L_{13} X T_1	3.33	1.065	0.539	8.25	1.029	-0.1263
L_{13} X T_2	4.67	3.228	1.104	8.99	1.031	-0.1263
L_{13} X T_3	4.00	1.958	2.786**	11.35	1.04	-0.1264
L_{14} X T_1	3.67	1.032	-0.126	11.77	1.041	-0.1264
L_{14} X T_2	4.00	1.065	0.539	11.35	1.04	-0.1264
L_{14} X T_3	4.00	1.112	0.421	9.36	1.033	-0.1263
L_{15} X T_1	4.33	1.076	0.011	10.94	1.038	-0.1264
L_{15} X T_2	4.67	0.194	5.857**	10.14	1.035	-0.1263
L_{15} X T_3	4.00	3.098	0.146	12.20	1.043	-0.1264
L_{16} X T_1	4.67	1.342	-0.126	10.54	1.037	-0.1263
L_{16} X T_2	3.00	1.011	0.073	10.94	1.038	-0.1264
L_{16} X T_3	4.00	1.205	3.876**	12.20	1.043	-0.1264
L_{17} X T_1	3.67	1.152	0.421	7.91	1.028	-0.1262
L_{17} X T_2	4.33	-0.946	1.464	11.86	1.042	-0.1264
L_{17} X T_3	5.00	1.076	0.011	11.43	1.04	-0.1264
L_{18} X T_1	3.67	1.076	0.011	10.68	1.037	-0.1264
L_{18} X T_2	5.33	-3.098	0.146	8.99	1.031	-0.1263
L_{18} X T_3	5.33	-2.152	0.421	10.14	1.035	-0.1263
L_{19} X T_1	4.00	-2.152	0.421	11.01	1.039	-0.1264
L_{19} X T_2	3.67	1.065	0.539	8.27	1.029	-0.1263
L_{19} X T_3	3.33	1.114	-0.126	7.91	1.028	-0.1262
L_{20} X T_1	4.50	-2.087	-0.120	10.77	1.038	-0.1264
L_{20} X T_2	4.50	-0.946	1.464	8.82	1.031	-0.1263
L_{20} X T_3	5.17	-3.163	-0.039	11.51	1.04	-0.1264
L_{21} X T_1	4.33	-3.098	0.146	10.14	1.035	-0.1263
L_{21} X T_2	4.67	-2.087	-0.120	10.94	1.038	-0.1264
L_{21} X T_3	4.33	1.076	0.011	8.25	1.029	-0.1263
HQPM- 1	5.00	1.205	3.876**	11.35	1.04	-0.1264
Shakti – 1	3.33	1.022	0.668	10.14	1.035	-0.1263
Pragati	3.33	1.011	0.073	10.94	1.038	-0.1264
Mean	4.20	1.00		10.28	1.00	
SE (±)	0.69	1.45		0.041	0.27	

*,** Significant at 5% and 1 % probability levels, respectively.

All the crosses showed non-significant bi values except $L_1 \times T_2$, $L_2 \times T_1$, $L_4 \times T_1$, $L_4 \times T_2$, $L_6 \times T_3$, $L_7 \times T_1$, $L_7 \times T_2$, $L_8 \times T_1$. The value of S^2di were significant for crosses, $L_1 \times T_1$, $L_2 \times T_1$, $L_5 \times T_1$, $L_{13} \times T_3$, $L_{15} \times T_2$, $L_{16} \times T_3$ with check HQPM-1. The most desirable and stable crosses having lower mean (<4.20), bi = 1 and $S^2di = 0$ for days to 50 per cent silking were $L_1 \times T_3$, $L_2 \times T_3$, $L_3 \times T_1$, $L_3 \times T_2$, $L_3 \times T_3$, $L_8 \times T_3$, $L_9 \times T_1$, $L_9 \times T_2$, $L_9 \times T_3$. $L_{10} \times T_1$, $L_{12} \times T_1$, $L_{13} \times T_1$, $L_{14} \times T_1$, $L_{14} \times T_2$, $L_{14} \times T_3$, $L_{16} \times T_2$, $L_{17} \times T_1$, $L_{18} \times T_1$, $L_{19} \times T_2$, $L_{19} \times T_3$ and Shakti-1 and Pragati. The hybrids $L_1 \times T_1$ and $L_{15} \times T_2$ were suitable for rich environment because of ($\overline{X}i < 4.20$, bi >1, high S^2di). However, $L_5 \times T_1$, $L_{13} \times T_3$, $L_{16} \times T_3$ and HQPM-1 were suitable for poor environment because of ($\overline{X}i > 4.20$, bi much less than 1, low S^2di).

4.5.4.4 Protein percentage

The mean performance of 90 genotypes for this quality trait varied from 7.91 to 12.63 with an overall mean value of 10.28. The bi values ranged from 1.028 to 1.044 (Table 4.5.7). All 24 parental lines exhibited non-significant bi and S^2di values showing their average and stable performance for protein percentage over environments. The most desirable and stable lines were L_2, L_3 L_4, L_5, L_7, L_9, L_{10}, L_{11} , L_{12}, L_{13} L_{16}, L_{17}, L_{19} because these also had mean value higher than population mean.

Among the crosses, none exhibited bi values significantly different from unity and S^2di from zero indicating their average and stable performance over environments. The most desirable and stable hybrids

having high mean (>10.28), bi = 1 and $S^2di = 0$ were $L_1 \times T_3$, $L_2 \times T_1$, $L_2 \times T_2$, $L_3 \times T_1$, $L_3 \times T_3$, $L_4 \times T_2$, $L_4 \times T_3$, $L_5 \times T_2$, $L_5 \times T_3$, $L_6 \times T_3$, $L_7 \times T_3$, $L_8 \times T_2$, $L_9 \times T_3$, $L_{10} \times T_2$, $L_{10} \times T_3$, $L_{11} \times T_1$, $L_{12} \times T_3$, $L_{13} \times T_3$, $L_{14} \times T_1$, $L_{14} \times T_2$, $L_{15} \times T_1$, $L_{15} \times T_3$, $L_{16} \times T_1$, $L_{16} \times T_2$, $L_{16} \times T_3$, $L_{17} \times T_2$, $L_{17} \times T_3$, $L_{18} \times T_1$, $L_{19} \times T_1$, $L_{20} \times T_1$, $L_{20} \times T_3$, $L_{21} \times T_2$ and checks, HQPM-1 and Pragati for this trait.

4.5.4.5 Lysine per cent

The mean performance of all the genotypes for this quality trait varying from 1.12 to 3.79 with an overall mean value of 2.90, is presented in Table 4.5.8. All 24 parental lines exhibited non-significant bi and S^2di values showing their average and stable performance for lysine percentage over environments. The most desirable and stable lines and testers were L_1, L_6 L_8, L_{10}, L_{18}, L_{19}, L_{21}, T_2 and T_3 because these also had mean value higher than population mean.

The most desirable and stable hybrids having high mean (>2.90), bi = 1 and $S^2di = 0$ were $L_1 \times T_1$, $L_1 \times T_3$, $L_2 \times T_1$, $L_2 \times T_2$, $L_3 \times T_2$, $L_3 \times T_3$, $L_4 \times T_1$, $L_4 \times T_3$, $L_6 \times T_1$, $L_6 \times T_3$, $L_8 \times T_1$, $L_8 \times T_2$, $L_{10} \times T_2$, $L_{10} \times T_3$, $L_{11} \times T_1$, $L_{11} \times T_1$, $L_{11} \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_2$, $L_{13} \times T_1$ $L_{14} \times T_2$, $L_{14} \times T_3$, $L_{15} \times T_1$, $L_{15} \times T_2$, $L_{16} \times T_1$, $L_{16} \times T_2$, $L_{16} \times T_3$, $L_{18} \times T_2$, $L_{18} \times T_3$, $L_{20} \times T_1$, $L_{20} \times T_2$, $L_{20} \times T_3$, $L_{21} \times T_1$ and check HQPM-1 for this trait.

4.5.4.6 Tryptophan per cent

The average performance of 90 genotypes for this quality trait varying from 0.28 to 0.96 with an overall mean value of 0.74, is

Table 4.5.8: Stability parameters for lysine % and tryptophan in different genotypes pooled over environments

Genotype	Lysine (%)			Tryptophan (%)		
	$\bar{X}i$	bi	S^2di	$\bar{X}i$	bi	S^2di
Parent						
L_1	3.31	1.00	-0.0001	0.84	1.004	-0.0001
L_2	2.63	1.00	-0.0001	0.67	1.004	-0.0001
L_3	2.71	1.00	-0.0001	0.69	1.004	-0.0001
L_4	2.23	1.00	-0.0001	0.57	1.004	-0.0001
L_5	2.43	1.00	-0.0001	0.62	1.004	-0.0001
L_6	3.31	1.00	-0.0001	0.84	1.004	-0.0001
L_7	2.15	1.00	-0.0001	0.55	1.004	-0.0001
L_8	2.95	1.00	-0.0001	0.75	1.004	-0.0001
L_9	2.79	1.00	-0.0001	0.71	1.004	-0.0001
L_{10}	2.99	1.00	-0.0001	0.76	1.004	-0.0001
L_{11}	2.47	1.00	-0.0001	0.63	1.004	-0.0001
L_{12}	2.84	1.00	-0.0001	0.73	1.004	-0.0001
L_{13}	2.76	1.00	-0.0001	0.71	1.004	-0.0001
L_{14}	2.63	1.00	-0.0001	0.67	1.004	-0.0001
L_{15}	2.41	1.00	-0.0001	0.63	1.004	-0.0001
L_{16}	2.71	1.00	-0.0001	0.69	1.004	-0.0001
L_{17}	2.83	1.00	-0.0001	0.72	1.004	-0.0001
L_{18}	3.12	1.00	-0.0001	0.80	1.004	-0.0001
L_{19}	3.27	1.00	-0.0001	0.83	1.004	-0.0001
L_{20}	2.87	1.00	-0.0001	0.73	1.004	-0.0001
L_{21}	2.92	1.00	-0.0001	0.75	1.004	-0.0001
T_1	2.80	1.00	-0.0001	0.72	1.004	-0.0001
T_2	3.28	1.00	-0.0001	0.84	1.004	-0.0001
T_3	3.16	1.00	-0.0001	0.81	1.004	-0.0001
L_1 X T_1	3.51	1.00	-0.0001	0.89	1.004	-0.0001
L_1 X T_2	2.63	1.00	-0.0001	0.67	1.004	-0.0001
L_1 X T_3	3.31	1.00	-0.0001	0.84	1.004	-0.0001
L_2 X T_1	2.99	1.00	-0.0001	0.76	1.004	-0.0001
L_2 X T_2	3.39	1.00	-0.0001	0.86	1.004	-0.0001
L_2 X T_3	2.59	1.00	-0.0001	0.66	1.004	-0.0001
L_3 X T_1	1.99	1.00	-0.0001	0.51	1.004	-0.0001
L_3 X T_2	3.35	1.00	-0.0001	0.85	1.004	-0.0001
L_3 X T_3	3.79	1.00	-0.0001	0.96	1.004	-0.0001
L_4 X T_1	3.51	1.00	-0.0001	0.89	1.004	-0.0001
L_4 X T_2	2.67	1.00	-0.0001	0.68	1.004	-0.0001
L_4 X T_3	3.35	1.00	-0.0001	0.85	1.004	-0.0001
L_5 X T_1	2.51	1.00	-0.0001	0.64	1.004	-0.0001
L_5 X T_2	2.19	1.00	-0.0001	0.56	1.004	-0.0001
L_5 X T_3	2.47	1.00	-0.0001	0.63	1.004	-0.0001
L_6 X T_1	3.71	1.00	-0.0001	0.94	1.004	-0.0001
L_6 X T_2	2.79	1.00	-0.0001	0.71	1.004	-0.0001
L_6 X T_3	3.11	1.00	-0.0001	0.79	1.004	-0.0001
L_7 X T_1	2.87	1.00	-0.0001	0.73	1.004	-0.0001
L_7 X T_2	2.83	1.00	-0.0001	0.72	1.004	-0.0001
L_7 X T_3	2.03	1.00	-0.0001	0.52	1.004	-0.0001
L_8 X T_1	3.43	1.00	-0.0001	0.87	1.004	-0.0001
L_8 X T_2	3.60	1.00	-0.0001	0.92	1.004	-0.0001
L_8 X T_3	1.99	1.00	-0.0001	0.51	1.004	-0.0001

Table 4.5.8: Contd...

Genotype	Lysine (%)			Tryptophan (%)		
	$\overline{X}i$	bi	S^2di	$\overline{X}i$	bi	S^2di
L_9 X T_1	2.71	1.00	-0.0001	0.69	1.004	-0.0001
L_9 X T_2	2.21	1.00	-0.0001	0.58	1.004	-0.0001
L_9 X T_3	2.71	1.00	-0.0001	0.69	1.004	-0.0001
L_{10} X T_1	2.63	1.00	-0.0001	0.67	1.004	-0.0001
L_{10} X T_2	2.91	1.00	-0.0001	0.74	1.004	-0.0001
L_{10}X T_3	3.51	1.00	-0.0001	0.89	1.004	-0.0001
L_{11} X T_1	3.55	1.00	-0.0001	0.90	1.004	-0.0001
L_{11} X T_2	3.31	1.00	-0.0001	0.84	1.002	-0.0001
L_{11} X T_3	3.51	1.00	-0.0001	0.89	1.002	-0.0001
L_{12} X T_1	2.75	1.00	-0.0001	0.70	1.004	-0.0001
L_{12} X T_2	3.47	1.00	-0.0001	0.88	1.004	-0.0001
L_{12} X T_3	2.75	1.00	-0.0001	0.70	1.004	-0.0001
L_{13} X T_1	3.55	1.00	-0.0001	0.90	1.002	-0.0001
L_{13} X T_2	2.63	1.00	-0.0001	0.67	1.004	-0.0001
L_{13} X T_3	2.75	1.00	-0.0001	0.70	1.004	-0.0001
L_{14} X T_1	2.52	1.00	-0.0001	0.65	1.004	-0.0001
L_{14} X T_2	3.60	1.00	-0.0001	0.92	1.004	-0.0001
L_{14} X T_3	3.19	1.00	-0.0001	0.81	1.004	-0.0001
L_{15} X T_1	3.12	1.00	-0.0001	0.80	1.004	-0.0001
L_{15} X T_2	3.03	1.00	-0.0001	0.77	1.002	-0.0001
L_{15} X T_3	2.87	1.00	-0.0001	0.73	1.004	-0.0001
L_{16} X T_1	3.24	1.00	-0.0001	0.83	1.002	-0.0001
L_{16} X T_2	3.31	1.00	-0.0001	0.84	1.004	-0.0001
L_{16} X T_3	3.15	1.00	-0.0001	0.80	1.004	-0.0001
L_{17} X T_1	2.88	1.00	-0.0001	0.74	1.002	-0.0001
L_{17} X T_2	2.84	1.00	-0.0001	0.73	1.004	-0.0001
L_{17} X T_3	2.92	1.00	-0.0001	0.75	1.004	-0.0001
L_{18} X T_1	2.60	1.00	-0.0001	0.67	1.004	-0.0001
L_{18} X T_2	3.23	1.00	-0.0001	0.82	1.004	-0.0001
L_{18} X T_3	3.43	1.00	-0.0001	0.87	1.004	-0.0001
L_{19} X T_1	2.75	1.00	-0.0001	0.70	1.004	-0.0001
L_{19} X T_2	2.75	1.00	-0.0001	0.70	1.004	-0.0001
L_{19} X T_3	2.71	1.00	-0.0001	0.69	1.004	-0.0001
L_{20} X T_1	3.11	1.00	-0.0001	0.79	1.004	-0.0001
L_{20} X T_2	3.27	1.00	-0.0001	0.83	1.004	-0.0001
L_{20} X T_3	3.19	1.00	-0.0001	0.81	1.004	-0.0001
L_{21} X T_1	2.91	1.00	-0.0001	0.73	1.004	0.0001
L_{21} X T_2	2.31	1.00	-0.0001	0.59	1.004	-0.0001
L_{21} X T_3	2.75	1.00	-0.0001	0.70	1.002	-0.0001
HQPM- 1	2.99	1.00	-0.0001	0.76	1.004	-0.0001
Shakti – 1	2.11	1.00	-0.0001	0.54	1.004	-0.0001
Pragati	1.12	1.00	-0.0001	0.28	1.003	-0.0001
Mean	2.90	1.00		0.74	1.00	
SE (±)	0.002	0.017		0.0007	0.021	

*,** Significant at 5% and 1 % probability levels, respectively.

presented in Table 4.5.8. All 24 parental lines exhibited non-significant bi and S^2di values showing their excellent and stable performance for tryptophan percentage over environments. The most desirable and stable lines and testers were L_1, L_6 L_8, L_{10}, L_{18}, L_{19}, L_{21}, T_2 and T_3 because these also had mean value higher than population mean.

Among the crosses, all exhibited unit bi values i.e. 1.00 and S^2di value nearly zero indicating their best and stable performance over environments. The most desirable and stable hybrids having high mean (>2.90), bi = 1 and S^2di = 0 were $L_1 \times T_1$, $L_1 \times T_3$, $L_2 \times T_1$, $L_2 \times T_2$, $L_3 \times T_2$, $L_3 \times T_3$, $L_4 \times T_1$, $L_4 \times T_3$, $L_6 \times T_1$, $L_6 \times T_3$, $L_8 \times T_1$, $L_8 \times T_2$, $L_{10} \times T_2$, $L_{10} \times T_3$, $L_{11} \times T_1$, $L_{11} \times T_1$, $L_{11} \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_2$, $L_{13} \times T_1$ $L_{14} \times T_2$, $L_{14} \times T_3$, $L_{15} \times T_1$, $L_{15} \times T_2$, $L_{16} \times T_1$, $L_{16} \times T_2$, $L_{16} \times T_3$, $L_{17} \times T_3$, $L_{18} \times T_2$, $L_{18} \times T_3$, $L_{20} \times T_1$, $L_{20} \times T_2$, $L_{20} \times T_3$ and check, HQPM-1 for this trait.

4.5.4.7 Grain yield (q per ha)

The mean performance of genotypes ranged from 12.92 to 61.8 with an overall mean of 30.53. The range of bi values (-1.312 to 2.695) is presented in Table 4.5.9. All the lines except L_2, L_7, L_{10}, L_{13}, exhibited bi values non-significantly different from unity indicating average response. All the parental lines except L_2 and T_2 exhibited magnitude of S^2di non-significantly different from zero by showing their stable performance across the environments. Although, most of the lines exhibited bi and S^2di values near about unity and zero, respectively, but the lines, L_1, L_3, L_4, L_5, L_6, L_{11} L_{12} and L_{19} had higher mean value than the population mean. So these lines were considered as most desirable

Table 4.5.9: Stability parameters for yield in different genotypes pooled over environments

Genotype	Grain yield (q/ha)		
	$\overline{X}i$	bi	S^2di
L_1	61.80	1.014	107.76
L_2	35.49	3.504*	466.15**
L_3	34.87	1.037	45.37
L_4	44.36	1.064	100.65
L_5	39.67	0.914	13.43
L_6	40.09	1.018	11.03
L_7	50.71	4.652**	29.05
L_8	25.51	1.029	119.7
L_9	26.61	-0.688	114.08
L_{10}	48.62	4.133**	13.48
L_{11}	30.83	1.035	11.71
L_{12}	34.93	0.738	57.06
L_{13}	33.87	3.78*	6.23
L_{14}	19.73	0.273	82.83
L_{15}	21.02	1.908	39.81
L_{16}	12.92	-0.102	0.11
L_{17}	16.82	0.469	12.57
L_{18}	21.95	0.825	52.92
L_{19}	34.98	0.998	56.4
L_{20}	28.73	1.794	19.9
L_{21}	30.41	1.608	115.48
T_1	13.99	0.165	12.29
T_2	31.96	0.283	732.75**
T_3	13.15	0.045	15.78
L_1 X T_1	47.74	3.237*	428.57**
L_1 X T_2	34.71	3.988*	10.52
L_1 X T_3	16.27	-0.666	23.76
L_2 X T_1	43.80	2.26	305.21**
L_2 X T_2	16.51	0.39	10.80
L_2 X T_3	30.69	1.023	10.94
L_3 X T_1	16.68	0.838	7.54
L_3 X T_2	19.29	1.477	23.86
L_3 X T_3	52.77	1.035	0.19
L_4 X T_1	26.30	-0.088	0.08
L_4 X T_2	21.88	0.807	53.80
L_4 X T_3	33.76	1.085	556.34**
L_5 X T_1	21.02	1.908	39.84
L_5 X T_2	33.91	1.099	35.31
L_5 X T_3	30.99	1.074	12.63
L_6 X T_1	39.05	3.072*	503.26**
L_6 X T_2	16.95	0.578	13.32
L_6 X T_3	20.07	0.358	77.79
L_7 X T_1	34.79	1.016	44.46
L_7 X T_2	36.86	0.479	212.81*
L_7 X T_3	30.56	2.747	511.72**

Table 4.5.9: Contd...

Genotype	Grain yield (q/ha)		
	$\overline{X}i$	bi	S^2di
L_8 X T_1	34.79	0.995	122.91
L_8 X T_2	39.31	1.025	15.66
L_8 X T_3	34.00	0.899	137.70
L_9 X T_1	14.09	-0.209	1.70
L_9 X T_2	25.29	0.197	28.64
L_9 X T_3	42.72	1.012	32.09
L_{10} X T_1	39.52	1.077	14.33
L_{10} X T_2	39.54	1.082	14.21
L_{10}X T_3	22.20	0.089	32.60
L_{11} X T_1	34.87	2.359	599.97**
L_{11} X T_2	39.94	0.986	116.70
L_{11} X T_3	39.75	0.936	108.48
L_{12} X T_1	38.31	1.074	37.81
L_{12} X T_2	35.54	0.137	180.44*
L_{12} X T_3	34.02	1.024	36.47
L_{13} X T_1	36.57	0.258	217.65*
L_{13} X T_2	34.11	0.093	212.41*
L_{13} X T_3	33.15	1.095	107.75
L_{14} X T_1	28.93	0.301	1.01
L_{14} X T_2	25.68	0.156	2.21
L_{14} X T_3	36.37	0.958	140.40
L_{15} X T_1	30.92	0.156	186.87*
L_{15} X T_2	15.07	-0.229	0.57
L_{15} X T_3	28.70	0.99	9.78
L_{16} X T_1	18.76	0.556	0.69
L_{16} X T_2	31.89	1.089	152.67
L_{16} X T_3	32.19	0.845	1.44
L_{17} X T_1	22.28	0.233	33.27
L_{17} X T_2	34.18	0.943	3.22
L_{17} X T_3	34.41	0.901	5.39
L_{18} X T_1	18.98	0.158	1.26
L_{18} X T_2	20.86	0.813	0.09
L_{18} X T_3	29.75	0.164	215.10*
L_{19} X T_1	25.39	0.221	227.80*
L_{19} X T_2	21.50	-0.087	331.67**
L_{19} X T_3	24.57	0.017	335.37**
L_{20} X T_1	26.11	0.597	325.25**
L_{20} X T_2	46.15	0.892	12.60
L_{20} X T_3	38.65	0.965	7.83
L_{21} X T_1	39.54	0.293	36.38
L_{21} X T_2	41.81	0.928	0.381
L_{21} X T_3	42.17	0.973	10.39
HQPM- 1	24.54	1.466	26.55
Shakti – 1	20.39	0.558	61.46
Pragati	61.80	1.114	107.76
Mean	30.38	1.00	
SE (±)	6.55	0.98	

*,** Significant at 5% and 1 % probability levels, respectively.

and stable one. Result showed that only one parental line, L_2 was suitable for rich environment ($\overline{X}i > 30.38$, bi >1, high S^2di). However, L_8, L_9, L_{14}, T_1 and T_3 were suitable for poor environment because of ($\overline{X}i > 30.38$, bi much less than 1, low S^2di) least sensitive to environmental conditions.

All the hybrids except $L_1 \times T_1$, $L_1 \times T_2$ and $L_6 \times T_1$ exhibited bi values non-significantly different from unity indicating their average performance over environments. All the hybrids except $L_1 \times T_1$, $L_4 \times T_3$ and $L_{11} \times T_1$ showed S^2di values non-significantly different from zero indicating their stable performance over environments. Among all the hybrids, the most desirable and stable ones were $L_2 \times T_3$, $L_3 \times T_3$, $L_5 \times T_2$, $L_5 \times T_3$, $L_7 \times T_1$, $L_7 \times T_3$, $L_8 \times T_1$, $L_8 \times T_2$, $L_8 \times T_3$, $L_9 \times T_3$, $L_{10} \times T_1$, $L_{10} \times T_2$, $L_{11} \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_1$, $L_{12} \times T_3$, , $L_{13} \times T_3$, $L_{14} \times T_3$, $L_{16} \times T_2$, $L_{16} \times T_3$, $L_{17} \times T_2$, $L_{17} \times T_3$, $L_{20} \times T_2$, $L_{20} \times T_3$, $L_{21} \times T_1$, $L_{21} \times T_2$, $L_{21} \times T_3$ and check Pragati for this trait. Results showed that hybrids suitable for rich environment ($\overline{X}i > 30.38$, bi >1, high S^2di)were $L_1 \times T_1$, $L_2 \times T_1$, $L_4 \times T_3$, $L_6 \times T_1$, $L_7 \times T_3$ and $L_{11} \times T_1$. This showed that they are very highly sensitive to environments i.e. they responded 3-4 times for a unit change in the environmental milieu. However, $L_7 \times T_2$, $L_{12} \times T_2$, $L_{13} \times T_1$, $L_{13} \times T_2$, $L_{15} \times T_1$, $L_{18} \times T_3$, $L_{19} \times T_1$, $L_{19} \times T_2$, $L_{19} \times T_3$ and $L_{20} \times T_1$ were suitable for poor environment because of ($\overline{X}i > 30.38$, bi much less than 1, low S^2di) least sensitive to environmental conditions.

Chapter – 5

Discussion

Chapter 5 DISCUSSION

Maize, one of the most important cereals, is grown in a sizable area both at national and international levels. In India, maize area and production have acquired a phenomenal growth over last decades and emerged from being a net importer to the levels of self sufficiency. This has been possible due to because of improved breeding programmes alongwith technological advancement. It is used for food, feed, fodder and other industrial products like starch, oil, glucose, ethanol etc. In this context Quality Protein Maize (QPM) makes its greatest contribution in improving the protein quality of the diet of the maize based population. The quality of the maize endosperm proteins can be favorably modified by the several genetic and breeding aspects providing improved varieties, hybrids and other source populations with improved agronomic practices. In tropics, the extreme climatic conditions, biotic and abiotic stresses pose challenging threats for maize production, in spite of all good and sufficient efforts. Among abiotic stresses, low-N and extremes of water availability i.e. drought and excess soil water (ESM) are the major constraints for the production and productivity of maize particularly in Asia.

Efforts therefore, should be made to investigate the mechanism for the stresses and to understand its genetic basis including identification of the genotypes with adaptive potential under the stress conditions. Therefore, it is necessary to screen and evaluate genotypes to different

environmental conditions accompanied with proper breeding methodology to develop genotypes tolerant to such conditions.

To develop high yielding varieties/hybrids and their better degree of stability over a wide range of environments is the prime objective of any maize breeding programme. More emphasis on hybrid as compared to open pollinated varieties is appropriate because it is a proven fact that hybrids are higher yielding than synthetics and composites. Therefore, to initiate any hybrid breeding programme important phases are:

(i) Choice of germplasm

(ii) Cyclic improvement of promising germplasm

(iii) Development of inbreds to be used as parents for hybrids

(iv) Development of hybrids

The first attempt to develop single cross hybrids in maize to increase grain yield was made by **Shull (1909)**. However, the first single cross hybrid (SR 52) could be developed and released in 1960 in Zimbabwe, just half of century later. Now days, single cross hybrids receive top priority because maximum exploitation of heterosis is possible only through single cross hybrids. The development of outstanding single cross hybrids involves crossing between two genetically diverse inbreds on the basis of their mean performance and combining ability.

Keeping in view all above such conditions, the present study was planned specifically to identify superior single cross QPM hybrids on the basis of study of heterosis, variability parameters, combining ability and phenotypic stability in a set of twenty one selected quality protein maize

(QPM) inbred lines and three broad-base QPM testers. Sixty-three hybrids were developed by crossing twenty one selected QPM inbred lines with three broad-base QPM testers in a line x tester fashion. The data collected on important economic characters were analyzed for combining ability following **Kempthorne (1957)**. The salient results obtained after appropriate statistical analysis have been discussed in this chapter under the following heads:

5.1 Analysis of variance

5.2 Heterosis

5.3 Variability parameters

5.4 Combining ability

5.5 Phenotypic stability

5.1 Analysis of Variance

The basic requirement for any crop improvement programme is sufficient genetic variability. Thus, it is very necessary to confirm whether or not sufficient genetic variability is present, before initiating any breeding programme for the various characters. Significant differences among parents and their crosses indicated inherent genetic differences among treatments for all the characters studied. This proved suitability of the experimental material chosen for the present investigation.

The analysis of variance for the line x tester exhibited highly significant differences among parents for all the characters in E_1, E_2 and E_3. Lines showing significant differences for most of the characters except 100-kernel weight and brace roots in E_1 and E_3; number of

kernels per row in E_3; days to 50% silking and anthesis-silking interval in E_2 and E_3 environments. Whereas, for testers all characters except number of nodes bearing brace roots in E_1 and E_2, days to 50% tasselling in E_1 environment. These findings of significance, beside suggesting sufficient diversity between parents also are in agreement with the findings of **Nagda *et al.* (1995); Dass *et al.* (1997); Mathur *et al.* (1998)**; **Petrovic (1998). Srinivasan and Vasal (1999); Konak *et al.* (2001); Venkatesh *et al.* (2001) Ramneek *et al.* (2005), Sofi *et al.* (2006)** and **Premlatha and Kalamani (2010).**

5.2 Heterosis

In maize, heterosis has been exploited extensively. The heterosis concept in maize started with the studies reported by **Shull (1908)** in his study on "The composition of field of maize". The word, heterosis was coined by **Shull (1914)**. The concept of heterosis is Shull's terminology was development of single crosses using homozygous inbred lines. In 1918, **Jones** suggested use of double cross hybrids to be developed by single crosses as parental stocks. The line x tester mating design has been extensively used to determine general and specific combining ability which is a prerequisite in the development of single and double cross hybrids.

Heterosis in relation to the average of the two inbred lines (mid parent), better parent inbred line and on the check are determined to find out the manifestation of heterosis which usually depend on :

(i) presence of some level of dominance and

(ii) the relative differences in the gene frequency of the two parents **(Falconer, 1960).**

In the present study heterosis has been studied with respect to superiority of hybrids over the better parent (heterobeltiosis), mid-parent (relative heterosis) and over the check (standard heterosis).

The best heterotic F_1s with respect to better-, mid- and check parent are summarized in Table 5.2.1, 5.2.2 and 5.2.3, respectively; however, the best two heterotic crosses for different characters are given in Table 5.2.4. Hybrid, $L_{14}\times T_3$ showed high better parent heterosis for ear height, number of kernels per row and anthesis silking interval. Cross, $L_5\times T_1$ showed high better parent heterosis for plant height, days to 50% tasselling and grain yield. Estimates of high negative heterobeltiosis in E_1 was exhibited by the hybrids, $L_5\times T_1$ and $L_{10}\times T_3$ for days to 50% tasselling and for days to 50% silking by the hybrids, $L_1\times T_1$ & $L_{21}\times T_2$. For lysine and tryptophan contents, hybrid, $L_{11}\times T_3$ showed high better parent heterosis. Hybrid, $L_1\times T_1$ showed high better parent heterosis for ear diameter, days to 50% silking and Lysine content in E_1.

Similarly in E_2, $L_3\times T_2$ exhibited better parent heterosis for days to early silking and anthesis-silking interval, hybrid, $L_{16}\times T_3$ for 100- kernel weight and protein content, hybrid $L_1\times T_1$ for number of kernels per row and grain yield. Cross combination, $L_{16}\times T_1$ showed better parent heterosis for number of nodes bearing brace roots and tryptophan content, while, $L_{16}\times T_2$ for lysine and tryptophan per cent exhibited better parent heterosis.

In E_3 environment, hybrid, $L_{14}\times T_2$ for ear height and number of kernels per row, $L_{14}\times T_3$ for ear height and 100- kernel weight, $L_{20}\times T_1$ for

Table 5.2.1: Summary of per cent heterosis for various quantitative and qualitative characters over better parent

Sl. No.	Character	Environment	No. of hybrids significantly superior over better parent	Cross combination(s) showing significant heterosis in desired direction over better parent
1.	Plant height (cm)	E_1	28	$L_2\times T_1$, $L_2\times T_2$, $L_2\times T_3$, $L_3\times T_2$, $L_3\times T_3$, $L_4\times T_1$, $L_4\times T_2$, $L_4\times T_3$, $L_5\times T_1$, $L_5\times T_3$, $L_6\times T_1$, $L_6\times T_3$, $L_9\times T_1$, $L_{10}\times T_1$, $L_{10}\times T_2$, $L_{10}\times T_3$, $L_{11}\times T_1$, $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{13}\times T_3$, $L_{14}\times T_1$, $L_{14}\times T_2$, $L_{14}\times T_3$, $L_{15}\times T_1$, $L_{15}\times T_3$, $L_{16}\times T_1$, $L_{17}\times T_3$ and $L_{18}\times T_3$
		E_2	16	$L_2\times T_2$, $L_2\times T_3$, $L_9\times T_1$, $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{14}\times T_1$, $L_{14}\times T_2$, $L_{14}\times T_3$, $L_{15}\times T_1$, $L_{15}\times T_2$, $L_{15}\times T_3$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{16}\times T_3$, $L_{17}\times T_3$ and $L_{19}\times T_3$
		E_3	15	$L_1\times T_2$, $L_2\times T_1$, $L_5\times T_1$, $L_7\times T_1$, $L_8\times T_1$, $L_8\times T_2$, $L_8\times T_3$, $L_9\times T_1$, $L_{11}\times T_1$, $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{13}\times T_1$, $L_{14}\times T_2$, $L_{14}\times T_3$ and $L_{19}\times T_1$
		P	5	$L_2\times T_3$, $L_4\times T_2$, $L_5\times T_1$, $L_{17}\times T_3$ and $L_{19}\times T_1$
2.	Ear height (cm)	E_1	27	$L_1\times T_1$, $L_1\times T_2$, $L_1\times T_3$, $L_2\times T_1$, $L_3\times T_3$, $L_4\times T_1$, $L_4\times T_2$, $L_4\times T_3$, $L_5\times T_1$, $L_6\times T_1$, $L_6\times T_2$, $L_6\times T_3$, $L_8\times T_3$, $L_{10}\times T_1$, $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{14}\times T_1$, $L_{14}\times T_2$, $L_{14}\times T_1$, $L_{14}\times T_3$, $L_{15}\times T_3$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{16}\times T_3$, $L_{20}\times T_1$, $L_{20}\times T_2$, $L_{21}\times T_2$
		E_2	20	$L_2\times T_2$, $L_3\times T_2$, $L_4\times T_2$, $L_5\times T_1$, $L_5\times T_2$, $L_{10}\times T_2$, $L_{10}\times T_3$, $L_{11}\times T_1$, $L_{11}\times T_2$, $L_{12}\times T_1$, $L_{13}\times T_3$, $L_{14}\times T_1$, $L_{14}\times T_2$, $L_{14}\times T_3$, $L_{15}\times T_1$, $L_{15}\times T_2$, $L_{15}\times T_3$, $L_{17}\times T_2$, $L_{20}\times T_1$ and $L_{21}\times T_3$
		E_3	24	$L_2\times T_1$, $L_4\times T_1$, $L_4\times T_2$, $L_4\times T_3$, $L_5\times T_1$, $L_5\times T_2$, $L_6\times T_3$, $L_8\times T_1$, $L_8\times T_2$, $L_{10}\times T_2$, $L_{12}\times T_1$, $L_{12}\times T_3$, $L_{13}\times T_3$, $L_{14}\times T_1$, $L_{14}\times T_2$, $L_{14}\times T_3$, $L_{15}\times T_1$, $L_{15}\times T_2$, $L_{15}\times T_3$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_2$ and $L_{20}\times T_2$
		P	3	$L_4\times T_2$, $L_5\times T_1$ and $L_{10}\times T_2$
3.	100-kernel weight (g)	E_1	10	$L_3\times T_1$, $L_4\times T_1$, $L_5\times T_1$, $L_9\times T_3$, $L_{13}\times T_3$, $L_{15}\times T_1$, $L_{15}\times T_2$, $L_{16}\times T_1$, $L_{16}\times T_2$ and $L_{20}\times T_1$
		E_2	12	$L_4\times T$, $L_5\times T_1$, $L_9\times T_1$, $L_9\times T_3$, $L_{10}\times T_1$, $L_{10}\times T_2$, $L_{10}\times T_3$, $L_{12}\times T_1$, $L_{17}\times T_3$, $L_{18}\times T_3$, $L_{20}\times T_1$ and $L_{21}\times T_1$
		E_3	8	$L_5\times T_1$, $L_{13}\times T_2$, $L_{14}\times T_2$, $L_{14}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_2$, $L_{19}\times T_3$ and $L_{20}\times T_1$
		P	4	$L_4\times T_3$, $L_5\times T_1$, $L_{15}\times T_1$ and $L_{15}\times T_2$
4.	Ear length (cm)	E_1	20	$L_3\times T_1$, $L_4\times T_1$, $L_4\times T$, $L_4\times T_3$, $L_5\times T_2$, $L_7\times T_3$, $L_{11}\times T_1$, $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_3$, $L_{13}\times T_1$, $L_{13}\times T_2$, $L_{13}\times T_2$, $L_{13}\times T_3$, $L_{15}\times T_1$, $L_{18}\times T_2$, $L_{19}\times T_1$, $L_{19}\times T_2$, $L_{19}\times T_3$ and $L_{21}\times T_2$
		E_2	17	$L_1\times T_1$, $L_1\times T_2$, $L_3\times T_1$, $L_3\times T_3$, $L_4\times T_1$, $L_4\times T_3$, $L_5\times T_2$, $L_7\times T_2$, $L_7\times T_3$, $L_9\times T_3$, $L_{10}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_3$, $L_{13}\times T_1$, $L_{13}\times T_3$, $L_{20}\times T_2$ and $L_{21}\times T_3$
		E_3	19	$L_1\times T_3$, $L_3\times T_1$, $L_5\times T_1$, $L_5\times T_2$, $L_{11}\times T_1$, $L_{11}\times T_3$, $L_{12}\times T_2$, $L_{13}\times T_1$, $L_{13}\times T_2$, $L_{13}\times T_3$, $L_{14}\times T_1$, $L_{14}\times T_2$, $L_{14}\times T_3$, $L_{15}\times T_3$, $L_{17}\times T_1$, $L_{17}\times T_2$, $L_{20}\times T_1$, $L_{20}\times T_2$ and $L_{21}\times T_1$
		P	8	$L_4\times T_3$, $L_{11}\times T_1$, $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_3$, $L_{13}\times T_3$, $L_{15}\times T_1$ and $L_{18}\times T_2$

Table 5.2.1: Contd....

5.	**Ear diameter (cm)**	**E_1**	4	$L_1 \times T_1$, $L_3 \times T_1$, $L_{11} \times T_1$ and $L_{21} \times T_3$
		E_2	21	$L_1 \times T_1$, $L_3 \times T_1$, $L_3 \times T_2$, $L_4 \times T_1$, $L_4 \times T_2$ $L_4 \times T_3$, $L_5 \times T_2$, $L_5 \times T_3$, $L_{10} \times T_1$, $L_{10} \times T_3$ $L_{11} \times T_1$, $L_{11} \times T_3$, $L_{12} \times T_1$, $L_{12} \times T_2$, $L_{12} \times T_3$ $L_{14} \times T_2$, $L_{15} \times T_1$, $L_{18} \times T_1$, $L_{18} \times T_2$, $L_{18} \times T_3$ and $L_{21} \times T_1$
		E_3	11	$L_5 \times T_1$, $L_5 \times T_2$, $L_9 \times T_1$, $L_9 \times T_2$, $L_{10} \times T_1$, $L_{11} \times T_1$, $L_{14} \times T_1$, $L_{16} \times T_3$, $L_{17} \times T_2$, $L_{21} \times T_1$ and $L_{20} \times T_2$
		P	2	$L_{17} \times T_1$ and $L_{21} \times T_3$
6.	**Number of kernel rows/ear**	**E_1**	16	$L_1 \times T_2$, $L_1 \times T_3$, $L_2 \times T_1$, $L_4 \times T_2$, $L_4 \times T_3$ $L_5 \times T_2$, $L_6 \times T_1$, $L_9 \times T_2$, $L_{12} \times T_3$ $L_{13} \times T_2$, $L_{14} \times T_3$, $L_{16} \times T_1$, $L_{16} \times T_3$, $L_{19} \times T_1$ $L_{20} \times T_1$ and $L_{21} \times T_1$
		E_2	18	$L_1 \times T_1$, $L_1 \times T_3$, $L_5 \times T_2$, $L_6 \times T_1$, $L_6 \times T_2$, $L_6 \times T_3$, $L_9 \times T_2$, $L_{11} \times T_1$ $L_{11} \times T_2$, $L_{11} \times T$, $L_{12} \times T_1$, $L_{14} \times T_3$, $L_{18} \times T_2$ $L_{20} \times T_3$, $L_{21} \times T_1$, $L_{21} \times T_2$ and $L_{21} \times T_3$
		E_3	15	$L_2 \times T_1$, $L_3 \times T_1$ $L_3 \times T_2$, $L_5 \times T_2$, $L_5 \times T_3$, $L_9 \times T_1$, $L_9 \times T_3$ $L_{10} \times T_1$, $L_{13} \times T_3$, $L_{14} \times T_1$ $L_{14} \times T_3$, $L_{16} \times T_1$, $L_{18} \times T_3$, $L_{20} \times T_1$ and $L_{20} \times T_2$
		P	2	$L_{14} \times T_3$ and $L_{20} \times T_1$
7.	**Number of kernels/row**	**E_1**	13	$L_1 \times T_1$, $L_2 \times T_3$, $L_4 \times T_1$, $L_4 \times T_2$, $L_5 \times T_3$ $L_{10} \times T_3$, $L_{11} \times T_3$, $L_{12} \times T_3$ $L_{13} \times T_3$, $L_{14} \times T_3$, $L_{16} \times T_2$, $L_{16} \times T_3$ and $L_{20} \times T_1$
		E_2	14	$L_1 \times T_1$, $L_1 \times T_2$, $L_2 \times T_2$, $L_4 \times T_1$, $L_4 \times T_2$ $L_4 \times T_3$, $L_6 \times T_2$, $L_7 \times T_1$, $L_7 \times T_2$ $L_8 \times T_2$, $L_9 \times T$, $L_{12} \times T_2$, $L_{15} \times T_1$ and $L_{15} \times T_2$
		E_3	13	$L_1 \times T_2$, $L_2 \times T_3$, $L_4 \times T_1$, $L_5 \times T_1$ $L_5 \times T$, $L_{12} \times T_3$, $L_{13} \times T_2$, $L_{13} \times T_3$ $L_{14} \times T_1$, $L_{14} \times T_2$, $L_{15} \times T_1$, $L_{15} \times T_2$ and $L_{19} \times T_3$
		P	2	$L_4 \times T_1$ and $L_{11} \times T_3$
8.	**Number of nodes bearing brace roots**	**E_1**	2	$L_2 \times T_2$ and $L_3 \times T_3$
		E_2	2	$L_{13} \times T_1$ and $L_{16} \times T_1$
		E_3	2	$L_3 \times T_3$ and $L_{20} \times T_3$
		P	2	$L_3 \times T_3$ and $L_2 \times T_1$
9.	**Days to 50% tasselling**	**E_1**	5	$L_5 \times T_1$, $L_7 \times T_2$, $L_7 \times T_3$, $L_{10} \times T_3$ and $L_{14} \times T_3$
		E_2	4	$L_3 \times T_1$, $L_{11} \times T_1$, $L_{21} \times T_2$ and $L_{21} \times T_3$
		E_3	8	$L_6 \times T_3$, $L_8 \times T_2$, $L_8 \times T_3$, $L_8 \times T_3$, $L_{12} \times T_1$, $L_{12} \times T_2$, $L_{15} \times T_2$ and $L_{16} \times T_3$
		P	2	$L_{14} \times T_3$ and $L_1 \times T_1$
10.	**Days to 50% silking**	**E_1**	3	$L_1 \times T_1$,$L_{21} \times T_2$ and $L_{21} \times T_1$
		E_2	3	$L_3 \times T_1$, $L_3 \times T_2$ and $L_{21} \times T_1$
		E_3	3	$L_{16} \times T_3$, $L_{11} \times T_3$ and $L_{14} \times T_2$
		P	2	$L_{21} \times T_1$ and $L_{16} \times T_3$

Table 5.2.1: Contd...

