

**STUDIES ON GENETIC DIVERGENCE, COMBINING
ABILITY AND STABILITY FOR PROTEIN, OIL AND
GRAIN YIELD IN MAIZE (*Zea mays* L.) GENOTYPES**

By

FARZANA JABEEN

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THESIS SUBMITTED TO THE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY

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DEPARTMENT OF GENETICS AND PLANT BREEDING
College of Agriculture

Acharya N.G. Ranga Agricultural University
Rajendranagar, Hyderabad – 500 030.

JUNE, 2005

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CERTIFICATE

This is to certify that the thesis entitled “**STUDIES ON GENETIC DIVERGENCE, COMBINING ABILITY AND STABILITY FOR PROTEIN, OIL AND GRAIN YIELD IN MAIZE (*Zea mays* L.) GENOTYPES**” submitted in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY** of the Acharya N.G. Ranga Agricultural University, Hyderabad is a record of the bonafide research work carried out by **Ms. FARZANA JABEEN** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee.

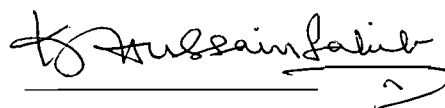
No part of the thesis has been submitted for any other degree or diploma or has been published. The published part has been fully acknowledged. All the assistance and help received during the course of investigation have been duly acknowledged by the author of the thesis.


(**K HUSSAIN SAHIB**)

Chairman of the Advisory Committee

Thesis approved by the student’s Advisory Committee.

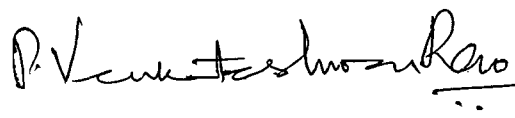
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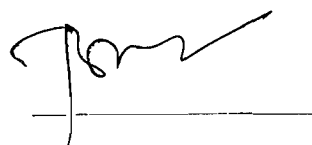
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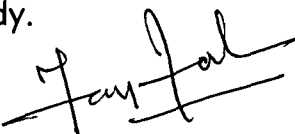
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(FARZANA JABEEN)

DECLARATION

I, Ms. FARZANA JABEEN, hereby declare that the thesis entitled “STUDIES ON GENETIC DIVERGENCE, COMBINING ABILITY AND STABILITY FOR PROTEIN, OIL AND GRAIN YIELD IN MAIZE (*Zea mays* L.) GENOTYPES” submitted to Acharya N.G. Ranga Agricultural University for the degree of DOCTOR OF PHILOSOPHY, is a result of the original research work done by me. I also declare that the thesis or part thereof has not been published earlier elsewhere in any manner.

Date:



(FARZANA JABEEN)

Place: Hyderabad

LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Per cent
σ^2g	:	Genotypic variance
σ^2p	:	Phenotypic variance
<	:	less than
$\geq$	:	More than or equal
ANOVA	:	Analysis of variance
C.D.	:	Critical difference
cm	:	Centimeter
d.f.	:	Degrees of freedom
<i>et al.</i>	:	and others
etc.	:	Extra
F ₁	:	First filial generation
g	:	Gram
gca	:	General combining ability
h ²	:	Heritability in broad sense
ha	:	hectare
<i>i.e.</i>	:	That is
kg ha ⁻¹	:	Kilogram per hectare
kg	:	Kilogram
m	:	Metre
No.	:	Number
sca	:	Specific combining ability
t	:	Tonne
<i>viz.</i>	:	Namely

Author : FARZANA JABEEN

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COMBINING ABILITY AND STABILITY
FOR PROTEIN, OIL AND GRAIN YIELD
IN MAIZE (*Zea mays* L.) GENOTYPES

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University : ACHARYA N. G. RANGA
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ABSTRACT

In the present investigation, 196 maize genotypes comprising Quality Protein Maize (QPM) and High Oil Lines (HOL) were evaluated during *kharif*, 2001 and data were subjected to Mahalanobis D² analysis. Ten divergent parents were selected and crossed in diallel fashion excluding reciprocals during *rabi*, 2001-2002. The resultant 45 crosses along with parents and two standard checks viz., Madhuri and BMH-1620 were evaluated in Randomized Block Design replicated thrice during *kharif*, 2002 at three locations viz., Rajendranagar, Palem and Karimnagar. The data were collected on days to 50 per cent tasseling, days to 50 per cent silking, days to 50 per cent brown husk, ear height, plant height, ear length, ear girth, number of kernel rows per ear, number of kernels per row, number of kernels per ear, 100 kernel weight, protein content, oil content and grain yield and studied for estimation of heterosis, nature of gene action, genetic parameters, character association, G x E interaction and stability.

The combining ability analysis revealed importance of both additive and non-additive gene actions in governing the characters but non-additive gene action was found predominant. Among the parental lines, P₃ (BHOL-107) was good general combiner for earliness viz., days to 50 per cent tasseling, days to 50 per cent silking and days to 50 per cent brown husk. The parents P₅ (BHOL-111) and P₁ (BQPML-142) for protein content, P₆ (BQPML-148) and P₈ (BQPML-152) for oil content and P₁ (BQPML-142), P₆ (BQPML-148), P₇ (BQPML-151) and P₈ (BQPML-152) for grain yield contributed maximum favourable genes. Considering all the characters over three locations, the parents P₁ (BQPML-142), P₆ (BQPML-148) and P₈ (BQPML-152) can be given status of good combiners.