11.	**Anthesis-silking interval**	**E_1**	6	$L_{14}\times T_2$, $L_{14}\times T_3$, $L_{15}\times T_1$, $L_{15}\times T_2$, $L_{15}\times T_3$ and $L_{21}\times T_2$
		E_2	3	$L_3\times T_2$, $L_6\times T_2$ and $L_6\times T_3$
		E_3	3	$L_5\times T_1$, $L_9\times T_3$ and $L_{15}\times T_3$
		P	3	$L_6\times T_2$, $L_{14}\times T_2$ and $L_{14}\times T_3$
12.	**Protein (%)**	**E_1**	8	$L_3\times T_1$, $L_3\times T_3$, $L_{10}\times T_1$, $L_{10}\times T_2$, $L_{17}\times T_1$, $L_{17}\times T_3$, $L_{18}\times T_2$ and $L_{18}\times T_3$
		E_2	8	$L_3\times T_1$, $L_3\times T_3$, $L_{10}\times T_1$, $L_{10}\times T_2$, $L_{17}\times T_1$, $L_{17}\times T_3$, $L_{18}\times T_2$ and $L_{18}\times T_3$
		E_3	8	$L_3\times T_1$, $L_3\times T_3$, $L_{10}\times T_1$, $L_{10}\times T_2$, $L_{17}\times T_1$, $L_{17}\times T_3$, $L_{18}\times T_2$ and $L_{18}\times T_3$
		P	4	$L_3\times T_3$, $L_{14}\times T_3$, $L_{17}\times T_3$ and $L_{18}\times T_2$
13.	**Lysine (%)**	**E_1**	17	$L_1\times T_1$, $L_8\times T_2$, $L_9\times T_1$, $L_{10}\times T_2$ $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{12}\times T_3$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_2$, $L_{19}\times T_3$, $L_{20}\times T_2$ and $L_{21}\times T_1$
		E_2	17	$L_1\times T_1$, $L_8\times T_2$, $L_9\times T_1$, $L_{10}\times T_2$ $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{12}\times T_3$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_2$, $L_{19}\times T_3$, $L_{20}\times T_2$ and $L_{21}\times T_1$
		E_3	17	$L_1\times T_1$, $L_8\times T_2$, $L_9\times T_1$, $L_{10}\times T_2$ $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{12}\times T_3$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_2$, $L_{19}\times T_3$, $L_{20}\times T_2$ and $L_{21}\times T_1$
		P	17	$L_1\times T_1$, $L_8\times T_2$, $L_9\times T_1$, $L_{10}\times T_2$ $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{12}\times T_3$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_2$, $L_{19}\times T_3$, $L_{20}\times T_2$ and $L_{21}\times T_1$
14.	**Tryptophan (%)**	**E_1**	6	$L_1\times T_1$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$ and $L_{18}\times T_3$
		E_2	6	$L_1\times T_1$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$ and $L_{18}\times T_3$
		E_3	6	$L_1\times T_1$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$ and $L_{18}\times T_3$
		P	6	$L_1\times T_1$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$ and $L_{18}\times T_3$
15.	**Grain yield (kg/ha)**	**E_1**	24	$L_1\times T_1$, $L_1\times T_2$, $L_1\times T_3$, $L_2\times T_1$, $L_2\times T_2$, $L_2\times T_3$ $L_3\times T_1$, $L_4\times T_1$, $L_4\times T_2$ $L_5\times T_1$, $L_5\times T_3$, $L_9\times T_1$, $L_9\times T$, $L_{10}\times T_1$, $L_{11}\times T_3$, $L_{13}\times T_2$, $L_{13}\times T_3$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{16}\times T_3$, $L_{18}\times T_1$, $L_{18}\times T_2$ and $L_{19}\times T_1$
		E_2	16	$L_1\times T_1$, $L_1\times T_2$, $L_1\times T_3$, $L_2\times T_1$, $L_2\times T_2$, $L_5\times T_1$, $L_7\times T_1$, $L_9\times T_1$, $L_9\times T_2$, $L_{10}\times T_1$, $L_{11}\times T_3$, $L_{12}\times T_3$, $L_{14}\times T_1$, $L_{17}\times T_3$, $L_{19}\times T_1$ and $L_{19}\times T_3$
		E_3	15	$L_1\times T_1$, $L_2\times T_1$, $L_4\times T_1$, $L_4\times T_3$, $L_5\times T_1$, $L_5\times T_2$, $L_7\times T_1$, $L_7\times T_2$, $L_7\times T_3$, $L_{10}\times T_1$, $L_{10}\times T_3$, $L_{11}\times T_3$, $L_{14}\times T_1$, $L_{17}\times T_3$ and $L_{19}\times T_2$
		P	8	$L_1\times T_1$, $L_2\times T_1$, $L_3\times T_1$, $L_4\times T_1$, $L_9\times T_1$, $L_{10}\times T_1$, $L_{11}\times T_3$ and $L_{14}\times T_1$

E_1: Normal (recommended dose of nitrogen), **E_2:** Low-nitrogen, **E_3:** Excess soil moisture, **P:** Pooled environment

ear length and ear diameter, $L_{11}\times T_3$ for days to 50% silking as well as for Lysine and tryptophan contents, exhibited better parent heterosis.

The results of pooled analysis revealed that none of the cross combinations showed heterobeltiosis for all characters. However, Hybrid, $L_{11}\times T_3$ exhibited heterobeltiosis for ear length, number of kernels per row and tryptophan content and hybrid, $L_4\times T_1$ for no. of kernels per row and grain yield. Over all results of heterobeltiosis revealed that $L_3\times T_1$ and $L_5\times T_1$ in E_1, $L_1\times T_1$ and $L_{19}\times T_3$ in E_2, $L_7\times T_1$ and $L_7\times T_3$ in E_3 and $L_1\times T_1$ and $L_4\times T_1$ across the environments exhibited high better parent heterosis with respect to grain yield, however, for lysine and tryptophan contents cross, $L_{11}\times T_3$ showed heterobeltiosis on overall study of results.

As regards of relative heterosis in E_1, $L_{14}\times T_3$ exhibited high mid parent heterosis for ear height, number of kernels per row and days to 50% tasselling in the desired direction. High relative heterosis for grain yield, protein content and days to 50%, tasselling was shown by cross combination, $L_{17}\times T_3$.

In E_2 environment, hybrid $L_{14}\times T_2$ for plant height and ear height, $L_{17}\times T_3$ for 100 kernel weight and protein content, $L_4\times T_1$ for ear diameter and number of kernels per row exhibited high relative heterosis. However, hybrid, $L_1\times T_1$ showed heterosis in desired direction for number of kernels per row and grain yield in E_2.

Perusals of results for relative heterosis in E_3 environment, high relative heterosis was exhibited by the hybrid, $L_{14}\times T_2$ for plant height and ear height, $L_{14}\times T_1$ for plant height and number of kernels per row,

Table 5.2.2: Summary of per cent heterosis for various quantitative and qualitative characters over mid parent

Sl. No.	Character	Environment	No. of hybrids significantly superior over better parent	Cross combination(s) showing significant heterosis in desired direction over mid parent
1.	Plant height (cm)	E_1	24	$L_2\times T_1$, $L_2\times T_3$ $L_3\times T_2$, $L_3\times T_3$, $L_4\times T_1$ $L_4\times T_2$, $L_4\times T_3$, $L_5\times T_1$ $L_5\times T_3$, $L_9\times T_1$, $L_{10}\times T_1$, $L_{10}\times T_2$, $L_{11}\times T_1$, $L_{11}\times T_2$ $L_{11}\times T_3$, $L_{13}\times T_3$, $L_{14}\times T_1$ $L_{14}\times T_2$, $L_{14}\times T_3$, $L_{15}\times T_1$ $L_{15}\times T_3$, $L_{16}\times T_1$, $L_{17}\times T_3$ and $L_{18}\times T_3$
		E_2	18	$L_2\times T_2$, $L_2\times T_3$, $L_4\times T_2$, $L_6\times T_2$ $L_9\times T_1$, $L_9\times T_2$, $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{14}\times T_1$, $L_{14}\times T_2$, $L_{14}\times T_3$, $L_{15}\times T_1$, $L_{15}\times T_2$, $L_{15}\times T_3$, $L_{16}\times T_1$, $L_{16}\times T_3$, $L_{17}\times T_3$ and $L_{19}\times T_3$
		E_3	5	$L_9\times T_1$, $L_{11}\times T_3$, $L_{14}\times T_1$, $L_{14}\times T_2$ and $L_{19}\times T_1$
		P	12	$L_2\times T_1$, $L_2\times T_3$, $L_4\times T_2$, $L_{11}\times T_1$, $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{14}\times T_2$, $L_{14}\times T_3$, $L_{15}\times T_1$, $L_{15}\times T_3$, $L_{17}\times T_3$ and $L_{19}\times T_1$
2.	Ear height (cm)	E_1	19	$L_1\times T_1$, $L_1\times T_2$, $L_1\times T_3$, $L_2\times T_1$, $L_3\times T_3$, $L_4\times T_1$, $L_4\times T_2$, $L_5\times T_1$, $L_8\times T_3$, $L_{10}\times T_1$, $L_{11}\times T_3$, $L_{14}\times T_1$, $L_{14}\times T_2$, $L_{14}\times T_3$, $L_{15}\times T_3$, $L_{16}\times T_1$, $L_{16}\times T_3$, $L_{18}\times T_3$ and $L_{20}\times T_2$
		E_2	17	$L_2\times T_2$, $L_3\times T_2$, $L_4\times T_2$, $L_5\times T_1$, $L_5\times T_2$, $L_{10}\times T_2$, $L_{10}\times T_3$, $L_{11}\times T_1$, $L_{12}\times T_1$, $L_{13}\times T_3$, $L_{14}\times T_1$, $L_{14}\times T_2$, $L_{14}\times T_3$, $L_{15}\times T_1$, $L_{19}\times T_1$, $L_{20}\times T_1$ and $L_{21}\times T_3$
		E_3	20	$L_1\times T_3$, $L_4\times T_2$, $L_4\times T_3$, $L_5\times T_1$, $L_5\times T_2$, $L_6\times T_3$, $L_8\times T_1$, $L_8\times T_2$, $L_{10}\times T_2$, $L_{10}\times T_3$, $L_{11}\times T_2$, $L_{13}\times T_3$, $L_{14}\times T_1$, $L_{14}\times T_2$, $L_{14}\times T_3$, $L_{15}\times T_2$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_2$ and $L_{20}\times T_2$
		P	21	$L_3\times T_2$, $L_4\times T_2$, $L_4\times T_3$, $L_5\times T_1$, $L_5\times T_2$, $L_6\times T_3$, $L_{10}\times T_2$, $L_{10}\times T_3$, $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{14}\times T_1$, $L_{14}\times T_2$, $L_{14}\times T_3$, $L_{15}\times T_1$, $L_{15}\times T_3$, $L_{16}\times T_1$, $L_{16}\times T_3$, $L_{17}\times T_3$, $L_{19}\times T_3$, $L_{20}\times T_2$ and $L_{20}\times T_3$
3.	100-kernel weight (g)	E_1	7	$L_2\times T_2$, $L_3\times T_1$, $L_4\times T_1$, $L_5\times T_1$, $L_9\times T_3$, $L_{13}\times T_3$ and $L_{16}\times T_2$
		E_2	9	$L_5\times T_1$, $L_9\times T_1$, $L_9\times T_3$, $L_{10}\times T_2$, $L_{12}\times T_1$, $L_{12}\times T_3$, $L_{17}\times T_3$, $L_{18}\times T_3$ and $L_{21}\times T_1$
		E_3	10	$L_5\times T_1$, $L_6\times T_3$, $L_{11}\times T_2$, $L_{13}\times T_2$, $L_{14}\times T_2$, $L_{14}\times T_3$, $L_{18}\times T_1$, $L_{19}\times T_1$, $L_{20}\times T_1$ and $L_{21}\times T_3$
		P	4	$L_4\times T_3$, $L_5\times T_1$ $L_{15}\times T_1$ and $L_{15}\times T_2$
4.	Ear length (cm)	E_1	22	$L_2\times T_3$, $L_3\times T_1$, $L_4\times T_1$, $L_4\times T_2$, $L_4\times T_3$, $L_5\times T_2$, $L_7\times T_3$, $L_{11}\times T_1$, $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_3$, $L_{13}\times T_1$, $L_{13}\times T_2$, $L_{13}\times T_3$, $L_{15}\times T_1$, $L_{15}\times T_3$, $L_{18}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_2$, $L_{19}\times T_3$ and $L_{21}\times T_2$
		E_2	17	$L_1\times T_1$, $L_1\times T_2$, $L_3\times T_1$, $L_3\times T_3$, $L_4\times T_1$, $L_4\times T_3$, $L_5\times T_2$, $L_7\times T_3$, $L_9\times T_3$, $L_{10}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_3$, $L_{13}\times T_1$, $L_{13}\times T_3$, $L_{14}\times T_3$, $L_{18}\times T_1$ and $L_{21}\times T_3$
		E_3	17	$L_3\times T_1$, $L_5\times T_1$, $L_5\times T_2$, $L_8\times T_1$, $L_{11}\times T_1$, $L_{12}\times T_2$, $L_{13}\times T_1$, $L_{13}\times T_2$, $L_{13}\times T_3$, $L_{14}\times T_1$, $L_{14}\times T_2$, $L_{14}\times T_3$, $L_{15}\times T_3$, $L_{17}\times T_1$, $L_{17}\times T_2$, $L_{20}\times T_1$, and $L_{21}\times T_1$
		P	12	$L_3\times T_1$, $L_4\times T_1$, $L_4\times T_3$, $L_{11}\times T_1$, $L_{11}\times T_3$, $L_{12}\times T_3$, $L_{13}\times T_2$, $L_{13}\times T_3$, $L_{14}\times T_3$, $L_{15}\times T_1$, $L_{15}\times T_3$ and $L_{18}\times T_2$

Table 5.2.2: Contd...

5.	**Ear diameter (cm)**	**E_1**	4	$L_2 \times T_1$ $L_{14} \times T_2$, $L_{17} \times T_1$ and $L_{21} \times T_3$
		E_2	15	$L_3 \times T_1$, $L_3 \times T_2$, $L_4 \times T_1$, $L_4 \times T_2$, $L_5 \times T_2$, $L_9 \times T_2$, $L_{10} \times T_3$ $L_{11} \times T_1$, $L_{12} \times T_2$, $L_{14} \times T_2$, $L_{15} \times T_1$, $L_{15} \times T_2$, $L_{18} \times T_1$, $L_{18} \times T_2$ and $L_{21} \times T_1$
		E_3	4	$L_5 \times T_1$, $L_{10} \times T_1$, $L_{14} \times T_2$ and $L_{20} \times T_1$
		P	2	$L_{17} \times T_1$ and $L_{21} \times T_3$
6.	**Number of kernel rows/ear**	**E_1**	7	$L_2 \times T_1$, $L_5 \times T_2$, $L_9 \times T_2$, $L_{14} \times T_3$, $L_{16} \times T_1$, $L_{16} \times T_3$ and $L_{20} \times T_1$
		E_2	5	$L_5 \times T_2$, $L_6 \times T_1$, $L_{12} \times T_1$, $L_{14} \times T_3$, and $L_{21} \times T_3$
		E_3	9	$L_2 \times T_1$, $L_3 \times T_1$ $L_3 \times T_2$, $L_5 \times T_3$, $L_{10} \times T_1$, $L_{13} \times T_3$, $L_{14} \times T_1$ $L_{14} \times T_3$ and $L_{16} \times T_1$
		P	5	$L_2 \times T_1$, $L_5 \times T_2$, $L_{14} \times T_3$, $L_{16} \times T_1$ and $L_{20} \times T_1$
7.	**Number of kernels/row**	**E_1**	9	$L_4 \times T_1$, $L_{11} \times T_3$, $L_{12} \times T_3$ $L_{13} \times T_3$, $L_{14} \times T$, $L_{15} \times T_1$, $L_{16} \times T_2$, $L_{16} \times T_3$ and $L_{20} \times T_1$
		E_2	20	$L_1 \times T_1$, $L_1 \times T_2$, $L_2 \times T_1$, $L_2 \times T_2$, $L_4 \times T_1$, $L_4 \times T_2$ $L_4 \times T_3$, $L_6 \times T_2$, $L_7 \times T_2$ $L_8 \times T_2$, $L_9 \times T_1$, $L_9 \times T_2$, $L_9 \times T$, $L_{12} \times T_2$, $L_{12} \times T_3$, $L_{15} \times T_1$, $L_{15} \times T_2$, $L_{18} \times T_3$, $L_{19} \times T_3$ and $L_{20} \times T_1$
		E_3	8	$L_1 \times T_2$, $L_4 \times T_1$, $L_5 \times T_1$ $L_5 \times T_3$, $L_{13} \times T_3$ $L_{14} \times T_1$, $L_{14} \times T_2$ and $L_{19} \times T_3$
		P	5	$L_4 \times T_1$, $L_{11} \times T_3$, $L_{16} \times T_2$, $L_{16} \times T_3$ and $L_{21} \times T_1$
8.	**Number of nodes bearing brace roots**	**E_1**	2	$L_2 \times T_2$ and $L_3 \times T_3$
		E_2	2	$L_{13} \times T_1$ and $L_{16} \times T_1$
		E_3	2	$L_3 \times T_1$ and $L_3 \times T_3$
		P	2	$L_2 \times T_1$ and $L_3 \times T_3$
9.	**Days to 50% tasselling**	**E_1**	4	$L_7 \times T_3$, $L_{14} \times T_3$, $L_{17} \times T_2$ and $L_{17} \times T_3$
		E_2	3	$L_3 \times T_1$, $L_{11} \times T_1$ and $L_{21} \times T_3$
		E_3	3	$L_6 \times T_3$, $L_8 \times T_2$ and $L_{12} \times T_2$
		P	2	$L_{14} \times T_3$ and $L_{15} \times T_2$
10.	**Days to 50% silking**	**E_1**	3	$L_1 \times T_1$, $L_{21} \times T_1$ and $L_{21} \times T_2$
		E_2	3	$L_3 \times T_1$, $L_3 \times T_2$ and $L_3 \times T_3$
		E_3	8	$L_6 \times T_3$, $L_7 \times T_1$, $L_7 \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_1$, $L_{14} \times T_2$, $L_{16} \times T_3$and $L_{17} \times T_1$
		P	2	$L_{21} \times T_1$ and $L_{16} \times T_3$
11.	**Anthesis-silking interval**	**E_1**	6	$L_{14} \times T_2$, $L_{14} \times T_3$, $L_{15} \times T_1$, $L_{15} \times T_2$, $L_{15} \times T_3$ and $L_{21} \times T_2$
		E_2	3	$L_3 \times T_2$, $L_6 \times T_2$ and $L_6 \times T_3$
		E_3	3	$L_5 \times T_1$, $L_9 \times T_3$ and $L_{15} \times T_3$
		P	4	$L_6 \times T_2$, $L_{14} \times T_2$ and $L_{14} \times T_3$

Table 5.2.2: Contd...

12.	**Protein (%)**	**E_1**	10	$L_1\times T_3$, $L_2\times T_1$, $L_3\times T_1$, $L_{10}\times T_1$, $L_{12}\times T_3$, $L_{13}\times T_3$, $L_{14}\times T_3$, $L_{17}\times T_3$, $L_{18}\times T_3$ and $L_{20}\times T_3$
		E_2	10	$L_1\times T_3$, $L_2\times T_1$, $L_3\times T_1$, $L_{10}\times T_1$, $L_{12}\times T_3$, $L_{13}\times T_3$, $L_{14}\times T_3$, $L_{17}\times T_3$, $L_{18}\times T_3$ and $L_{20}\times T_3$
		E_3	10	$L_1\times T_3$, $L_2\times T_1$, $L_3\times T_1$, $L_{10}\times T_1$, $L_{12}\times T_3$, $L_{13}\times T_3$, $L_{14}\times T_3$, $L_{17}\times T_3$, $L_{18}\times T_3$ and $L_{20}\times T_3$
		P	10	$L_1\times T_3$, $L_2\times T_1$, $L_3\times T_1$, $L_{10}\times T_1$, $L_{12}\times T_3$, $L_{13}\times T_3$, $L_{14}\times T_3$, $L_{17}\times T_3$, $L_{18}\times T_3$ and $L_{20}\times T_3$
13.	**Lysine (%)**	**E_1**	17	$L_1\times T_1$, $L_8\times T_2$, $L_9\times T_1$, $L_{10}\times T_2$ $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{12}\times T_3$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_2$, $L_{19}\times T_3$, $L_{20}\times T_2$ and $L_{21}\times T_1$
		E_2	17	$L_1\times T_1$, $L_8\times T_2$, $L_9\times T_1$, $L_{10}\times T_2$ $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{12}\times T_3$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_2$, $L_{19}\times T_3$, $L_{20}\times T_2$ and $L_{21}\times T_1$
		E_3	17	$L_1\times T_1$, $L_8\times T_2$, $L_9\times T_1$, $L_{10}\times T_2$ $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{12}\times T_3$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_2$, $L_{19}\times T_3$, $L_{20}\times T_2$ and $L_{21}\times T_1$
		P	17	$L_1\times T_1$, $L_8\times T_2$, $L_9\times T_1$, $L_{10}\times T_2$ $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{12}\times T_3$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_2$, $L_{19}\times T_3$, $L_{20}\times T_2$ and $L_{21}\times T_1$
14.	**Tryptophan (%)**	**E_1**	17	$L_1\times T_1$, $L_8\times T_2$, $L_9\times T_1$, $L_{10}\times T_2$ $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{12}\times T_3$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_2$, $L_{19}\times T_3$, $L_{20}\times T_2$ and $L_{21}\times T_1$
		E_2	17	$L_1\times T_1$, $L_8\times T_2$, $L_9\times T_1$, $L_{10}\times T_2$ $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{12}\times T_3$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_2$, $L_{19}\times T_3$, $L_{20}\times T_2$ and $L_{21}\times T_1$
		E_3	17	$L_1\times T_1$, $L_8\times T_2$, $L_9\times T_1$, $L_{10}\times T_2$ $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{12}\times T_3$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_2$, $L_{19}\times T_3$, $L_{20}\times T_2$ and $L_{21}\times T_1$
		P	17	$L_1\times T_1$, $L_8\times T_2$, $L_9\times T_1$, $L_{10}\times T_2$ $L_{11}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{12}\times T_3$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_2$, $L_{19}\times T_3$, $L_{20}\times T_2$ and $L_{21}\times T_1$
15.	**Grain yield (kg/ha)**	**E_1**	17	$L_1\times T_1$, $L_1\times T_2$, $L_2\times T_1$, $L_2\times T_2$, $L_2\times T_3$ $L_3\times T_1$, $L_4\times T_1$, $L_5\times T_1$, $L_9\times T_1$, $L_9\times T$, $L_{10}\times T_1$, $L_{11}\times T_3$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{18}\times T_1$, $L_{18}\times T_2$ and $L_{19}\times T_1$
		E_2	13	$L_1\times T_1$, $L_1\times T_3$, $L_2\times T_1$, $L_2\times T_2$, $L_5\times T_1$, $L_5\times T_2$, $L_9\times T_3$, $L_{10}\times T_1$, $L_{11}\times T_3$, $L_{14}\times T_1$, $L_{17}\times T_3$, $L_{19}\times T_1$ and $L_{19}\times T_3$
		E_3	6	$L_1\times T_1$, $L_2\times T_1$, $L_{10}\times T_1$, $L_{11}\times T_3$, $L_{14}\times T_1$ and $L_{19}\times T_2$
		P	8	$L_1\times T_1$, $L_2\times T_1$, $L_3\times T_1$, $L_4\times T_1$, $L_{10}\times T_1$, $L_{11}\times T_3$, $L_{14}\times T_1$ and $L_{17}\times T_3$

E_1: Normal (recommended dose of nitrogen), **E_2:** Low-nitrogen, **E_3:** Excess soil moisture, **P:** Pooled environment

$L_{20}\times T_1$ and $L_{13}\times T_2$ for 100- kernel weight and ear length. Hybrid, $L_{11}\times T_3$ showed high mid parent heterosis for lysine content and grain yield in E_3. Results of relative heterosis pooled over environments revealed that cross combinations, $L_1\times T_1$ and $L_4\times T_1$ exhibited high relative heterosis for grain yield. However, $L_{14}\times T_3$ showed high mid-parent heterosis for plant height, ear height and days to 50% tasselling in desired direction. Hybrid, $L_{16}\times T_2$ exhibited mid parent heterosis for number of kernels per row, lysine and tryptophan contents.

The overall results of relative heterosis for grain yield reveled that none of the hybrids showed high relative heterosis in all the environments. Only one hybrid, $L_1\times T_1$ exhibited high relative heterosis for grain yield in E_2 and across the environments. For quality traits as lysine and tryptophan contents, high relative heterosis was exhibited by crosses, $L_{16}\times T_1$ and $L_{16}\times T_2$ in E_1, E_2, E_3 and across the environments.

An estimate of high negative standard heterosis in E1 for days to 50% tasselling and days to 50% silking was exhibited by cross, $L_1\times T_1$. High check parent heterosis for grain yield and 100- kernel weight was exhibited by cross $L_3\times T_1$. However, cross, $L_4\times T_1$ exhibited high standard heterosis for grain yield. Hybrid, $L_{14}\times T_3$ showed standard heterosis for ear height, number of kernels per row and anthesis – silking interval in desired direction. Similarly in E_2, hybrid, $L_3\times T_1$ showed high negative standard heterosis for days to 50% tasselling and days to 50% silking. Hybrid, $L_{12}\times T_3$ exhibited high check parent heterosis for grain yield, 100-kernel weight and ear length. Hybrid $L_{14}\times T_3$ exhibited high heterosis for

Table 5.2.3: Summary of per cent heterosis for various quantitative and qualitative characters over standard parent

Sl. No.	Character	Environment	No. of hybrids significantly superior over better parent	Cross combination(s) showing significant heterosis in desired direction over better parent
1.	Plant height (cm)	E_1	6	$L_9 \times T_1$, $L_9 \times T_2$, $L_{11} \times T_3$, $L_{14} \times T_1$ $L_{14} \times T_2$ and $L_{15} \times T_3$
		E_2	18	$L_2 \times T_2$, $L_2 \times T_3$, $L_3 \times T_1$, $L_4 \times T_1$, $L_4 \times T_2$, $L_4 \times T_3$, $L_5 \times T_1$, $L_9 \times T_1$, $L_9 \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_3$, $L_{14} \times T_1$ $L_{14} \times T_2$, $L_{14} \times T_3$, $L_{15} \times T_1$ $L_{17} \times T_3$, $L_{18} \times T_1$ and $L_{19} \times T_3$
		E_3	4	$L_9 \times T_1$, $L_{11} \times T_3$, $L_{14} \times T_2$ and $L_{19} \times T_1$
		P	3	$L_4 \times T_2$, $L_5 \times T_1$ and $L_{19} \times T_1$
2.	Ear height (cm)	E_1	2	$L_{14} \times T_1$ and $L_{14} \times T_3$
		E_2	2	$L_{14} \times T_1$ and $L_{14} \times T_3$
		E_3	3	$L_5 \times T_1$, $L_{14} \times T_1$ and $L_{14} \times T_3$
		P	10	$L_1 \times T_2$, $L_1 \times T_3$, $L_2 \times T_2$, $L_2 \times T_3$, $L_5 \times T_2$ $L_6 \times T_3$, $L_8 \times T_2$ $L_8 \times T_3$ $L_9 \times T_1$ and $L_{19} \times T_1$
3.	100-kernel weight (g)	E_1	4	$L_3 \times T_1$, $L_5 \times T_1$, $L_9 \times T_3$ and $L_{13} \times T_3$
		E_2	23	$L_1 \times T_3$, $L_2 \times T_3$, $L_4 \times T_3$, $L_5 \times T_1$, $L_5 \times T_2$, $L_9 \times T_1$, $L_9 \times T_3$, $L_{10} \times T_2$, $L_{11} \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_1$, $L_{12} \times T_3$, $L_{13} \times T_1$, $L_{14} \times T_2$, $L_{15} \times T_1$, $L_{15} \times T_2$, $L_{17} \times T_3$, $L_{18} \times T_1$, $L_{18} \times T_3$, $L_{19} \times T_3$, $L_{20} \times T_3$, $L_{21} \times T_1$ and $L_{21} \times T_3$
		E_3	6	$L_5 \times T_1$, $L_6 \times T_3$, $L_{13} \times T_2$, $L_{18} \times T_1$, $L_{19} \times T_1$ and $L_{20} \times T_1$
		P	5	$L_4 \times T_3$, $L_5 \times T_1$, $L_9 \times T_3$, $L_{15} \times T_1$ and $L_{18} \times T_3$
4.	Ear length (cm)	E_1	6	$L_3 \times T_1$, $L_5 \times T_2$, $L_6 \times T_2$, $L_8 \times T_3$, $L_9 \times T_3$ and $L_{11} \times T_2$
		E_2	4	$L_5 \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_3$ and $L_{21} \times T_3$
		E_3	9	$L_1 \times T_2$, $L_5 \times T_2$, $L_6 \times T_1$, $L_6 \times T_2$, $L_9 \times T_2$, $L_{16} \times T_1$, $L_{17} \times T_3$, $L_{19} \times T_2$ and $L_{19} \times T_3$
		P	5	$L_6 \times T_2$, $L_8 \times T_3$, $L_{11} \times T_2$, $L_{17} \times T_1$ and $L_{20} \times T_2$

Table 5.2.3: Contd...

5.	Ear diameter (cm)	E_1	2	$L_{21}\times T_3$ and $L_{17}\times T_1$
		E_2	3	$L_3\times T_1$, $L_5\times T_2$ and $L_{15}\times T_1$
		E_3	4	$L_{17}\times T_2$, $L_3\times T_3$, $L_{10}\times T_1$ and $L_{16}\times T_3$
		P	2	$L_3\times T_1$ and $L_9\times T_2$
6.	Number of kernel rows/ear	E_1	6	$L_2\times T_1$, $L_5\times T_2$, $L_9\times T_2$, $L_{14}\times T_3$, $L_{16}\times T_1$, and $L_{21}\times T_1$
		E_2	6	$L_2\times T_1$, $L_4\times T_1$, $L_5\times T_2$, $L_{12}\times T_1$, $L_{14}\times T_3$ and $L_{21}\times T_3$
		E_3	6	$L_2\times T_1$, $L_3\times T_2$, $L_5\times T_3$, $L_{10}\times T_1$, $L_{14}\times T_3$ and $L_{16}\times T_1$
		P	5	$L_2\times T_1$, $L_5\times T_2$, $L_{14}\times T_3$, $L_{17}\times T_2$ and $L_{20}\times T_1$
7.	Number of kernels/row	E_1	5	$L_1\times T_3$, $L_4\times T_1$, $L_{11}\times T_3$, $L_{14}\times T_3$ and $L_{21}\times T_1$
		E_2	12	$L_1\times T_1$, $L_1\times T_2$, $L_4\times T_1$, $L_4\times T_2$ $L_4\times T_3$, $L_5\times T_2$, $L_9\times T_3$, $L_{10}\times T_3$, $L_{12}\times T_2$, $L_{12}\times T_3$, $L_{15}\times T_1$ and $L_{15}\times T_2$
		E_3	2	$L_1\times T_2$ and $L_4\times T_1$
		P	5	$L_4\times T_1$, $L_8\times T_1$, $L_9\times T_3$, $L_{11}\times T_3$ and $L_{12}\times T_3$
8.	Number of nodes bearing brace roots	E_1	2	$L_1\times T_3$ and $L_{11}\times T_2$
		E_2	5	$L_1\times T_1$, $L_{10}\times T_2$, $L_{11}\times T_2$, $L_{13}\times T_1$ and $L_{16}\times T_1$
		E_3	2	$L_3\times T_3$ and $L_{11}\times T_2$
		P	3	$L_2\times T_1$, $L_4\times T_1$ and $L_{11}\times T_2$
9.	Days to 50% tasselling	E_1	3	$L_2\times T_2$ and $L_1\times T_1$ and $L_6\times T_1$
		E_2	5	$L_{11}\times T_3$, $L_3\times T_1$, $L_3\times T_3$, $L_{21}\times T_2$ and $L_{21}\times T_3$
		E_3	3	$L_{15}\times T_2$, $L_4\times T_3$ and $L_{13}\times T_3$
		P	5	$L_1\times T_1$, $L_1\times T_2$, $L_6\times T_3$, $L_7\times T_1$ and $L_{20}\times T_3$
10.	Days to 50% silking	E_1	4	$L_1\times T_1$, $L_1\times T_2$, $L_2\times T_1$ and $L_{21}\times T_2$
		E_2	5	$L_2\times T_3$, $L_3\times T_1$, $L_3\times T_2$, $L_{11}\times T_3$ and $L_{18}\times T_1$
		E_3	4	$L_6\times T_3$, $L_7\times T_1$, $L_{11}\times T_3$ and $L_{16}\times T_3$
		P	5	$L_1\times T_3$, $L_2\times T_1$, $L_3\times T_1$, $L_{21}\times T_1$ and $L_{21}\times T_3$

Table 5.2.3: Contd...

11.	Anthesis-silking interval	E_1	3	$L_{11}\times T_2$, $L_{14}\times T_2$ and $L_{14}\times T_3$
		E_2	2	$L_1\times T_2$ and $L_3\times T_2$
		E_3	4	$L_5\times T_1$, $L_6\times T_1$, $L_9\times T_3$ and $L_{10}\times T_1$
		P	3	$L_8\times T_1$, $L_{10}\times T_1$ and $L_{11}\times T_2$
12.	Protein (%)	E_1	2	$L_{10}\times T_1$ and $L_5\times L_2$
		E_2	2	$L_{10}\times T_1$ and $L_5\times L_2$
		E_3	2	$L_{10}\times T_1$ and $L_5\times L_2$
		P	2	$L_5\times L_2$ and $L_{18}\times T_3$
13.	Lysine (%)	E_1	3	$L_1\times T_1$, $L_{16}\times T_2$ and $L_{18}\times T_2$
		E_2	3	$L_1\times T_1$, $L_{16}\times T_2$ and $L_{18}\times T_2$
		E_3	3	$L_1\times T_1$, $L_{16}\times T_2$ and $L_{18}\times T_2$
		P	12	$L_9\times T_1$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_3$, $L_{20}\times T_2$ and $L_{21}\times T_1$
14.	Tryptophan (%)	E_1	5	$L_{11}\times T_3$, $L_{14}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_3$ and $L_{21}\times T_1$
		E_2	12	$L_9\times T_1$, $L_{10}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_3$, , $L_{20}\times T_2$ and $L_{21}\times T_1$
		E_3	12	$L_9\times T_1$, $L_{10}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_3$, , $L_{20}\times T_2$ and $L_{21}\times T_1$
		P	12	$L_9\times T_1$, $L_{10}\times T_2$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{14}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{18}\times T_3$, $L_{19}\times T_1$, $L_{19}\times T_3$, , $L_{20}\times T_2$ and $L_{21}\times T_1$
15.	Grain yield (kg/ha)	E_1	15	$L_1\times T_1$, $L_1\times T_2$, $L_1\times T_3$, $L_2\times T_1$, $L_2\times T_2$, $L_2\times T_3$, $L_3\times T_1$, $L_4\times T_1$, $L_5\times T_1$, $L_9\times T_1$, $L_9\times T_2$, $L_{10}\times T_1$, $L_{11}\times T_3$, $L_{14}\times T_1$ and $L_{20}\times T_1$
		E_2	35	$L_1\times T_1$, $L_1\times T_2$, $L_1\times T_3$, $L_2\times T_1$, $L_2\times T_2$, $L_2\times T_3$, $L_3\times T_1$, $L_3\times T_2$, $L_3\times T_3$, $L_4\times T_1$, $L_4\times T_2$ $L_4\times T_3$, $L_5\times T_2$, $L_7\times T_1$, $L_9\times T_1$, $L_9\times T_3$, $L_{10}\times T_1$, $L_{11}\times T_3$, $L_{12}\times T_1$, $L_{12}\times T_3$, $L_{13}\times T_2$, $L_{13}\times T_3$, $L_{14}\times T_1$, $L_{15}\times T_1$, $L_{16}\times T_2$, $L_{17}\times T_3$, $L_{18}\times T_1$, $L_{18}\times T_2$, $L_{19}\times T_1$ $L_{19}\times T_2$, $L_{19}\times T_3$, $L_{20}\times T_1$, $L_{20}\times T_2$, $L_{20}\times T_3$ and $L_{21}\times T_3$
		E_3	7	$L_1\times T_1$, $L_2\times T_1$, $L_8\times T_2$, $L_{10}\times T_1$, $L_{11}\times T_3$, $L_{14}\times T_1$ and $L_{19}\times T_2$
		P	25	$L_1\times T_1$, $L_1\times T_2$, $L_1\times T_3$, $L_2\times T_1$, $L_2\times T_2$, $L_2\times T_3$, $L_3\times T_1$, $L_4\times T_1$, $L_4\times T_3$, $L_7\times T_1$, $L_9\times T_1$, $L_9\times T_2$, $L_{10}\times T_1$, $L_{11}\times T_3$, $L_{14}\times T_1$, $L_{15}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{17}\times T_3$, $L_{18}\times T_1$, $L_{18}\times T_2$, $L_{19}\times T_1$ $L_{19}\times T_2$, $L_{19}\times T_3$ and $L_{20}\times T_1$

E_1: Normal (recommended dose of nitrogen), **E_2:** Low-nitrogen, **E_3:** Excess soil moisture, **P:** Pooled environment

Table 5.2.4: Two best heterotic hybrids for important economic characters in Quality Protein Maize (QPM)

S. No.	Character	Hybrids											
		E_1			E_2			E_3			Pooled		
		BP	MP	CP	BP	MP	CP	BP	MP	CP	BP	MP	CP
1	Plant height (cm)	$L_{15} \times T_3$	$L_{15} \times T_3$	$L_{15} \times T_3$	$L_{15} \times T_1$	$L_{14} \times T_2$	$L_5 \times T_1$	$L_{11} \times T_3$	$L_{14} \times T_2$	$L_{19} \times T_1$	$L_{19} \times T_1$	$L_{19} \times T_1$	$L_{19} \times T_1$
		$L_5 \times T_1$	$L_5 \times T_1$	$L_{14} \times T_2$	$L_{15} \times T_2$	$L_{14} \times T_3$	$L_{14} \times T_3$	$L_{11} \times T_1$	$L_{14} \times T_1$	$L_9 \times T_1$	$L_4 \times T_2$	$L_{14} \times T_3$	$L_4 \times T_2$
2	Ear height (cm)	$L_{14} \times T_3$	$L_3 \times T_3$	$L_{14} \times T_3$	$L_{14} \times T_3$	$L_{14} \times T_1$	$L_{14} \times T_3$	$L_{14} \times T_2$	$L_5 \times T_1$	$L_{14} \times T_3$	$L_{10} \times T_2$	$L_{14} \times T_3$	$L_{17} \times T_1$
		$L_{14} \times T_2$	$L_{14} \times T_3$	$L_{14} \times T_1$	$L_{11} \times T_1$	$L_{14} \times T_2$	$L_{14} \times T_1$	$L_{14} \times T_8$	$L_{14} \times T_2$	$L_{14} \times T_1$	$L_5 \times T_1$	$L_5 \times T_1$	$L_{19} \times T_1$
3	100-kernel weight	$L_9 \times T_3$	$L_9 \times T_3$	$L_3 \times T_3$	$L_{10} \times T_2$	$L_9 \times T_1$	$L_{17} \times T_3$	$L_{20} \times T_1$	$L_{20} \times T_1$	$L_{19} \times T_1$	$L_4 \times T_3$	$L_4 \times T_3$	$L_9 \times T_3$
		$L_3 \times T_1$	$L_{13} \times T_3$	$L_3 \times T_1$	$L_{18} \times T_3$	$L_{17} \times T_3$	$L_{12} \times T_3$	$L_{14} \times T_3$	$L_{13} \times T_2$	$L_{13} \times T_2$	$L_{15} \times T_1$	$L_{15} \times T_1$	$L_4 \times T_3$
4	Ear length (cm)	$L_4 \times T_1$	$L_{12} \times T_3$	$L_{11} \times T_2$	$L_4 \times T_3$	$L_{12} \times T_3$	$L_5 \times T_2$	$L_{13} \times T_2$	$L_{20} \times T_1$	$L_9 \times T_2$	$L_{11} \times T_3$	$L_{11} \times T_3$	$L_{11} \times T_2$
		$L_{19} \times T_1$	$L_{13} \times T_2$	$L_9 \times T_3$	$L_1 \times T_2$	$L_4 \times T_3$	$L_{12} \times T_3$	$L_{20} \times T_1$	$L_{13} \times T_2$	$L_1 \times T_2$	$L_{12} \times T_3$	$L_{12} \times T_3$	$L_6 \times T_2$
5	Ear diameter (cm)	$L_{21} \times T_3$	$L_{21} \times T_3$	$L_{21} \times T_3$	$L_4 \times T_1$	$L_3 \times T_1$	$L_3 \times T_1$	$L_9 \times T_2$	$L_{21} \times T_1$	$L_{17} \times T_2$	$L_{17} \times T_1$	$L_{21} \times T_3$	$L_3 \times T_1$
		$L_1 \times T_1$	$L_{17} \times T_1$	$L_{17} \times T_1$	$L_{18} \times T_1$	$L_4 \times T_1$	$L_5 \times T_2$	$L_{20} \times T_1$	$L_{14} \times T_2$	$L_3 \times T_3$	$L_{21} \times T_3$	$L_{17} \times T_1$	$L_9 \times T_2$
6	Number of kernel rows/ear	$L_{16} \times T_1$	$L_{16} \times T_1$	$L_{16} \times T_1$	$L_6 \times T_1$	$L_5 \times T_2$	$L_5 \times T_2$	$L_5 \times T_3$	$L_{16} \times T_1$	$L_{16} \times T_1$	$L_{20} \times T_1$	$L_{20} \times T_1$	$L_{20} \times T_1$
		$L_{16} \times T_3$	$L_{20} \times T_1$	$L_{20} \times T_1$	$L_6 \times T_3$	$L_6 \times T_1$	$L_{21} \times T_3$	$L_{16} \times T_1$	$L_5 \times T_3$	$L_3 \times T_2$	$L_{14} \times T_3$	$L_{16} \times T_1$	$L_{17} \times T_2$
7	Number of kernels/row	$L_{16} \times T_2$	$L_{11} \times T_3$	$L_{14} \times T_3$	$L_1 \times T_2$	$L_4 \times T_1$	$L_{15} \times T_2$	$L_{14} \times T_1$	$L_1 \times T_2$	$L_1 \times T_2$	$L_{11} \times T_3$	$L_{11} \times T_3$	$L_4 \times T_1$
		$L_{14} \times T_3$	$L_{14} \times T_3$	$L_1 \times T_3$	$L_1 \times T_1$	$L_1 \times T_1$	$L_{15} \times T_1$	$L_{14} \times T_2$	$L_{14} \times T_1$	$L_4 \times T_1$	$L_4 \times T_1$	$L_{16} \times T_2$	$L_{11} \times T_3$
8	Number of nodes bearing brace roots	$L_2 \times T_2$	$L_2 \times T_2$	$L_1 \times T_3$	$L_{13} \times T_1$	$L_{13} \times T_1$	$L_{10} \times T_2$	$L_3 \times T_3$	$L_3 \times T_1$	$L_3 \times T_3$	$L_3 \times T_3$	$L_2 \times T_1$	$L_2 \times T_1$
		$L_3 \times T_3$	$L_3 \times T_3$	$L_{11} \times T_2$	$L_{16} \times T_1$	$L_{16} \times T_1$	$L_{11} \times T_2$	$L_{20} \times T_3$	$L_3 \times T_3$	$L_{11} \times T_2$	$L_2 \times T_1$	$L_3 \times T_3$	$L_{11} \times T_2$
9	Days to 50% tasselling	$L_5 \times T_1$	$L_{14} \times T_3$	$L_1 \times T_1$	$L_{11} \times T_1$	$L_{11} \times T_1$	$L_3 \times T_1$	$L_6 \times T_3$	$L_8 \times T_2$	$L_{15} \times T_2$	$L_{14} \times T_3$	$L_{14} \times T_3$	$L_1 \times T_1$
		$L_{10} \times T_3$	$L_{17} \times T_3$	$L_2 \times T_2$	$L_{21} \times T_2$	$L_3 \times T_1$	$L_3 \times T_3$	$L_8 \times T_2$	$L_6 \times T_3$	$L_4 \times T_3$	$L_1 \times T_2$	$L_{15} \times T_2$	$L_6 \times T_3$
10	Days to 50% silking	$L_1 \times T_1$	$L_{21} \times T_2$	$L_1 \times T_1$	$L_3 \times T_1$	$L_3 \times T_1$	$L_3 \times T_1$	$L_{16} \times T_3$	$L_{16} \times T_3$	$L_{16} \times T_3$	$L_{21} \times T_1$	$L_{21} \times T_1$	$L_1 \times T_3$
		$L_{21} \times T_2$	$L_{21} \times T_1$	$L_{21} \times T_2$	$L_3 \times T_2$	$L_3 \times T_2$	$L_3 \times T_2$	$L_{11} \times T_3$	$L_{12} \times T_1$	$L_6 \times T_3$	$L_{16} \times T_3$	$L_{16} \times T_3$	$L_{21} \times T_1$
11	Anthesis-silking interval	$L_{14} \times T_2$	$L_{14} \times T_2$	$L_{14} \times T_2$	$L_3 \times T_2$	$L_3 \times T_2$	$L_3 \times T_2$	$L_5 \times T_1$	$L_5 \times T_1$	$L_6 \times T_1$	$L_{14} \times T_3$	$L_{11} \times T_2$	$L_8 \times T_1$
		$L_{14} \times T_3$	$L_{15} \times T_1$	$L_{14} \times T_3$	$L_6 \times T_2$	$L_1 \times T_2$	$L_1 \times T_2$	$L_9 \times T_3$	$L_6 \times T_1$	$L_5 \times T_1$	$L_{14} \times T_2$	$L_{15} \times T_3$	$L_{10} \times T_1$
12	Protein (%)	$L_{10} \times T_1$	$L_{17} \times T_3$	$L_{10} \times T_1$	$L_{10} \times T_1$	$L_{17} \times T_3$	$L_{10} \times T_1$	$L_{10} \times T_1$	$L_{17} \times T_3$	$L_{10} \times T_1$	$L_{17} \times T_3$	$L_{17} \times T_3$	$L_{18} \times T_3$
		$L_{17} \times T_3$	$L_{18} \times T_3$	$L_5 \times T_2$	$L_{17} \times T_3$	$L_{18} \times T_3$	$L_5 \times T_2$	$L_{17} \times T_3$	$L_{18} \times T_3$	$L_5 \times T_2$	$L_{18} \times T_3$	$L_{18} \times T_3$	$L_5 \times T_2$
13	Lysine (%)	$L_1 \times T_1$	$L_{11} \times T_3$	$L_{16} \times T_2$	$L_1 \times T_1$	$L_{11} \times T_3$	$L_{16} \times T_2$	$L_1 \times T_1$	$L_{11} \times T_3$	$L_{16} \times T_2$	$L_1 \times T_1$	$L_{11} \times T_3$	$L_{16} \times T_2$
		$L_{11} \times T_3$	$L_{16} \times T_2$	$L_{18} \times T_2$	$L_{11} \times T_3$	$L_{16} \times T_2$	$L_{18} \times T_2$	$L_{11} \times T_3$	$L_{16} \times T_2$	$L_{18} \times T_2$	$L_{11} \times T_3$	$L_{16} \times T_2$	$L_{18} \times T_2$
14	Tryptophan (%)	$L_{11} \times T_3$	$L_{16} \times T_1$	$L_{11} \times T_3$	$L_{11} \times T_3$	$L_{16} \times T_1$	$L_{11} \times T_3$	$L_{11} \times T_3$	$L_{16} \times T_1$	$L_{11} \times T_3$	$L_{11} \times T_3$	$L_{16} \times T_1$	$L_{11} \times T_3$
		$L_{16} \times T_2$	$L_{16} \times T_2$	$L_{14} \times T_1$	$L_{16} \times T_2$	$L_{16} \times T_2$	$L_{14} \times T_1$	$L_{16} \times T_2$	$L_{16} \times T_2$	$L_{14} \times T_1$	$L_{16} \times T_2$	$L_{16} \times T_2$	$L_{14} \times T_1$
15	Grain yield (kg/ha)	$L_3 \times T_1$	$L_4 \times T_1$	$L_3 \times T_1$	$L_{19} \times T_3$	$L_1 \times T_1$	$L_1 \times T_1$	$L_7 \times T_1$	$L_{19} \times T_2$	$L_{11} \times T_3$	$L_1 \times T_1$	$L_1 \times T_1$	$L_1 \times T_1$
		$L_5 \times T_1$	$L_{17} \times T_3$	$L_4 \times T_1$	$L_1 \times T_1$	$L_{19} \times T_3$	$L_{12} \times T_3$	$L_7 \times T_3$	$L_{11} \times T_3$	$L_{19} \times T_2$	$L_4 \times T_1$	$L_4 \times T_1$	$L_3 \times T_1$

E_1: Normal (recommended dose of nitrogen), **E_2:** Low-nitrogen, **E_3:** Excess soil moisture; **BP:** Better parent**, MP:** Mid parent, **CP:** Check parent

check parent with respect to plant height and ear height. In E_3 environment, hybrid $L_{19}\times T_1$ for plant height and 100-kernal weight, hybrid $L_{14}\times T_1$ for ear height and tryptophan content, hybrid $L_3\times T_3$ for ear diameter and number of nodes bearing brace roots exhibited high standard heterosis in desired direction. Cross combinations, $L_{13}\times T_3$ and $L_{19}\times T_2$ showed high standard heterosis for grain yield, however, hybrid $L_{11}\times T_3$ exhibited high check parent heterosis for tryptophan content and grain yield.

Overall results for standard heterosis revealed that cross combinations, $L_1\times T_1$, $L_{10}\times T_1$, $L_{11}\times T_3$ and $L_{14}\times T_1$ exhibited high standard heterosis for grain yield in E_1, E_2 and E_3 environments, however, hybrids, $L_1\times T_1$, $L_1\times T_2$, $L_1\times T_3$, $L_2\times T_1$, $L_2\times T_2$, $L_3\times T_3$, $L_3\times T_1$ and $L_4\times T_1$ showed high standard heterosis in E_1, E_2 and pooled environment, respectively. For quality traits crosses, $L_{10}\times T_1$ and $L_5\times T_2$, $L_{16}\times T_2$ and $L_{18}\times T_2$, $L_{11}\times T_3$ and $L_{14}\times T_1$, exhibited high check parent heterosis in overall results for protein, lysine and tryptophan contents, respectively.

It seems quite reasonable by looking at these heterotic responses that none of the hybrids was consistently good with respect to all 15 characters in all the three and pooled environment for heterobeltiosis, standard heterosis and relative heterosis. However, in E_1 environment, 1cross revealed higher standard heterosis for plant height, number of kernel rows per ear and grain yield, 1 for plant height, number of kernels per row, grain yield, 1 for plant height, ear height, tryptophan per cent and grain yield, 1 for ear height, number of kernels per row and

Table 5.2.5: Cross(es) common with respect to standard parent heterosis in normal (recommended dose of nitrogen) environment

Sl. No.	No. cross common	Character
1.	1	Plant height, number of kernel rows/ear and Grain yield (kg/ha)
2.	1	Plant height, number of kernels /row, Grain yield (kg/ha)
3.	1	Plant height (cm), Ear height (cm), tryptophan per cent and Grain yield (kg/ha)
4.	1	Ear height (cm), number of kernels/row and anthesis-silking interval
5.	1	100-kernels weight) and Grain yield (kg/ha)
6.	1	Ear length (cm) and Grain yield (kg/ha)
7.	1	Ear length (cm) and number of kernel rows / ear
8.	1	number of kernel rows / ear, days to 50% silking and Grain yield (kg/ha)
9.	1	days to 50% tasselling, days to 50% silking, lysine per cent and Grain yield (kg/ha)
10.	1	days to 50% tasselling and Grain yield (kg/ha)
11.	1	Protein per cent and Grain yield (kg/ha)
12.	1	Lysine percent and tryptophan percent
13.	2	number of kernels /row and Grain yield (kg/ha)
14.	3	100-kernels weight, Ear length (cm) and Grain yield (kg/ha)
15.	3	days to 50% silking and Grain yield (kg/ha)
16.	4	Plant height and Grain yield (kg/ha)

anthesis-silking interval, 1 for 100-kernel weight and grain yield, 1 for ear length and grain yield, 1 for ear length and number of kernel rows per ear, 1 for number of kernel rows per ear, days to 50% silking and grain yield, 1 for days to 50% tasselling, days to 50% silking, lysine per cent and grain yield, 1 for days to 50% tasselling and rain yield, 1 for protein per cent and rain yield, 1 for lysine percent and tryptophan percent, 2 for number of kernels per row and grain yield (kg per ha), 3 for 100-kernel weight, ear length and grain yield, 3 for days to 50% silking and grain yield and 4 for plant height and grain yield, Similarly, in E_2 (Table 5.2.6), 1 for plant height, 100-kernels weight, number of kernels/row and grain yield (kg/ha),1 for plant height (cm), Ear diameter (cm), days to 50% tasselling and grain yield (kg/ha),1 for 100-kernel weight, number of kernel rows per ear, tryptophan per cent and grain yield (kg/ha),1 for plant height, number of kernel rows per ear, number of kernels per row and grain yield (kg/ha),1 for plant height, ear height (cm), tryptophan per cent and grain yield (kg/ha),1 for plant height, ear length (cm), 100-kernels weight, number of kernels per row and grain yield (kg/ha), 1 for plant height, Tryptophan per cent and Grain yield (kg/ha),1 for plant height, 100-kernels weight, days to 50% silking, Tryptophan per cent and grain yield (kg/ha),1 for 100-kernel weight, ear length (cm), days to 50% silking, tryptophan per cent and grain yield (kg/ha), 1 for 100-kernel weight, ear length (cm), number of kernel rows per ear, days to 50% tasselling and grain yield (kg/ha),1 for plant height, ear height (cm) and number of kernel rows per ear,1 for ear length (cm),

Table 5.2.6: Cross(es) common with respect to standard parent heterosis in low-nitrogen environment

Sl. No.	No. cross common	Character
1.	1	Plant height, 100-kernels weight, number of kernels/row and Grain yield (kg/ha)
2.	1	Plant height (cm), Ear diameter (cm), days to 50% tasselling and Grain yield (kg/ha)
3.	1	100-kernels weight, number of kernel rows / ear, tryptophan per cent and Grain yield (kg/ha)
4.	1	Plant height, number of kernel rows / ear, number of kernels/row and Grain yield (kg/ha)
5.	1	Plant height, ear height (cm), tryptophan per cent and Grain yield (kg/ha)
6.	1	Plant height, ear length (cm), 100-kernels weight, number of kernels /row and Grain yield (kg/ha)
7.	1	Plant height, Tryptophan per cent and Grain yield (kg/ha)
8.	1	Plant height, 100-kernels weight, days to 50% silking, Tryptophan per cent and Grain yield (kg/ha)
9.	1	100-kernels weight, ear length (cm), days to 50% silking, tryptophan per cent and Grain yield (kg/ha)
10.	1	100-kernels weight, ear length (cm), number of kernel rows / ear, days to 50% tasselling and Grain yield (kg/ha)
11.	1	Plant height, ear height (cm) and number of kernel rows / ear
12.	1	Ear length (cm), ear diameter (cm), number of kernel rows / ear, number of kernels/row, protein per cent and Grain yield (kg/ha)
13.	1	Days to 50% silking, anthesis-silking interval and Grain yield (kg/ha)
14.	2	Plant height, 100-kernels weight, days to 50% silking and Grain yield (kg/ha)
15.	2	Plant height, 100-kernels weight, number of kernels/row and Grain yield (kg/ha)
16.	2	100-kernels weight and ear length (cm)
17.	2	Ear height (cm) and Grain yield (kg/ha)
18.	2	Plant height, 100-kernels weight, days to 50% silking and Grain yield (kg/ha)
19.	2	Tryptophan per cent and Grain yield (kg/ha)
20.	2	Plant height, number of kernel rows / ear and Grain yield (kg/ha)
21.	2	Plant height (cm) and Ear height (cm)
22.	2	Anthesis-silking interval and Grain yield (kg/ha)
23.	3	Days to 50% silking and Grain yield (kg/ha)
24.	3	Ear length (cm) and grain yield (kg/ha)
25.	3	100-kernels weight and number of kernels / row
26.	4	Number of kernels /row and plant height (cm)
27.	4	Plant height, 100-kernels weight and Grain yield (kg/ha)
28.	5	100-kernels weight and Grain yield (kg/ha)
29.	13	Plant height and Grain yield (kg/ha)

ear diameter (cm), number of kernel rows per ear, number of kernels/row, protein per cent and grain yield (kg/ha),1 for days to 50% silking, anthesis-silking interval and grain yield (kg/ha),2 for plant height, 100-kernels weight, days to 50% silking and grain yield (kg/ha),2 for plant height, 100-kernels weight, number of kernels per row and grain yield (kg/ha), 2 for 100-kernels weight and ear length (cm),2 for ear height (cm) and grain yield (kg/ha),2 for plant height, 100-kernels weight, days to 50% silking and grain yield (kg/ha),2 for tryptophan per cent and Grain yield (kg/ha),2 for plant height, number of kernel rows per ear and grain yield (kg/ha),2 for plant height (cm) and ear height (cm), 2 for anthesis-silking interval and grain yield (kg/ha),3 for days to 50% silking and grain yield (kg/ha),3 for ear length (cm) and grain yield (kg/ha),3 for 100-kernel weight and number of kernels per row, 4 for number of kernels per row and plant height (cm),4 for plant height, 100-kernels weight and grain yield (kg/ha),5 for 100-kernel weight and grain yield (kg/ha) and13 for plant height and grain yield (kg/ha), whereas, in excess soil moisture environment, 1 for plant height, days to 50% silking, tryptophan per cent and grain yield, 1 for ear height, anthesis-silking interval and 100-kernel weight,1 for ear height, tryptophan per cent and grain yield, 1 for ear length and grain yield, 1 for 100-kernel weight and days to 50% silking, 1 for 100-kernel weight and tryptophan per cent, 1 for number of kernel rows per ear and grain yield, 1 for ear length and number of kernels per row, 1 for ear length and anthesis-silking interval, 1 for ear length, number of kernel rows per ear and

Table 5.2.7: Cross(es) common with respect to standard parent heterosis in excess soil moisture environment

Sl. No.	No. cross common	Character
1.	1	Plant height, days to 50% silking, tryptophan per cent and Grain yield (kg/ha)
2.	1	Ear height (cm), anthesis-silking interval and 100-kernels weight
3.	1	Ear height (cm), tryptophan per cent and Grain yield (kg/ha)
4.	1	Ear length (cm) and Grain yield (kg/ha)
5.	1	100-kernels weight and days to 50% silking
6.	1	100-kernels weight and tryptophan per cent
7.	1	Number of kernel rows / ear and Grain yield (kg/ha)
8.	1	Ear length (cm) and number of kernels / row
9.	1	Ear length (cm) and anthesis-silking interval
10.	1	Ear length (cm), number of kernel rows / ear and tryptophan per cent
11.	1	Ear height (cm) and number of kernel rows / ear
12.	1	Ear diameter (cm), number of kernel rows / ear, anthesis-silking interval and Grain yield (kg/ha)
13.	3	Plant height (cm) and tryptophan per cent)

tryptophan per cent, 1 for ear height and number of kernel rows per ear, 1 for Ear diameter , number of kernel rows per ear, anthesis-silking interval and grain yield and 3 for plant height and tryptophan per cent (Table 5.2.7).

However, in pooled environment, 1 for plant height and 100-kernel weight, 1 for plant height, Ear height, lysine per cent, tryptophan per cent and grain yield, 1 for ear height, days to 50% tasselling and grain yield, 1 for Ear height, days to 50% silking and grain yield, 1 for number of kernel per row, lysine per cent, tryptophan per cent and grain yield, 1 for ear height, number of kernel rows per ear and protein per cent, 1 for ear height and ear length, 1 for 100-kernel weight and number of kernel per row, 1 for 100-kernel weight, lysine per cent and tryptophan per cent, 1 for ear length (cm) , lysine per cent and tryptophan per cent, 1 for number of kernel rows per ear, nodes bearing brace roots, days to 50% silking and grain yield, 1 for days to 50% silking and grain yield, 1 for protein per cent, lysine per cent and tryptophan per cent, 2 for Ear height and days to 50% tasselling, 2 for Ear diameter and grain yield, 2 for 100-kernel weight and grain yield, 2 for number of kernel rows per ear and grain yield, 2 for number of kernel per row and grain yield, 2 for days to 50% tasselling and grain yield, 6 for ear height and grain yield, 7 for lysine per cent, tryptophan per cent and Grain yield and 10 lysine per cent and tryptophan per cent (Table 5.2.8). The results are in agreement with those of **Vasal *et al.* (1995), Singh and Mishra (1996), Mukherjee (1997), Sinha *et al.* (1997), Pradhan (1999), Kabdal**

Table 5.2.8: Cross(es) common with respect to standard parent heterosis in pooled environment

Sl. No.	No. cross common	Character
1.	1	Plant height and 100-kernels weight
2.	1	Plant height (cm), Ear height (cm), lysine per cent, tryptophan per cent and Grain yield (kg/ha)
3.	1	Ear height (cm), days to 50% tasselling and Grain yield (kg/ha)
4.	1	Ear height (cm), days to 50% silking and Grain yield (kg/ha)
5.	1	Number of kernels / row, lysine per cent, tryptophan per cent and Grain yield (kg/ha)
6.	1	Ear height (cm), number of kernel rows/ear and protein per cent
7.	1	Ear height (cm) and ear length (cm)
8.	1	100-kernels weight and number of kernels/row
9.	1	100-kernels weight, lysine per cent and tryptophan per cent
10.	1	Ear length (cm) , lysine per cent and tryptophan per cent
11.	1	Number of kernel rows / ear, nodes bearing brace roots, days to 50% silking and Grain yield (kg/ha)
12.	1	Days to 50% silking and Grain yield (kg/ha)
13.	1	Protein per cent, lysine per cent and tryptophan per cent
14.	2	Ear height (cm) and days to 50% tasselling
15.	2	Ear diameter (cm) and Grain yield (kg/ha)
16.	2	100-kernels weight and Grain yield (kg/ha)
17.	2	Number of kernel rows / ear and Grain yield (kg/ha)
18.	2	Number of kernels / row and Grain yield (kg/ha)
19.	2	Days to 50% tasselling and Grain yield (kg/ha)
20.	6	Ear height (cm) and Grain yield (kg/ha)
21.	7	Lysine per cent, tryptophan per cent and Grain yield (kg/ha)
22.	10	Lysine per cent and tryptophan per cent

(2000), Dubey (2001), Pandey and Kumar (2001), Singh *et al.* (2002), Yousif *et al.* (2003), Reddy and Ahuja (2004), Rezaei *et al.* (2005) and Mohanraj Gopalan (2005) and Singhal *et al.* (2006). However, hybrid $L_{19}\times T_1$ for plant height, $L_{14}\times T_1$ and $L_{14}\times T_3$ for ear height, $L_5\times T_1$ for 100- kernels weight, $L_5\times T_2$ for ear length, $L_{14}\times T_3$ for number of kernel rows per ear, $L_4\times T_1$ for number of kernels per row, $L_{11}\times T_2$ for brace roots, $L_{21}\times T_1$ for days to 50% silking, $L_1\times T_1$ for grain yield exhibited significant heterosis (BP, MP and CP) in all the environments. Moreover, 1 cross $L_{10}\times T_1$ for protein, 3 crosses $L_1\times T_1$, $L_{16}\times T_2$ and $L_{18}\times T_3$ for Lysine and tryptophan showed positive and significant heterosis (BP, MP& CP) in study of overall environments.

5.3 Variability Parameters

5.3.1 Heritability

The heritability expresses the proportion of the total variance that is attributed to the average effect of genes and this is what determines the degree of resemblance between parents and off-springs. Heritability in broad sense is the proportion of genetic variance to phenotypic variance and it denotes the success of selection. However, it is worth mentioning that estimates of heritability are not constant and are more valid for the populations from which it was estimated. In the present investigation, highest heritability was obtained for quality traits, 100-kernel weight and grain yield **(Robinson *et al.*, 1952; Singh, 1984; Debnath, 1987; Debnath and Sarkar, 1987; Claudio and Patricio, 1988; Debnath and**

Khan, 1991; Saha and Mukherjee, 1993; Osuna *et al.*, 1995; Singh *et al.*, 1998; Srivastava, 2001; Kabdal *et al.*, 2003 and Mahmood *et al.*, 2004; Kabdal, 2000 and Srivastava, 2001) in all the three environments except grain yield in E_2 environment where it showed moderate estimates of heritability. However, ear length, ear diameter, number of kernels per ear row in E_1, ear height in E_2 and ear length and ear height in E_3 also exhibited high estimates of broad sense heritability. However, number of kernel rows per ear and anthesis-silking interval in E_1, days to 50% tasselling, days to 50% silking, ear length, plant height and number of kernel rows per ear in E_2 and plant height and brace roots in E_3 environment showed moderate heritability estimates **(Dawood and Mohamed, 1989; Hema *et al.*, 1999; Garbuglio *et al.*, 2009 and Rafiq *et al.*, 2010)** This indicated that these characters were less influenced by the environmental fluctuations and selection for such traits on the basis of phenotype will be effective. Whereas, some characters like days to 50% tasseling, days to 50% silking, plant height, ear height, brace roots in E_1, ear diameter, number of kernels per row, brace roots, anthesis-silking interval in E_2 and days to 50% tasselling, days to 50% silking, ear diameter, number of kernel rows per ear, number of kernels per row and anthesis-silking interval in E_3 had low heritability estimates, indicating marked effect of the environment in the expression of these traits. **Reddy and Agarwal (1992), Viola *et al.* (2003)**, **Rezaei *et al.* (2004)** and **Abirami *et al.* (2005)** also reported high heritability for ear diameter, number of kernels per row, number of kernel rows per ear and 100-kernel

weight, whereas, high heritability for grain yield along with other characters was reported by **Singh (1989)**, **Satyanarayana and Saikumar (1996) and Kabdal (2000)**.

5.3.2 Expected genetic advance

Expected genetic advance indicates gain to be obtained as the result of one cycle of selection for a character. Highest estimate of genetic advance in percent of mean was obtained for grain yield and quality characters in all the three (E1, E2 and E3) environments, however, moderate to low estimates of genetic advance were shown by the characters, ear height, ear diameter, ear length, plant height, ear length, ear diameter number of kernel rows per ear, number of kernels per row, number of nodes bearing brace roots, days to 50 percent tasselling and silking. These results are in accordance with **Satyanarayana (1994)**, **Shreekumar and Bai (1995)**, **Mani and Bisht (1996)**, **Kabdal (2000)**, **Srivastava (2001)**, **Rezaei *et al.* (2004)**, **Abirami *et al.* (2005)** and **Singhal *et al.* (2006)**. Characters indicating high expected genetic advance coupled with high heritability such as grain yield and quality traits indicated that genotypic variation present in the genetic material studied may be possibly due to high additive genetic variance for these traits in all the three environments.

5.3.3 Coefficient of variation

The success of any plant breeding programme depends on the extent of variability present in the breeding material in which the

improvement is to be made. Variation at phenotypic level is made up of genotypic and environmental variability and therefore, does not necessarily ensure effective selection as it may be largely due to the environmental influence. It is the genotypic variability and more specially the additive genetic variance which is most important for plant breeder to decide the genetic gain through selection. The phenotypic and genotypic coefficients of variation for grain yield, ear height, ear length, ear diameter, number of kernels per row and 100-kernel weight were quite high **(Abirami *et al.*, 2005; Bhoite and Sonone, 2007** and **Yusuf, 2010)**. However, genotypic coefficient of variation was found low when compared to phenotypic coefficient of variation for all the characters. Similar results were reported by **Mani and Bisht (1996)** in maize. Almost similar values in quality traits for genotypic and phenotypic coefficient of variation indicated that these characters were less influenced by the environment. However, phenotypic and genotypic coefficients of variation were found lower for days to 50 percent tasselling and silking. Genotypic coefficient of variation could provide an effective selection criteria for improving the traits studied. The results are in agreement with **Kabdal *et al.* (2003)** and **Rafiq *et al.* (2010).**

5.4 Combining Ability

All progeny testing procedures depend upon the estimation of combining abilities of inbred lines in the production of commercial hybrids in maize. In practice, therefore, problem before the breeders are (i) isolating numerous inbred lines, (ii) testing combinations of inbreds

i.e., hybrids, (iii) using shortcut methods of testing combinations and (iv) developing methods of efficient seed production at the commercial scale. The value of inbred lines in the commercial production of hybrids is determined by two factors :

(i) the characteristics of line *per se* with respect to yield and other quantitative traits and

(ii) the behaviour of lines in the hybrid combinations.

Combining ability analysis as an effective tool for identifying superior parents for hybrids was first reported by **Sprague and Tatum (1942)**. General combining ability has been defined as the average performance of the lines in the hybrid combinations and the SCA as deviation from expectation on the basis of GCA. Both GCA and SCA variances have been determined and also, possible types of gene action involved. The variance of GCA includes additive genetic portion, while, SCA variance usually includes non-additive genetic variance of the total genetic variance arising largely from dominance and epistatic deviation. In the present investigation, combining ability analysis was performed through line x tester technique (Kempthorne, 1957) in order to sort out promising QPM inbred lines which may have good potential for yield and may be utilized for the commercial production of hybrids in different environments.

The point of major interest was to see the consistency of GCA and SCA estimates when the experiment was carried out over three environments. The interaction of the crosses × environment might make

substantial contribution to both GCA and SCA and their relative variances.

Variance due to lines was significant for most of the characters except 100-kernel weight and brace roots in $E_1$and E_3, number of kernels per row in E3; days to 50% silking and anthesis-silking interval in E2 and E3 environments. High variances in lines observed here were due to wide range of diversity among the lines. Variance due to tester was significant for all the characters except brace roots in E_1 and E_2 environments and days to 50% tasselling in E1 environment. All the characters showed significant differences in all the three environments for line x tester component. Similar results have been reported by **Nagda *et al.* (1995); Dass *et al.* (1997); Mathur *et al.* (1998)**; **Petrovic (1998); Srinivasan; Vasal (1999); Konak *et al.* (2001); Venkatesh *et al.* (2001); Srivastava and Singh, (2002); Nayankar and Wali (2003)** and **Ramneek *et al.* (2005).**

Pooled analysis of variance over environments for combining ability indicated that variance due to lines was significant for all the characters except quality parameters which indicated that sufficient variability among the lines except quality parameters. Whereas, variance due to testers was significant for plant height, ear height, 100-kernel weight ear length, ear diameter, number of kernel rows per ear, number of kernels per row and grain yield, showed that testers were highly divergent which satisfies the choice of the testers. For line x tester interaction component, the variance was significant for all the

characters. Component for line x environment interaction was non significant for number of kernels per row, protein, lysine and tryptophan content, suggested that selection of genotypes for these traits may be useful under adverse environmental conditions. While tester x environment component of variance was significant for plant height, ear height, 100-kernel weight, ear length, ear diameter, number of kernels row per ear and grain yield. Higher order interaction i.e. (line x tester) x environment was significant for all fifteen characters. The present findings are, in agreement with the earlier reports of **Soliman and Sadek (1999), Srinivasan and Vasal (1999), Chen *et al.* (2000), Avila and Rodriguez, (2005); Jaykumar and Sundaram, (2007) and Dar *et al.* (2007).**

Estimates of variances due to specific combining ability (σ^2 SCA) were greater than general combining ability (σ^2 GCA) for all the characters over all the three environments. For all the characters, the ratio of variance of GCA to SCA was lesser than unity in all the environments indicating pre-dominance of non-additive variance.

The non-additive (dominance) variance (σ^2D) was higher than the additive variance (σ^2A) at both F=0 and F=1. Therefore, as the dominance variance is predominant, transgrassive (recombinant) breeding may not be useful. Heterosis breeding is a better choice for these conditions. **Takachenku and Goncharenko (1973)**, **Jha and Khehra (1992)**, **Singh (1994)**, **Zheng *et al.* (1995)** and **Dahlan *et al.* (1997)** also reported similar findings.

Perusal of Table 5.4.1 revealed that none of the parents was excellent for all the characters across the environments. It suggested the importance of multiple crosses or some system of random mating to realize substantial improvement in grain yield. The GCA effects of the parents in the E_1 indicated parental lines and testers L_1, L_2, L_3, L_4, T_1 and T_3 to be the best general combiners with six, seven, four, five, seven and six characters each respectively. The line L_1 exhibited significant GCA effects for ear height, number of nodes bearing brace roots, days to 50% tasselling, days to 50% silking, anthesis-silking interval and grain yield, L_2 for ear length, number of kernels per row, days to 50% tasselling, days to 50% silking, protein content and grain yield, L_3 for 100-kernel weight, anthesis-silking interval, protein content and grain yield, L_4 for plant height, 100-kernel weight, number of kernels per row and grain yield in desired direction, while, tester T_1 excelled for GCA among all parents for number of kernel rows per ear, number of nodes bearing brace roots, days to 50% tasselling, days to 50% silking, anthesis-silking interval, tryptophan content and grain yield and T_3 for plant height, ear height, ear length, number of kernels per row, protein and lysine content. In the E_2, the significant GCA effects for a maximum of eight characters were observed in respect of line L_3 followed by six, six, five, four, four, four and four in L_{12}, L_{14}, L_{13}, L_1, L_4, L_{11} and L_{16}, respectively. While, among testers T_1 and T_3 exhibited maximum significant GCA effects for eight and six characters, respectively. The line L_3 showed significant GCA effects for plant height, ear length, ear

Table 5.4.1: Summary of GCA effects of parents for important economic characters in Quality Protein Maize (QPM)

Parent	Environment	Characters															Overall performance		
		Plant height (cm)	Ear height (cm)	100-kernel weight	Ear length (cm)	Ear diameter (cm)	number of kernel-rows/ear	number of kernels/ row	Number of nodes bearing brace root	Days to 50% tasselling	Days to 50% silking	Anthesis-silking interval	Protein (%)	Lysine (%)	Tryptophan (%)	Grain yield (kg/ha	G	A	P
L_1	E_1	A	G	A	P	A	A	P	G	G	G	G	A	P	P	G	6	5	4
	E_2	P	P	A	A	P	A	A	G	G	G	P	A	P	P	G	4	5	6
	E_3	P	P	P	P	A	P	P	P	P	P	P	A	P	P	A	-	3	12
	P	P	P	A	P	A	G	P	G	A	G	A	A	P	P	G	4	5	6
L_2	E_1	A	A	P	G	P	P	G	G	G	G	P	G	P	P	G	7	2	6
	E_2	G	P	P	A	A	P	A	P	A	A	P	G	P	P	A	2	6	7
	E_3	A	P	P	A	A	P	A	A	A	P	P	G	P	P	G	2	6	7
	P	A	P	A	A	A	P	G	G	A	A	P	G	P	P	G	4	6	5
L_3	E_1	A	A	G	A	A	P	A	A	A	A	G	G	P	P	G	4	8	3
	E_2	G	A	P	G	G	A	G	P	A	G	G	G	P	P	G	8	3	4
	E_3	P	A	A	A	G	P	P	G	A	P	P	G	P	P	P	3	4	8
	P	A	A	A	A	G	P	A	A	A	G	A	G	P	P	A	3	9	3
L_4	E_1	G	A	G	A	P	P	G	A	A	A	P	G	P	P	G	5	5	5
	E_2	G	A	P	A	A	G	G	P	A	A	P	G	P	P	A	4	6	5
	E_3	A	A	P	A	A	A	A	G	G	P	P	G	P	P	G	4	6	5
	P	G	A	A	A	A	A	G	A	A	P	P	G	P	P	G	4	7	4
L_5	E_1	A	P	P	P	P	P	P	P	P	P	P	P	P	P	P	-	1	14
	E_2	P	A	A	P	P	P	A	G	P	P	P	P	P	P	P	1	3	11
	E_3	G	A	A	A	A	A	G	A	P	P	A	P	P	P	P	2	7	6
	P	A	A	A	P	P	A	A	A	P	P	P	P	P	P	P	-	6	9
L_6	E_1	P	P	P	P	P	A	P	A	A	A	A	A	P	A	P	-	7	8
	E_2	P	P	P	P	P	G	P	P	A	A	A	A	P	A	P	1	5	9
	E_3	P	P	A	P	A	P	A	A	A	A	A	A	P	G	P	1	8	6
	P	P	P	A	P	P	P	P	A	A	A	A	A	P	P	P	-	6	9
L_7	E_1	P	P	P	P	P	P	A	P	A	P	P	P	A	A	P	-	4	11
	E_2	P	A	P	A	P	G	P	P	A	A	P	P	A	A	P	1	6	8
	E_3	A	P	P	P	G	P	A	A	A	G	G	P	A	A	G	4	6	5
	P	P	P	G	P	P	P	P	P	A	A	P	P	A	A	A	1	5	9
L_8	E_1	A	A	P	P	P	P	P	P	A	A	A	P	A	G	P	1	6	8
	E_2	P	P	A	P	P	P	P	P	P	P	A	P	A	G	P	1	3	11
	E_3	G	G	A	A	G	P	A	G	A	G	A	P	A	A	P	5	7	3
	P	A	A	A	P	P	P	P	P	A	A	A	P	A	A	P	-	8	7

Table 5.4.1: Contd....

L_9	E_1	P	P	A	P	A	A	P	P	P	P	A	P	A	G	G	2	5	8
	E_2	A	A	G	P	A	A	A	P	P	P	P	P	A	G	A	2	7	6
	E_3	G	P	P	P	G	A	P	P	A	A	P	P	A	G	P	3	4	8
	P	P	P	A	P	A	A	P	P	P	P	P	P	A	G	A	1	5	9
L_{10}	E_1	G	G	A	P	A	P	A	P	P	P	A	A	A	A	A	2	8	5
	E_2	P	G	A	A	A	A	G	G	P	P	P	A	A	A	A	3	8	4
	E_3	A	A	P	A	A	G	P	A	P	P	A	A	A	A	P	1	9	5
	P	A	G	A	P	G	A	A	P	P	P	A	A	A	A	P	2	8	5
L_{11}	E_1	G	A	P	A	P	A	G	A	G	P	G	A	A	A	P	4	7	4
	E_2	A	A	P	A	G	P	P	G	G	P	G	A	A	A	A	4	7	4
	E_3	G	A	P	A	A	P	P	A	G	A	A	A	A	A	P	2	9	4
	P	A	A	P	A	P	P	A	A	G	P	G	A	A	A	P	2	8	5
L_{12}	E_1	A	P	A	G	A	P	P	P	P	P	A	G	A	G	P	3	5	7
	E_2	P	A	G	G	G	G	P	A	P	P	P	G	A	G	A	6	4	5
	E_3	P	P	P	A	A	A	P	P	A	A	A	G	A	G	P	2	7	6
	P	P	P	A	A	A	A	P	P	P	P	A	G	A	G	P	2	6	7
L_{13}	E_1	P	P	A	G	A	P	P	A	P	P	A	A	G	G	A	3	6	6
	E_2	A	G	G	A	A	A	A	G	P	P	A	A	G	G	P	5	7	3
	E_3	A	A	A	A	A	A	P	P	A	P	P	A	G	G	P	2	8	5
	P	P	A	A	G	A	A	P	A	P	P	P	A	G	G	P	3	6	6
L_{14}	E_1	A	P	P	A	A	A	P	P	P	P	G	P	G	G	P	3	4	8
	E_2	G	G	P	G	A	G	P	A	A	P	P	P	G	G	P	6	3	6
	E_3	A	A	P	G	A	P	A	P	P	P	P	P	G	G	P	3	4	8
	P	A	A	P	G	A	P	P	P	P	P	P	P	G	G	P	3	3	9
L_{15}	E_1	A	A	G	A	P	P	P	P	P	P	G	P	P	P	P	2	3	10
	E_2	A	G	A	A	P	P	A	P	P	P	P	P	P	P	P	1	4	10
	E_3	A	A	A	G	G	A	G	P	P	P	A	P	P	P	P	3	5	7
	P	A	A	G	A	P	A	G	P	P	P	P	P	P	P	P	2	4	9
L_{16}	E_1	P	A	G	P	A	G	A	P	P	P	P	P	A	A	A	2	6	7
	E_2	P	P	P	P	G	G	G	G	A	P	P	P	A	A	P	4	3	8
	E_3	P	P	P	P	A	P	P	P	A	A	A	P	A	A	G	1	6	8
	P	P	P	A	P	G	G	G	P	P	P	P	P	A	A	A	3	4	8

Table 5.4.1: Contd....

L_{17}	E_1	P	P	P	P	P	P	A	P	P	P	A	P	P	P	P	-	2	13
	E_2	P	P	P	P	P	P	P	P	P	A	G	P	P	P	A	1	2	12
	E_3	A	P	A	P	A	G	P	P	P	A	G	P	P	P	P	2	4	9
	P	P	P	A	P	P	A	P	P	P	A	G	P	P	P	P	1	3	11
L_{18}	E_1	A	A	P	A	P	P	P	P	P	P	P	P	A	A	A	-	6	9
	E_2	A	P	G	P	P	P	P	P	A	A	G	P	A	A	A	2	6	7
	E_3	P	P	A	A	G	A	A	P	P	P	P	P	A	A	G	2	6	7
	P	P	P	G	A	P	P	P	P	A	P	P	P	A	A	A	1	5	9
L_{19}	E_1	P	P	P	A	P	P	P	G	A	P	P	A	G	G	A	3	4	8
	E_2	A	A	P	A	P	P	P	A	P	P	P	A	G	G	G	3	5	7
	E_3	P	A	G	A	A	P	A	P	A	P	P	A	G	G	A	3	7	5
	P	G	A	A	A	P	P	P	A	A	P	P	A	G	G	G	4	6	5
L_{20}	E_1	P	A	P	P	P	G	G	P	A	G	A	P	A	A	A	3	6	6
	E_2	P	A	P	P	A	P	P	P	A	A	A	P	A	A	A	-	8	7
	E_3	P	A	A	P	A	A	P	P	A	P	A	P	A	A	P	-	8	7
	P	P	A	A	P	P	G	P	P	A	A	P	P	A	A	A	1	7	7
L_{21}	E_1	P	P	A	A	G	A	A	P	G	G	A	P	A	A	P	3	7	5
	E_2	P	P	G	P	A	P	A	P	A	G	P	P	A	A	P	2	6	7
	E_3	P	A	P	A	A	A	A	G	P	G	A	P	A	A	A	2	9	4
	P	P	G	A	A	G	P	A	P	A	G	A	P	A	A	P	3	7	5
T_1	E_1	A	A	A	A	A	G	A	G	G	G	G	P	A	G	G	7	7	1
	E_2	A	P	P	P	G	G	P	G	P	A	G	P	G	G	A	6	3	6
	E_3	G	A	A	G	A	P	P	P	G	A	A	P	A	G	G	5	6	4
	P	G	A	A	A	G	G	P	A	A	G	A	P	A	G	G	6	7	4
T_2	E_1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	-	-	15
	E_2	P	G	A	P	P	P	P	P	P	P	P	P	P	P	P	1	1	13
	E_3	P	P	P	A	A	G	P	P	P	P	P	P	P	P	P	1	2	12
	P	P	A	P	P	P	P	P	P	P	P	P	P	P	P	P	-	1	14
T_3	E_1	G	G	A	G	A	A	G	P	A	P	P	G	G	A	P	6	5	4
	E_2	G	P	A	G	A	P	G	A	G	G	P	G	G	A	G	8	4	3
	E_3	P	G	G	P	G	A	G	G	P	A	A	G	A	A	A	6	6	3
	P	P	P	A	G	A	P	G	A	G	G	A	G	A	A	P	5	6	4

A = Average, **P** = Poor, **G** = Good; **E_1:** Normal (recommended dose of nitrogen), **E_2:** Low-nitrogen, **E_3:** Excess soil moisture

diameter, number of kernels per row, days to 50% silking, anthesis-silking interval, protein content and grain yield, L_{12} for 100-kernel weight, ear length, ear diameter, number of kernel rows per ear, protein and tryptophan content, L_{14} for plant height, ear height, ear length, number of kernel rows per ear lysine and tryptophan contents, L_{13} for ear height, 100-kernel weight, number of nodes bearing brace roots, lysine and tryptophan contents, L_1 for number of nodes bearing brace roots, days to 50% tasselling, days to 50% silking and grain yield, L_4 for plant height, number of kernel rows per ear, number of kernels per row and protein content, L_{11} for ear diameter, number of nodes bearing brace roots, days to 50% tasselling and anthesis-silking interval and L_{16} for ear diameter, number of kernel rows per ear, number of kernels per row and number of nodes bearing brace roots. While, tester T_3 excelled for GCA among all parents for plant height, ear length, number of kernels per row, days to 50% tasselling, days to 50% silking, protein content, lysine content and grain yield and T_1 for ear diameter, number of kernel rows per ear, number of nodes bearing brace roots, anthesis-silking interval, lysine and tryptophan contents.

The GCA effects of the parents in the E_3 indicated that lines, L_8, L_4, L_7 and testers, T_3 and T_1 were the best general combiners with significant GCA effects for a maximum of five, four, four and six and five characters for lines and testers, respectively. Parental line, L_8 excelled for plant height, ear height, ear diameter, number of nodes bearing brace roots and days to 50% tasselling, L_4 for number of nodes bearing

brace roots, protein content and grain yield and L_7 for ear diameter, days to 50% silking, anthesis-silking interval and grain yield. While, tester T_3 excelled for GCA among all testers for ear height, 100-kernel weight, ear diameter, number of kernels per row, number of nodes bearing brace roots and protein content and T_1 for plant height, ear length, days to 50% tasselling, tryptophan content and grain yield.

On the basis of pooled analysis, lines L_1, L_2, L_4 and testers T_1 and T_3 were the best combiners for the maximum of four characters each for line and six and five characters for testers, respectively. The line, L_1 exhibited significant GCA effects for number of kernel rows per ear, number of nodes bearing brace roots, days to 50% silking and grain yield, while, L_2 and L_4 had significant GCA effects for number of kernels per row, number of nodes bearing brace roots, protein content and grain yield and for plant height, number of kernels per row, protein content and grain yield, respectively. However, tester T_1 excelled for GCA among all testers for plant height, ear diameter, number of kernel rows per ear, days to 50% silking, tryptophan content and grain yield. While, T_3 exhibited significant GCA effect for ear length, number of kernels per row, days to 50% tasselling, days to 50% silking and protein content. Similar findings were reported by **Dass *et al.* (1997)**; **Mathur *et al.* (1998); Petrovic (1998); Soliman and Sadek (1999); Srinivasan and Vasal (1999); Srivastava (2001)**; **Venkatesh *et al.* (2001); Li-Mingshun *et al.* (2005); Ramneek *et al.* (2005); Jaykumar and Sundaram (2007)** and **Gurung *et al.* (2009).**

The SCA effects represent mainly dominance, additive × dominance, dominance × dominance effects. The crosses showing SCA effects involving parents with good GCA could be exploited. However, if a cross having high SCA has parents of which one is good combiner and other as poor or average combiner, such crosses are likely to throw some good segregants only if additive genetic system is present in a good general combiner and epistatic effects in the cross, act in the same direction so as to maximize the desirable expression of the characters in question **(Whitehouse, 1958; Lonnquist, 1961)**. Parental *per se* performance has been suggested as useful index in maize for selecting parents for hybridization. However, observations from the present study revealed no such relationship. The parents showing the best *per se* performance were not the best general combiners for almost all the characters (Table 5.4.2). Therefore, *per se* performance may not necessarily be the criteria in selecting the parents for hybridization.

Table 5.4.2 revealed that none of the crosses showed good response for all the characters in all three and pooled environment. In E_1, the cross, $L_{13}\times T_3$ (poor/good) appeared as good specific combiner for plant height, $L_5\times T_1$ (poor/average) for ear height, $L_9\times T_3$ (average/average) for 100-kernel weight, $L_{18}\times T_2$ (average/poor) for ear length, $L_{21}\times T_3$ (good/average) for ear diameter, $L_{20}\times T_1$ (good/good) for number of kernel rows per ear, $L_{12}\times T_3$ (good/good) for Number of kernels per row, $L_4\times T_1$ (good/good) for number of nodes bearing brace roots, $L_{14}\times T_1$ (good/good) for days to 50% tasselling, $L_2\times T_1$ (good/good)

Table 5.4.2: Best three parents and specific crosses for different characters in E_1, E_2, E_3 and pooled over environments

Sl. No.	Character	Env.	Parent				Specific crosses		GCA of parents in specific cross
			lines		tester				
			Per se performance	GCA	*Per se* performance	GCA	*Per se* performance	SCA	
1.	Plant height (cm)	E_1	L_{19}	L_4	T_1	T_3	$L_3 \times T_2$	$L_{13} \times T_3$	P/G
			L_{20}	L_{11}	T_2	-	$L_{14} \times T_2$	$L_9 \times T_1$	P/A
			L_{16}	L_{10}	-	-	$L_9 \times T_1$	$L_5 \times T_1$	A/A
		E_2	L_{20}	L_4	T_2	-	$L_4 \times T_2$	$L_{12} \times T_3$	P/G
			L_1	L_{14}	-	T_3	$L_{14} \times T_3$	$L_5 \times T_1$	P/A
			L_{19}	L_3	-	-	$L_{12} \times T_3$	$L_6 \times T_2$	P/P
		E_3	L_{17}	L_5	T_1	-	$L_{19} \times T_1$	$L_{17} \times T_3$	A/P
			L_{21}	L_{11}	T_2	T_1	$L_{10} \times T_3$	$L_5 \times T_1$	G/G
			L_{15}	L_8	T_3	-	$L_{11} \times T_3$	$L_6 \times T_3$	P/P
		P	L_{13}	L_{19}	T_1	-	$L_{11} \times T_1$	$L_{19} \times T_1$	G/G
			L_{11}	L_{11}	T_2	T_3	$L_9 \times T_3$	$L_5 \times T_1$	A/G
			L_4	L_4	-	-	$L_6 \times T_3$	$L_{17} \times T_3$	P/P
2.	Ear height (cm)	E_1	L_7	L_1	T_1	-	$L_2 \times T_1$	$L_5 \times T_1$	P/A
			L_1	L_{10}	T_2	T_3	$L_8 \times T_3$	$L_2 \times T_1$	A/A
			L_{12}	-	-	-	$L_5 \times T_1$	$L_3 \times T_3$	A/G
		E_2	L_8	L_{10}	T_2	-	$L_5 \times T_1$	$L_5 \times T_1$	A/P
			L_{13}	L_{14}	T_3	T_2	$L_9 \times T_3$	$L_{15} \times T_1$	G/P
			L_7	L_{13}	-	-	$L_{21} \times T_2$	$L_{17} \times T_3$	P/P
		E_3	L_9	L_8	T_1	-	$L_{18} \times T_1$	$L_5 \times T_1$	A/A
			L_{21}		T_2	T_3	$L_{20} \times T_3$	$L_1 \times T_3$	P/G
			L_3		-	-	$L_5 \times T_1$	$L_6 \times T_3$	P/G
		P	L_1	L_{21}	T_1	-	$L_2 \times T_2$	$L_5 \times T_1$	A/A
			L_5	L_{10}	T_2	-	$L_7 \times T_1$	$L_5 \times T_3$	A/P
			L_9		T_3	-	$L_6 \times T_3$	-	-
3.	100-kernel weight (g)	E_1	L_{19}	L_4	T_1	-	$L_3 \times T_1$	$L_9 \times T_3$	A/A
			L_{17}	L_{15}	-	-	$L_{13} \times T_3$	$L_{13} \times T_3$	A/A
			L_6	L_{16}	-	-	$L_2 \times T_2$	$L_3 \times T_1$	G/A
		E_2	L_5	L_{12}	T_3	-	$L_{21} \times T_3$	$L_{11} \times T_1$	P/P
			L_{17}	L_{18}	-	-	$L_9 \times T_1$	$L_4 \times T_3$	P/A
			L_8	L_9	-	-	$L_{14} \times T_2$	$L_{19} \times T_2$	P/A
		E_3	L_7	L_{19}	T_2	-	$L_{15} \times T_2$	$L_{14} \times T_1$	P/A
			L_{13}		-	T_3	$L_{19} \times T_3$	$L_{12} \times T_1$	P/A
			L_{18}		-	-	$L_{20} \times T_3$	$L_{13} \times T_2$	A/P
		P	L_{12}	L_{18}	T_1	-	$L_{19} \times T_2$	$L_4 \times T_3$	A/A
			L_{13}	L_{15}	-	-	$L_1 \times T_3$	$L_{16} \times T_3$	A/A
			L_{18}	L_7	-	-	$L_{14} \times T_2$	$L_2 \times T_1$	A/A

Table 5.4.2: Contd...

Sl. No.	Character	Env.	Parent				Specific crosses		GCA of parents in specific cross
			lines		tester				
			Per se performance	GCA	*Per se* performance	GCA	*Per se* performance	SCA	
4.	Ear length (cm)	E_1	L_{14}	L_{13}	T_1	-	$L_{11} \times T_1$	$L_{18} \times T_2$	A/P
			L_2	L_{12}	-	T_3	$L_{13} \times T_3$	$L_{12} \times T_3$	G/G
			L_{17}	L_2	-	-	$L_2 \times T_3$	$L_7 \times T_3$	P/G
		E_2	L_6	L_{14}	-	-	$L_{13} \times T_3$	$L_{10} \times T_2$	A/P
			L_5	L_{12}	-	T_3	$L_{11} \times T_3$	$L_{13} \times T_3$	A/G
			L_{17}	L_3	-	-	$L_{11} \times T_1$	$L_{21} \times T_2$	P/P
		E_3	L_4	L_{15}	T_2	-	$L_4 \times T_2$	$L_{11} \times T_3$	A/P
			L_3	L_{14}	T_3	T_1	$L_2 \times T_3$	$L_1 \times T_3$	P/P
			L_2		-	-	$L_8 \times T_2$	$L_{18} \times T_2$	A/A
		P	L_{12}	L_{14}	-	-	$L_4 \times T_3$	$L_{11} \times T_2$	A/P
			L_7	L_{13}	-	T_3	$L_{10} \times T_2$	$L_{18} \times T_2$	A/P
			L_6		-	-	$L_3 \times T_3$	$L_2 \times T_3$	A/G
5.	Ear diameter (cm)	E_1	L_2	L_{21}	T_1	-	$L_{21} \times T_3$	$L_{21} \times T_3$	G/A
			L_{17}		T_2	-	$L_{19} \times T_1$	$L_9 \times T_3$	A/A
			L_{10}		-	-	$L_1 \times T_3$	$L_{12} \times T_3$	A/A
		E_2	L_{14}	L_3	T_1	-	$L_3 \times T_1$	$L_9 \times T_3$	A/A
			L_2	L_{16}	T_2	T_1	$L_{12} \times T_1$	$L_{17} \times T_3$	P/A
			L_8	L_{12}	-	-	$L_9 \times T_3$	-	-
		E_3	L_1	L_8	T_2	-	$L_{11} \times T_3$	$L_9 \times T_3$	G/G
			L_4	L_9	T_3	T_3	$L_9 \times T_1$	$L_8 \times T_1$	G/A
			L_{14}	L_3	-	-	$L_{18} \times T_2$	$L_{13} \times T_2$	A/A
		P	L_7	L_{21}	T_1	-	$L_{13} \times T_3$	$L_9 \times T_3$	A/A
			L_6	L_3	-	T_1	$L_{12} \times T_1$	$L_1 \times T_3$	A/A
			L_9	L_{10}	-	-	$L_1 \times T_2$	$L_5 \times T_3$	P/A
6.	Number of kernel row per ear	E_1	L_{15}	L_{16}	T_1	-	$L_{16} \times T_1$	$L_{20} \times T_1$	G/G
			L_5	L_{20}	T_2	T_1	$L_{20} \times T_1$	$L_9 \times T_2$	A/P
			L_7		-	-	$L_6 \times T_1$	$L_{14} \times T_3$	A/A
		E_2	L_{15}	L_4	T_1	-	$L_6 \times T_1$	$L_{16} \times T_1$	G/G
			L_7	L_7	T_2	T_1	$L_1 \times T_3$	$L_{21} \times T_2$	P/P
			L_2	L_6	T_3	-	$L_{11} \times T_1$	$L_1 \times T_2$	A/P
		E_3	L_8	L_{17}	T_1	-	$L_{17} \times T_2$	$L_5 \times T_3$	A/A
			L_3	L_{10}	T_2	T_2	$L_{11} \times T_3$	$L_{10} \times T_1$	G/P
			L_{18}		T_3	-	$L_{15} \times T_2$	$L_{17} \times T_2$	G/G
		P	L_{15}	L_{16}	-	-	$L_8 \times T_1$	$L_{16} \times T_2$	G/P
			L_{16}	L_{20}	-	T_1	$L_{12} \times T_1$	$L_{14} \times T_3$	P/P
			L_3	L_1	-	-	$L_2 \times T_1$	$L_5 \times T_3$	A/P

for days to 50% silking, $L_{16}\times T_1$(good/good) for anthesis-silking interval, $L_1\times T_1$(good/poor) for protein content, $L_{11}\times T_3$(good/good) for lysine per cent, $L_{11}\times T_3$ (good/average) for tryptophan per cent and $L_{14}\times T_1$ (good/good) for grain yield, however, in E2, crosses, $L_{12}\times T_3$ (average/average), $L_5\times T_1$ (average/poor), $L_{11}\times T_1$ (poor/poor), $L_{10}\times T_2$ (average/poor), $L_9\times T_3$ (average/average), $L_{16}\times T_1$ (good/good), $L_{14}\times T_1$ (average/poor), $L_3\times T_2$ (average/poor), $L_{11}\times T_3$ (average/good), $L_{11}\times T_3$ (average/good), $L_{16}\times T_3$ (average/poor), $L_1\times T_1$ (average/poor), $L_{11}\times T_3$ (average/good), $L_{11}\times T_3$ (average/average) and $L_1\times T_1$ (average/average) for plant height, ear height, 100-kernel weight, ear length, ear diameter, number of kernel rows per ear, number of kernels per row, number of nodes bearing brace roots, days to 50% tasselling, days to 50% silking, anthesis-silking interval, protein per cent, lysine per cent, tryptophan per cent and grain yield, respectively, exhibited good specific combining ability. While, crosses, $L_{17}\times T_3$ (average/poor), $L_5\times T_1$ (average/average), $L_{14}\times T_1$ (poor/average), $L_{11}\times T_3$ (average/poor), $L_9\times T_3$ (good/good), $L_5\times T_3$ (average/average), $L_{14}\times T_1$ (average/poor), $L_{15}\times T_3$ (average/good), $L_{11}\times T_3$ (average/poor), $L_{15}\times T_3$ (average/average), $L_6\times T_1$ (average/average), $L_1\times T_1$ (average/poor), $L_{11}\times T_3$ (average/average), $L_{11}\times T_3$ (average/average) and $L_3\times T_2$ (average/poor) for plant height, ear height, 100-kernel weight, ear length, ear diameter, number of kernel rows per ear, number of kernels per row, number of nodes bearing brace roots, days to 50% tasselling, days to 50% silking, anthesis-silking interval, protein per cent, lysine per cent, tryptophan per cent and grain yield, respectively, exhibited good specific combining ability in E_3 environment.

Table 5.4.2: Contd...

Sl. No.	Character	Env.	Parent				Specific crosses		GCA of parents in specific cross
			lines		tester				
			Per se performance	GCA	*Per se* performance	GCA	*Per se* performance	SCA	
7.	Number of kernels per row	E_1	L_{14}	L_{11}	T_1	-	$L_{12} \times T_3$	$L_{12} \times T_3$	G/G
			L_7	L_4	T_2	T_3	$L_{13} \times T_3$	$L_{11} \times T_3$	P/G
			L_5	L_{20}	-	-	$L_4 \times T_1$	$L_{20} \times T_1$	P/P
		E_2	L_5	L_4	T_2	-	$L_{14} \times T_1$	$L_{14} \times T_1$	A/P
			L_{12}	L_{16}	T_3	T_3	$L_{16} \times T_2$	$L_{13} \times T_3$	G/G
			L_{15}	L_{10}	-	-	$L_4 \times T_3$	$L_{12} \times T_3$	A/G
		E_3	L_2	L_{15}	T_1	T_3	$L_{14} \times T_3$	$L_{14} \times T_1$	A/P
			L_{10}	L_5	T_2	-	$L_5 \times T_2$	$L_{11} \times T_3$	A/G
			L_{20}		T_3	-	$L_{11} \times T_3$	$L_{12} \times T_1$	A/P
		P	L_{10}	L_4	-	-	$L_3 \times T_3$	$L_1 \times T_1$	A/P
			L_1	L_{15}	-	T_3	$L_6 \times T_1$	$L_{11} \times T_3$	A/G
			L_{12}	L_2	-	-	$L_{13} \times T_1$	$L_{14} \times T_1$	A/P
8.	Number of nodes bearing brace roots	E_1	L_{18}	L_2	T_1	-	$L_3 \times T_1$	$L_4 \times T_1$	G/G
			L_{20}	L_1	-	T_1	$L_2 \times T_2$	$L_1 \times T_3$	P/P
			L_7	L_{19}	-	-	$L_{21} \times T_1$	$L_7 \times T_2$	A/P
		E_2	L_9	L_{11}	T_1	-	$L_{11} \times T_3$	$L_3 \times T_2$	A/P
			L_8	L_{16}	T_2	T_1	$L_{11} \times T_2$	$L_4 \times T_2$	A/P
			L_5	L_5	-	-	$L_{11} \times T_1$	$L_{17} \times T_1$	G/G
		E_3	L_4	L_3	T_3	-	$L_3 \times T_3$	$L_{15} \times T_3$	A/G
			L_5	L_4	-	T_3	$L_5 \times T_1$	$L_8 \times T_1$	A/P
			L_2	L_{21}	-	-	$L_6 \times T_1$	$L_{17} \times T_1$	A/P
		P	L_4	L_2	-	-	$L_5 \times T_1$	$L_{15} \times T_3$	A/A
			L_{10}	L_1	-	-	$L_3 \times T_3$	$L_8 \times T_1$	A/A
			L_3		-	-	$L_{11} \times T_2$	$L_5 \times T_3$	P/A
9.	Days to 50 % tasselling	E_1	L_7	L_1	T_1	-	$L_1 \times T_1$	$L_{14} \times T_1$	G/G
			L_1	L_{21}	T_2	T_1	$L_1 \times T_2$	$L_{13} \times T_1$	P/G
			L_4	L_{11}	T_3	-	$L_{14} \times T_1$	$L_8 \times T_3$	P/A
		E_2	L_2	L_1	T_2	-	$L_{11} \times T_3$	$L_{11} \times T_3$	A/G
			L_1	L_{11}	T_3	T_3	$L_1 \times T_1$	$L_{13} \times T_1$	G/P
			L_5		-	-	$L_2 \times T_1$	$L_8 \times T_3$	A/G
		E_3	L_9	L_4	T_1	-	$L_7 \times T_1$	$L_{11} \times T_3$	A/P
			L_2	L_{11}	-	T_1	$L_8 \times T_3$	$L_{13} \times T_1$	A/G
			L_5		-	-	$L_2 \times T_1$	$L_{14} \times T_1$	A/G
		P	L_1	L_{11}	T_2	-	$L_{13} \times T_1$	$L_{11} \times T_3$	A/G
			L_2		T_3	T_3	$L_{13} \times T_2$	$L_{13} \times T_1$	A/A
			L_4		-	-	$L_{12} \times T_3$	$L_{14} \times T_1$	A/A

Table 5.4.2: Contd...

Sl. No.	Character	Env.	Parent				Specific crosses		GCA of parents in specific cross
			lines		tester				
			Per se performance	GCA	*Per se* performance	GCA	*Per se* performance	SCA	
10.	Days to 50 % silking	E_1	L_9	L_1	T_2	-	$L_1 \times T_1$	$L_2 \times T_1$	G/G
			L_{10}	L_{21}	T_3	T_1	$L_1 \times T_2$	$L_9 \times T_1$	P/G
			L_4	L_2	-	-	$L_3 \times T_3$	$L_{13} \times T_1$	P/G
		E_2	L_2	L_3	T_1	-	$L_{11} \times T_3$	$L_{11} \times T_3$	A/G
			L_5	L_{21}	T_2	T_3	$L_2 \times T_1$	$L_{19} \times T_2$	G/P
			L_{18}		-	-	$L_3 \times T_3$	$L_{16} \times T_3$	A/G
		E_3	L_5	L_7	T_1	-	$L_8 \times T_3$	$L_{15} \times T_3$	A/A
			L_{11}	L_8	-	-	$L_{11} \times T_3$	$L_{14} \times T_2$	A/P
			L_{16}	L_{21}	-	-	$L_7 \times T_3$	$L_{10} \times T_1$	A/A
		P	L_3	L_{21}	T_1	T_1	$L_{13} \times T_1$	$L_{13} \times T_2$	A/P
			L_4	L_3	T_2	T_3	$L_{14} \times T_1$	$L_{14} \times T_2$	A/P
			L_7	L_1	T_3	-	$L_3 \times T_3$	$L_{10} \times T_3$	A/G
11.	Anthesis-silking interval	E_1	L_9	L_{15}	T_3	-	$L_6 \times T_2$	$L_{16} \times T_1$	G/G
			L_8	L_1	-	T_1	$L_{10} \times T_3$	$L_{17} \times T_3$	P/P
			L_1	L_{14}	-	-	$L_1 \times T_2$	$L_{10} \times T_3$	A/P
		E_2	L_5	L_3	T_1	-	$L_{18} \times T_1$	$L_{16} \times T_3$	A/P
			L_{18}	L_{17}	T_2	T_1	$L_{13} \times T_1$	$L_5 \times T_2$	A/P
			L_2	L_{11}	-	-	$L_8 \times T_1$	$L_1 \times T_3$	G/P
		E_3	L_8	L_7	T_1	-	$L_8 \times T_2$	$L_6 \times T_1$	A/A
			L_{16}	L_{17}	T_3	-	$L_{11} \times T_3$	$L_9 \times T_3$	A/A
			L_{11}		-	-	$L_7 \times T_3$	$L_{15} \times T_3$	A/A
		P	L_3	L_{11}	T_1	-	$L_3 \times T_2$	$L_{19} \times T_2$	A/P
			L_4	L_{17}	T_2	-	$L_3 \times T_3$	$L_{15} \times T_3$	A/A
			L_7		-	-	$L_2 \times T_3$	-	-
12.	Protein (%)	E_1	L_9	L_4	T_1	-	$L_2 \times T_1$	$L_1 \times T_1$	G/P
			L_6	L_3	T_2	T_3	$L_6 \times T_1$	$L_{13} \times T_1$	P/P
			L_1	L_2	-	-	$L_3 \times T_3$	$L_2 \times T_1$	P/P
		E_2	L_6	L_4	T_1	-	$L_6 \times T_1$	$L_1 \times T_1$	A/P
			L_9	L_3	T_2	T_3	$L_2 \times T_1$	$L_{13} \times T_1$	G/P
			L_1	L_2	-	-	$L_{13} \times T_2$	$L_2 \times T_1$	A/P
		E_3	L_6	L_4	T_2	-	$L_6 \times T_1$	$L_1 \times T_1$	A/P
			L_9	L_3	-	T_3	$L_2 \times T_1$	$L_{13} \times T_1$	A/P
			L_1	L_2	-	-	$L_3 \times T_1$	$L_2 \times T_1$	A/P
		P	L_4	L_4	T_2	-	$L_4 \times T_3$	$L_1 \times T_1$	A/P
			L_3	L_3	T_3	T_3	$L_5 \times T_2$	$L_{13} \times T_1$	A/P
			L_{16}	L_2	-	-	$L_{15} \times T_3$	$L_2 \times T_1$	A/P

Table 5.4.2: Contd...

Sl. No.	Character	Env.	Parent				Specific crosses		GCA of parents in specific cross
			lines		tester				
			Per se performance	GCA	*Per se* performance	GCA	*Per se* performance	SCA	
13.	Lysine (%)	E_1	L_2	L_{19}	T_1	-	$L_{11} \times T_3$	$L_{11} \times T_3$	G/G
			L_{15}	L_{13}	T_2	T_3	$L_{16} \times T_1$	$L_2 \times T_3$	P/G
			L_{20}	L_{14}	-	-	$L_{14} \times T_2$	$L_{21} \times T_1$	P/A
		E_2	L_2	L_{19}	T_1	T_1	$L_{11} \times T_3$	$L_{11} \times T_3$	A/G
			L_{15}	L_{13}	T_2	T_3	$L_{16} \times T_1$	$L_2 \times T_3$	G/G
			L_{20}	L_{14}	-	-	$L_{14} \times T_2$	$L_{21} \times T_1$	A/G
		E_3	L_2	L_{19}	T_1	-	$L_{11} \times T_3$	$L_{11} \times T_3$	A/A
			L_{15}	L_{13}	T_2	-	$L_{16} \times T_1$	$L_2 \times T_3$	A/A
			L_{20}	L_{14}	-	-	$L_{14} \times T_2$	$L_{21} \times T_1$	A/A
		P	L_{19}	L_{19}	T_2	-	$L_6 \times T_1$	$L_{11} \times T_3$	A/A
			L_1	L_{13}	T_3	-	$L_8 \times T_2$	$L_2 \times T_3$	A/A
			L_6	L_{14}	-	-	$L_{11} \times T_1$	$L_{21} \times T_1$	A/A
14.	Tryptophan (%)	E_1	L_2	L_{19}	T_1	-	$L_{11} \times T_3$	$L_{11} \times T_3$	G/A
			L_{15}	L_{13}	T_2	T_1	$L_{16} \times T_1$	$L_2 \times T_3$	P/A
			L_{20}	L_{14}	-	-	$L_{14} \times T_2$	$L_{21} \times T_1$	A/G
		E_2	L_2	L_{19}	T_1	-	$L_{11} \times T_3$	$L_{11} \times T_3$	A/A
			L_{15}	L_{13}	T_3	T_1	$L_{16} \times T_1$	$L_2 \times T_3$	A/A
			L_{20}	L_{14}	-	-	$L_{14} \times T_2$	$L_{21} \times T_1$	G/G
		E_3	L_2	L_{19}	T_1	-	$L_{11} \times T_3$	$L_{11} \times T_3$	A/A
			L_{15}	L_{13}	T_2	T_1	$L_{16} \times T_1$	$L_2 \times T_3$	A/A
			L_{20}	L_{14}	-	-	$L_{14} \times T_2$	$L_{21} \times T_1$	A/G
		P	L_{19}	L_{19}	T_2	-	$L_6 \times T_1$	$L_{11} \times T_3$	A/A
			L_1	L_{13}	T_3	T_1	$L_8 \times T_2$	$L_2 \times T_3$	A/A
			L_6	L_{14}	-	-	$L_{11} \times T_1$	$L_{21} \times T_1$	P/G
15.	Grain yield (kg/ha)	E_1	L_{20}	L_1	T_1	-	$L_{18} \times T_2$	$L_{14} \times T_1$	G/G
			L_8	L_2	T_2	T_1	$L_9 \times T_1$	$L_{11} \times T_3$	P/P
			L_{13}	L_4	T_3	-	$L_{18} \times T_1$	$L_3 \times T_1$	G/G
		E_2	L_{20}	L_{19}	T_1	-	$L_{14} \times T_1$	$L_1 \times T_1$	A/A
			L_3	L_1	T_2	T_3	$L_2 \times T_1$	$L_{11} \times T_3$	G/G
			L_{12}	L_3	T_3	-	$L_4 \times T_1$	$L_{17} \times T_3$	A/G
		E_3	L_{20}	L_2	T_1	-	$L_{11} \times T_3$	$L_8 \times T_2$	A/P
			L_8	L_{16}	T_2	T_1	$L_{19} \times T_2$	$L_{11} \times T_3$	A/A
			L_3	L_{18}	T_3	-	$L_{21} \times T_3$	$L_{19} \times T_2$	A/P
		P	L_1	L_1	T_2	-	$L_3 \times T_3$	$L_{12} \times T_3$	G/P
			L_7	L_2	-	T_1	$L_1 \times T_1$	$L_{11} \times T_3$	A/P
			L_{10}	L_{19}	-	-	$L_{20} \times T_2$	$L_{17} \times T_3$	P/P

E_1: Normal (recommended dose of nitrogen), **E_2:** Low-nitrogen, **E_3:** Excess soil moisture, **P:** Pooled environment, **GCA:** General combining ability, **SCA:** Specific combining ability
A: Average, **P:** Poor, **G:** Good

Perusal of data showing the highest SCA effects for grain yield were obtained with parents involving good/poor '$L_{12}\times T_3$, average/poor '$L_{11}\times T_3$' and poor/poor '$L_{17}\times T_3$' in pooled analysis. Results in the individual environments showed that $L_{14}\times T_1$ (good/good), $L_{11}\times T_3$ (poor/poor) and $L_3\times T_1$(good/good) in E_1, $L_1\times T_1$(average/average), $L_{11}\times T_3$(good/good) and $L_{17}\times T_3$(average/good) in E_2, and $L_8\times T_2$ (average/poor), $L_{11}\times T_3$(average/ average) and $L_{19}\times T_2$ (average/poor) in E_3 had mixing of GCA effects for expression of high SCA effects for grain yield. Thus in the majority of cases, high SCA effects for grain yield were attributed to dominance and epistasis gene interactions. The crosses between high GCA parents did not always result in good F_1 combinations, however, additive-additive gene interaction were also observed for some of the crosses.

On the basis of the GCA of the parents in specific crosses, out of 63 crosses in E1, 31.74% of crosses were of 'poor/poor' parental combination, 31.74% were of 'good/poor or poor/good', 19.04% were of 'average/poor' or 'poor/average' 9.52% were of 'good/average or average/good' and 6.34% were of 'good/good', however in E2, 30.15% were of 'average/poor' or 'poor/average' , 19.04% of crosses were of 'good/average or average/good', 17.46% were of 'good/poor or poor/good', 14.28% were of 'average/average', 14.28% were of 'poor/poor' and 3.17% were of 'good/good' parental combination, while in E3, 28.57% of crosses were of 'good/poor or poor/good', parental combination, 25.39% were of 'average/poor' or 'poor/average' 20.63% were of 'poor/poor' 12.69% were of 'good/average or average/good',

Table 5.4.3: Per cent of cross combinations on the basis of GCA of parents in specific cross for grain yield (kg/ha)

Sl. No.	GCA of parents in specific cross	Per cent of cross in different environments			
		E1	E2	E3	p
1.	G/G	6.34	3.17	7.93	6.34
2.	G/A or A/G	9.52	19.04	12.69	9.52
3.	G/P or P/G	31.74	17.46	28.57	30.15
4.	A/A	0.00	14.28	4.76	0.00
5.	A/P or P/A	19.04	30.15	25.39	19.04
6.	P/P	31.74	14.28	20.63	34.92

7.93% were of 'good/good and 4.76% were of 'average/average parental combination. However, in pooled environment 34.92% of crosses were of 'poor/poor' parental combination, 30.15% were of 'good/poor or poor/good', 19.04% were of 'average/poor' or 'poor/average' 9.52% were of 'good/average or average/good' and 6.34% were of 'good/good' parental combinations (Table 5.4.3). These findings revealed that the crosses between high GCA parents did not always result in good F_1 combinations.

A close observation of data on top hybrids showing higher SCA effects for grain yield and other quantitative traits (Table 5.4.2) indicated that the cross, $L_{11}\times T_3$ appeared as best specific combiner for tryptophan content, lysine content and grain yield, whereas, cross, $L_{14}\times T_1$ for days to 50% tasselling and grain yield and cross $L_3\times T_1$ for 100-kernel weight and grain yield in E_1, however, in E_2, cross having best SCA effect was $L_{11}\times T_3$ for days to flowering (tasselling and silking), tryptophan content, lysine content and grain yield, whereas, cross, $L_{17}\times T_3$ for ear height, ear diameter and grain yield and cross $L_1\times T_1$ for protein per cent and grain yield. While, cross, $L_{11}\times T_3$ appeared as best specific combiner for ear length, number of kernels per row, days to 50% tasselling, tryptophan content, lysine content and grain yield in E_3 environment. Results of pooled analysis indicated that cross $L_{11}\times T_3$ appeared as best specific combiner for number of kernels per row, days to 50% tasselling, tryptophan content, lysine content and grain yield , whereas, cross, $L_{17}\times T_3$ for plant height and grain yield

Overall results revealed that cross $L_{11} \times T_3$ appeared as best specific combiner for number of kernels per row, tryptophan content, lysine content and grain yield in all the environments. While rest of the crosses exhibited differential response for SCA effects in different environments for all the quantitative traits i.e., there were very little or no reproducibility for SCA effects of the crosses in all the environments. It showed effect of environment in the performance of the crosses. Similar results were reported by **Nagada *et al.* (1995); Rastogi and Rastogi, (1995); Dass *et al.* (1997); Petrovic, (1998); Choukan (1999); Soliman and Sedek (1999); Srinivasan and Vasal (1999); Chen *et al.* (2000)**, **Konak *et al.* (2001) ; Srivastava, (2001); dodiya and Joshi, (2003); Narro *et al.* (2003); Ramneek et al. (2005), Singhal et *al.* (2006), Sofi *et al.* (2006), Jaykumar and Sundaram (2007); Dar *et al.* (2007); Gurung *et al.* (2009) and Premlatha and Kalamani (2010).**

5.5 Phenotypic Stability

Stability of crop yield over environments repeated in space and time has been always a challenge. The response of genotypes to environmental fluctuations due to genotype × environment interaction is less defined and non-predictable. The information on the genotype × environment (G×E) interaction and identification of phenotypically stable genotypes thus becomes important. The existence of G×E interaction has been recognized by **Johansen (1909)**, while expounding the concept of the genotype and the phenotype. According to him, phenotype is the result of interplay of genotype and its environments. Therefore, it was

considered desirable to carryout stability analysis for parents and their resultant crosses on the basis of data obtained from three environments. Statistical methods for determining stability of genotypes in diverse environments are generally used to assist plant breeder in selecting superior genotypes. Here in this study, the data collected on different characters were analyzed for phenotypic stability **(Eberhart and Russell, 1966)** over three environments.

The combined analysis of variance revealed that the mean squares due to genotypes were significant for ear height, ear length, ear diameter, number of kernel rows per ear, days to 50% tasselling, days to 50% silking, protein, lysine, tryptophan and grain yield indicating enough genetic variability among all the genotypes for these traits. **Sharma and Bhalla (1982); Vulchainkova and Vulchinkov (1990)**; **Agarwal *et al.* (2000)**; **Srivastava (2001)**; **Reddy *et al.* (2004)** and **Kumar and Singh (2004)**.

The mean squares due to environments were also significant for all the characters indicating sufficient differences among environments and effectiveness of environments in influencing the performance genotypes. The G×E interaction mean squares were highly significant for all the traits except quality traits like protein, lysine and tryptophan contents indicating differential response of genotypes in different environments, however, quality traits were unaffected by the changing environments. The mean squares due to environment (linear) were highly significant for all the characters, whereas, genotypes × environment (linear) mean squares showed significant differences for plant height, days to 50% silking, anthesis-silking interval, protein, lysine and tryptophan contents. The non-

linear (pooled deviation) mean squares due to G×E interaction were also highly significant for all the characters except quality traits i.e., protein, lysine and tryptophan contents. Similar results were reported by **Sharma and Bhalla (1982)**; **Vulchainkova and Vulchinkov (1990)**; **Agarwal *et al.* (2000)**; **Srivastava (2001)**; **Reddy and Ahuja (2004)**; **Kumar and Singh (2007)**; **Abdulai *et al.* (2009) and Rahman *et al.* (2010).**

In the present investigation, the inbred line, L_1 (DQPMC-3(Y) ⊗101-1-2-1-1) was found to be most desirable and stable for ear length, number of kernels per row, days to 50% tasselling, days to 50% silking, lysine per cent, tryptophan per cent and grain yield. However, lines, L_3 and L_4 (Pool $17C_8$(TEYFQPM)-B-1-1-1-1, Pool $17C_8$(TEYFQPM) -B-76-1-1-1, respectively) showed highly stable and desired performance for days to 50% tasselling, days to 50% silking , protein per cent, and grain yield. Inbred line, L_5 (Pool $17C_8$(TEYFQPM)-B-93-1-1-1) exhibited high stability for plant height, ear length, number of kernels per row, number of nodes bearing brace roots, days to 50% tasselling, protein per cent and grain yield. The inbred line, L_6 (DQPMC-3(Y)⊗56-2-3-1-1) was found to be most desirable for grain yield and its component traits like ear length, ear diameter, number of kernels per row moreover, L_6 was also stable for plant height, number of nodes bearing brace roots, days to 50% tasselling tryptophan and lysine contents. Line, L_{12} (POP 61 C_9(TEYFQPM)-B-20-1-1-1) exhibited high stability for 100-kernel weight, ear length, number of kernels per row, protein percentage and grain yield. Lines, L_{10} (DQPMC-3(Y)⊗50-1-1-1-1) showed stability for quality traits and also for ear diameter, number of kernel row per ear, number of kernels per row,

Table 5.5.1: Inbred lines and single crosses with desirable and stable performance for different characters

S. No.	Character	Inbred line	Single crosses
1.	Plant height (cm)	L_5 , L_6 and tester T_1 and T_2	$L_6 \times T_3$, $L_{11} \times T_1$ and $L_{11} \times T_3$
2.	Ear height (cm)	L_7, L_{12}, L_{13} and T_1	$L_3 \times T_1$, $L_3 \times T_2$, $L_9 \times T_3$, $L_{10} \times T_2$, $L_{11} \times T_3$ and $L_{13} \times T_2$
3.	100- kernel weight (g)	L_3, L_8 and L_{12}	$L_2 \times T_1$, $L_7 \times T_1$, $L_8 \times T_1$, $L_{13} \times T_2$, $L_{15} \times T_3$, $L_{16} \times T_2$, and $L_{19} \times T_3$
4.	Ear length (cm)	L_1, L_5, L_6 and L_{12}	$L_1 \times T_3$, $L_6 \times T_1$, $L_9 \times T_1$, $L_{11} \times T_1$, $L_{12} \times T_1$ and $L_{20} \times T_2$
5.	Ear diameter (cm)	L_6, L_8, L_{10}, L_{15}, L_{19} T_1 and T_3	$L_1 \times T_2$, $L_5 \times T_2$, $L_{14} \times T_2$, $L_{16} \times T_2$, $L_{18} \times T_2$, $L_{19} \times T_2$ and $L_{19} \times T_3$
6.	Number of kernel rows/ear	L_9, L_{10} and L_{16}	$L_1 \times T_1$, $L_2 \times T_3$, $L_3 \times T_1$, $L_3 \times T_2$, $L_4 \times T_3$, $L_5 \times T_1$, $L_5 \times T_2$, $L_6 \times T_3$, $L_7 \times T_1$, $L_{10} \times T_2$, $L_{14} \times T_2$, $L_{15} \times T_1$, $L_{15} \times T_2$, $L_{16} \times T_1$, $L_{17} \times T_1$, $L_{21} \times T_1$, $L_{21} \times T_2$, $L_{21} \times T_3$ and HQPM-1
7.	Number of kernels/row	L_1, L_5, L_6, L_7, L_{10}, L_{12}, and L_{18}	$L_1 \times T_1$, $L_2 \times T_3$, $L_6 \times T_1$, $L_8 \times T_3$, $L_9 \times T_3$, $L_{10} \times T_2$, $L_{13} \times T_1$, $L_{13} \times T_2$, $L_{14} \times T_3$, $L_{17} \times T_1$, $L_{17} \times T_3$, $L_{19} \times T_2$, $L_{19} \times T_3$, $L_{20} \times T_2$ and HQPM-1
8.	Number of nodes bearing brace roots	L_2, L_5, L_6, L_{13} and L_{16}	$L_2 \times T_1$, $L_2 \times T_2$, $L_3 \times T_1$, $L_3 \times T_2$, $L_8 \times T_1$, $L_{10} \times T_3$, $L_{11} \times T_2$, $L_{12} \times T_1$, $L_{13} \times T_1$, $L_{15} \times T_3$, $L_{18} \times T_1$, $L_{18} \times T_3$, $L_{19} \times T_3$ and $L_{21} \times T_1$.
9.	Days to 50% tasselling	L_1, L_2, L_3, L_4, L_5, L_6 L_7, L_8, L_{10}, L_{16}, L_{18}, L_{19} L_{20}, L_{21} and T_3	$L_1 \times T_1$, $L_6 \times T_1$, $L_8 \times T_3$, $L_9 \times T_1$, $L_{10} \times T_1$, $L_{10} \times T_3$, $L_{11} \times T_1$, $L_{11} \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_3$, $L_{13} \times T_1$, $L_{13} \times T_2$, $L_{13} \times T_3$, $L_{14} \times T_1$, $L_{14} \times T_2$, $L_{14} \times T_3$ $L_{15} \times T_1$, $L_{15} \times T_2$, $L_{15} \times T_3$, $L_{16} \times T_2$, $L_{16} \times T_3$, $L_{17} \times T_1$, $L_{17} \times T_2$, $L_{17} \times T_3$, $L_{18} \times T_2$, $L_{18} \times T_3$, $L_{19} \times T_3$, $L_{20} \times T_1$, $L_{20} \times T_2$, $L_{21} \times T_2$, $L_{21} \times T_3$ and Shakti-1
10.	Days to 50% silking	L_1, L_3 L_4, L_{10}, L_{20} and T_2	$L_4 \times T_1$, $L_5 \times T_1$, $L_6 \times T_1$, $L_9 \times T_1$, $L_9 \times T_3$, $L_{11} \times T_2$, $L_{12} \times T_1$, $L_{13} \times T_1$, $L_{13} \times T_2$. $L_{14} \times T_1$, $L_{14} \times T_2$, $L_{15} \times T_1$, $L_{15} \times T_2$, $L_{15} \times T_3$, $L_{16} \times T_1$, $L_{16} \times T_2$, $L_{16} \times T_3$, $L_{17} \times T_1$, $L_{17} \times T_3$, $L_{19} \times T_3$, $L_{20} \times T_2$, $L_{21} \times T_2$, $L_{21} \times T_3$ and Shakti-1

Table 5.5.1: Contd....

S. No.	Character	Inbred line	Single crosses
11.	Anthesis-silking interval	L_3, L_9, L_{14}, L_{18}, L_{19}, L_{20} , T_1 and T_2	$L_1 \times T_3$, $L_2 \times T_3$, $L_3 \times T_1$, $L_3 \times T_2$, $L_3 \times T_3$, $L_8 \times T_3$, $L_9 \times T_1$, $L_9 \times T_2$, $L_9 \times T_3$. $L_{10} \times T_1$, $L_{12} \times T_1$, $L_{13} \times T_1$, $L_{14} \times T_1$, $L_{14} \times T_2$, $L_{14} \times T_3$, $L_{16} \times T_2$, $L_{17} \times T_1$, $L_{18} \times T_1$, $L_{19} \times T_2$, $L_{19} \times T_3$, Shakti-1 and Pragati
12.	Protein (%)	L_2, L_3 L_4, L_5, L_7, L_9, L_{10}, L_{11} , L_{12}, L_{13} L_{16}, L_{17}, L_{19}	$L_1 \times T_3$, $L_2 \times T_1$, $L_2 \times T_2$, $L_3 \times T_1$, $L_3 \times T_3$, $L_4 \times T_2$, $L_4 \times T_3$, $L_5 \times T_2$, $L_5 \times T_3$, $L_6 \times T_3$, $L_7 \times T_3$, $L_8 \times T_2$, $L_9 \times T_3$, $L_{10} \times T_2$, $L_{10} \times T_3$, $L_{11} \times T_1$, $L_{12} \times T_3$, $L_{13} \times T_3$, $L_{14} \times T_1$, $L_{14} \times T_2$, $L_{15} \times T_1$, $L_{15} \times T_3$, $L_{16} \times T_1$, $L_{16} \times T_2$, $L_{16} \times T_3$, $L_{17} \times T_2$, $L_{17} \times T_3$, $L_{18} \times T_1$, $L_{19} \times T_1$, $L_{20} \times T_1$, $L_{20} \times T_3$, $L_{21} \times T_2$, HQPM-1 and Pragati
13.	Lysine (%)	L_1, L_6 L_8, L_{10}, L_{18}, L_{19}, L_{21}, T_2 and T_3	$L_1 \times T_1$, $L_1 \times T_3$, $L_2 \times T_1$, $L_2 \times T_2$, $L_3 \times T_2$, $L_3 \times T_3$, $L_4 \times T_1$, $L_4 \times T_3$, $L_6 \times T_1$, $L_6 \times T_3$, $L_8 \times T_1$, $L_8 \times T_2$, $L_{10} \times T_2$, $L_{10} \times T_3$, $L_{11} \times T_1$, $L_{11} \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_2$, $L_{13} \times T_1$ $L_{14} \times T_2$, $L_{14} \times T_3$, $L_{15} \times T_1$, $L_{15} \times T_2$, $L_{16} \times T_1$, $L_{16} \times T_2$, $L_{16} \times T_3$, $L_{18} \times T_2$, $L_{18} \times T_3$, $L_{20} \times T_1$, $L_{20} \times T_2$, $L_{20} \times T_3$, $L_{21} \times T_1$ and HQPM-1
14.	Tryptophan (%)	L_1, L_6 L_8, L_{10}, L_{18}, L_{19}, L_{21}, T_2 and T_3	$L_1 \times T_1$, $L_1 \times T_3$, $L_2 \times T_1$, $L_2 \times T_2$, $L_3 \times T_2$, $L_3 \times T_3$, $L_4 \times T_1$, $L_4 \times T_3$, $L_6 \times T_1$, $L_6 \times T_3$, $L_8 \times T_1$, $L_8 \times T_2$, $L_{10} \times T_2$, $L_{10} \times T_3$, $L_{11} \times T_1$, $L_{11} \times T_1$, $L_{11} \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_2$, $L_{13} \times T_1$ $L_{14} \times T_2$, $L_{14} \times T_3$, $L_{15} \times T_1$, $L_{15} \times T_2$, $L_{16} \times T_1$, $L_{16} \times T_2$, $L_{16} \times T_3$, $L_{17} \times T_3$, $L_{18} \times T_2$, $L_{18} \times T_3$, $L_{20} \times T_1$, $L_{20} \times T_2$, $L_{20} \times T_3$ and HQPM-1
15.	Grain yield (Kg/ha)	L_1, L_3, L_4, L_5, L_6, L_{11} L_{12} and L_{19}	$L_2 \times T_3$, $L_3 \times T_3$, $L_5 \times T_2$, $L_5 \times T_3$, $L_7 \times T_1$, $L_7 \times T_3$, $L_8 \times T_1$, $L_8 \times T_2$, $L_8 \times T_3$, $L_9 \times T_3$, $L_{10} \times T_1$, $L_{10} \times T_2$, $L_{11} \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_1$, $L_{12} \times T_3$, , $L_{13} \times T_3$, $L_{14} \times T_3$, $L_{16} \times T_2$, $L_{16} \times T_3$, $L_{17} \times T_2$, $L_{17} \times T_3$, $L_{20} \times T_2$, $L_{20} \times T_3$, $L_{21} \times T_1$, $L_{21} \times T_2$, $L_{21} \times T_3$

days to 50% tasselling, days to 50% silking. However, tester, T_1 (DMRQPM-03-106-#-⊗-1-1-1) exhibited stable performance for plant height, ear height, ear diameter and anthesis-silking interval and T_2 (DMRQPM-03-103-#-⊗-2-3-1) for plant height, days to 50% silking, anthesis-silking interval, tryptophan and lysine contents, while, T_3 (Pool 17C_8(TEYFQPM) -B-57-2-1-1) showed stability for ear diameter, days to 50% silking, tryptophan and lysine contents (Table 5.5.1).

The stability of single crosses for important economic characters are presented in Table 5.5.1. Among these crosses, $L_3 \times T_3$ anthesis-silking interval, protein percentage, lysine percentage, tryptophan percentage and grain yield. $L_5 \times T_2$ and $L_5 \times T_3$ exhibited desirable and stable performance for grain yield and protein percentage. $L_8 \times T_3$ for number of kernels per row, days to 50% tasselling, anthesis-silking interval and grain yield. $L_9 \times T_3$ for ear height, number of kernels per row, days to 50% silking, anthesis-silking interval, protein percentage and grain yield. For ear height, number of kernels per row, number of kernel rows per ear, protein percentage, lysine percentage, tryptophan percentage and grain yield, $L_{10} \times T_2$ was found to be stable and desirable. Cross, $L_{19} \times T_3$ showed desirable and stable performance for 100 kernel weight, ear diameter and crosses, $L_9 \times T_1$, $L_{11} \times T_2$, $L_{13} \times T_1$, $L_{14} \times T_1$, $L_{14} \times T_2$, $L_{15} \times T_1$, $L_{15} \times T_2$, $L_{15} \times T_3$, $L_{16} \times T_2$ and $L_{16} \times T_3$ exhibited stability for early flowering. For quality traits like protein tryptophan and lysine contents, crosses, $L_1 \times T_1$, $L_1 \times T_3$, $L_2 \times T_1$, $L_2 \times T_2$, $L_3 \times T_3$, $L_4 \times T_3$, $L_6 \times T_3$, $L_8 \times T_2$, $L_{10} \times T_2$, $L_{10} \times T_3$, $L_{11} \times T_1$, $L_{11} \times T_1$, $L_{14} \times T_2$, $L_{15} \times T_1$, $L_{16} \times T_1$, $L_{16} \times T_2$, $L_{16} \times T_3$, $L_{17} \times T_3$, $L_{20} \times T_3$ and HQPM-1were found to be desirable and stable. The overall

results of the stability revealed that none of the single cross hybrids showed stable performance for all the characters over all the environments. Similar findings were advocated by **Adams and Shank (1959, 1690)**; **Sharma and Bhalla (1982)**; **Jha *et al.* (1986)**; **Mahajan and Khehra (1992)**; **Choukan (1999)**; **Dehganpour and Mogadam (1999)**; **Agrawal *et al.* (2000)**; **Cardoso *et al.* (2000)**; **Srivastava (2001)**; **Reddy *et al.* (2004)**; **Kumar and Singh (2004), Kumar and Singh (2007), Abdulai *et al.* (2009) and Rahman *et al.* (2010).** The crosses, $L_2 \times T_3$, $L_3 \times T_3$, $L_5 \times T_2$, $L_5 \times T_3$, $L_7 \times T_1$, $L_7 \times T_3$, $L_8 \times T_1$, $L_8 \times T_2$, $L_8 \times T_3$, $L_9 \times T_3$, $L_{10} \times T_1$, $L_{10} \times T_2$, $L_{11} \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_1$, $L_{12} \times T_3$, , $L_{13} \times T_3$, $L_{14} \times T_3$, $L_{16} \times T_2$, $L_{16} \times T_3$, $L_{17} \times T_2$, $L_{17} \times T_3$, $L_{20} \times T_2$, $L_{20} \times T_3$, $L_{21} \times T_1$, $L_{21} \times T_2$ and $L_{21} \times T_3$ showed stable and desirable performance for grain yield. For intensive agriculture when inputs are no limitation i.e., rich environment parental inbred lines, L_1 for number of kernels per row and grain yield, L_9 for plant height, ear height, 100-kernel weight, ear diameter and number of nodes bearing brace roots showed stable performance. For plant height and ear height, lines L_1 and L_4 were good. Line, L_{21} for ear length and ear diameter exhibited stable performance under high inputs conditions. For early flowering in rich environment, L_{13}, T_1 and T_2 showed stable and desirable performance. However, under poor environment, L_{14} for ear height, days to 50% silking and grain yield, L_8 for ear height, number of nodes bearing brace roots and grain yield, L_{12} for plant height and ear diameter exhibited stable and desirable performance. However, for grain yield and its contributing traits like ear length, ear diameter, number of kernel rows per ear and number of kernels per row, line L_{13} exhibited

Table 5.5.2: Inbred lines and single crosses suitable for rich and poor environment for different characters

S.No.	Character	Rich environment		Poor environment	
		Inbred lines	Single crosses	Inbred lines	Single crosses
1.	Plant height (cm)	L_1, L_4, L_9 ,L_{19}	$L_1 \times T_1$, $L_2 \times T_2$, $L_3 \times T_1$, $L_8 \times T_1$, $L_9 \times T_3$, $L_{10} \times T_2$, $L_{21} \times T_1$ and $L_{21} \times T_2$	L_{10} , L_{12}	$L_2 \times T_1$, $L_5 \times T_3$, $L_6 \times T_2$ and $L_8 \times T_3$
2.	Ear height (cm)	L_1, L_4, L_9, L_{10}, L_{20} and T_3	$L_1 \times T_1$, $L_5 \times T_2$, $L_5 \times T_3$, $L_8 \times T_1$, $L_8 \times T_3$, $L_{12} \times T_2$, $L_{16} \times T_1$, $L_{16} \times T_2$ and Shakti-1	L_3, L_5, L_8, L_{14}, L_{19} and T_2	$L_2 \times T_2$, $L_2 \times T_3$, $L_5 \times T_1$, $L_4 \times T_2$, $L_7 \times T_2$, $L_{10} \times T_1$, $L_{14} \times T_1$, $L_{12} \times T_3$ and $L_{16} \times T_3$
3.	100- kernel weight (g)	L_5, L_9 and L_{18}	$L_3 \times T_1$, $L_5 \times T_3$, $L_6 \times T_1$, $L_9 \times T_2$, $L_{10} \times T_3$, $L_{11} \times T_3$, $L_{12} \times T_3$, $L_{13} \times T_1$, $L_{14} \times T_2$, $L_{16} \times T_1$, $L_{18} \times T_1$, $L_{20} \times T_1$ and Shakti-1	L_{13}	$L_1 \times T_3$, $L_4 \times T_2$, $L_4 \times T_3$, $L_5 \times T_2$, $L_7 \times T_3$, $L_8 \times T_2$, $L_{10} \times T_2$ and $L_{19} \times T_2$
4.	Ear length (cm)	L_{10} and L_{21}	$L_4 \times T_3$, $L_5 \times T_3$, $L_7 \times T_2$, $L_{13} \times T_1$ and $L_{18} \times T_2$	L_3, L_{13} and T_2	$L_3 \times T_1$, $L_4 \times T_1$, $L_9 \times T_3$ and $L_{18} \times T_3$, $L_{12} \times T_1$
5.	Ear diameter (cm)	L_9, L_{17} and L_{21}	$L_4 \times T_3$, $L_6 \times T_3$, $L_8 \times T_2$, $L_{10} \times T_2$, $L_{13} \times T_2$ and $L_{18} \times T_1$	L_1, L_7, L_{12} and L_{13}	$L_5 \times T_3$, $L_7 \times T_2$, $L_8 \times T_1$, $L_9 \times T_3$ and $L_{16} \times T_1$
6.	Number of kernel rows/ear	L_{15}	$L_1 \times T_2$, $L_2 \times T_1$, $L_8 \times T_1$, $L_9 \times T_2$, $L_{14} \times T_3$ and $L_{18} \times T_3$	L_{13}, L_{19} and L_{20}	$L_4 \times T_2$, $L_7 \times T_2$ and $L_{16} \times T_2$
7.	Number of kernels/row	L_2, L_3 and T_2	$L_4 \times T_3$, $L_6 \times T_3$, $L_{10} \times T_1$, $L_{11} \times T_3$ and $L_{12} \times T_1$	L_{13}, L_{15} and L_{19}	$L_3 \times T_3$, $L_4 \times T_2$, $L_5 \times T_2$, $L_7 \times T_2$, $L_{11} \times T_2$, $L_{15} \times T_2$ and $L_{16} \times T_1$

Table 5.5.2 : Contd...

S.No.	Character	Rich environment		Poor environment	
		Inbred lines	**Single crosses**	**Inbred lines**	**Single crosses**
8.	Number of nodes bearing brace roots	L_1, L_9 and L_{10}	-	L_4 and L_8	$L_9 \times T_2$ and $L_{11} \times T_1$
9.	Days to 50% tasselling	L_{12}, L_{13}, T_1 and T_2	-	L_9 and L_{17}	HQPM-1 and Pragati
10.	Days to 50% silking	L_5, L_6, L_8, L_{13}, T_1 and T_2	$L_3 \times T_3$, $L_8 \times T_3$ and $L_9 \times T_2$	L_{14}, L_{16} and L_{17}	$L_2 \times T_3$, $L_{10} \times T_1$, $L_{12} \times T_2$ and $L_{18} \times T_2$
11.	Anthesis-silking interval	L_8 and L_{16}	$L_1 \times T_1$ and $L_{15} \times T_2$	L_{13}, L_{17} and L_{21}	$L_5 \times T_1$, $L_{13} \times T_3$, $L_{16} \times T_3$ and HQPM-1
12.	Protein (%)	-	-	-	-
13.	Lysine (%)	-	-	-	-
14.	Tryptophan (%)	-	-	-	-
15.	Grain yield (Kg/ha)	L_2	$L_1 \times T_1$, $L_2 \times T_1$, $L_4 \times T_3$, $L_6 \times T_1$, $L_7 \times T_3$ and $L_{11} \times T_1$	L_8, L_9, L_{14}, T_1 and T_3	$L_7 \times T_2$, $L_{12} \times T_2$, $L_{13} \times T_1$, $L_{13} \times T_2$, $L_{15} \times T_1$, $L_{18} \times T_3$, $L_{19} \times T_1$, $L_{19} \times T_2$, $L_{19} \times T_3$ and $L_{20} \times T_1$

L: line, **T:** tester

stable and desirable performance. For early flowering, L_{17} showed stable performance. Lines L_8, L_9, L_{14}, T_1 and T_3 exhibited stable and desirable performance for grain yield under poor environment.

The stability of single crosses for important economic characters under rich environment is presented in Table 5.5.2. In these crosses, $L_1 \times T_1$ for plant height, ear height, anthesis-silking interval and grain yield, $L_2 \times T_1$ for number of kernel rows per ear and grain yield, $L_4 \times T_3$ for ear length, ear diameter, number of kernels per row and g rain yield, $L_4 \times T_3$ for 100-kernel weight and grain yield, $L_3 \times T_3$ and $L_{13} \times T_1$ for 100-kernel weight and ear length, $L_{18} \times T_1$ for 100-kernel weight and ear diameter exhibited stable and desirable performance. However, in poor environment, cross $L_7 \times T_2$ for ear height, ear diameter, number of kernel rows per ear, number of kernels per row and grain yield, $L_{18} \times T_3$ for plant height and grain yield, $L_{19} \times T_2$ for 100-kernel weight and grain yield, $L_4 \times T_2$ and $L_5 \times T_2$ for 100-kernel weight and number of kernels per row showed desirable and stable performance. Similar findings were advocated by **Srivastava (2001); Tariq *et al.* (2003); Kumar and Singh (2007) and Rahman *et al.* (2010).** While, for quality characters no specific cross was found good under both rich and poor environments which indicated that these characters were not much more affected by the environmental changes in quality protein maize.

Chapter – 6

Summary & Conclusion

Chapter 6 SUMMARY AND CONCLUSION

The present investigation entitled "combining ability, heterosis and phenotypic stability for yield and other desirable characters in Quality Protein Maize (*Zea mays* L.)" was undertaken in a line x tester mating design involving twenty one quality protein maize (QPM) inbred lines and three broad-base QPM testers at Norman E. Borlaug Crop Research Centre, Pantnagar, Uttarakhand, India during *Kharif*, 2008 with the main objectives (i) to identify superior single cross hybrids (ii) to determine nature and magnitude of heterosis (iii) estimating variability parameters and (iv) to work out combining ability and phenotypic stability of parental inbreds and hybrids over three environments [normal (recommended dose of nitrogen), low-nitrogen and excess soil moisture for important economic characters in quality protein maize (QPM). The experimental material consisted of twenty one quality protein maize (QPM) inbred lines and three broad-base QPM testers. All the 24 parents and 63 single cross QPM hybrids were evaluated with three checks in randomized complete block design in single-row plots of 4 m length with three replications following spacing of 0.75 m between rows and 0.25 m between plants over three environments during *Kharif*, 2009. The data recorded on 15 different characters like plant height, ear height, 100-kernel weight, ear length, ear diameter, number of kernel rows/ear, number of kernels/row, number of nodes bearing brace roots, days to 50% tasselling, days to 50% silking, anthesis-silking interval, protein

percentage, tryptophan and lysine contents and grain yield were subjected to appropriate statistical and biometrical analysis and the results obtained are summarized as follows:

1. Analysis of variance of parents and single crosses showed that these genotypes differed significantly for all the 15 characters. This indicated that the experimental material contained sufficient amount of variability.
2. (i) The nature and magnitude of heterosis revealed that high heterosis for grain yield was mostly accompanied by heterosis for major yield contributing traits.

   (ii) On the basis of heterosis for grain yield, range of heterobeltiosis in E_1, E_2, E_3 and across environments was -66.19 to 193.31, -59.97 to 166.59, -72.17 to 130.53 and -68.81 to 56.31, respectively. High heterobeltiosis in E_1 was observed in cross, $L_3 \times T_1$ (Pool 17C_8(TEYFQPM)-B-1-1-1-1× DMRQPM-03-106-#-⊗-1-1-1) followed by $L_5 \times T_1$ (Pool 17C_8(TEYFQPM)-B-93-1-1-1× DMRQPM-03-106-#-⊗-1-1-1) and $L_5 \times T_3$ (Pool 17C_8(TEYFQPM)-B-93-1-1-1×Pool 17C_8(TEYFQPM)-B-57-2-1-1); $L_{19} \times T_3$ (DQPMC-3(Y)⊗14-2-1×Pool 17C8(TEYFQPM) B-57-2) followed by $L_1 \times T_1$ (DQPMC-3(Y)⊗101-1-2×DMRQPM-03-106-#-⊗-1) and $L_{17} \times T_3$ (DQPMC-3(Y) ⊗2-1-1×Pool 17C8(TEYFQPM)-B-57-2) in E_2, $L_7 \times T_1$ (DQPMC-3(Y)⊗135-2-1×DMRQPM-03-106-#-⊗-1) followed by $L_7 \times T_3$ (DQPMC-3(Y)⊗135-2-1×Pool 17C8(TEYFQPM)-B-57-2) and $L_2 \times T_1$ (DQPMC-3(Y)⊗101-1-2×DMRQPM-03-103-#-⊗-2) in

E_3. However, cross $L_1 \times T_1$ (DQPMC-3(Y)⊗101-1-2×DMRQPM-03-106-#-⊗-1) followed by $L_4 \times T_1$ (Pool 17C8(TEYFQPM)-B-76-1×DMRQPM-03-106-#-⊗-1) and $L_3 \times T_1$ (Pool 17C8(TEYFQPM)-B-1-1×DMRQPM-03-106-#-⊗-1) showed high heterobeltiosis in pooled environment.

(iii) The estimates of relative heterosis for grain yield ranged from -70.10 to 166.77, -62.24 to 117.26, -70.10 to 50.90 and -64.93 to 80.53 in the E_1, E_2, E_3 and across the environments, respectively. The most heterotic combinations was $L_4 \times T_1$ (Pool 17C8(TEYFQPM)-B-76-1×DMRQPM-03-106-#-⊗-1) followed by $L_3 \times T_1$ (Pool 17C8(TEYFQPM)-B-1-1×DMRQPM-03-106-#-⊗-1-1-1) and $L_5 \times T_1$ (Pool 17C8(TEYFQPM)-B-93-1×DMRQPM-03-106-#-⊗ -1) in E1; $L_1 \times T_1$ (DQPMC-3(Y)⊗101-1-2×DMRQPM-03-106-#-⊗-1) followed by $L_{19} \times T_3$ (DQPMC-3(Y) ⊗14-2-1×Pool 17C8(TEYFQPM)-B-57-2) and $L_{17} \times T_3$ (DQPMC-3(Y)⊗2-1-1× Pool 17C8(TEYFQPM)-B-57-2) in E2, $L_{10} \times T_1$ (DQPMC-3(Y)⊗50-1-1× DMRQPM-03-106-#-⊗-1) followed by $L_1 \times T_1$ (DQPMC-3(Y) ⊗101-1-2×DMRQPM-03-106-#-⊗ -1) and $L_{14} \times T_1$ (DMRQPM-28-5-⊗-⊗-#-⊗3-⊗-1× DMRQPM-03-106-#-⊗-1) in E3 and $L_1 \times T_1$ (DQPMC-3(Y)⊗101-1-2×DMRQPM-03-106-#-⊗-1) followed by $L_4 \times T_1$ (Pool 17C8(TEYFQPM)-B-76-1×DMRQPM-03-106-#-⊗-1) and $L_{14} \times T_1$ (DMRQPM-28-5-⊗-⊗-#-⊗3-⊗-1×DMRQPM-03-106-#-⊗-1) across the environments.

(iv) The magnitude of standard heterosis, ranged from -64.00 to 154.09, -99.70 to 199.52, -50.00 to 99.88 and -42.98 to 151.85 in E_1, E_2, E_3 and across environments, respectively. The most heterotic hybrid combination was $L_3 \times T_1$ (Pool 17C8(TEYFQPM)-B-1-1×DMRQPM-03-106-#-⊗-1) followed by $L_4 \times T_1$ (Pool 17C8 (TEYFQPM)-B-76-1×DMRQPM-03-106-#-⊗-1) and $L_9 \times T_1$ (DQPMC-3(Y)⊗31-1-3×DMRQPM-03-106-#-⊗-1) in E_1; $L_1 \times T_1$ (DQPMC-3(Y)⊗101-1-2×DMRQPM-03-106-#-⊗-1) followed by $L_{12} \times T_3$ (POP 61 C9(TEYFQPM)-B- 20-1× Pool 17C8(TEYFQPM)-B-57-2) and $L_9 \times T_1$ (DQPMC-3(Y)⊗31-1-3×DMRQPM-03-106-#-⊗-1) in E_2; $L_{11} \times T_3$ (Pool 18C8(TEYFQPM)-B-9-1×Pool 17C8(TEYFQPM)-B-57-2) followed by $L_{19} \times T_2$ (DQPMC-3(Y)⊗14-2-1×DMRQPM-03-103-#-⊗-2) and $L_1 \times T_1$ (DQPMC-3(Y) ⊗101-1-2× DMRQPM-03-106-#-⊗-1) in E_3. However, cross $L_1 \times T_1$ (DQPMC-3(Y)⊗101-1-2×DMRQPM-03-106-#-⊗-1) followed by $L_3 \times T_1$ (Pool 17C8 (TEYFQPM)-B-1-1×DMRQPM-03-106-#-⊗-1) and $L_{11} \times T_3$ (Pool 18C8(TEYFQPM)-B-9-1×Pool17C8(TEYFQPM)-B-57-2) exhibited high estimates of standard heterosis in the pooled analysis, indicating that the inbreds involved in these crosses can be used for the better exploitation of heterosis to get superior single crosses for their respective environments

(v) The cross, $L_1 \times T_1$, $L_1 \times T_2$, $L_2 \times T_1$, $L_2 \times T_2$, $L_2 \times T_3$, $L_3 \times T_1$, $L_4 \times T_1$, $L_5 \times T_1$, $L_9 \times T_1$, $L_9 \times T_2$, $L_{10} \times T_1$, $L_{11} \times T_3$ and $L_{14} \times T_1$ in E_1, $L_1 \times T_1$, $L_1 \times T_3$, $L_2 \times T_1$, $L_2 \times T_2$, $L_5 \times T_1$, $L_{10} \times T_1$, $L_{11} \times T_3$, $L_{14} \times T_1$, $L_{17} \times T_3$,

$L_{19}\times T_1$ and $L_{19}\times T_3$ in E_2, $L_1\times T_1$, $L_2\times T_1$, $L_{10}\times T_1$, $L_{11}\times T_3$, $L_{14}\times T_1$ and $L_{19}\times T_2$ in E_3 and cross, $L_1\times T_1$, $L_2\times T_1$, $L_3\times T_1$, $L_4\times T_1$, $L_{10}\times T_1$, $L_{11}\times T_3$ and $L_{14}\times T_1$ in pooled environment exhibited significant and positive heterosis (BP, CP and MP) for grain yield.

(vi) Based on the study over all the three and pooled environment for grain yield, hybrids, $L_1\times T_1$ (DQPMC-3(Y)⊗101-1-2-1-1× DMRQPM-03-106-#-⊗-1-1-1), $L_2\times T_1$ (DQPMC-3(Y)⊗101-1-2-1-1× DMRQPM-03-103-#-⊗-2-1-1-1), $L_{10}\times T_1$ (DQPMC-3(Y)⊗50-1-1-1-1×DMRQPM-03-106-#-⊗-1-1-1-1), $L_{11}\times T_3$ (Pool 18C8 (TEYFQPM)-B-9-1-1-1-×Pool17C8(TEYFQPM)-B-57-2-1-1) and $L_{14}\times T_1$ (DMRQPM-28-5-⊗-⊗-#-⊗3-⊗-1-1-1× DMRQPM-03-106-#-⊗-1-1-1) were found suitable having significantly positive heterosis (BP, CP and MP) in E_1, E_2, E_3 and pooled environment.

3. (i) High estimates of broad sense heritability were observed for quality traits, 100-kernel weight and grain yield in all the three environments except grain yield in E2 environment where it showed moderate estimates of heritability, whereas, low heritability values were recorded for characters like days to 50% tasselling, days to 50% silking, plant height, ear height, number of nodes bearing brace roots in E_1, ear diameter, number of kernels per row, brace roots, anthesis-silking interval in E_2 and days to 50% tasselling, days to 50% silking, ear diameter, number of kernel rows per ear, number of kernels per row and anthesis-silking interval in E_3.

(ii) Highest expected genetic advance as per cent of mean was observed for grain yield and quality characters in all the three (E_1, E_2 and E_3) environments, however, moderate estimates were observed for ear length, ear diameter, anthesis-silking interval and number of nodes bearing brace roots in E_1, ear height in E_2 and ear height, anthesis-silking interval and number of nodes bearing brace roots in E_3. Hence, selection for grain yield and quality characters along with other characters showing high to moderate genetic advance will give effective response in the desired direction.

(iii) In general, phenotypic coefficients of variation were higher as compared to genotypic coefficients of variation for all the characters except quality traits in the similar direction. Grain yield showed maximum PCV and GCV (percent) followed by ear height, ear length, ear diameter, number of kernels/row and 100-kernel weight in all the environments.

4. (i) Variance due to lines was significant for most of the characters except 100-kernels weight and number of nodes bearing brace roots in $E_1$and E_3, number of kernels per row in E3; days to 50% silking and anthesis-silking interval in E_2 and E_3 environments. Variance due to tester was significant for all the characters except number of nodes bearing brace roots in E_1 and E_2 and days to 50% tasselling in E_1 environment. All the characters showed significant differences in all the three environments for line x tester component.

(ii) Pooled analysis of variance pooled over environments for combining ability indicated that variance due to lines was significant for all the characters except quality parameters. Whereas, variance due to testers was significant for plant height, ear height, 100-kernel weight, ear length, ear diameter, number of kernel rows per ear, number of kernels per row and grain yield. For line x tester interaction component, the variance was significant for all the characters. Component for line x environment interaction was non significant for number of kernels per row, protein, lysine and tryptophan contents, While, tester x environment component of variance was significant for plant height, ear height, 100-kernel weight, ear length, ear diameter, number of kernels row per ear and grain yield. Higher order interaction i.e. (line x tester) x environment was significant for all fifteen characters studied.

(iii) Estimates of variances due to specific combining ability (σ^2 SCA) were greater than general combining ability (σ^2 GCA) for all the characters over all the three environments. For all the characters, the ratio of variance of GCA to SCA was lesser than unity in all the environments indicating pre-dominance of non-additive variance. Therefore, as the dominance variance was predominant, transgrassive (recombinant) breeding may not be useful. Heterosis breeding is a better choice for these conditions.

(iv) The GCA effects of the parents in the E_1 indicated parental lines and testers, L_1, L_2, L_3, L_4, T_1 and T_3 to be the best general combiners. In the E_2, the significant GCA effects were observed in respect of lines, L_1, L_3, L_4, L_{11}, L_{12}, L_{13}, L_{14}, and L_{16}. While, among testers, T_1 and T_3 exhibited maximum significant GCA effects for ear height. The GCA effects of the parents in the E_3 indicated that lines, L_8, L_4, L_7 and testers, T_3 and T_1 to be the best general combiners with significant GCA effects. On the basis of pooled analysis, lines, L_1, L_2, L_4 and testers, T_1 and T_3 were the best combiners.

(v) The finding of combining ability analysis revealed that the crosses between high GCA parents did not always result in good F_1 combinations. While, poor/ good, poor / average, poor/poor and its reciprocal can also result in good combinations.

(vi) Results on top hybrids showing higher SCA effects for grain yield and other quantitative traits indicated that the cross, $L_{11}\times T_3$, $L_{14}\times T_1$ and $L_3\times T_1$ in E_1, $L_{11}\times T_3$, $L_{17}\times T_3$ and $L_1\times T_1$ in E_2, $L_{11}\times T_3$ in E_3 and $L_{11}\times T_3$ and $L_{17}\times T_3$ in pooled environment appeared as best specific combiner for grain yield and its contributing traits as well as for quality traits. Overall results revealed that cross $L_{11}\times T_3$ appeared as best specific combiner for grain yield and its contributing traits as well as for quality traits in overall environments.

(vii) Pooled analysis of variance over three environments for stability exhibited that mean squares due to genotypes were significant

for ear height, ear length, ear diameter, number of kernel rows/ear, days to 50% tasselling, days to 50% silking, protein, lysine, tryptophan and grain yield contents indicating sufficient genetic variability among all the genotypes for these traits. The mean squares due to environments were also significant for all the characters, indicating sufficient differences among environments and effectiveness of environments in influencing the performance of genotypes. The G×E interaction mean squares were highly significant for all the traits except quality traits as protein, lysine and tryptophan contents, indicating differential response of genotypes in different environments, however, quality traits were unaffected by the changing environments.

(viii) Among 21 QPM inbred lines and 3 testers, the lines, L_1 (DQPMC-3(Y)⊗101-1-2-1-1), L_3 (Pool 17C_8(TEYFQPM) -B-1-1-1-1), L_4 (Pool 17C_8(TEYFQPM)-B-76-1-1-1), L_5 (Pool 17C_8 (TEYFQPM)-B-93-1-1-1), L_6 (DQPMC-3(Y)⊗56-2-3-1-1), L_{10} (DQPMC-3(Y)⊗50-1-1-1-1) and L_{12} (POP61 C_9(TEYFQPM) -B- 20-1-1-1) and testers, T_1 (DMRQPM-03-106-#-⊗-1-1-1) and T_2 (DMRQPM-03-103-#-⊗-2-3-1) showed desirable stability for grain yield and its components along with quality characters

(ix) Out of 63 single crosses evaluated for their stability, most desirable and stable ones were L_2×T_3, L_3×T_3, L_5×T_2, L_5× T_3, L_7×T_1, L_7×T_3, L_8×T_1, L_8×T_2, L_8×T_3, L_9×T_3, L_{10} × T_1, L_{10}×T_2, L_{11}×T_2,

$L_{11}\times T_3$, $L_{12}\times T_1$, $L_{12}\times T_3$,, $L_{13}\times T_3$, $L_{14}\times T_3$, $L_{16}\times T_2$, $L_{16}\times T_3$, $L_{17}\times T_2$, $L_{17}\times T_3$, $L_{20}\times T_2$, $L_{20}\times T_3$, $L_{21}\times T_1$, $L_{21}\times T_2$ and $L_{21}\times T_3$ with high mean, bi = 1 and $S^2di = 0$ for grain yield. For quality traits like protein, tryptophan and lysine contents, $L_1\times T_1$, $L_1\times T_3$, $L_2\times T_1$, $L_2\times T_2$, $L_3\times T_3$, $L_4\times T_3$, $L_6\times T_3$, $L_8\times T_2$, $L_{10}\times T_2$, $L_{10}\times T_3$, $L_{11}\times T_1$, $L_{11}\times T_1$, $L_{14}\times T_2$, $L_{15}\times T_1$, $L_{16}\times T_1$, $L_{16}\times T_2$, $L_{16}\times T_3$, $L_{17}\times T_3$ and $L_{20}\times T_3$ were found to be desirable and stable.

(x) For intensive agriculture where inputs are no limitation i. e., rich environment, the parental inbred lines, L_1 (DQPMC-3(Y)⊗101-1-2-1-1), L_2(DQPMC-3(Y)⊗101-1-2), L_4 (Pool17C_8 (TEYFQPM)-B-76-1-1-1), L_9(DQPMC-3(Y)⊗31-1-3-2-1-1), L_{13} (DMRQPM-03-101-#-⊗-1-1-1) and L_{21} (POP 61 C_9(TEYFQPM)-B-35-2-1-1) and testers, T_1 (DMRQPM-03-106-#-⊗-1-1-1) and T_2 (DMRQPM-03-103-#-⊗-2-3-1) and crosses, $L_1\times T_1$, $L_2\times T_1$, $L_4\times T_3$, $L_6\times T_1$, $L_7\times T_3$ and $L_{11}\times T_1$ showed stable and desirable performance with high mean, higher value of regression coefficient i.e., bi >1 and much higher deviation from linearity . However, under poor environment, the lines, L_1 (DQPMC-3(Y)⊗101-1-2-1-1), L_8 (DMRQPM-03-103-#-⊗3-1-1-1), L_9 (DQPMC-3(Y)⊗31-1-3-2-1-1), L_{13} (DMRQPM-03-101-#-⊗-1-1-1), L_{14} (DMRQPM-28-5-⊗-⊗-#-⊗3-⊗-1-2-1) and L_{17} (DQPMC-3(Y)⊗2-1-1-2-1) and testers, T_1 (DMRQPM-03-106-#-⊗-1-1-1) and T_3 (Pool 17C_8(TEYFQPM)-B-57-2-1-1) and crosses, $L_4\times T_2$, $L_5\times T_2$, $L_7\times T_2$, $L_{18}\times T_3$ and $L_{19}\times T_2$ exhibited stable and desirable performance

for grain yield and its component traits under poor environment with high mean, very low value of regression coefficient i.e., bi <1 and low deviation from linearity. While, for quality characters no specific cross was found good under both rich and poor environments which indicated that these characters were not much more affected by the environmental changes in quality protein maize.

Literature Cited

LITERATURE CITED

A.O.A.C. 1965. Official Methods of Analysis of the Association of Official Agricultural Chemists. 10th Ed., 744-45.

Abdulai *et al.* 2009. Genotypic stability and adaptability in tropical maize. *Genet. Mol. Res.* **8** (4): 1311-1322

Abirami, S.; Vanniarajan, C. and Arumugachamy, S. 2005. Genetic variability studies in maize germplasm. *Plant Archives*, **5** (1):105-108.

Adams, M.V. and Shank, D.B. 1959. The relationship of heterozygosity to homeostasis in maize hybrids. *Genetics*, **44** : 777-783.

Agarwal, P.; Verma, S.S. and Mishra, S.N. 2000. Phenotypic stability for different quantitative traits in maize hybrids. *Indian J. Agric. Res.*, **34** (2) : 107-111.

Agrawal, R.L. and Dhawan, N.L. 1968. Phenotypic stability of maize composites over generations and locations. *In* : The Fifth Inter-Asian Corn Improvement Workshop, pp. 87-90.

Allard, R.W. 1960. Principles of plant breeding, John Wiley and Sons, Inc., New York, 463 p.

Allard, R.W. 1960. Principles of plant breeding. John Wiley and Sons, Inc. New York, 463p.

Allard, R.W. and Bradshaw, A.D. 1964. Implications of genotype environment interaction in applied plant breeding. *Crop Sci.*, **4** : 503-508.

Altinbas, M. 1995. Heterosis and combining ability in maize for grain yield and some plant characters. *Anadolu*, **5** (2) : 35-51.

Altinbas, M. 1995. Heterosis and combining ability in maize for grain yield and some plant characters. *Anadolu*, **5** (2) : 35-50.

Andrew, R.H. 1967. Influence of environment on stability of corn during vegetative growth. *Crop Sci.*, **7** : 253-254.

Arba, M.D.; Sarda, R.P. and Agrawal, K.N. 1990. Studies on maize gene pools. II. Heritability and expected genetic advance. *Acta Agronomica ungarica*, **39** (1-2) : 121-125.

Arnold, J.M. and Bauman, L.F. 1976. Inheritance and interrelationship among maize kernel traits and elemental contents. *Crop Sci.*, **16** (3) : 439-440.

Beal, W.J. 1980. Indian Corn. *Annual Report*. Mich. Board Agric., pp. 279-289.

Beck, D.L.; Vasal, S.K. and Crossa, J. 1990. Heterosis and combining of CIMMYT's tropical early and intermediate maturity maize (*Zea mays* L.) germplasm. *Maydica*, **35** : 279-285.

Benti-tolessa; Mulatu; Legese-Walde; Gezahagne, Bogale. 1992. Heterosis and genetic diversity in crosses of adapted maize composite. *Ethiopian Journal of Agricultural Sciences.* **1**: 1-8

Bertoia, L.; Lopez, C. and Burak, R. 2006. Biplot analysis of forage combining ability in maize landraces. *Crop Science*. 46(3): 1346-1353

Bhargava, S.C. and Utkhede, R.S. 1978. Response of maize varieties to altitudes and environments for yields and protein. *Indian J. Genet. Plant Breed.*, **38** (2) : 231-238.

Bhoite, K. D. and Sonone, A. H. 2007. Variability, heritability and genetic advance in forage maize. *Journal of Maharashtra Agricultural Universities.* 32(2): 283-284

Bruce, A.B. 1910. The mendelian theory of heredity and the augmentation of vigour. *Science*, **32** : 627-628.

Burak, R. and Broccoli, A.M. 2001. Stability analysis for yield and expansion volume in popcorn hybrids. *Maize Genet. Coop. Newsl.*, **75** : 37-38.

Burgos, G.B. 1982. Diallel analysis of detected maize inbred lines under high plant density. *College Layuma*, 149.

Cardoso, M.J.; Carvalho, H.W.L.; Leal, M.L. and Santos, M.X. 2000a. Stability of maize cultivars in Piaui State. *Revista Cientifica Rural*, **5** (1) : 62-67.

Cardoso, M.J.; Carvalho, H.W.L.; Leal, M.L. and Santos, M.X. 2000b. Behaviour adaptability and stability of hybrids of corn in the State of Piaui. *Revista Cientifica Rural*, **5** (1) : 142-149.

Carnaham, H.L.; Horin, A.W.; Graumaun, H.W.; Kour, W.R.; Davis, R.L.; Eling, L.S. and Handson, 1960. General vs. specific combining ability in alfa-alfa for seedling vigour and fall growth habit in year of establishment. *Agron. J.*, **52** : 511-516.

Carvalho, H.L.; Leal, M.L.; Cardoso, M.J.; Santos, M.X.; Carvalho, B.C.L.; Tabosa, J.N.; Lira, M.A. and Albuquerque, M.M. 2001. Adaptability and yield stability of corn cultivars in the Brazilian North West in the Agriculture year of 1998.

Chen, L.; Cui, S.P. and Sun, Y.B. 1996. Analysis of the gene effect on ear characters in maize. *Acta Agriculturae Sinica*, **11** (2) : 28-32.

Chen, Z.H. and Gao, X.A. 2000. Study on the combining ability and heterosis of suwan germplasm line. *Scientia Agricultura Sinica*, **33** (1) : 113-118.

Choukan, R. 1999. Stability analysis of yield of grain maize hybrids using different stability indices. *Seed and Plant*, **15** (3) : 170-183.

Claudio, J.F. and Patricio, B.B. 1988. Genetic variance of field and other quantitative characters in a population of maize. I. Estimation of the components of variance and heritability. *Agro. Sur.*, **16** (2) : 73-83.

Cosmin, O.; Bica, B. and Bagin, C. 1991. Study of combining ability in some inbred lines of maize. *Problems de Genetica Theoretical si Aplicata*, **23** : 105-122.

Crossa, H.Z. and Wiidakas, W. 1975. ND 240 and ND 241 new inbred lines for producing early maturing corn hybrids. *North Dacota Farm Res.*, **32** (4) : 5-8.

Cruz, LE.; Hutierrez del R.; Palomo, G. and Robriguez, H. 2003. Combining ability and heterosis of maize inbred lines at the *Camarca lugunera. Revista Fitotecnia Maxicana*, **26** (4) : 279-284.

Dahlan, M.; Mejaya, M.J.; Slamet, S.; Mudjiono, J. and Kasim, F. 1997. combining ability among S_2 lines derived from two late maize population. *Indonesian J. Crop Sci.*, **12** : 1-6.

Dar , S.A; Gowhar, Ali., Rather, A.G. and Khan, M.N. 2007. Combining ability for yield and maturity traits in elite inbred lines of maize (*Zea mays* L.). *International Journal of Agricultural Sciences.* 3(**2**):290-293.

Dass, S., Singh, M. and Arora, P. 1997. Genetics of grain yield and cob traits in maize (*Zea mays* L.). *Annals of Biology,* 13 (**2**): 283-287.

Dawood, K.M. and Mahamed, A.S.A. 1989. Estimates of heritability and path-coefficient analysis for some characters in maize (*Zea mays* L.). *Mesopot. J. Agric.*, **21** (4) : 243-254.

Debnath, S.C. 1984. Heterosis in maize. I. Grain yield and some of its attributes. *Bangladesh J. Agric. Res.*, **9** : 78-83.

Debnath, S.C. 1987. Genetic variability in maize (*Zea mays* L.). *Bangladesh J. Agric. Res.*, **12** (4) : 217-21.

Debnath, S.C. and Khan, M.F. 1991. Genotypic variation, correlation and path coefficient analysis in maize. *Pakistan J. Scientific Indus. Res.*, **34** : 391-394.

Debnath, S.C. and Sarkar, K.R. 1987. Genetic analysis of grain yield and some of its attributes in maize (*Zea mays* L.). *Thai. J. Agril. Res.*, **15** : 64-69.

Debnath, S.C.; Sarkar, K.R. and Singh, D. 1983. Combining ability anlaysis in maize 3 : ear and grain characters. *Bangladesh Association for the Advancement of Science*, 46 p.

Dehganpour, Z. and Moghadam, A. 1996. Simultaneous selection for yield and stability in early and very early maturity hybrids of maize. *Seed and Plant*, **15** (3) : 206-217.

Dhillon, B.S. and Singh, J. 1977. Combining ability and heterosis in diallel crosses of maize. *Theor. Appl. Genet.*, **49** (3) : 117-122.

Diaz, A.C. and Torregroza, C.M. 1979. Environmental response of six cold climate maize varieties. *Revista Instituto Colombiano Agropecurario*, **14** (3) : 129-140.

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* L.). *Crop Rsearch Hisar,* 26 (**1**): 114-118.

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 (*Zea mays* L.). *Indian J. Genet.*, **61** (4) : 353-355.

East, E.M. and Hayes, H.K. 1912. Heterozygosis in evolution and in plant breeding. USDA Bur. Plant Indian Bull., 243 p.

Eberhart, S.A. and Russell, W.A. 1966. Stability parameters for comparing varieties. *Crop Sci.*, **6** : 36-40.

El-Hosary, A. A. and Sedhom, S.A. 1985. Performance and combining ability in diallel crosses in maize. *Annals of Agricultural Sciences, Moshtohor.* 32 (**1**):203-215.

El-Hosary, A.A. 1985. Study of combining ability in some top crosses in maize. *Egyptian J. Agron.*, **10** : 1-2.

Falconer, D.S. 1960. Introduction to quantitative genetics. Ronald Press, New York.

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. *Maydica.* 53(1): 39-46.

FAO. 2005. FAO Database. http://www.fao.org.

Finlay, K.W. and Wilkinson, G.N. 1963. The analysis of adaptation in the plant breeding programme. *Abst. J. Agric. Res.*, **14** : 742-754.

Fisher, R.A. 1946. Statistical methods for research workers. (10th edition). Olivar and Byod, Ed. In burg.

Ganguli, D.K.; Haque, M.F. and Sinha, S.K. 1989. Heterosis in inter-population crosses in maize. *J. Res. Birsa Agril. Univ.*, **1** : 59-63.

Garbuglio, D. D.; Miranda-Filho, J. B. de; Cella, M. 2009. Genetic variability in S1 families from different maize populations. *Acta Scientiarum Agronomy.* 31(2): 209-213.

Genova, I. 1984. Inheritance of quantitative characters in maize and variation n genetics parameters. V. yield and yield component. *Genetica i seleklsiya,* **17** : 323-332.

Gissa, D. W.; Zelleke, H.; Labuschagne, M. T.; Hussien, T. and Singh, H. 2007. Heterosis and combining ability for grain yield and its components in selected maize inbred lines. *South African Journal of Plant and Soil.* 24(3): 133-137

Gonzales, S.; Cordova, H.; Rodriguez, S.; Leon, H.; Serrato, V.M. and Deleon, H. 1997. Determination of heterotic pattern from a diallel of ten subtropical lines of maize. *Agronomia Mesoamericana*, **8** (1) : 1-7.

Gorban, V.F. 1978. Reduction in heterosis in early inbred generation of single interline hybrids. Byul. VN II Kukuruzy No. 2/3, 9-11.

Gupta, S. C.; Kulmi, G.K.; Nagda, A.K.; Trivedi, H.K. 1994. Heterosis and combining ability in intervarietal crosses in some local exotic pools and population of maize (*Zea mays* L.). *Crop Research Hissar.* 8 : 315-319.

Gurung, D.B; Maria Luz C. Geroge and Quirino D. Delecrug. 2009. Determination of heterotic group of in Nepalese yellow maize population. *Nepal Journal of Science & Technology*. **10** (1): 8-15.

Guzman, P. S. 1992. Genetics of yield and other agronomic traits in native maize varieties. *College Layuna (Philippines).*

Hema, D.; Kim, S.; Tro, T.B. and Kim, S.K. 1999. Genetic analysis of maize yield components in dry areas of Bukina Faso. *Cabiers Agric.*, **8** (1) : 64-66.

Henderson, C.R. 1952. Specific and general combining ability. *In* : Heterosis ed. John W. Gowen, Iowa State College Press, Ames, Iowa, pp. 352-371.

Ho-Changlee; Lu Hung Shung; Ho, C. L.; Lu, H.S. 1995. Identification of heterotic patterns with inbred line, testers in maize. *Journal of Agricultural Research in China.* 44:242-250

Hohls, T.; Shanahan, P.E.; Clarke, G.P. and Gevers, H.O. 1995. Genotype × environmental interactions in a 10 × 10 diallel cross of quality protein maize (*Zea mays* L.). *Euphytica,* **84** (3) : 209-218.

Hornandez, H. and Bates, L.S. 1969. A modified method for rapid tryptophan analysis of maize. *Res. Bull.* No. 13. CIMMYT.

Iqbal, A.M., F.A. Nehvi, S.A. Wani, R. Qadir and Z.A. Dar, 2007. Combining ability analysis for yield and yield related traits in Maize (*Zea mays* L.). *Int. J. Plant Breed. Genet.,* 1: 101-105.

Iqbal, M.; Salum, M. and Rasid, O. 2001. Inter-raceal heterosis in maize hybrids. *Pakistan J. Scientif. Indus. Res.*, **44** (4) : 239-343.

Jaykumar, J. and Sundaram, T. 2007. Combining ability studies for grain yield and other yield components in maize (*Zea mays* L.). *Crop Research Hissar.* 33 (**1/3**): 179-186

Jha, P.B. and Khehra, A.S. 1992. Evaluation of maize inbred lines derived from two heterotic population. *Indian J. Genet.*, **52** : 126-131.

Jha, P.B.; Khehra, A.S. and Akhter, S.A. 1986. Stability analysis for grain development and yield in maize. *Crop Improve.*, **13** (1) : 16-19.

Ji, H. C.; Cho, J. W. and Yamakawa, T. 2006. Diallel analysis of plant and ear heights in tropical maize (*Zea mays* L.). *J. Fac. Agr., Kyushu Univ.* **51** (2):233–238.

Jones, D.F. 1918. The effect of inbreeding and cross breeding upon development. *Conn. Agric. Exp. Stn. Bull.*, **205** : 5-100.

Jones, D.F. 1958. Heterosis and homeostasis in evaluation and applied genetics. *Am. Nat.*, 82 : 321-328.

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.*, **58** (4) : 519-524.

Kabdal, M. and Verma, S.S. 2003. Combining ability and heterosis for yield and its components in maize. Diamond Jubilee Symposium, I.S.G. & P.B., New Delhi, Nov. 6-9, pp. 131.

Kabdal, M.K. 2000. Combining ability and heterosis analysis for grain yield and its components in maize (*Zea mays* L.). M.Sc. (Ag.) Thesis, G.B.P.U.A. & T., Pantnagar, India, 115 p.

Kempthorne, O. 1957. An introduction to statistics. *John Wiley and Sons. Inc. New York.* Pp: 468-471

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

Kovach, Z. and Khertseg, M. 1971. Investigation of the breeding value of inbreeding lines. *In* : *Selektsiya i Semenovodstovo Kloikurzy*, pp. 92-100.

Kravenchko, V.A.; Karol, L.; Chuk, M.C. and Morshed, G.A. 1971. Heterosis in maize in respect of some economically valuable characters after interline crossing. *Neuk. Pratsi. Ukr Sil 's' Kogospod, Akad. No.* **40** : 47-49.

Kumar, A. and Singh, N. 2004. Stability studies of inbred and their single crosses in maize. *Annals of Agricultural Sciences.* **25** (1):142-148

Kumar, A. and Singh, N. 2007. Stability studies of inbred and their single crosses in maize. *Ann. Agril. Res.*, **25** (1) : 142-148.

Kumar, P. 1994. Heterosis in varietal crosses of maize (*Zea mays* L.). *New Botanica*, **2** : 15-19.

Kumar, S. 1974. Correlation between yield and yield components and their combining ability in maize (*Zea mays* L.). *Madras Agric. J.*, **61**: 111-117.

Kumari, J.; Gadag, R. N. and Jha, G. K. 2008. Genetic distance based on simple sequence repeats and its relationship to specific combining ability and heterosis in maize (*Zea mays* L.). *Indian Journal of Genetics and Plant Breeding.* **68**(2): 124-131.

Lamkey, K.P. 1986. Mean performance and heterosis of high × high, high × low and low × low crosses of lines from BSSS maize synthetic. *Crop Sci.*, **26** : 1114-1118.

Landi, P.C.; Verdario, A. and Lorenzone, C. 1986. Combining ability of early maize (*Zea mays* L.) inbred lines as well as evaluated under conditions of double cropping. *Maydica*, **31** : 369-377.

Lerner, I.M. 1954. Genetic homeostasis. John Wiley and Sons Inc., New York.

Li, M.; Zhang, S.H.; Pan, G.; Li, X.; Xia, X.C.; Tian, Q..Z. and Bai, L. 2005. Combining ability and heterosis grouping of CIMMYT subtropical quality protein maize lines. *Scientia Agricultura Sinica*, **38** (4) : 671-677.

Liao, S.J.; Xu, Z.B. and Wen, S.P. 1987. Analysis of combining ability for maize quantitative characters in some maize inbred lines. *Nengxia Ag and Forestry Sci. & Tech.*, **5** : 10-12.

Lonnquist, J.H. 1961. Progress from recurrent selection procedures for the improvement of corn populations. *Nabraska Agric. Exp. Sta. Res. Bull.*, pp. 197.

Luchsinger, A. and Violic, A. 1972. General and specific combining ability for yield and its components in ten lines of maize (*Zea mays* L.). Anales del instituto nacional de Investigaciones Agraraias, Production Vegetal No. **2** : 47-61.

Lush, J.L. 1949. Heritability of quantitative characters in farm animals. Proc. 8th Int. Cong. of Genetics. Suppl. *Heridities*, pp. 356-375.

Mahajan, V. and Khehra, A.S. 1992. Stability analysis of kernel yield and its component in maize (*Zea mays* L.) in winter and monsoon seasons. *Indian J. Genet.*, **52** (1) : 63-67.

Mani, V.P. and Bisht, G.S. 1996. Genetic variability in local maize germplasm of U.P. hills. *J. Hill Res.*, **9** (1) :131-134.

Mann, C.E.; Pollmar, W.G. and Klein, D. 1981. Magnitude and stability over environments of reciprocal cross differences in maize hybrids and their implication on maize breeding. *Maydica*, **26** (4) : 239-252.

Manoliu, M. 1969. Studies on the heritability of some quantitative characters in maize. *Lucrari Stiintifice, Institutul Agronomic N. Balcescee. A.*, **12** : 35-43.

Mathur, K.K.; Chuni Lal, S.K.; Bhatnagar, S.K. and Singh, V. 1998. Combining ability for yield, phonological and ear characters in white seeded maize. *Indian J. Genet.* **58** (2): 177-182

Matzinger, D.F.; Sprague, G.F. and Cockrhan, C.C. 1959. Diallel crosses of maize in experiments repeated over locations and years. *Agron. J.*, **51** : 346-350.

Mehmood, A.; Saleem, M. and Khabir, A. 2004. Evaluation of heterosis for grain yield and some agronomic characters in maize hybrids between parents of diverse genetic origin. *Sarhad Journal of Agriculture (Pakistan),* **19** (3): 365-368

Mertz, E.T.; Hambunathan, R. and Misra, P.S. 1975. *In* : Protein quality agricultural research Stn. Bull. No. 7, Purdue Univ., USA, p. 9.

Mohmoud, I.M.; Rashed, M.A.; Fahmi, E.M. and Abo, D.M.H. 1990. Heterosis, combining ability and types of gene action in 6 × 6 diallel of maize. *Ann. Agril. Sci. Cairo*. Special Issue, pp. 307-317.

Moll, R.H.; Longquist, J.H.; Fortuna, J.V. and Johnson, E.C. 1965. The relation of heterosis and genetic divergence in maize. *Genetics*, **52** : 152-194.

Moll, R.H.; Sathauna, W.S. and Robinson, H.F. 1962. Heterosis and genetic diversity in variety crosses of maize. *Crop Sci.*, **2** : 197-198.

Mukherjee, A. 1997. Line × tester analysis for certain agronomic traits in early maturing inbred lines of maize (*Zea mays* L.). M.Sc. (g.) Thesis, G.B.P.U.A. & T., Pantnagar (India), 169 p.

Nagda, A.K.; Dubey, R.B. and Pandiya, N.K. 1995. Studies on combining ability in *Rabi* maize (*Zea mays* L.). *Crop Sci.*, **9** : 309-312.

Ojo, 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. of Sustainable Development in Agriculture & Environment.* **3**:49-57.

Ordas, A. 1991. Heterosis in crosses between American and Spanish population. *Crop Sciences.* 31: 931-935

Osuna, A.J.; Churata, B.G.; Avila, L.G. and Cespedes, P.L.M. 1995. Estimates of genetic parameters in the maize composite (*Zea mays* L.). Memorias de la III Reunion Latinoamericana Maize. Cochabamba, Santa Cruz, Bolivia, pp. 769-779.

Pandey, B.P. and Kumar, Prem. 2001. Heterosis in varietal crosses of maize. Diamond Jubilee Symposium, I.S.G. & P.B., New Delhi, Nov. 6-9, pp. 129.

Paterniani, F. and Lonnquist, J.H. 1963. Heterosis in interracial crosses of maize (*Zea mays* L.). *Crop Sci.*, **3** : 504-507.

Petrenko, A.I. 1985. Selection of parental forms on the basis of combining ability in producing maize hybrids for irrigation. *Nauchno-tekhnicheskii byulletan: Vsesoyuznago selektsionno geneticheskogo institututa,* No. **2** : 8-12.

Petrovic, Z. 1998. Combining ability and mode of inheritance of yield and yield components in maize (*Zea mays* L.). *Novi Sad (Yugoslavia).* 85 p.

Piovarci, A. 1973. An analysis of combining ability to the inbred lines of maize in a diallel cross system. *Pel, rohospodarstvo*, **19** (3) : 163-171.

Piovarci, A. and Nestichy, M. 1975. Combining ability for plant height and leaf area in creation of an ideotype of the maize plant. *Genetica Slechteni*, **11** : 321-327.

Poskannaya, S.I.; Kapusta, I.B.; Tarutina, L.A. and Khotyleva, L.V.1990. Development of heterotic effect of single inter line maize hybrid during outogeny. In 2 vsesoyuznoe soneschanie "Genetica razyitiya" 29-31 Tezisydokladov, tom 1 chast 2. Tashkent, 137-138.

Powers, L. 1944. Relative yield of inbred lines and F_1 hybrid of tomato. *Bot. G*, **106** : 247-268.

Pradhan, 1999. Classification and characterization of inbred lines of maize (*Zea mays* L.). Ph.D. Thesis, G.B.P.U.A. & T., Pantnagar, India, 137 p.

Premlatha, M. and Kalamani, A. 2010. Heterosis and Combining Ability Studies for Grain Yield and Growth Characters in Maize (*Zea Mays* L.). *Indian Journal of Agricultural Research.*44 (**1**):315-324

Rafiq, C. M.; Rafique, M.; Hussain, A. and Altaf, M. 2010. Studies on heritability, correlation and path analysis in maize (*zea mays* L.). *J. Agric. Res.* **48**(1):35-38.

Rahman *et al.* 2010. Stability analysis of maize hybrids across North West of Pakistan. *Pak. J. Bot.*, 42(**2**): 1083-1091, 2010.

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

Ramneek, Kooner.; Malhi, M.S.; Pal, S.S. and Harjinder, Singh. 2005. Identification of promising parental inbred lines for development of quality protein maize hybrids. *Crop Improvement.* 32 (**1**): 44-48.

Rastogi, N.K. and Rastogi, V.K. 1995. Combining ability of top cross derivatives of maize. *Intl. J. Tropical Agric.* 13 (**1-4**):237-244.

Raul, W.R.; Emiliano, G.-del-R.; Arturo, P. G.; Sergio, R. H.; Hugo, C. O.; Armando, E. B. and Jaime, L. G.J. 2007. Combining ability for yield components in grain corn lines at La Comarca Lagunera, Mexico. *Revista Fitotecnia Mexicana*. 30(2): 181-189

Reddy, D.M. and Agrawal, A.P. 1992. Heritability and heterosis studies over environments for grain yield and its components for grain yield and its components in maize (*Zea mays* L.). *National J. Plant Improv.*, **6** (1) : 26-28.

Reddy, D.M. and Ahuja, V.P. 2004. Phenotypic stability in recycled inbreds of maize. *National J. Plant Improv.*, **6** (1) : 29-30.

Reddy, D.M.; Ahuja, V.P.; Singh, R.P. and Gadag, R.N. 2001. Investigations on magnitude of heterosis and combining ability in maize over environments. Diamond Jubilee Symposium, I.S.G. & P.G., New Delhi, Nov. 6-9, pp. 293.

Reif, J.; Melchinger, A.E.; Xia, X.; Warburton, M.; Holsington, D.; Vasal, S.K.; Srinivasan, G.; Bohn, M. and Frish, M. 2002. Genetic diversity and heterosis in seven CIMMYT maize population. 8th Asian Regional Maize Workshop, Bangkok, Thailand, 5-8 Sept. (online reference).

Rezaei, A.; Yazdisamadi, B.; Zali, A.; Tallei, A.; Zeinali, H. and Rezaei, A. 2004. Estimate of heterosis and combining ability in maize using diallel crossing method. Proc. 17th EUCARPIA Gen. Cong. Tulln, pp. 395-397.

Rezaei, A.H.; Yazdisamodi, B.; Zali, A.; Regaei, A.M.; Tallei, A. and Zeinali, H. 2005. An estimate of heterosis and combining ability in corn using diallel crosses of inbred lines. *Iranian J. Agril. Sci.*, **36** (2) : 385-397.

Robinson, H.F.; Comstock, R.E. and Harvey, P.H. 1952. Genotypic, phenotypic and environmental correlation in corn in their implications in selection. *Agron. J.*, **43** : 282-287.

Rodriguez, M.C. and Chaves, L.J. 2002. Heterosis and its components in crosses among high quality maize populations. *Crop breed. Appl. Biotech.*, **2** (2) : 281-289.

Rowe, F.R. and Andrew, R.H. 1964. Phenotypic stability for a systematic series of corn genotypes. *Crop Sci.*, **4** : 563-567.

Saha, C. and Mukherjee, B.K. 1985. Analysis of heterosis for number of grains in maize (*Zea mays* L.). *Indian J. Genet.* 45 : 240-246

Saha, C. and Mukherjee, B.K. 1993. Grain yield of maize in relation to grain farming potential and other traits. *J. Res. Birsa Agril. Univ.*, **5** (1) : 27-31.

Sahu, R.S. and Kapoor, W.R. 1993. Manifestation of heterosis and inbreeding depression at two planting density in maize (*Zea mays* L.). *Crop Improvement Society of India.* Pp: 23-24

Satyanarayana, E. 1994. Heritability and genetic advance of yield and its attributes under charcol rot stress in maize. *J. Maharashtra Agric. Univ.*, **19** (2) :296-297.

Satyanarayana, E. and Saikumar, R. 1996. Genetic variability of yield and maturity components in maize hybrids. *Curr. Res. Univ. Agric. Sci. Bangalore*, **25** (1) : 10-11.

Scherbak, V.S. and Zabireva, E.R. 1979. A study of the heritability of individual yield components following crosses of exotic maize races with elite lines. 5 bbauch tr. Krasnodar, N. lis. *Kh.* **21** :113-129.

Schnell, F.W. 1974. Trends and problems in breeding method for hybrid corn. Proc. 16th British Poultry Breeder Round Table, Birmingham, England, pp. 86-98.

Sedhom, S.A. 1994. Genetic study on some top crosses in maize under two environments. *Annals of Agric. Sci.* 32: 131-141

Shakoor, A. and Ataullah, M. 1979. Study of heterosis in grain and stover yield components in some local and exotic inbred lines of maize. Fac. Agric. Univ. Peshawar, Pakistan, Abst. 32A-33A.

Sharma, J.K. and Bhalla, S.K. 1982. Phenotypic stability for different plant and disease characters in composite variety of maize. *Crop. Improv.*, **9** (2) : 146-151.

Sharma, J.K. and Bhalla, S.K. 1991. Heterosis in crossing among drought tolerant inbred lines of maize (*Zea mays* L.). *Indian J. Agric. Sci.*, 61 **(8)** : 543-545.

Shieh, G. and Shieh, G.J. 1995. The effects of crop seasons on the heterosis of agronomic characteristics in maize. *J. Agril. Res. China*, **43** (4) : 345-353.

Shull, G.F. 1908. The composition of a field of maize. *Rep. Am. Breed. Assoc.*, **5** : 51-59.

Shull, G.F. 1909. A pure line method of corn breeding. *Amer. Breed. Assoc. Rep.*, **5** : 55-60

Shull, G.H. 1914. Duplicate genes for capsule form in Bursa bursapastoris. *Z. Ind. Abstr. Ver.*, **12** : 97-149.

Shull, G.H. 1952. Beginning of the heterosis concept heterosis (J.W. Gowen ed.), Iowa State College Press, 14-48.

Singh, A.K.; Shahi, J.P.; Singh, J.K. and Singh, R.N. 1998. Heritability and genetic advance for maturity and yield attributes in maize. *J. Appl. Biol.*, **8** (1) : 42-45.

Singh, A.K.; Singh, J.P.; Singh, J.K. and Singh, R.N. 1998. Heritability and genetic advance for maturity and yield attributes in maize. *J. Appl. Biol.,* 8 (**1**): 42-45

Singh, D.N. 1984. Evaluation of early generation inbreds of maize (*Zea mays* L.). M.Sc. (Ag.) Thesis, G.B. Pant Univ. of Agric. and Tech., Pantnagar (India).

Singh, D.N. and Singh, I.S. 1998. Line x tester analysis in maize (*Zea mays* L.). *Journal of Research, Birsa Agricultural University.* 10 (**2**): 177-182

Singh, Daljeet, 1973. Diallel analysis over several environments II. *Indian J. Genet.*, **33** : 469-81.

Singh, I.S. and Asnani, V.L. 1979. Combining ability analysis for yield and some yield components in maize. *Indian J. Genet.*, **39** : 154-157.

Singh, P.K.; Chaudhary, L.B. and Akhtar, S.A. 2002. Heterosis in relation to combining ability in maize. *J. Res.*, **14** (1) : 37-43.

Singh, S.B. 2001. Combining ability studies for yield and components in maize. Diamond Jubilee Symposium, I.S.G.&P.G., New Delhi, Nov. 6-9, pp. 82.

Singh, S.D. 1994. Combining ability and heterosis in diallel crosses of maize (*Zea mays* L.). Ph.D. Thesis, G.B. Pant Univ. of Agric. and Tech., Pantnagar, India, 102 pp.

Singh, S.D. and Mishra, S.N. 1996. Combining ability of maize inbred lines over environment. *Crop Improv.*, **23** (2) : 229-232.

Singh, S.N.; Singh, K.N. and Singh, H.G. 1989. Characters association in maize (*Zea mays* L.). *Farm Sci. J.*, **4** (1-2) : 32-37.

Singhal, N.; Verma, S.S.; Baskheti, D.C. and Kumar, A. 2006. Heterosis and combining ability analysis in quality protein maize inbred lines. *J. Bio-Sci.*, **1** (2) : 54-56, 85-88.

Sinha, A. and Mishra, S.N. 1996. Combining ability analysis in varietal crosses of maize. *Indian J. Genet.*, **57** (2) : 149-153.

Sinha, S.S.; Dubey, R.B.; Lakshyadeep and Punia, S.S. 2004. Heterosis for quality traits in single cross hybrids of maize (*Zea mays* L.). *Indian J. Agric. Biochem.*, **17** (1): 37-39.

Sofi, P.A.; Rather, A.G. and Zahoor, Dar. 2007. Association of heterotic expression for grain yield and its component traits in maize (*Zea mays* L.) *Inernational Journal of Agricultural Research.* 2 (**5**): 500-503.

Soliman, F.H.S. and Sadek, S.K. 1999. Combining ability of new maize inbred lines and its utilization in the Egyptian hybrid program. *Bull. of Fac. of Agric., Univ. of Cairo*, **50** (1) : 1-20.

Sprague, G.F. and Tatum, L.A. 1942. General vs. specific combining ability in single crosses of corn. *J. Am. Soc. Agron.*, **34** : 923-932.

Sreekumar, S.C. and Bai, D.S. 1995. Genetic analysis of yield and its components of fodder maize. *J. Trop. Agric.*, **33** (1) : 8-10.

Srivastava, A and Singh, I.S. 2002. Evaluation and classification of exotic inbreds over locations based on line x tester analysis in maize (*Zea mays* L.). *Crop Improv.,* 29 (**2**): 184-189

Srivastava, A. 2001. Heterosis, combining ability and phenotypic stability studies in exotic × indigenous single cross hybrids of maize. Ph.D. Thesis, G.B. Pant Univ. of Agric. and Tech., Pantnagar, India, pp. 196.

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

Stupar, R. M.; Gardiner, J. M.; Oldre, A. G.; Haun, W. J.; Chandler, V. L. and Springer, N. M. 2008. Gene expression analyses in maize inbreds and hybrids with varying levels of heterosis. *BMC Plant Biology*. 8(33).

Suvarna; Nehru, S. D.; Manjunath, A. 2008. Variability, correlation and path coefficient analysis in maize under dry land condition. *Environment and Ecology*. 26(4C): 2296-2299.

Tariq, M.; Irshad-ul H.; Hiani, A. and Kamal, N. 2003. Phenotypic stability for grain yield in maize genotypic under varied rainfed environments. *Asian J. Plant Sci.*, **2** (1) : 80-82.

Thong, S.N. and Attaullah, M. 1980. Study of combining ability in maize crosses. *Fac. Agril. Univ. Peshawar, Pakistan,* 31A-32A.

Tkachenko, I.K. and Gomcharenko, A.A. 1973. Comparative study of general combining ability of maize lines on the basis of reproductive of vegetative characters. *Sci. Skokhozyaris Vennaya Biologia*, **8** : 823-829.

Turgut, I.; Yanikoglu, S.; Kucuk, I. and Demir, H. 2000. Determination of adaptation and stability ability of certain promising corn hybrids and cultivars under Marmara and Cukurova condition. *Aanadolu*, **10** (2) : 76-87.

Utkhede, R.S. and Rai, T.B. 1975. Stability performance of some composites and hybrids in maize (*Zea mays* L.). *In* : Fifth Eastern African Cereals Research Conference, Malawi, March 10-15, 1974 [II], pp. 128-135.

Vacaro, E.; Barbosa, N.J.; pegoraro, D.G.; Nuss, C.N. and Coneeicao, L.D.H. 2002. Combining ability of twelve maize population. *Pesquisa Agropeeuaria Brasileira*, **37** (1) : 67-72.

Vasal, S. K. 2000. Quality Protein Maize Story. *Food Nutr. Bull.,* **21** (4): 445-450.

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

Vasal, S.K.; Srinivasan, G.; Vergura, A.N. and Gonzalez, C.F. 1995. Heterosis and combining ability in maize germplasm of the high valleys. *Revista Ritotecnia Mexicana*, **18** (2) : 123-139.

Venkatesh, S.; Singh, N.N. and Gupta, N.P. 2001. Use of inbred testers for evaluating combining ability in modified single cross hybrids of maize. *Indian J. Genet.* **61** (4): 309-313

Viola, G.; Ganesh, M.; Reddy, S.S. and Kumar, C.V.S. 2003. Study on heritability and genetic advances in elite body corn (*Zea mays* L.) lines. *Prog. Agric.* **3** (1/2) : 127-128.

Vulchinkov, S. 1992. Genotype environment interaction in inbred lines and hybrids of maize. III. Interrelation between parameters of stability for various characters in maize hybrids. *Genetika I Selektsiya*, **25** (1) : 16-27.

Whitehouse, R.N.H.; Thompson, J.B. and Valle Ribeins, M.A.M. 1958. studies on the breeding of pollinated cereals. II. The use of diallel cross analysis in yield production. *Euphytica*, **7** : 147-178.

Wright, S. 1921. Systems of mating. *Genetics*, 11-78.

Yates, F. and Cochran, W.B. 1938. The analysis of group of experiments. *J. Agric. Sci.*, **28** : 555-580.

Yousif, D.P.; Ali, H.C. and Baker, R. 2003. Estimation of heterosis and combining ability in local maize inbred lines. *Dirasat Agril. Sci.*, **30** (2) : No pagination.

Yusuf, M. (2010). Genetic variability and correlation in single cross hybrids of quality protein maize (*zea mays* L.). *African J. of Food Ag. Nutrition and Development.* **10** (2):2166-2175.

Zao, K.M. and Niu, S.Q. 1981. Genetic relationship between main F_1 and parental characters in maize. *Shanxi Agric. Sci.*, **7** : 2-4.

Zelleke, H. 2000. Combining ability of grain yield and agronomic characters in inbred lines of maize. *Indian J. Genet.*, **60** (1) : 63-70.

Zheng, ZuPing; Du-KeZhu; Zheng, Z.P. and Du, K.Z. 1995. A study of the general parameters of several quantitative characters of maize. *J. Southwest Agril. Univ.*, **17** : 359-362.

Appendices

APPENDIX-Ia

Weekly weather data for experimental period (2008)

Month	Date	Metro Week No.	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	No. of Rainy Days	Sun-Shine Hrs.	Wind Velocity (km/hr.)
			Max.	Min.	0712 am	1412 pm				
Jan	**01-07**	1	21.0	5.5	91	44	000.0	0	05.2	2.4
Jan	**08-14**	2	22.4	8.5	90	49	001.8	1	05.7	5.2
Jan	**15-21**	3	19.7	7.3	91	60	000.0	0	03.8	4.2
Jan	**22-28**	4	18.6	2.6	91	45	000.0	0	05.6	3.6
Jan-Feb	**29-04**	5	17.3	3.4	90	44	000.0	0	05.5	3.5
Feb	**05-11**	6	20.2	7.0	90	52	001.0	1	06.4	5.4
Feb	**12-18**	7	21.3	4.8	87	44	000.0	0	08.5	4.9
Feb	**19-25**	8	24.1	9.3	87	47	000.0	0	07.0	4.0
Feb-Mar	**26-04**	9	26.0	10.9	85	48	000.0	0	07.4	3.7
Mar	**05-11**	10	27.8	13.3	83	50	000.0	0	06.2	5.5
Mar	**12-18**	11	27.7	12.7	87	48	000.0	0	05.2	4.3
Mar	**19-25**	12	31.6	12.6	81	30	000.0	0	08.2	4.9
Mar-Apr	**26-01**	13	31.6	14.0	79	30	010.2	1	08.0	5.9
Apr	**02-08**	14	28.4	15.3	79	35	014.4	3	05.3	5.9
Apr	**09-15**	15	35.2	17.3	75	22	000.0	0	09.5	6.8
Apr	**16-22**	16	36.9	16.9	68	19	000.0	0	10.0	6.9
Apr	**23-29**	17	40.5	17.5	59	8	000.0	0	11.0	7.3
Apr-May	**30-06**	18	39.4	19.9	55	17	005.4	1	09.3	7.7
May	**07-13**	19	36.9	22.1	53	23	000.0	0	08.8	6.9
May	**14-20**	20	35.9	22.2	65	34	011.2	3	05.8	6.8
May	**21-27**	21	30.0	21.7	81	51	018.0	4	05.2	5.9
May-Jun	**28-03**	22	39.0	22.9	57	27	000.0	0	10.5	7.1
Jun	**04-10**	23	30.9	23.4	84	65	241.4	6	04.7	7.4
Jun	**11-17**	24	32.2	25.5	87	68	112.6	5	06.0	6.6
Jun	**18-24**	25	30.9	25.3	84	70	009.6	3	04.7	6.0
Jun-Jul	**25-01**	26	30.6	25.0	87	76	087.2	4	03.3	4.4
Jul	**02-08**	27	30.6	25.4	88	73	192.2	5	04.8	5.7
Jul	**09-15**	28	32.1	25.2	84	70	054.6	5	06.0	7.7
Jul	**16-22**	29	28.3	24.3	95	84	293.8	7	01.0	4.8
Jul	**23-29**	30	30.5	25.4	92	72	030.8	4	02.8	4.5
Jul-Aug	**30-05**	31	30.8	24.8	89	76	168.6	4	04.5	5.9
Aug	**06-12**	32	31.5	25.5	86	72	105.6	2	05.4	4.6
Aug	**13-19**	33	28.1	24.5	89	84	212.6	6	01.1	7.0
Aug	**20-26**	34	31.6	24.8	90	74	313.4	5	05.1	3.8
Aug-Sep	**27-02**	35	32.1	24.5	87	65	056.4	2	06.7	5.4
Sep	**03-09**	36	32.3	23.9	88	61	016.4	1	08.4	3.6
Sep	**10-16**	37	31.3	24.0	85	68	024.8	2	06.2	2.7
Sep	**17-23**	38	29.1	22.0	89	75	373.2	4	03.4	5.9
Sep	**24-30**	39	31.2	21.4	88	60	000.0	0	09.5	3.1
Oct	**01-07**	40	31.1	23.1	87	65	019.6	2	05.1	2.7
Oct	**08-14**	41	30.9	19.8	82	57	004.8	1	08.7	2.6
Oct	**15-21**	42	30.2	15.9	80	47	000.0	0	09.2	2.6
Oct	**22-28**	43	29.6	15.1	83	40	000.0	0	09.0	2.6
Oct-Nov	**29-04**	44	29.2	14.7	84	47	000.0	0	07.8	2.8
Nov	**05-11**	45	29.0	14.8	86	45	000.0	0	07.7	1.7
Nov	**12-18**	46	27.8	12.6	87	47	000.0	0	05.5	1.8
Nov	**19-25**	47	25.2	10.0	89	46	002.4	1	07.1	2.7
Nov-Dec	**26-02**	48	26.2	10.8	86	42	000.0	0	07.4	2.0
Dec	**03-09**	49	25.7	10.9	92	44	000.0	0	07.9	2.3
Dec	**10-16**	50	26.2	8.6	91	40	000.0	0	07.2	2.6
Dec	**17-23**	51	21.5	11.6	92	68	000.0	0	02.9	3.2
Dec	**24-31**	52	21.8	7.0	91	62	000.0	0	05.6	2.0

APPENDIX-Ib

Weekly weather data for experimental period (2009)

Month	Date	Metro Week No.	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	No. of Rainy Days	Sun-Shine Hrs.	Wind Velocity (km/hr.)	Evap. (mm)
			Max.	Min.	0712 am	1412 pm					
Jan	**01-07**	1	16.8	7.7	92	64	000.0	0	02.4	2.8	0.8
Jan	**08-14**	2	22.7	6.6	92	50	000.0	0	07.0	3.5	1.7
Jan	**15-21**	3	22.0	9.1	90	60	000.0	0	04.0	5.0	1.5
Jan	**22-28**	4	21.4	9.1	92	59	000.0	0	03.3	4.9	1.4
Jan-Feb	**29-04**	5	20.1	6.6	93	57	000.0	0	04.6	3.3	1.4
Feb	**05-11**	6	25.2	8.2	92	48	005.2	1	07.6	4.1	2.2
Feb	**12-18**	7	22.9	8.5	93	52	009.0	1	08.0	5.3	2.6
Feb	**19-25**	8	27.0	10.4	91	50	000.0	0	08.7	7.5	4.0
Feb-Mar	**26-04**	9	27.0	10.3	91	47	000.0	0	09.8	8.5	5.0
Mar	**05-11**	10	30.1	10.7	89	35	000.0	0	08.3	7.5	4.4
Mar	**12-18**	11	31.2	11.6	80	34	000.0	0	09.4	4.9	4.5
Mar	**19-25**	12	31.8	14.6	82	29	000.8	1	08.0	4.6	4.6
Mar-Apr	**26-01**	13	31.2	14.2	81	29	002.6	2	07.4	6.7	5.6
Apr	**02-08**	14	35.2	16.9	73	20	000.0	0	08.9	7.5	9.0
Apr	**09-15**	15	33.8	15.9	76	24	018.0	2	09.5	6.5	6.5
Apr	**16-22**	16	38.8	19.0	62	15	000.0	0	09.9	8.4	9.6
Apr	**23-29**	17	38.6	17.6	67	16	000.0	0	10.4	8.3	10.5
Apr-May	**30-06**	18	39.3	20.8	63	29	008.4	2	09.6	8.4	9.5
May	**07-13**	19	37.4	19.9	70	30	004.8	2	10.5	9.8	10.9
May	**14-20**	20	36.5	25.1	64	42	000.0	0	08.3	9.1	9.8
May	**21-27**	21	37.4	23.9	73	41	008.8	1	10.4	8.3	8.5
May-Jun	**28-03**	22	36.5	23.2	60	33	004.6	1	09.3	8.8	8.9
Jun	**04-10**	23	38.7	22.8	65	35	043.8	1	10.7	7.5	9.9
Jun	**11-17**	24	39.4	24.2	64	33	000.0	0	09.5	8.9	9.5
Jun	**18-24**	25	41.8	22.9	56	21	000.0	0	11.7	11.0	12.5
Jun-Jul	**25-01**	26	36.1	26.4	74	53	053.4	3	05.9	10.0	8.6
Jul	**02-08**	27	35.6	26.5	81	48	000.0	0	08.9	6.9	8.4
Jul	**09-15**	28	34.3	26.4	84	67	037.8	3	06.2	7.3	4.6
Jul	**16-22**	29	34.8	25.8	88	65	070.6	5	08.4	5.8	6.7
Jul	**23-29**	30	34.0	26.4	87	77	032.8	5	07.3	4.8	4.7
Jul-Aug	**30-05**	31	34.4	27.1	86	63	002.2	1	07.5	7.7	4.8
Aug	**06-12**	32	32.7	26.1	90	65	043.4	4	04.4	5.5	4.9
Aug	**13-19**	33	29.6	24.3	92	86	325.6	7	01.8	7.5	4.3
Aug	**20-26**	34	33.1	25.1	85	63	000.0	0	08.7	5.4	4.3
Aug-Sep	**27-02**	35	32.8	25.2	84	68	020.2	4	06.8	4.6	4.1
Sep	**03-09**	36	31.4	23.9	85	75	045.6	4	05.0	5.6	3.4
Sep	**10-16**	37	30.8	23.0	88	73	142.4	2	05.6	7.7	3.2
Sep	**17-23**	38	32.8	24.0	87	63	000.4	1	08.6	3.6	3.3
Sep	**24-30**	39	33.1	24.9	86	64	000.0	0	05.7	3.4	2.8
Oct	**01-07**	40	30.1	22.6	89	75	029.8	5	05.0	4.6	3.7
Oct	**08-14**	41	30.8	16.6	91	56	000.0	0	08.9	2.8	3.1
Oct	**15-21**	42	30.8	13.8	84	48	000.0	0	09.7	2.6	3.1
Oct	**22-28**	43	29.7	11.6	87	40	000.0	0	09.6	1.8	2.5
Oct-Nov	**29-04**	44	30.1	13.8	85	39	000.0	0	08.7	2.4	2.8
Nov	**05-11**	45	29.4	12.3	87	36	000.0	0	07.8	2.4	2.4
Nov	**12-18**	46	26.0	14.7	87	53	020.6	2	03.9	4.1	2.2
Nov	**19-25**	47	24.7	8.8	90	44	000.0	0	08.0	2.1	1.6
Nov-Dec	**26-02**	48	25.1	9.5	90	43	000.0	0	07.6	2.0	1.6
Dec	**03-09**	49	24.8	8.1	91	44	000.0	0	07.6	2.5	2.2
Dec	**10-16**	50	23.9	9.2	91	47	000.0	0	05.3	2.7	1.4
Dec	**17-23**	51	23.4	5.8	93	45	000.0	0	07.4	3.1	1.6
Dec	**24-31**	52	20.3	4.0	94	54	000.0	0	06.9	2.8	1.3

APPENDIX (IIa) : Means of parents, $F_{1's}$ and checks of 15 characters in normal environment (E_1)

S.No.	Genotypes	Plant height	Ear height	100 kernel weight	Ear length	Ear diameter	Number of Kernel rows/ear	Number of kernels/ row	Brace roots	Days to 50% tasselling	Days to 50% silking	Anthesis-silking interval	Protein	Lysine	Trypto-phan	Grain yield
1.	L_1	180.00	80.33	36.15	16.46	4.17	12.17	28.33	1.27	48.33	51.33	3.00	11.48	2.63	0.66	2933.23
2.	L_2	176.67	72.50	37.31	17.56	4.78	14.11	30.78	1.07	48.67	51.67	3.00	10.66	3.69	0.92	2638.94
3.	L_3	173.33	65.00	35.76	15.72	4.22	12.61	29.78	1.40	48.67	51.67	3.00	8.60	3.33	0.83	4611.80
4.	L_4	175.00	66.67	36.29	13.05	4.00	13.33	35.33	1.13	48.33	51.33	3.00	10.34	3.23	0.81	2356.43
5.	L_5	169.33	63.00	35.78	16.13	4.17	14.33	35.67	1.00	48.33	51.33	3.00	9.60	3.07	0.77	1850.55
6.	L_6	176.67	65.33	38.28	15.61	4.06	12.22	30.39	1.33	48.33	51.33	3.00	11.54	2.95	0.74	3320.24
7.	L_7	172.22	82.22	37.71	16.43	4.17	14.33	37.33	1.73	47.67	51.33	3.67	9.59	3.36	0.84	1871.98
8.	L_8	180.00	72.33	36.50	14.56	4.33	14.17	33.23	1.13	49.33	52.00	2.67	10.41	3.37	0.84	4932.93
9.	L_9	166.67	72.33	34.65	14.62	4.17	12.94	31.00	1.00	48.33	50.67	2.33	11.55	3.29	0.82	3370.15
10.	L_{10}	173.33	71.00	36.69	17.35	4.67	14.17	35.67	1.00	48.33	51.33	3.00	7.40	2.95	0.74	2552.70
11.	L_{11}	173.33	59.67	34.15	15.17	4.06	13.56	35.11	1.33	50.33	53.33	3.00	11.44	2.93	0.73	4033.31
12.	L_{12}	185.00	75.83	36.63	16.33	4.19	13.33	33.41	1.00	48.33	52.33	4.00	11.22	3.03	0.76	3875.68
13.	L_{13}	183.27	70.67	35.61	14.35	4.00	12.00	29.33	1.33	50.33	53.33	3.00	10.75	2.73	0.68	2127.25
14.	L_{14}	146.67	53.67	34.13	18.50	4.67	14.33	37.75	1.00	49.33	54.33	5.00	8.55	3.32	0.83	2570.68
15.	L_{15}	160.00	69.00	35.95	14.46	3.83	16.89	34.00	1.33	49.33	54.33	5.00	9.52	3.57	0.89	3156.07
16.	L_{16}	186.50	65.83	36.17	16.46	4.17	12.17	28.33	1.00	50.33	54.00	3.67	10.61	2.93	0.73	2765.43
17.	L_{17}	170.67	65.83	38.66	17.56	4.78	14.11	30.78	1.00	48.67	52.33	3.67	8.41	2.89	0.72	2308.72
18.	L_{18}	169.67	63.33	37.45	15.72	4.22	12.61	29.78	2.00	49.33	52.67	3.33	7.58	2.89	0.72	2690.22
19.	L_{19}	194.50	70.50	38.77	13.05	3.56	13.33	35.33	1.00	49.67	53.33	3.67	10.34	3.25	0.81	3082.50
20.	L_{20}	191.33	62.33	37.91	16.13	4.17	14.33	35.67	2.00	49.00	52.67	3.67	8.36	3.41	0.85	5301.41
21.	L_{21}	173.89	64.22	37.36	15.61	4.06	12.22	30.39	1.07	48.67	53.00	4.33	10.71	3.33	0.83	4091.43
22.	T_1	190.83	83.17	38.63	16.43	6.39	14.33	37.33	2.00	49.00	54.00	5.00	10.56	3.97	0.76	4795.07
23.	T_2	187.00	73.67	35.89	14.56	4.33	14.17	33.23	1.00	49.00	52.67	3.67	10.38	3.53	0.83	4419.56
24.	T_3	183.33	74.33	36.22	14.62	4.17	12.94	31.00	1.07	48.33	51.33	3.00	7.67	2.91	0.73	4254.92
25.	$L_1 \times T_1$	190.00	74.83	35.67	17.06	4.39	13.39	33.11	1.73	48.67	51.33	2.67	7.54	3.00	0.75	6109.97
26.	$L_1 \times T_2$	176.00	75.33	35.85	15.33	4.22	13.61	29.89	1.40	48.33	50.67	2.33	11.20	2.72	0.68	5761.88
27.	$L_1 \times T_3$	171.00	75.67	37.17	16.00	5.00	14.22	30.17	1.73	49.00	52.00	3.00	11.56	2.91	0.73	3847.87
28.	$L_2 \times T_1$	203.33	89.00	37.44	15.56	4.00	12.44	32.22	2.13	49.00	51.67	2.67	12.20	2.25	0.56	5312.38
29.	$L_2 \times T_2$	189.00	74.67	40.77	16.00	4.06	14.61	33.78	1.67	50.00	53.33	3.33	10.31	2.53	0.63	5062.55
30.	$L_2 \times T_3$	183.33	73.33	38.60	18.39	4.33	13.56	35.00	1.53	49.33	54.33	5.00	9.44	3.41	0.85	4468.80
31.	$L_3 \times T_1$	191.33	80.67	42.94	16.78	4.67	13.11	34.00	2.20	49.33	52.00	2.67	11.57	2.25	0.56	5700.20
32.	$L_3 \times T_2$	208.83	76.17	36.15	15.33	4.22	13.22	31.78	1.47	49.67	52.67	3.00	9.88	3.04	0.76	3655.01
33.	$L_3 \times T_3$	195.33	80.67	35.52	16.94	4.22	14.56	33.39	1.40	48.67	51.00	2.33	11.18	2.92	0.73	5748.29
34.	$L_4 \times T_1$	199.67	80.00	39.21	17.61	4.33	13.67	36.72	1.80	49.33	53.00	3.67	11.18	3.07	0.77	4840.94
35.	$L_4 \times T_2$	193.00	76.83	35.19	15.89	4.33	13.78	34.56	1.20	50.67	54.67	4.00	10.62	2.59	0.65	3918.43
36.	$L_4 \times T_3$	188.67	73.33	36.94	15.67	4.11	12.44	34.67	1.13	50.67	53.33	2.67	10.38	2.92	0.73	4662.71

APPENDIX (IIa) : Contd...

37.	$L_5 \times T_1$	202.67	86.56	37.83	15.28	4.19	14.19	33.03	1.33	50.67	55.00	4.33	10.69	2.88	0.72	4108.16
38.	$L_5 \times T_2$	182.50	73.33	34.23	15.33	4.11	12.00	30.33	1.00	50.00	53.00	3.00	8.43	2.69	0.67	2319.07
39.	$L_5 \times T_3$	190.56	73.06	34.45	15.89	4.06	13.00	34.00	1.20	50.00	53.33	3.33	9.68	2.52	0.63	3236.35
40.	$L_6 \times T_1$	175.67	66.67	35.90	14.89	4.22	14.72	32.68	1.40	48.67	52.00	3.33	12.20	2.88	0.72	1291.20
41.	$L_6 \times T_2$	168.00	72.50	39.31	13.38	3.56	14.00	31.98	1.33	49.33	51.33	2.00	9.92	2.97	0.74	1850.55
42.	$L_6 \times T_3$	178.83	66.33	36.29	15.83	4.09	12.53	32.28	1.00	50.00	53.67	3.67	8.54	3.31	0.83	2845.92
43.	$L_7 \times T_1$	184.50	78.17	34.65	15.67	4.22	14.00	33.39	1.47	49.00	52.00	3.00	11.29	3.40	0.85	4254.51
44.	$L_7 \times T_2$	170.17	70.00	35.26	14.67	4.11	13.00	31.33	1.60	50.33	54.00	3.67	8.34	3.00	0.75	2690.69
45.	$L_7 \times T_3$	178.67	73.00	38.03	16.89	4.06	13.33	33.44	1.07	49.67	54.00	4.33	8.63	2.97	0.74	2948.89
46.	$L_8 \times T_1$	195.33	78.67	39.33	13.22	4.22	12.67	27.22	1.07	49.00	51.33	2.33	8.62	2.91	0.73	1701.80
47.	$L_8 \times T_2$	191.50	75.33	35.62	14.50	4.17	13.44	28.33	1.07	50.33	54.67	4.33	9.71	3.40	0.85	3279.84
48.	$L_8 \times T_3$	199.17	87.67	37.78	13.39	3.89	12.44	30.78	1.33	48.67	51.67	3.00	9.43	3.32	0.83	1450.09
49.	$L_9 \times T_1$	206.67	81.33	37.29	15.17	4.33	12.44	33.00	1.40	49.67	52.33	2.67	7.43	3.63	0.91	6807.21
50.	$L_9 \times T_2$	184.50	72.67	36.18	15.39	4.50	14.44	33.78	1.33	51.33	53.67	2.33	8.42	2.68	0.67	4275.41
51.	$L_9 \times T_3$	191.33	72.00	38.25	15.33	4.61	13.11	30.44	1.07	51.00	54.00	3.00	10.65	3.40	0.85	2562.11
52.	$L_{10} \times T_1$	198.33	75.00	38.75	17.78	4.44	13.44	34.56	1.47	51.67	54.33	2.67	11.21	3.11	0.78	6475.84
53.	$L_{10} \times T_2$	194.33	78.00	36.97	15.56	4.50	13.67	33.17	1.47	49.67	53.33	3.67	10.75	3.44	0.86	2019.58
54.	$L_{10} \times T_3$	196.67	77.33	39.63	15.44	4.39	12.89	34.50	1.13	52.00	54.00	2.00	8.79	2.73	0.68	4306.77
55.	$L_{11} \times T_1$	178.67	76.22	35.03	18.61	4.56	14.22	34.83	1.40	50.67	54.33	3.67	10.40	2.13	0.53	2336.95
56.	$L_{11} \times T_2$	198.61	73.83	34.31	12.50	4.00	13.17	31.39	1.07	51.67	54.67	3.00	9.48	3.45	0.86	3293.01
57.	$L_{11} \times T_3$	202.00	80.00	36.89	17.22	4.39	13.33	36.11	1.47	50.00	53.33	3.33	11.40	3.88	0.97	5598.81
58.	$L_{12} \times T_1$	184.67	69.00	36.61	16.39	4.44	12.22	26.93	1.27	49.33	52.00	2.67	9.69	3.65	0.91	3838.46
59.	$L_{12} \times T_2$	182.33	71.67	36.96	16.33	4.00	12.89	32.22	1.47	51.67	55.00	3.33	10.37	2.87	0.72	2137.71
60.	$L_{12} \times T_3$	192.75	78.00	35.00	17.78	4.67	13.11	39.22	1.20	51.00	53.67	2.67	11.46	3.44	0.86	4798.08
61.	$L_{13} \times T_1$	176.17	65.67	36.99	16.83	4.56	14.06	29.78	1.47	49.67	52.67	3.00	7.45	2.57	0.64	2669.99
62.	$L_{13} \times T_2$	178.00	78.00	36.65	16.00	4.17	13.89	28.78	1.53	49.67	52.33	2.67	11.51	2.33	0.58	3631.49
63.	$L_{13} \times T_3$	194.67	79.17	40.98	18.44	4.33	13.00	38.17	1.80	50.33	53.00	2.67	11.29	2.55	0.64	4406.08
64.	$L_{14} \times T_1$	193.50	73.83	34.89	16.67	4.33	13.33	35.83	1.13	48.33	51.00	2.67	8.43	3.80	0.95	5530.86
65.	$L_{14} \times T_2$	208.00	78.17	36.00	16.11	4.42	12.44	29.56	1.47	51.67	54.67	3.00	9.66	2.91	0.73	2152.55
66.	$L_{14} \times T_3$	203.33	78.00	36.31	16.17	4.50	14.67	27.83	1.00	51.67	54.00	2.33	10.75	3.28	0.82	2190.60

APPENDIX (IIa) : Contd...

67.	$L_{15} \times T_1$	198.00	80.00	39.68	17.72	4.00	12.67	31.22	1.27	52.00	54.33	2.33	8.12	2.97	0.74	6381.76
68.	$L_{15} \times T_2$	183.78	74.72	39.71	14.50	4.19	13.78	33.25	1.27	49.67	52.33	2.67	7.47	2.92	0.73	1861.53
69.	$L_{15} \times T_3$	205.00	82.83	38.68	16.67	4.00	12.44	33.11	1.33	51.33	53.67	2.33	10.41	2.21	0.55	5117.95
70.	$L_{16} \times T_1$	199.33	78.67	37.17	16.00	4.28	15.56	29.00	1.33	49.67	52.00	2.33	8.49	3.51	0.88	4679.96
71.	$L_{16} \times T_2$	181.67	74.00	37.22	15.72	4.67	13.56	36.44	1.33	50.33	53.33	3.00	10.86	3.71	0.93	4061.64
72.	$L_{16} \times T_3$	176.83	75.00	38.64	16.44	3.83	13.78	35.44	1.40	49.33	52.33	3.00	10.16	2.13	0.53	4782.61
73.	$L_{17} \times T_1$	186.11	71.67	36.43	14.72	3.56	14.00	34.50	1.33	49.67	53.00	3.33	10.37	2.85	0.71	1640.55
74.	$L_{17} \times T_2$	194.33	73.00	35.30	16.32	4.17	12.00	32.50	1.27	52.00	55.33	3.33	7.58	2.24	0.56	3113.53
75.	$L_{17} \times T_3$	196.33	79.50	37.27	16.00	4.28	13.78	33.11	1.07	52.67	55.33	2.67	11.44	2.91	0.73	4177.57
76.	$L_{18} \times T_1$	191.67	83.83	36.09	15.06	4.06	12.89	30.17	1.67	50.33	54.33	4.00	7.34	2.65	0.66	6491.52
77.	$L_{18} \times T_2$	191.00	76.17	35.80	18.11	4.17	14.44	33.78	1.80	49.33	53.00	3.67	9.83	2.97	0.74	6932.65
78.	$L_{18} \times T_3$	202.89	81.11	37.80	16.39	4.17	12.83	34.28	1.67	49.00	52.00	3.00	10.67	3.67	0.92	2304.75
79.	$L_{19} \times T_1$	189.33	74.00	33.07	16.56	5.33	12.22	30.78	1.73	49.33	53.67	4.33	10.31	3.67	0.92	6413.12
80.	$L_{19} \times T_2$	175.83	72.17	33.86	17.44	4.11	12.22	30.67	1.40	50.33	54.33	4.00	9.56	3.39	0.85	4869.69
81.	$L_{19} \times T_3$	183.50	80.17	40.05	16.89	4.00	12.67	36.44	1.53	49.33	54.33	5.00	9.55	3.67	0.92	4364.27
82.	$L_{20} \times T_1$	197.67	76.50	38.59	16.33	4.28	15.33	35.56	1.60	49.00	51.67	2.67	8.57	2.88	0.72	5362.56
83.	$L_{20} \times T_2$	173.33	73.67	33.60	14.67	4.11	13.78	30.56	1.30	49.00	52.00	3.00	8.45	3.59	0.90	4071.57
84.	$L_{20} \times T_3$	189.50	69.33	36.55	15.22	4.00	12.67	33.22	1.20	49.00	52.33	3.33	9.54	2.92	0.73	4467.23
85.	$L_{21} \times T_1$	184.67	72.33	36.82	15.67	4.22	14.00	33.00	1.93	49.33	52.00	2.67	7.66	3.67	0.92	3080.60
86.	$L_{21} \times T_2$	183.33	68.33	37.64	17.50	4.11	14.00	35.17	1.40	49.00	52.00	3.00	8.51	2.71	0.68	1741.53
87.	$L_{21} \times T_3$	193.33	76.50	37.77	16.67	6.39	12.89	29.11	1.32	49.67	52.67	3.00	10.61	2.91	0.73	4662.71
88.	Check-1	178.17	86.83	34.25	19.11	4.39	14.44	37.89	1.67	52.33	55.67	3.33	10.72	3.13	0.78	4139.52
89.	Check-2	180.33	69.78	41.74	15.56	3.56	12.44	33.78	1.07	49.00	52.00	3.00	9.63	2.27	0.57	3537.41
90.	Check-3	173.33	72.67	35.81	17.35	4.67	14.17	35.67	1.27	49.00	51.67	2.67	10.41	1.12	0.28	6840.66
91.	Grand mean	185.77	74.16	36.91	15.98	4.28	13.43	32.84	1.36	49.70	52.90	3.20	9.82	3.01	0.75	3834.51
92.	CD at 1%	32.645	17.514	5.16	2.394	0.865	1.963	5.645	0.829	3.021	3.458	1.853	0.405	0.231	0.057	2492.182
93.	CD at 5%	24.744	13.273	3.91	1.813	0.656	1.484	4.278	0.628	2.290	2.621	1.404	0.307	0.175	0.043	1888.745
94.	CV (%)	8.26	11.10	6.57	7.04	9.48	6.86	8.08	28.60	2.85	3.07	27.2	1.94	3.60	3.60	30.56

APPENDIX (IIb) : Means of parents, $F_{1's}$ and checks of 15 characters in low Nitrogen environment (E_2)

S.No.	Genotypes	Plant height	Ear height	100 kernel weight	Ear length	Ear diameter	Number of Kernel rows/ear	Number of kernels / row	Brace roots	Days to 50% tasselling	Days to 50% silking	Anthesis-silking interval	Protein	Lysine	Trypto-phan	Grain yield
1	L_1	178.33	68.33	31.69	12.17	3.56	12.08	23.56	1.40	48.33	52.33	4.00	11.35	2.40	0.60	2665.60
2	L_2	165.33	53.33	30.60	13.68	4.17	13.11	25.85	1.07	48.00	51.00	3.00	10.54	3.47	0.87	2221.33
3	L_3	168.00	62.33	31.88	13.89	3.83	12.39	28.00	1.20	48.67	52.67	4.00	8.48	3.11	0.78	3554.13
4	L_4	164.67	57.67	30.23	12.17	3.50	12.94	29.44	1.33	51.00	55.33	4.33	10.22	3.00	0.75	2399.04
5	L_5	157.33	61.67	34.33	15.19	3.78	12.94	33.85	1.47	48.33	51.00	2.67	9.48	2.84	0.71	1510.51
6	L_6	172.33	52.33	32.90	15.56	4.00	10.67	28.19	1.27	48.33	52.33	4.00	11.42	2.72	0.68	2221.33
7	L_7	166.67	73.33	28.12	13.11	4.00	13.22	30.22	1.27	48.67	52.00	3.33	9.46	3.13	0.78	1510.51
8	L_8	171.33	75.67	33.87	14.44	4.11	13.11	23.04	1.60	48.33	52.33	4.00	10.29	3.15	0.79	2798.88
9	L_9	164.40	67.67	28.50	13.27	3.96	12.61	25.52	1.73	48.33	52.00	3.67	11.42	3.07	0.77	2310.19
10	L_{10}	168.00	65.00	26.22	14.56	3.56	12.78	31.89	1.47	48.67	51.67	3.00	7.28	2.72	0.68	2310.19
11	L_{11}	170.67	55.00	32.06	13.31	4.06	12.22	25.56	1.33	48.33	52.33	4.00	11.31	2.71	0.68	2949.93
12	L_{12}	177.50	64.00	30.24	14.56	3.67	13.11	33.07	1.33	48.67	53.00	4.33	11.10	2.80	0.70	3065.44
13	L_{13}	173.33	75.67	29.21	14.28	3.50	12.00	25.13	1.47	48.33	52.00	3.67	10.63	2.51	0.63	1777.07
14	L_{14}	133.33	28.33	30.58	15.00	4.28	12.39	28.49	1.27	48.33	52.33	4.00	8.43	3.09	0.77	1599.36
15	L_{15}	148.33	52.33	31.20	13.94	3.56	13.89	32.47	1.27	48.67	52.00	3.33	9.40	3.35	0.84	2310.19
16	L_{16}	140.00	63.67	31.25	14.22	4.00	11.67	26.37	1.40	49.00	52.67	3.67	10.49	2.71	0.68	2132.48
17	L_{17}	143.33	51.67	33.97	15.11	4.11	12.22	28.67	1.33	49.67	54.33	4.67	8.29	2.67	0.67	1954.77
18	L_{18}	163.33	61.33	31.56	13.61	3.96	12.00	28.79	1.27	48.67	51.33	2.67	7.46	2.67	0.67	2310.19
19	L_{19}	178.00	69.00	28.34	14.17	3.50	12.89	26.36	1.33	48.33	52.33	4.00	10.22	3.03	0.76	2176.91
20	L_{20}	179.67	55.00	33.81	13.69	4.06	12.56	28.94	1.40	48.67	52.67	4.00	8.24	3.19	0.80	3998.40
21	L_{21}	166.67	67.67	29.99	12.83	3.78	12.00	25.89	1.13	49.33	52.67	3.33	10.59	3.11	0.78	3021.01
22	T_1	170.00	63.33	28.15	13.94	4.17	13.33	26.33	1.33	49.67	53.33	3.67	10.44	2.85	0.70	3287.57
23	T_2	178.33	70.00	30.42	14.22	3.56	12.83	29.67	1.53	48.33	51.00	2.67	10.26	2.81	0.58	3607.45
24	T_3	173.33	66.67	33.58	14.00	4.11	12.72	28.67	1.13	49.33	54.33	5.00	7.55	2.68	0.67	3332.00
25	$L_1 \times T_1$	176.00	57.67	33.10	15.33	4.22	12.67	28.11	1.33	48.33	52.00	3.67	7.41	3.11	0.78	4264.96
26	$L_1 \times T_2$	176.44	68.22	34.13	15.33	3.89	13.11	27.11	1.40	48.67	53.67	5.00	11.08	2.49	0.62	2221.33
27	$L_1 \times T_3$	174.00	48.33	34.22	13.44	4.11	14.07	26.93	1.27	50.33	54.00	3.67	11.44	2.68	0.67	1777.07
28	$L_2 \times T_1$	184.67	55.00	29.91	15.56	4.00	12.22	31.33	1.20	48.33	51.67	3.33	12.07	2.03	0.51	4442.67
29	$L_2 \times T_2$	192.67	67.00	32.68	14.56	4.00	12.67	29.67	1.47	52.00	56.33	4.33	10.19	2.31	0.58	3109.87
30	$L_2 \times T_3$	190.33	58.67	33.80	15.22	4.22	12.67	28.67	1.33	49.00	53.67	4.67	9.32	3.19	0.80	3554.13
31	$L_3 \times T_1$	194.00	72.00	32.92	15.67	4.33	13.11	27.89	1.13	49.00	53.33	4.33	11.45	2.03	0.51	2221.33
32	$L_3 \times T_2$	195.50	71.92	32.17	14.67	4.22	13.11	29.00	1.40	49.33	53.00	3.67	9.75	2.81	0.70	1865.92
33	$L_3 \times T_3$	189.33	58.67	31.73	15.83	4.00	13.56	30.78	1.20	48.67	51.67	3.00	11.06	2.69	0.67	3998.40
34	$L_4 \times T_1$	190.67	69.67	25.26	14.89	4.00	12.44	27.89	1.13	49.00	53.33	4.33	11.05	2.84	0.71	4442.67
35	$L_4 \times T_2$	202.33	71.33	29.60	13.28	3.94	11.78	31.17	1.43	51.00	54.00	3.00	10.50	2.36	0.59	3109.87
36	$L_4 \times T_3$	185.33	63.00	30.01	15.67	3.89	12.08	33.82	1.27	50.00	53.67	3.67	10.25	2.69	0.67	3376.43

APPENDIX (IIb) : Contd...

37	$L_5 \times T_1$	197.33	81.67	29.26	13.22	4.11	13.33	27.36	1.47	54.00	58.00	4.00	10.56	2.65	0.66	2310.19
38	$L_5 \times T_2$	173.00	60.00	31.47	12.71	3.94	11.33	29.56	1.27	49.00	52.67	3.67	8.31	2.47	0.62	2088.05
39	$L_5 \times T_3$	175.50	64.33	29.63	14.67	4.00	12.67	29.56	1.33	49.67	54.67	5.00	9.55	2.29	0.57	1421.65
40	$L_6 \times T_1$	167.17	56.00	30.53	13.83	4.07	14.22	28.67	1.13	49.67	55.00	5.33	12.08	2.65	0.66	1421.65
41	$L_6 \times T_2$	185.00	53.33	27.71	12.83	3.28	12.39	28.11	1.07	49.33	53.00	3.67	9.80	2.75	0.69	1510.51
42	$L_6 \times T_3$	170.00	57.25	32.29	13.53	3.61	12.39	26.89	1.13	48.67	52.67	4.00	8.41	3.08	0.77	2221.33
43	$L_7 \times T_1$	175.00	72.33	29.08	14.06	4.11	13.22	27.28	1.20	50.33	54.67	4.33	11.17	3.17	0.79	3065.44
44	$L_7 \times T_2$	169.00	62.67	34.60	15.33	3.89	13.00	26.89	1.40	48.67	54.00	5.33	8.21	2.77	0.69	2310.19
45	$L_7 \times T_3$	173.67	70.67	29.39	15.21	3.83	11.94	28.11	1.40	49.00	53.33	4.33	8.50	2.75	0.69	2221.33
46	$L_8 \times T_1$	180.67	69.78	32.96	13.23	4.06	12.39	25.04	1.00	53.00	55.33	2.33	8.49	2.68	0.67	1599.36
47	$L_8 \times T_2$	170.58	52.33	27.29	13.69	3.33	12.89	27.12	1.20	52.00	54.67	2.67	9.58	3.17	0.79	1688.21
48	$L_8 \times T_3$	166.25	56.33	32.15	13.67	3.78	11.83	24.89	1.27	49.33	53.00	3.67	9.31	3.09	0.77	1421.65
49	$L_9 \times T_1$	187.33	73.00	35.87	13.44	4.06	12.17	29.33	1.33	49.00	54.33	5.33	7.31	3.40	0.85	3998.40
50	$L_9 \times T_2$	187.67	65.67	31.65	14.33	4.22	13.78	28.26	1.33	49.33	55.00	5.67	8.30	2.45	0.61	2932.16
51	$L_9 \times T_3$	179.00	77.00	35.06	14.94	4.28	12.22	30.22	1.33	48.67	52.33	3.67	10.53	3.17	0.79	2532.32
52	$L_{10} \times T_1$	187.83	78.50	31.76	13.55	4.28	13.12	29.73	1.27	48.67	53.33	4.67	11.09	2.88	0.72	3109.87
53	$L_{10} \times T_2$	183.33	75.67	33.97	15.72	4.11	12.39	30.33	1.47	50.00	54.67	4.67	10.62	3.21	0.80	1688.21
54	$L_{10} \times T_3$	187.00	69.67	31.36	14.39	4.17	11.94	31.44	1.33	48.67	54.00	5.33	8.67	2.51	0.63	4442.67
55	$L_{11} \times T_1$	175.78	61.78	33.99	16.67	4.17	14.00	29.78	1.53	52.00	55.00	3.00	10.27	1.91	0.48	1777.07
56	$L_{11} \times T_2$	202.67	72.50	24.53	12.17	3.94	12.61	28.00	1.60	51.33	56.00	4.67	9.35	3.23	0.81	1332.80
57	$L_{11} \times T_3$	182.33	69.67	29.51	17.00	3.89	12.33	31.84	1.60	47.67	51.00	3.33	11.28	3.65	0.91	4442.67
58	$L_{12} \times T_1$	183.33	64.33	34.35	15.67	4.33	11.83	24.82	1.47	49.00	53.33	4.33	9.57	3.43	0.86	3554.13
59	$L_{12} \times T_2$	151.11	67.00	33.32	15.78	3.89	12.44	31.56	1.13	52.33	56.67	4.33	10.25	2.64	0.66	1510.51
60	$L_{12} \times T_3$	200.67	64.58	32.49	16.33	4.00	13.00	30.44	1.33	51.00	54.33	3.33	11.34	3.21	0.80	3376.43
61	$L_{13} \times T_1$	185.56	61.56	34.76	14.39	4.00	13.22	28.00	1.60	52.33	54.00	1.67	7.32	2.35	0.59	1421.65
62	$L_{13} \times T_2$	174.67	66.33	32.93	14.78	3.83	12.89	26.44	1.33	50.00	54.00	4.00	11.39	2.11	0.53	3554.13
63	$L_{13} \times T_3$	180.00	67.33	34.99	18.11	4.06	12.67	33.06	1.47	51.33	56.00	4.67	11.16	2.32	0.58	1901.46
64	$L_{14} \times T_1$	191.00	73.33	30.95	15.78	4.22	13.19	34.53	1.47	48.67	52.67	4.00	8.31	3.57	0.89	4886.93
65	$L_{14} \times T_2$	188.73	67.33	35.42	16.56	4.00	12.06	28.00	1.40	50.33	55.33	5.00	9.54	2.68	0.67	1688.21
66	$L_{14} \times T_3$	201.10	65.25	31.64	16.11	4.00	13.44	23.00	1.33	51.33	56.00	4.67	10.63	3.05	0.76	2887.73
67	$L_{15} \times T_1$	188.00	74.67	34.35	16.33	3.94	11.33	26.78	1.27	49.33	55.33	6.00	7.99	2.75	0.69	3109.87

APPENDIX (IIb) : Contd...

68	$L_{15} \times T_2$	171.83	62.67	30.17	14.08	4.00	13.28	31.89	1.00	48.67	53.00	4.33	7.34	2.69	0.67	1510.51
69	$L_{15} \times T_3$	170.00	63.33	31.66	15.28	4.00	11.56	27.67	1.33	49.67	53.00	3.33	10.29	1.99	0.50	3109.87
70	$L_{16} \times T_1$	176.67	71.00	31.33	15.00	4.00	14.00	28.68	1.40	49.33	53.67	4.33	8.37	3.28	0.82	2665.60
71	$L_{16} \times T_2$	180.67	63.73	32.68	14.61	4.22	13.39	34.23	1.27	49.67	55.00	5.33	10.74	3.48	0.87	2976.59
72	$L_{16} \times T_3$	183.67	57.33	29.48	14.61	3.85	12.39	29.33	1.20	50.33	53.00	2.67	10.03	1.91	0.48	2487.89
73	$L_{17} \times T_1$	173.67	53.67	32.95	12.89	3.33	11.56	26.78	1.33	51.00	54.67	3.67	10.25	2.63	0.66	1421.65
74	$L_{17} \times T_2$	181.50	65.73	30.67	13.69	3.53	11.33	23.75	1.13	50.67	54.33	3.67	7.45	2.01	0.50	2132.48
75	$L_{17} \times T_3$	185.00	63.00	33.47	13.00	4.28	12.67	27.11	1.20	49.33	54.00	4.67	11.31	2.68	0.67	3109.87
76	$L_{18} \times T_1$	200.67	66.33	33.03	13.94	3.89	12.61	29.11	1.33	50.33	51.67	1.33	7.22	2.43	0.61	3554.13
77	$L_{18} \times T_2$	190.67	74.00	30.52	14.22	4.11	11.56	26.22	1.53	48.67	53.00	4.33	9.70	2.75	0.69	2221.33
78	$L_{18} \times T_3$	175.00	66.00	34.79	13.78	3.83	12.00	30.56	1.27	48.33	52.33	4.00	10.55	3.44	0.86	1954.77
79	$L_{19} \times T_1$	184.58	66.17	31.30	15.36	4.00	12.00	28.63	1.27	49.33	54.00	4.67	10.19	3.44	0.86	3642.99
80	$L_{19} \times T_2$	173.67	70.92	32.56	15.56	3.78	12.00	26.32	1.27	49.00	52.67	3.67	9.43	3.16	0.79	3109.87
81	$L_{19} \times T_3$	182.11	67.11	32.34	12.56	4.00	12.00	27.11	1.27	49.33	55.00	5.67	9.43	3.44	0.86	2665.60
82	$L_{20} \times T_1$	171.00	65.00	29.83	14.22	4.00	13.11	28.67	1.07	49.67	53.67	4.00	8.45	2.65	0.66	2932.16
83	$L_{20} \times T_2$	171.33	69.50	29.87	13.35	4.00	12.17	29.11	1.33	49.00	53.33	4.33	8.32	3.36	0.84	3998.40
84	$L_{20} \times T_3$	187.33	66.83	31.38	14.44	3.96	12.22	27.11	1.47	48.67	53.00	4.33	9.42	2.69	0.67	2487.89
85	$L_{21} \times T_1$	171.67	56.87	30.61	12.67	4.06	12.67	31.71	1.40	49.00	52.33	3.33	7.54	3.44	0.86	2487.89
86	$L_{21} \times T_2$	191.00	80.67	33.29	15.33	3.78	11.78	28.67	1.07	49.67	54.00	4.33	8.39	2.48	0.62	1554.93
87	$L_{21} \times T_3$	179.67	62.00	36.58	13.44	3.67	12.78	28.22	1.33	48.33	52.67	4.33	10.49	2.68	0.67	3820.69
88	Check-1	177.00	73.33	30.78	15.00	4.11	13.78	28.67	1.20	51.67	56.00	4.33	10.59	2.91	0.73	1777.07
89	Check-2	166.00	59.33	28.12	13.31	3.56	12.08	25.89	1.13	48.00	51.00	3.00	9.51	2.04	0.51	3154.29
90	Check-3	142.67	57.33	29.26	13.83	3.83	12.44	24.99	1.33	50.33	54.00	3.67	10.29	1.08	0.27	4931.36
91	Grand mean	174.54	64.57	31.53	14.45	3.94	12.58	28.46	1.31	49.50	53.47	4.02	9.70	2.79	.69	2672.71
92	CD at 1%	32.373	17.109	7.056	2.884	0.690	1.900	7.017	0.400	3.018	3.192	2.436	0.406	0.168	0.042	2304.657
93	CD at 5%	24.534	12.966	5.347	2.186	0.523	1.440	5.318	0.303	2.287	2.419	1.846	0.308	0.127	0.031	1746.626
94	CV (%)	8.72	12.46	10.52	9.38	8.23	7.10	11.59	14.30	2.86	2.80	28.44	1.97	2.82	2.82	40.55

APPENDIX (IIc): Means of parents, $F_{1's}$ and checks of 15 characters in excess soil moisture environment (E_3)

S.No	Genotypes	Plant height	Ear height	100 kernel weight	Ear length	Ear diameter	Number of Kernel rows/ear	Number of kernels/ row	Brace roots	Days to 50% tasselling	Days to 50% silking	Anthesis-silking interval	Protein	Lysine	Trypto-phan	Grain yield
1	L_1	172.67	62.36	34.12	14.33	4.51	14.30	30.89	1.40	48.67	52.33	3.67	11.37	2.45	0.61	2976.59
2	L_2	164.33	52.64	38.78	15.50	4.00	14.40	35.11	1.53	48.33	52.33	4.00	10.56	3.52	0.88	2612.29
3	L_3	184.33	62.64	36.65	15.67	4.06	16.24	33.56	1.33	48.67	53.00	4.33	8.50	3.16	0.79	4442.67
4	L_4	193.33	52.36	35.45	16.00	4.44	14.19	32.11	1.60	49.67	55.33	5.67	10.24	3.05	0.76	2034.74
5	L_5	180.00	45.00	35.42	12.17	3.94	12.12	28.44	1.53	48.33	52.00	3.67	9.50	2.89	0.72	1643.79
6	L_6	170.00	52.36	34.12	14.69	4.00	14.20	32.06	1.47	49.00	53.00	4.00	11.44	2.77	0.69	3038.78
7	L_7	166.00	62.36	42.48	15.17	4.30	14.20	28.22	1.40	48.33	53.33	5.00	9.48	3.19	0.80	1661.56
8	L_8	151.67	62.64	36.02	15.50	4.11	16.27	33.00	1.40	51.00	54.00	3.00	10.31	3.20	0.80	4487.09
9	L_9	175.00	67.64	37.15	14.50	3.83	12.30	32.33	1.53	47.67	52.00	4.33	11.44	3.12	0.78	2932.16
10	L_{10}	180.00	57.64	39.21	15.00	4.33	14.28	34.36	1.47	48.33	52.67	4.33	7.30	2.77	0.69	1777.07
11	L_{11}	154.00	62.64	37.29	13.67	3.61	12.26	28.21	1.20	48.67	52.00	3.33	11.33	2.76	0.69	3376.43
12	L_{12}	163.33	52.64	35.07	14.62	4.33	14.23	29.56	1.40	48.67	53.67	5.00	11.12	2.85	0.71	3509.71
13	L_{13}	172.67	52.36	42.12	14.50	4.17	14.26	30.11	1.27	48.33	52.33	4.00	10.65	2.56	0.64	1839.26
14	L_{14}	156.33	35.28	34.55	12.17	4.39	12.11	30.06	1.20	49.33	55.00	5.67	8.45	3.15	0.79	2176.91
15	L_{15}	194.33	52.64	36.04	11.25	3.83	12.33	29.89	1.47	49.67	54.00	4.33	9.42	3.40	0.85	3252.03
16	L_{16}	193.33	42.36	36.92	13.50	4.17	12.44	29.00	1.27	49.00	52.00	3.00	10.51	2.76	0.69	2665.60
17	L_{17}	200.00	62.36	38.39	14.33	4.00	14.39	33.04	1.53	49.00	52.67	3.67	8.31	2.72	0.68	2016.97
18	L_{18}	175.00	62.64	39.62	15.50	4.17	14.45	31.78	1.40	49.33	53.00	3.67	7.48	2.72	0.68	2665.60
19	L_{19}	178.33	52.64	35.91	14.50	4.33	14.31	32.72	1.27	49.00	52.67	3.67	10.24	3.08	0.77	2576.75
20	L_{20}	191.67	52.36	32.26	14.33	4.06	12.37	33.83	1.33	48.67	53.00	4.33	8.26	3.24	0.81	4487.09
21	L_{21}	195.00	67.64	39.28	12.33	4.06	12.34	28.67	1.53	49.00	53.33	4.33	10.61	3.16	0.79	3820.69
22	T_1	205.00	62.64	30.73	14.00	3.94	14.44	32.92	1.27	48.33	52.00	3.67	9.46	2.86	0.72	4176.11
23	T_2	215.00	62.36	36.76	16.00	4.67	14.42	33.33	1.40	49.33	53.67	4.33	10.28	2.96	0.79	4264.96
24	T_3	191.67	57.36	34.76	15.67	4.27	14.15	34.33	1.67	49.33	52.67	3.33	7.57	2.73	0.68	3598.56
25	$L_1 \times T_1$	212.67	64.67	34.37	15.67	4.17	13.11	29.89	1.53	48.67	53.33	4.67	7.43	2.83	0.71	3998.40
26	$L_1 \times T_2$	160.83	40.67	40.34	14.56	4.29	14.00	27.89	1.53	49.00	53.33	4.33	11.10	2.55	0.64	2221.33
27	$L_1 \times T_3$	165.42	65.33	34.47	14.67	4.32	13.33	30.33	1.47	48.00	52.00	4.00	11.46	2.73	0.68	2665.60
28	$L_2 \times T_1$	200.67	64.00	34.54	14.78	4.17	12.67	32.51	1.73	47.67	52.33	4.67	12.09	2.08	0.52	4442.67
29	$L_2 \times T_2$	187.50	61.33	32.74	16.11	4.06	12.67	32.00	1.53	48.67	53.67	5.00	10.21	2.36	0.59	4442.67
30	$L_2 \times T_3$	189.00	68.00	35.11	17.78	4.50	13.33	35.89	1.73	48.00	52.00	4.00	9.34	3.24	0.81	3998.40
31	$L_3 \times T_1$	193.83	65.00	39.50	17.06	4.22	12.44	35.33	1.60	48.00	52.33	4.33	11.47	2.08	0.52	3998.40
32	$L_3 \times T_2$	194.25	67.00	39.25	16.44	3.96	12.67	30.11	1.47	48.67	52.33	3.67	9.77	2.87	0.72	2221.33
33	$L_3 \times T_3$	185.78	57.67	38.74	17.00	4.61	13.78	32.11	1.93	48.33	53.33	5.00	11.08	2.75	0.69	2221.33
34	$L_4 \times T_1$	188.67	66.00	35.14	15.78	4.22	12.67	35.28	1.73	50.67	54.67	4.00	11.07	2.89	0.72	4442.67
35	$L_4 \times T_2$	192.00	68.00	34.95	18.00	4.11	13.33	33.44	1.60	48.67	53.00	4.33	10.52	2.41	0.60	2665.60
36	$L_4 \times T_3$	187.00	66.67	37.42	15.67	3.89	12.67	34.11	1.40	49.67	54.00	4.33	10.27	2.75	0.69	3109.87

APPENDIX (IIc): Contd...

37	$L_5 \times T_1$	205.00	74.00	39.96	15.94	4.39	12.22	34.22	1.80	48.67	51.67	3.00	10.58	2.71	0.68	2665.60
38	$L_5 \times T_2$	172.44	54.00	35.23	14.44	3.94	12.67	31.44	1.20	48.67	52.00	3.33	8.33	2.52	0.63	1510.51
39	$L_5 \times T_3$	175.00	45.00	35.82	13.11	4.06	14.00	28.89	1.60	49.33	53.00	3.67	9.57	2.35	0.59	1599.36
40	$L_6 \times T_1$	170.28	60.28	36.96	14.89	4.33	13.56	30.44	1.80	51.67	55.33	3.67	12.10	2.71	0.68	1554.93
41	$L_6 \times T_2$	181.83	51.33	33.17	14.11	4.06	13.33	29.44	1.53	49.00	54.00	5.00	9.82	2.80	0.70	1377.23
42	$L_6 \times T_3$	182.56	64.67	37.89	14.56	3.82	12.22	32.56	1.33	48.00	51.67	3.67	8.43	3.13	0.78	2088.05
43	$L_7 \times T_1$	205.00	68.00	38.03	15.44	4.00	14.78	31.22	1.40	47.33	51.00	3.67	11.19	3.23	0.81	4442.67
44	$L_7 \times T_2$	195.33	60.00	25.18	15.00	3.79	12.67	31.00	1.73	47.67	50.67	3.00	8.23	2.83	0.71	3038.78
45	$L_7 \times T_3$	186.00	56.67	38.38	14.33	3.28	13.33	31.00	1.47	47.67	50.33	2.67	8.52	2.80	0.70	3216.49
46	$L_8 \times T_1$	195.00	71.33	32.71	15.94	4.17	13.78	31.11	1.67	47.67	51.00	3.33	8.51	2.73	0.68	2088.05
47	$L_8 \times T_2$	166.33	72.33	36.71	17.22	4.30	13.33	35.15	1.73	48.00	50.33	2.33	9.60	3.23	0.81	4273.85
48	$L_8 \times T_3$	184.33	62.00	35.84	13.94	3.72	12.00	31.11	1.53	47.33	50.00	2.67	9.33	3.15	0.79	1599.36
49	$L_9 \times T_1$	186.00	56.67	34.54	15.11	4.72	12.89	30.22	1.40	48.00	54.00	6.00	7.33	3.45	0.86	3109.87
50	$L_9 \times T_2$	200.33	56.00	35.46	13.78	4.33	12.22	27.71	1.60	48.67	52.33	3.67	8.32	2.51	0.63	3998.40
51	$L_9 \times T_3$	192.00	64.00	36.29	15.67	4.28	12.44	29.26	1.40	48.67	52.00	3.33	10.55	3.23	0.81	1777.07
52	$L_{10} \times T_1$	198.00	52.33	35.39	15.22	4.22	14.67	29.00	1.47	48.33	51.33	3.00	11.11	2.93	0.73	3198.72
53	$L_{10} \times T_2$	192.44	71.33	32.33	16.78	4.12	14.67	32.56	1.40	49.00	53.00	4.00	10.64	3.27	0.82	2576.75
54	$L_{10} \times T_3$	211.00	72.00	36.27	15.44	4.39	12.44	33.83	1.67	48.33	51.33	3.00	8.69	2.56	0.64	3109.87
55	$L_{11} \times T_1$	195.67	67.33	34.78	13.89	4.22	13.78	28.89	1.60	48.67	52.67	4.00	10.29	1.96	0.49	1777.07
56	$L_{11} \times T_2$	205.67	66.00	35.32	14.44	3.88	13.44	28.44	1.67	48.33	51.00	2.67	9.37	3.28	0.82	1777.07
57	$L_{11} \times T_3$	209.33	72.00	35.99	16.33	5.17	15.33	35.72	1.33	47.67	50.00	2.33	11.30	3.71	0.93	4886.93
58	$L_{12} \times T_1$	159.67	53.33	37.89	16.33	4.11	12.89	33.00	1.40	48.33	51.33	3.00	9.59	3.48	0.87	2665.60
59	$L_{12} \times T_2$	178.67	65.33	35.26	13.00	3.94	12.89	26.22	1.47	48.33	52.00	3.67	10.27	2.69	0.67	2043.63
60	$L_{12} \times T_3$	196.67	64.00	32.61	15.78	4.18	12.67	31.78	1.40	48.67	54.00	5.33	11.36	3.27	0.82	2221.33
61	$L_{13} \times T_1$	187.33	58.33	35.94	13.89	4.06	12.44	27.06	1.47	48.33	54.00	5.67	7.34	2.40	0.60	2088.05
62	$L_{13} \times T_2$	200.00	62.00	35.24	16.00	4.39	14.44	33.00	1.53	48.67	53.67	5.00	11.41	2.16	0.54	3109.87
63	$L_{13} \times T_3$	176.17	59.50	35.64	13.50	3.89	13.78	27.33	1.53	49.00	52.67	3.67	11.18	2.37	0.59	3109.87
64	$L_{14} \times T_1$	194.67	70.00	39.36	17.11	4.43	12.00	34.22	1.47	48.00	53.33	5.33	8.33	3.63	0.91	3554.13
65	$L_{14} \times T_2$	201.67	64.33	33.94	16.56	4.11	11.33	29.82	1.80	48.00	50.33	2.33	9.56	2.73	0.68	1777.07
66	$L_{14} \times T_3$	200.67	68.67	32.46	16.00	4.00	13.00	36.00	1.47	49.67	54.00	4.33	10.65	3.11	0.78	2487.89
67	$L_{15} \times T_1$	207.33	70.00	37.47	16.56	4.19	13.89	33.72	1.40	50.00	55.67	5.67	8.01	2.80	0.70	3554.13

APPENDIX (IIc): Contd...

68	$L_{15} \times T_2$	183.61	63.33	42.27	16.78	3.38	14.89	35.67	1.47	49.33	54.33	5.00	7.36	2.75	0.69	1554.93
69	$L_{15} \times T_3$	182.67	71.33	34.64	14.78	4.00	12.00	33.00	1.53	48.33	50.67	2.33	10.31	2.04	0.51	3998.40
70	$L_{16} \times T_1$	197.33	57.33	37.22	15.22	4.12	12.44	31.11	1.40	48.33	53.00	4.67	8.39	3.33	0.83	3820.69
71	$L_{16} \times T_2$	190.67	48.00	36.84	14.89	3.83	12.44	30.00	1.47	48.00	51.33	3.33	10.76	3.53	0.88	3554.13
72	$L_{16} \times T_3$	169.50	54.67	35.12	16.11	4.28	12.44	31.33	1.33	47.67	50.33	2.67	10.05	1.96	0.49	2665.60
73	$L_{17} \times T_1$	166.67	44.17	37.64	14.94	4.44	12.78	28.26	1.53	48.33	52.33	4.00	10.27	2.68	0.67	1457.19
74	$L_{17} \times T_2$	188.33	63.33	38.83	15.44	4.22	15.44	30.89	1.07	49.33	53.33	4.00	7.47	2.07	0.52	2612.29
75	$L_{17} \times T_3$	209.33	70.00	37.54	15.61	4.33	13.11	31.89	1.40	48.67	52.00	3.33	11.33	2.73	0.68	3376.43
76	$L_{18} \times T_1$	209.67	76.00	34.80	14.89	4.11	12.89	30.67	1.27	48.33	52.00	3.67	7.24	2.48	0.62	3554.13
77	$L_{18} \times T_2$	199.67	69.33	36.61	16.22	4.72	14.67	31.11	1.53	48.00	53.33	5.33	9.72	2.80	0.70	3998.40
78	$L_{18} \times T_3$	184.33	52.00	39.64	14.67	4.06	13.11	30.89	1.60	48.67	53.00	4.33	10.57	3.49	0.87	2221.33
79	$L_{19} \times T_1$	324.00	68.00	37.15	15.44	4.34	13.11	32.89	1.53	48.67	54.33	5.67	10.21	3.49	0.87	1777.07
80	$L_{19} \times T_2$	193.33	74.00	34.95	15.67	4.17	12.00	31.67	1.47	48.67	54.00	5.33	9.45	3.21	0.80	4886.93
81	$L_{19} \times T_3$	185.33	66.67	40.54	14.89	4.39	13.33	30.33	1.53	48.33	53.00	4.67	9.45	3.49	0.87	2665.60
82	$L_{20} \times T_1$	190.00	60.00	38.34	14.78	3.89	13.56	32.11	1.27	48.33	53.00	4.67	8.47	2.71	0.68	3109.87
83	$L_{20} \times T_2$	178.00	55.33	35.94	15.00	4.32	12.78	28.82	1.40	48.33	53.00	4.67	8.34	3.41	0.85	1777.07
84	$L_{20} \times T_3$	194.00	74.67	40.43	13.67	4.00	12.89	31.78	1.73	48.67	52.67	4.00	9.44	2.75	0.69	2088.05
85	$L_{21} \times T_1$	174.33	54.67	37.59	16.11	4.06	12.67	34.00	1.73	48.33	50.67	2.33	7.56	3.49	0.87	2665.60
86	$L_{21} \times T_2$	192.50	67.33	36.51	16.33	4.22	13.56	31.22	1.53	48.33	52.67	4.33	8.41	2.53	0.63	1421.65
87	$L_{21} \times T_3$	194.00	66.00	32.12	14.00	4.00	14.27	31.61	1.40	49.67	52.67	3.00	10.51	2.73	0.68	4886.93
88	Check-1	207.00	72.67	34.19	17.06	3.67	13.11	29.33	1.60	49.67	56.00	6.33	10.61	2.96	0.74	3554.13
89	Check-2	172.00	52.00	36.15	13.83	3.88	12.67	28.48	1.60	48.33	50.67	2.33	9.53	2.09	0.52	2665.60
90	Check-3	184.67	60.00	36.39	14.78	4.06	13.56	31.00	1.53	48.00	51.67	3.67	10.31	1.00	0.25	5775.47
91	Grand mean	186.95	61.15	36.25	15.10	4.14	13.33	31.44	1.49	48.64	52.64	4.00	9.72	2.84	0.71	2949.93
92	CD at 1%	33.159	12.919	6.231	2.636	0.827	2.882	6.852	0.348	2.282	3.560	2.377	0.406	0.057	0.231	1825.189
93	CD at 5%	25.131	9.791	4.722	1.998	0.627	2.184	5.193	0.264	1.729	2.698	1.801	0.308	0.043	0.175	1383.252
94	CV (%)	8.34	9.93	8.08	8.20	9.39	10.16	10.25	10.99	2.20	3.18	27.9	1.96	3.82	3.82	29.10

APPENDIX (IId): Means of parents, $F_{1's}$ and checks of 15 characters in across the environments

S.No.	Genotypes	Plant height	Ear height	100 kernel weight	Ear length	Ear diameter	Number of Kernel rows/ear	Number of kernels / row	Brace roots	Days to 50% tasselling	Days to 50% silking	Anthesis-silking interval	Protein	Lysine	Trypto-phan	Grain yield
1.	L_1	194.80	69.50	20.04	16.21	4.43	13.21	33.88	1.70	48.67	52.33	4.33	8.25	3.31	0.84	61.80
2.	L_2	177.70	68.70	34.86	14.39	4.13	13.50	28.52	1.70	48.67	52.67	4.67	11.77	2.63	0.67	35.49
3.	L_3	180.00	69.90	36.33	14.72	4.37	14.17	29.32	1.90	49.00	51.67	3.33	12.20	2.71	0.69	34.87
4.	L_4	204.20	75.23	31.41	15.83	4.17	11.94	31.83	2.03	48.67	52.00	4.00	12.63	2.23	0.57	44.36
5.	L_5	192.40	70.23	35.83	16.32	4.17	12.99	34.61	1.70	48.67	53.33	5.00	10.60	2.43	0.62	39.67
6.	L_6	195.20	63.90	35.40	16.77	4.53	13.21	34.39	1.77	48.67	53.00	4.67	9.80	3.31	0.84	40.09
7.	L_7	192.50	73.23	35.63	16.88	4.67	12.99	34.61	1.77	48.67	52.00	3.67	11.86	2.15	0.55	50.71
8.	L_8	199.40	77.43	36.36	15.10	4.47	12.65	30.92	1.57	49.00	52.33	3.67	10.20	2.95	0.75	25.51
9.	L_9	190.00	72.23	36.23	15.88	4.50	13.88	33.50	1.83	49.00	52.33	4.00	11.77	2.79	0.71	26.61
10.	L_{10}	204.20	73.23	34.40	16.43	4.47	13.77	35.94	1.97	49.67	53.33	4.33	11.77	2.99	0.76	48.62
11.	L_{11}	206.20	80.23	33.43	15.32	4.20	13.21	35.28	1.47	49.33	54.00	5.33	11.35	2.47	0.63	30.83
12.	L_{12}	198.90	73.23	40.07	16.96	4.27	13.27	34.83	1.63	50.00	54.00	4.67	10.94	2.84	0.73	34.93
13.	L_{13}	217.20	87.90	38.56	15.22	4.33	13.28	33.83	1.77	51.67	55.00	4.00	11.35	2.76	0.71	33.87
14.	L_{14}	186.90	68.23	34.66	14.99	3.93	11.66	31.94	1.30	50.00	53.67	4.00	8.65	2.63	0.67	19.73
15.	L_{15}	180.50	56.73	35.60	15.06	4.37	15.17	34.06	1.90	50.00	54.67	5.00	10.20	2.41	0.63	21.02
16.	L_{16}	172.70	60.33	34.29	15.17	4.27	14.33	31.36	1.90	49.33	53.00	3.67	11.96	2.71	0.69	12.92
17.	L_{17}	178.20	56.90	34.70	13.33	3.77	12.61	29.58	1.70	50.00	53.33	4.00	10.54	2.83	0.72	16.82
18.	L_{18}	183.50	67.90	37.57	14.69	3.93	12.56	32.28	1.23	48.67	52.33	3.67	8.69	3.12	0.80	21.95
19.	L_{19}	190.20	68.23	35.03	15.06	4.27	13.28	32.39	1.37	48.67	52.67	4.00	11.10	3.27	0.83	34.98
20.	L_{20}	185.90	74.57	30.60	15.17	4.00	12.56	30.72	1.77	49.00	52.67	4.00	8.65	2.87	0.73	28.73
21.	L_{21}	179.20	66.23	34.47	16.39	3.90	12.83	31.61	1.43	49.33	53.67	4.67	8.83	2.92	0.75	30.41
22.	T_1	191.20	76.00	35.63	14.61	4.50	13.00	29.13	1.43	50.33	53.00	3.00	9.02	2.80	0.72	13.99
23.	T_2	200.60	69.30	35.37	14.94	3.83	12.83	31.72	1.43	49.67	53.33	4.00	10.30	3.28	0.84	31.96
24.	T_3	185.70	68.90	35.26	13.78	3.83	12.61	31.72	1.50	49.00	53.00	4.67	10.34	3.16	0.81	13.15
25.	$L_1 \times T_1$	195.60	69.63	37.20	14.61	4.50	13.44	32.57	1.37	49.67	53.67	4.67	8.25	3.51	0.89	47.74
26.	$L_1 \times T_2$	187.00	63.90	34.90	14.28	4.67	14.17	31.72	1.50	51.00	55.00	4.67	8.99	2.63	0.67	34.71
27.	$L_1 \times T_3$	179.00	67.23	39.00	14.61	4.17	13.06	29.94	1.30	50.33	53.33	3.67	11.35	3.31	0.84	16.27
28.	$L_2 \times T_1$	192.50	76.07	37.13	15.50	4.63	14.98	32.61	1.57	50.67	54.00	4.00	11.77	2.99	0.76	43.80
29.	$L_2 \times T_2$	196.50	83.23	34.56	15.83	4.27	12.72	32.44	1.57	51.00	55.33	4.67	11.01	3.39	0.86	16.51
30.	$L_2 \times T_3$	196.50	74.90	36.07	15.17	4.67	13.39	34.44	1.50	50.33	53.67	3.67	9.02	2.59	0.66	30.69
31.	$L_3 \times T_1$	196.00	73.47	36.57	16.89	4.50	13.50	31.78	1.70	52.00	55.33	3.67	10.60	1.99	0.51	16.68
32.	$L_3 \times T_2$	201.40	73.63	31.80	13.00	4.10	13.94	29.27	1.70	52.33	55.33	3.00	9.47	3.35	0.85	19.29
33.	$L_3 \times T_3$	201.10	74.50	33.93	17.72	4.10	12.17	37.21	1.83	49.00	52.33	3.33	11.53	3.79	0.96	52.77
34.	$L_4 \times T_1$	181.40	65.77	37.60	16.11	4.27	13.06	28.63	1.50	50.00	53.33	3.67	10.20	3.51	0.89	26.30
35.	$L_4 \times T_2$	175.60	71.23	37.10	15.06	4.17	14.17	29.94	1.43	50.00	54.00	4.33	10.60	2.67	0.68	21.88
36.	$L_4 \times T_3$	199.20	66.90	36.83	18.28	4.67	13.50	34.17	1.30	50.33	54.00	4.33	12.20	3.35	0.85	33.76

APPENDIX (IId): Contd...

37.	$L_5 \times T_1$	185.40	68.23	35.40	15.44	4.33	13.33	28.28	1.90	49.00	52.67	4.33	8.25	2.51	0.64	21.02
38.	$L_5 \times T_2$	183.70	74.70	36.59	17.28	4.33	14.17	31.75	1.43	50.67	54.33	4.33	12.20	2.19	0.56	33.91
39.	$L_5 \times T_3$	200.70	75.10	38.40	17.17	4.23	13.06	34.14	1.77	51.33	55.67	5.00	11.77	2.47	0.63	30.99
40.	$L_6 \times T_1$	188.70	73.37	36.85	16.61	4.43	13.17	36.63	1.43	49.33	53.00	4.33	8.99	3.71	0.94	39.05
41.	$L_6 \times T_2$	198.50	74.90	31.72	16.61	4.33	12.22	30.10	1.37	50.33	54.00	4.00	9.80	2.79	0.71	16.95
42.	$L_6 \times T_3$	203.20	77.90	33.34	16.89	4.50	14.39	28.89	1.37	51.67	55.67	4.33	11.01	3.11	0.79	20.07
43.	$L_7 \times T_1$	202.50	82.57	38.50	16.72	4.20	13.28	32.72	1.37	51.00	55.00	4.33	8.27	2.87	0.73	34.79
44.	$L_7 \times T_2$	181.40	70.57	37.47	15.50	3.93	14.50	35.14	1.23	51.67	55.67	5.00	8.58	2.83	0.72	16.86
45.	$L_7 \times T_3$	194.20	75.23	36.76	16.60	3.93	12.54	33.17	1.43	50.67	53.67	3.33	10.60	2.03	0.52	30.56
46.	$L_8 \times T_1$	198.20	73.23	37.87	14.95	4.40	15.28	29.03	1.57	50.33	54.33	4.33	8.65	3.43	0.87	34.79
47.	$L_8 \times T_2$	175.90	60.30	36.28	14.61	4.60	13.06	34.69	1.50	50.00	54.67	5.33	11.35	3.60	0.92	39.31
48.	$L_8 \times T_3$	188.50	68.90	32.86	16.05	4.27	13.50	34.83	1.43	49.33	52.33	3.67	10.14	1.99	0.51	34.00
49.	$L_9 \times T_1$	167.50	54.23	34.96	13.66	3.67	12.99	30.17	1.37	49.67	52.67	3.33	10.60	2.71	0.69	14.09
50.	$L_9 \times T_2$	188.90	65.30	36.26	15.11	4.00	14.72	29.83	1.17	51.33	54.67	3.67	7.91	2.21	0.58	25.29
51.	$L_9 \times T_3$	207.20	71.57	35.26	14.89	4.47	13.72	32.72	1.37	50.00	53.00	3.33	11.86	2.71	0.69	42.72
52.	$L_{10} \times T_1$	192.50	70.57	34.70	15.22	4.13	13.05	29.50	1.30	49.33	52.67	3.67	7.91	2.63	0.67	39.52
53.	$L_{10} \times T_2$	192.90	72.07	37.57	17.83	4.57	13.95	32.72	1.43	50.00	54.00	4.67	10.54	2.91	0.74	39.54
54.	$L_{10} \times T_3$	185.50	67.23	38.49	15.44	4.07	12.77	32.72	1.77	49.67	54.00	5.00	11.35	3.51	0.89	22.20
55.	$L_{11} \times T_1$	311.20	65.23	36.38	15.92	4.17	13.28	29.98	1.63	49.67	55.33	6.33	10.94	3.55	0.90	34.87
56.	$L_{11} \times T_2$	179.90	75.23	35.97	16.39	4.33	12.83	31.78	1.83	49.67	53.33	4.00	9.80	3.31	0.84	39.94
57.	$L_{11} \times T_3$	191.20	76.57	36.00	14.88	3.97	12.77	30.83	1.77	49.33	54.33	5.33	10.20	3.51	0.89	39.75
58.	$L_{12} \times T_1$	184.90	68.40	31.43	15.44	4.17	15.21	35.17	1.57	49.50	52.83	3.83	9.00	2.75	0.70	38.31
59.	$L_{12} \times T_2$	176.50	76.40	34.54	13.77	4.23	13.21	29.94	1.37	49.17	53.50	4.83	9.19	3.47	0.88	25.54
60.	$L_{12} \times T_3$	185.40	72.07	36.37	14.99	4.10	13.21	31.17	1.50	48.83	52.50	4.17	10.37	2.75	0.70	34.02
61.	$L_{13} \times T_1$	178.90	64.77	36.77	15.83	4.47	13.28	35.43	1.83	48.67	51.33	3.33	8.25	3.55	0.90	26.57
62.	$L_{13} \times T_2$	186.40	71.90	36.83	16.33	4.23	13.06	32.72	1.37	48.67	52.67	4.67	8.99	2.63	0.67	14.11
63.	$L_{13} \times T_3$	181.90	67.23	37.43	14.89	5.10	13.28	30.78	1.43	48.67	52.00	4.00	11.35	2.75	0.70	33.15
64.	$L_{14} \times T_1$	179.50	68.47	34.36	14.40	4.13	12.90	28.17	1.50	48.67	51.67	3.67	11.77	2.52	0.65	28.93
65.	$L_{14} \times T_2$	165.50	60.00	38.56	15.73	4.63	13.90	31.17	1.43	49.00	52.33	4.00	11.35	3.60	0.92	25.68
66.	$L_{14} \times T_3$	180.20	65.67	35.63	14.99	4.23	14.04	33.61	1.37	49.33	52.67	4.00	9.36	3.19	0.81	36.37
67.	$L_{15} \times T_1$	181.90	57.80	34.47	14.07	4.07	13.34	31.39	1.50	49.33	53.00	4.33	10.94	3.12	0.80	21.92

APPENDIX (IId): Contd...

68.	$L_{15} \times T_2$	173.20	51.23	35.56	14.33	3.90	13.44	34.56	1.57	48.67	52.67	4.67	10.14	3.03	0.77	15.07
69.	$L_{15} \times T_3$	165.50	52.80	36.33	15.16	4.10	12.32	33.56	1.70	49.00	52.33	4.00	12.20	2.87	0.73	28.70
70.	$L_{16} \times T_1$	182.90	76.80	37.84	15.25	4.40	14.18	35.83	1.37	48.67	52.67	4.67	10.54	3.24	0.83	18.76
71.	$L_{16} \times T_2$	175.20	70.00	36.47	14.99	4.40	14.17	30.59	1.50	49.67	52.00	3.00	10.94	3.31	0.84	31.89
72.	$L_{16} \times T_3$	178.90	70.00	34.90	13.99	3.93	12.77	29.83	1.50	49.00	52.33	4.00	12.20	3.15	0.80	32.19
73.	$L_{17} \times T_1$	173.90	65.00	32.90	15.68	4.17	13.57	34.52	1.57	49.33	52.67	3.67	7.91	2.88	0.74	22.28
74.	$L_{17} \times T_2$	154.50	59.00	35.46	14.23	4.13	12.90	31.02	1.77	49.00	53.00	4.33	11.86	2.84	0.73	34.18
75.	$L_{17} \times T_3$	184.50	64.67	35.66	15.23	4.07	12.90	34.92	1.50	48.67	53.33	5.00	11.43	2.92	0.75	34.41
76.	$L_{18} \times T_1$	179.80	68.47	36.83	14.57	3.80	12.90	30.42	1.70	50.00	53.67	3.67	10.68	2.60	0.67	18.98
77.	$L_{18} \times T_2$	148.90	41.13	35.20	14.89	4.50	13.00	32.93	1.23	49.33	54.00	5.33	8.99	3.23	0.82	20.86
78.	$L_{18} \times T_3$	157.20	58.00	33.23	13.82	3.70	14.82	30.17	1.63	49.67	54.33	5.33	10.14	3.43	0.87	29.75
79.	$L_{19} \times T_1$	172.20	53.47	35.50	14.82	4.10	12.27	27.69	1.30	50.33	54.00	4.00	11.01	2.75	0.70	25.39
80.	$L_{19} \times T_2$	181.20	58.47	39.42	15.27	4.33	13.21	34.50	1.43	50.00	53.33	3.67	8.27	2.75	0.70	21.50
81.	$L_{19} \times T_3$	186.20	69.00	37.06	15.27	4.33	13.21	33.99	1.63	49.67	52.67	3.33	7.91	2.71	0.69	24.57
82.	$L_{20} \times T_1$	183.90	66.67	36.33	13.77	3.53	12.54	32.38	1.43	48.83	52.83	4.50	10.77	3.11	0.79	26.11
83.	$L_{20} \times T_2$	187.50	58.13	34.12	14.43	4.17	13.16	33.35	1.70	49.17	53.17	4.50	8.82	3.27	0.83	46.15
84.	$L_{20} \times T_3$	187.70	65.53	36.38	13.43	3.83	12.32	29.78	1.37	49.83	54.17	5.17	11.51	3.19	0.81	38.65
85.	$L_{21} \times T_1$	195.50	73.33	34.49	14.60	5.03	14.04	32.14	1.57	50.00	53.67	4.33	10.14	2.91	0.73	39.54
86.	$L_{21} \times T_2$	193.90	67.80	34.00	15.37	4.43	14.04	30.88	1.37	49.00	53.00	4.67	10.94	2.31	0.59	41.81
87.	$L_{21} \times T_3$	185.70	66.27	35.50	14.66	4.33	13.65	31.97	1.37	48.67	52.33	4.33	8.25	2.75	0.70	42.17
88.	Check-1	202.50	81.90	34.63	18.10	4.27	14.10	33.39	1.57	52.00	56.33	5.00	11.35	2.99	0.76	24.54
89.	Check-2	182.20	69.90	35.49	15.21	3.67	12.49	29.09	1.30	49.00	51.67	3.33	10.14	2.11	0.54	20.39
90.	Check-3	172.10	62.10	35.43	16.00	4.33	13.06	32.59	1.70	50.67	53.33	3.33	10.94	1.67	0.43	48.20
91.	Grand mean	187.92	68.71	35.52	15.37	4.24	13.34	32.13	1.55	49.69	53.40	4.20	10.29	2.91	0.74	30.38
92.	CD at 1%	28.645	15.514	4.16	2.564	0.785	1.873	4.655	0.869	3.124	3.566	1.566	0.345	0.431	0.045	2542.182
93.	CD at 5%	23.744	12.273	2.91	1.443	0.556	1.655	4.253	0.658	2.666	2.666	1.656	0.343	0.155	0.053	1548.745
94.	CV (%)	7.26	10.10	5.57	6.04	8.48	5.86	7.08	24.60	2.34	3.43	24.2	1.67	3.78	3.89	28.66

VITA

The author of this manuscript was born on 11th April 1982 at Pantnagar district Udham Singh Nagar (Uttarakhand). He passed Higher Secondary and Senior Secondary Examinations from P.I.C. Pantnagar, U. S. Nagar, Uttarakhand in 1997 and 1999, respectively. He earned B.Sc. degree from G. B. Pant University of Agriculture and Technology, Pantnagar in 2004. Thereafter, he completed M.Sc. (Ag.) degree programme with major in Genetics and Plant breeding at G. B. Pant University of Agriculture and Technology, Pantnagar in 2007, after completion of his Master's degree, he joined the same department of the University for the Ph.D. degree in 2007-08. He has qualified ICAR-ARS-NET examination in 2009.

Address:

Jitendra Bhaskar
D-4/123, Jankipuram Extention
Lucknow, Uttar Pradesh-226020
(Res): 9454709799
: 91-9411324351, 9634463918
: bhaskar.jitendra@gmail.com,
jeetu_sun@rediffmail.com

ABSTRACT

Name	:	**Jitendra Bhaskar**	**Id. No.**	:	27940
Year of Admission	:	I Sem., 2007-08	**Degree**	:	Ph.D.
Major	:	Genetics & Plant Breeding	**Deptt.**	:	Genetics & Plant Breeding
Minor	:	Agricultural Statistics			
Thesis Title	:	**"Combining ability, heterosis and phenotypic stability for yield and other desirable characters in high quality protein maize (*Zea mays* L.)"**			
Advisor	:	Dr. S.S. Verma			

The present investigation was conducted during *Kharif*, 2009 at Norman E. Borlaug Crop Research Centre, Pantnagar under normal (recommended dose of nitrogen, E_1), low-nitrogen(E_2) and excess soil moisture (E_3) environments with the objectives: (i) to identify superior single cross quality protein maize (QPM) hybrids, (ii) to determine nature and magnitude of heterosis, (iii) to estimate variability parameters, combining ability and phenotypic stability of parental inbreds and hybrids for important economic characters in quality protein maize (QPM). The experimental material consisted of 21 QPM inbred lines and 3 broad-base testers crossed in a line x tester fashion. All the 24 parents, 63 F_1's along with three checks HQPM-1, Shakti-1 and Pragati, were evaluated in a randomized complete block design. Observations on 15 characters, like plant height, ear height, 100-kernel weight, ear length, ear diameter, number of kernel rows/ear, number of kernels/row, number of nodes bearing brace roots, days to 50% tasselling, days to 50% silking, anthesis-silking interval, protein, tryptophan and lysine contents and grain yield were recorded.

Analysis of variance revealed that these genotypes differed significantly for all the 15 characters, indicated the presence of sufficient amount of variability among genotypes. As regards heterosis, high per cent heterobeltiosis, standard heterosis and relative heterosis in all the three and pooled over environments was observed in crosses, $L_1 \times T_1$ (DQPMC-3(Y)⊗101-1-2-1-1×DMRQPM-03-106-#-⊗-1-1-1), $L_2 \times T_1$ (DQPMC-3(Y)⊗101-1-2-1-1×DMRQPM-03-103-#-⊗-2-1-1-1), $L_{10} \times T_1$ (DQPMC-3(Y)⊗50-1-1-1-1×DMRQPM-03-106-#-⊗-1-1-1-1), $L_{11} \times T_3$ (Pool 18C8(TEYFQPM)-B-9-1-1-1×Pool17C8(TEYFQPM)-B-57-2-1-1) and $L_{14} \times T_1$ (DMRQPM-28-5-⊗-⊗-#-⊗3-⊗-1-1-1× DMRQPM-03-106-#-⊗-1-1-1) for grain yield. High estimates of heritability were observed for quality traits, 100-kernel weight and grain yield in all the three environments, whereas, high estimates of expected genetic advance as per cent of mean were recorded for grain yield and quality characters, under all the environments. Combining ability analysis revealed significant variances due to GCA and SCA for most of the characters in all the three environments indicating importance of both additive and non-additive genetic variances. The magnitude of SCA variance was greater than GCA variance for all the characters in all the environments showing preponderance of non-additive variance and suitability of material for hybrid breeding. The GCA effects of the parents indicated that parental lines, L_1, L_2, L_3, L_4 in E_1; L_1, L_3, L_4, L_{11}, L_{12}, L_{13}, L_{14} and L_{16} in E_2; L_8, L_4 and L_7 in E_3 and L_1, L_2 and L_4 in pooled environment and testers, T_1 and T_3 in over all environments, were the best combiners. The maximum SCA effects were observed in crosses, $L_{11} \times T_3$, $L_{14} \times T_1$ and $L_3 \times T_1$ in E_1, $L_{11} \times T_3$, $L_{17} \times T_3$ and $L_1 \times T_1$ in E_2, $L_{11} \times T_3$ in E_3 and $L_{11} \times T_3$ and $L_{17} \times T_3$ in pooled environment for grain yield and its contributing traits as well as for quality traits. The pooled analysis of variance for phenotypic stability indicated that mean squares due to genotypes and environments were significant for most of the characters. It indicated substantial variability among genotypes and environments. G×E interaction was also highly significant for all the traits except quality characters. Among the 21 lines and 3 testers, L_1, L_4, L_6, L_{10}, L_{12}, T_1 and T_2 showed desirable stability for grain yield and its components along with quality characters. Out of 63 single crosses, most desirable and stable were $L_2 \times T_3$, $L_3 \times T_3$, $L_5 \times T_2$, $L_5 \times T_3$, $L_7 \times T_1$, $L_7 \times T_3$, $L_8 \times T_1$, $L_8 \times T_2$, $L_8 \times T_3$, $L_9 \times T_3$, $L_{10} \times T_1$, $L_{10} \times T_2$, $L_{11} \times T_2$, $L_{11} \times T_3$, $L_{12} \times T_1$, $L_{12} \times T_3$, , $L_{13} \times T_3$, $L_{14} \times T_3$, $L_{16} \times T_2$, $L_{16} \times T_3$, $L_{17} \times T_2$, $L_{17} \times T_3$, $L_{20} \times T_2$, $L_{20} \times T_3$, $L_{21} \times T_1$, $L_{21} \times T_2$ and $L_{21} \times T_3$ for grain yield. However, $L_1 \times T_1$, $L_1 \times T_3$, $L_2 \times T_1$, $L_2 \times T_2$, $L_3 \times T_3$, $L_4 \times T_3$, $L_6 \times T_3$, $L_8 \times T_2$, $L_{10} \times T_2$, $L_{10} \times T_3$, $L_{11} \times T_1$, $L_{14} \times T_2$, $L_{15} \times T_1$, $L_{16} \times T_1$, $L_{16} \times T_2$, $L_{16} \times T_3$, $L_{17} \times T_3$ and $L_{20} \times T_3$ were found to be desirable and stable for quality traits. For rich environment, L_1, L_2, L_4, L_9, L_{13} and L_{21}, tester, T_1 and T_2 and crosses, $L_1 \times T_1$, $L_2 \times T_1$, $L_4 \times T_3$, $L_6 \times T_1$, $L_7 \times T_3$ and $L_{11} \times T_1$ showed stable and desirable performance. However, under poor environment, L_1, L_8, L_9, L_{13}, L_{14} and L_{17}, tester, T_1 and T_3 and crosses, $L_4 \times T_2$, $L_5 \times T_2$, $L_7 \times T_2$, $L_{18} \times T_3$ and $L_{19} \times T_2$ exhibited stable and desirable performance for grain yield and its contributing traits. While, for quality characters no specific cross was found good under both rich and poor environment.

(S.S. Verma)
Advisor

(Jitendra Bhaskar)
Author

सारांश

नाम : जितेन्द्र भास्कर **परिचायंक सं.** : 27940
षटमास एवं वर्ष : प्रथम षटमास, 2007–08 **उपाधि** : पी एच0डी0
मुख्य विषय : आनुवांशिकी एवं पादप प्रजनन **विभाग** : आनुवांशिकी एवं पादप प्रजनन
उप विषय : कृषि सांख्यिकी

शोध शीर्षक : **उच्च प्रोटिन गुणवत्ता मक्का में उपज व अन्य वांछनीय लक्षणों के लिए संयोजन क्षमता, संकर ओज एवं दृष्यरूपिक स्थायित्व।**

परामर्शदाता : डॉ0 एस0 एस0 वर्मा

वर्तमान जाँच खरीफ, 2009, नारमन ई. बोरलॉग फसल अनुसंधान केन्द्र, पन्तनगर में सामान्य (नत्रजन की सुझाई गई मात्रा, $ई_1$), न्यूनतम नत्रजन ($ई_2$) एवं उच्च मृदा नमी ($ई_3$) वातावरणों के अन्तर्गत, निम्न उद्देष्यों, 1. विशिष्ट एकल संकरण गुणवत्ता प्रोटीन मक्का (क्यू. पी. एम.) संकरों की पहचान, 2. संकर ओज की तीव्रता एवं प्रकृति का निर्धारण, 3. पैतृक अन्तः प्रजात एवं संकरों के विविधता मानकों का मूल्यांकन, संयोजन क्षमता एवं दृष्यरूपिक स्थायित्व, के साथ गुणवत्ता प्रोटीन मक्का में आवश्यक आर्थिक लक्षणों, के लिए की गयी। प्रायोगिक सामग्री में 21 गुणवत्ता प्रोटीन मक्का अन्तः प्रजात क्रमों एवं तीन विस्तृत आधार परीक्षकों का संकरण क्रम × परीक्षक दशा में किया गया। सभी 24 पैतृकों, 63 $एफ_1$ (प्रथम पीढ़ी) को तीन जाचकों एच. क्यू. पी एम –1, शक्ति– 1 और प्रगति के साथ यादृच्छिक खण्ड अभिकल्पना में मूल्यांकन किया गया। 15 लक्षणों जैसे– पौधे की ऊचाई, भुट्टे की ऊचाई, 100 दानों का भार, भुट्टे की लम्बाई, भुट्टे का व्यास, दानों की पक्तियों की संख्या/भुट्टा, दानों की संख्या/पंक्ति, गाठों की संख्या जिन पर ब्रेस जडें पायी गई, 50 प्रतिशत नर पुष्प क्रम निकलने के दिन, 50 प्रतिशत मादा पुष्प क्रम निकलने के दिन, नर–मादा पुष्पक्रम मध्यानतर, प्रोटीन प्रतिशतता, लाइसीन व ट्रिपटोफॅान की मात्रा एवं दानों की उपज की जाँच की गई।

प्रसरण विश्लेषण, ये प्रकट करता है कि ये जीन प्ररूप सभी 15 लक्षणों के लिए सार्थक रूप से भिन्न थे, जो जीन प्ररूपों के मध्य विविधता की उचित मात्रा कों दर्शाता है। संकर ओज के सम्बन्ध में, दानों की उपज के लिए उच्च हेटेरोवेलटिओसिस, मानक संकर ओज एवं सम्बधित संकर ओज, एल1 × टी1 (डी क्यू पी एम सी–3 (वाई)⊗101-1-2-1-1 × डी एम आर क्यू पी एम–03-103-#-⊗-1-1-1), एल 10× टी1 (डी क्यू पी एम सी–3(वाई)⊗50-1-1-1-1 × डी क्यू पी एम सी 03-106-#-⊗-1-1-1-1 , एल11 ×टी3 (पूल 18 सी8 (टीई वाई एफ क्यू पी एम)–बी 9-1-1-1-1 × पूल 17 सी 8(टी ई वाई एफ क्यू पी एम)–बी-57-2-1-1) और एल11 × टी1(डी एम आर क्यू पी एम -28-5-⊗-⊗-#-⊗3-⊗-1-1-1× डी एम आर क्यू पी एम-03-106-#-⊗-1-1-1), संकरणों में पाया गया। उच्च वंशगत्तिव अनुमान तीनों वातावरणों में गुणवत्ता लक्षणों, 100 दानों के भार एवं दानों की उपज के लिए पायी गयी, जबकि उच्च सम्भावित आनुवांशिक उन्नति सभी वातावरणों में दानों की उपज एवं गुणवत्ता लक्षणों के लिए दर्ज की गयी। सभी तीनों वातावरणों में, अधिकतर लक्षणों के लिए, संयोजन क्षमता अन्वेषण, सामान्य संयोजन क्षमता एवं विशिष्ट संयोजन क्षमता की सार्थक विविधता को दर्षाता है, जोकि योज्य एवं अयोज्य आनुवांशिक प्रसरण के महत्व को बताता है। विशिष्ट संयोजन क्षमता प्रसरण की तीव्रता तीनों वातावरणों में सभी लक्षणों के सामान्य संयोजन क्षमता प्रसरण से ज्यादा थी, जोकि अयोज्य प्रसरण की अधिकता व संकर प्रजनन के लिए सामाग्री की अनुकूलता को दर्शाता है। पैतृकों की सामान्य संयोजन क्षमता का प्रभाव इंगित करता है कि पैतृक क्रम, एल 1, एल 2, एल 3, एल 4, ई 01 में, एल 8, एल 4, एल 11, एल 12, एल 13, एल 14 एवं एल 16, ई0 2 में, एल 8, एल 4 एवं एल 7 ई0 3 में और एल1, एल 2, एवं एल 4 संयुक्त वातावरण में एवं परीक्षक टी1 व टी 3 सभी वातावरणों में सबसे अच्छे संयोजक थे। अधिकतम विशिष्ट संयोंजन क्षमता प्रभाव, संकरणों, एल11× टी3, एल14 × टी1 और एल3 × टी1 ई01 में, एल11× टी3 , एल17 × टी3 और एल1 × टी1 ई02 में, एल11 × टी3 ई03 में एवं एल11 × टी3 संयुक्त वातावरण में दानों की उपज व इसमें योगदान करने वाले लक्षणों, साथ ही साथ गुणवत्ता लक्षणों के लिए पाया गया। दृश्यरूपिक स्थायित्व के लिए प्रसरण का संयुक्त विश्लेषण इंगित करता है कि जीन प्ररूपों एवं वातावरणों के माध्यवर्ग अधिकतर लक्षणों के लिए सार्थक थे, जोकि जीन प्ररूपों व वातावरणों के मध्य पर्यापत विविधता को दर्शाता है। गुणवत्ता लक्षणों को छोड़कर, जीन प्ररूप × वातावरणीय सम्बधता की उच्चतम सार्थकता सभी लक्षणों के लिए थी। 21 क्रमों एवं 3 परीक्षकों के मध्य, एल 4, एल 6, एल 10, एल 12, टी1 व टी2 में दानों की उपज एवं इसके संधटकों, साथ ही साथ गुणवत्ता लक्षणों के लिए वांछनीय स्थायित्व को दर्शाती है। 63 एकल संकरणो के मध्य, एल2×टी3, एल3×टी 3, एल5×टी2, एल5×टी3, एल7×टी1, एल7×टी3, एल8×टी1, एल8×टी2, एल8×टी3, एल9×टी3, एल10×टी1, एल10×टी2, एल11×टी2,एल11×टी3, एल12×टी1, एल12×टी3, एल13×टी3, एल14×टी3, एल16×टी2, एल16×टी3, एल17×टी2, एल17×टी3, एल20×टी2, एल20×टी3, एल21×टी1, एल21×टी2 और एल21×टी3 दानों की उपज के लिए स्थायी एवं वांछनीय थे। यद्यपि एल1×टी1, एल1 ×टी3, एल2×टी1, एल2×टी2, एल3×टी3, एल4×टी3, एल6×टी3, एल8×टी2, एल10×टी2, एल10×टी3, एल11×टी1, एल14×टी2, एल15 × टी1, एल16×टी1, एल16×टी2, एल16×टी3, एल17×टी3 और एल20×टी3 को गुणवत्ता लक्षणों के लिए स्थायी एवं वांछनीय पाया गया। समृद्व वातावरण के लिए, क्रम एल 1, एल 2, एल 4, एल 9, एल 13 एवं एल 21 जाचक टी1 एवं टी2 व संकरणों एल1×टी1, एल2×टी1, एल4×टी3, एल6×टी1, एल7×टी3 और एल11×टी1 स्थायी एवं वांछनीय प्रदर्शन को दर्शाते है। यद्यपि असमृद्व वातावरण में एल 1, एल 8, एल 9, एल 13 एवं एल17, जाचक टी1 व टी2 तथा संकरण एल4×टी2, एल5 ×टी2, एल7×टी2, एल18×टी3 एवं एल19 टी2, दाना उपज एवं इसमें योगदान देने वाले लक्षणों के लिए स्थायी व वांछनीय प्रदर्शन को दिखाते है, जबकि गुणवत्ता लक्षणों के लिए दोनों समृद्ध एवं असमृद्ध वातावरणों में कोई भी विशिष्ट संकरण अच्छा नहीं पाया गया।

(एस. एस. वर्मा)
परामर्शदाता

(जितेन्द्र भास्कर)
लेखक