The hybrids, P₃ x P₆ (BHOL-107 x BQPML-148) and P₄ x P₈ (BQPML-145 x BQPML-152) for protein content, P₃ x P₈ (BHOL-107 x BQPML-152) and P₆ x P₈ (BQPML-148 x BQPML-152) for oil content and P₄ x P₁₀ (BQPML-145 x BQPML-157), P₁ x P₄ (BQPML-142 x BQPML-145), P₂ x P₁₀ (BHOL-104 x BQPML-157) and P₁ x P₃ (BQPML-142 x BHOL-107) for grain yield were the

good specific combiners. Hence, these crosses could be advanced further for isolation of transgressive segregants and also to develop good inbred lines.

Estimates of heterosis, heterobeltiosis and standard heterosis were variable among crosses in desirable direction and some of them turned out to be best specific crosses. The cross combinations $P_2 \times P_5$ (BHOL-104 x BHOL-111) and $P_2 \times P_6$ (BHOL-104 x BQPML-148) for earliness, $P_3 \times P_6$ (BHOL-107 x BQPML-148) and $P_6 \times P_8$ (BQPML-148 x BQPML-152) for protein content, $P_6 \times P_8$ (BQPML-148 x BQPML-152) and $P_3 \times P_8$ (BHOL-107 x BQPML-152) for oil content and $P_2 \times P_{10}$ (BHOL-104 x BQPML-157) and $P_1 \times P_3$ (BQPML-142 x BHOL-107) for grain yield were the superior crosses. The hybrids $P_2 \times P_5$ (BHOL-104 x BHOL-111), $P_5 \times P_6$ (BHOL-111 x BQPML-148) and $P_6 \times P_8$ (BQPML-148 x BQPML-152) performed well for protein content, oil content and grain yield.

Estimates of genetic parameters exhibited high heritability coupled with high genetic advance for ear height, plant height, ear length, number of kernels per row, number of kernels per ear, oil content and grain yield may bring about desired improvement in grain yield by selection for these characters. Character association among grain yield and yield contributing characters exhibited that number of kernels per ear, 100 kernel weight, number of kernels per row, ear girth, ear length, plant height and number of kernel rows per ear had significant and positive correlations with grain yield over three locations.

Path coefficient analysis had shown direct relationship of number of kernels per ear, 100 kernel weight, number of kernels per row, number of kernel rows per ear and ear length with grain yield. The indirect effect of these characters on grain yield influenced much by number of kernels per ear and 100 kernel weight.

Genotypes x Environment interaction was significant for days to 50 per cent tasseling, days to 50 per cent silking, days to 50 per cent brown husk, ear height, plant height and number of kernels per row. The non-linear component of G x E interaction alone accounted for variation in respect of days to 50 per cent brown husk, number of kernels per ear, 100 kernel weight and grain yield. The parents P_3 (BHOL-107) and P_8 (BQPML-152) for earliness, P_3 (BHOL-107), P_5 (BHOL-111) and P_{10} (BQPML-157) for protein content, P_3 (BHOL-107), P_5 (BHOL-111), P_9 (BQPML-154) and P_{10} (BQPML-157) for oil content and P_6 (BQPML-148), P_7 (BQPML-151) and P_8 (BQPML-152) for grain yield were stable with desired *per se* performance.

Among the single crosses $P_2 \times P_5$ (BHOL-104 x BHOL-111), $P_5 \times P_6$ (BHOL-111 x BQPML-148) and $P_3 \times P_6$ (BHOL-107 x BQPML-148) for protein content, $P_6 \times P_8$ (BQPML-148 x BQPML-152), $P_3 \times P_8$ (BHOL-107 x BQPML-152) and $P_3 \times P_{10}$ (BHOL-107 x BQPML-157) for oil content, $P_6 \times P_7$ (BQPML-148 x BQPML-151), $P_2 \times P_{10}$ (BHOL-104 x BQPML-157), $P_1 \times P_4$ (BQPML-142 x BQPML-145) and $P_8 \times P_{10}$ (BQPML-152 x BQPML-157) were stable with higher *per se* performance. Considering grain yield, protein content and oil content over three locations, $P_2 \times P_5$ (BHOL-104 x BHOL-111), $P_6 \times P_8$ (BQPML-148 x BQPML-152), $P_7 \times P_8$ (BQPML-151 x BQPML-152) and $P_1 \times P_4$ (BQPML-142 x BQPML-145) were adjudged as the superior crosses.

INTRODUCTION

CHAPTER I

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops and occupies a prominent position in global agriculture. In India, it ranks fourth next to rice, wheat and sorghum with an area of 7.32 million ha, producing 14.92 million tonnes with productivity of 2039 kg ha⁻¹. In Andhra Pradesh, it covers an area of 7.21 lakh hectares with a production of 24.17 lakh tonnes with average productivity of 3436 kg ha⁻¹ (Centre for Monitoring Indian Economy, 2004).

Maize is widely grown in India suggesting its wide adaptability. The crop has assumed a place of prominence in Indian agriculture owing to its varied uses *viz.*, human consumption, poultry feed, green fodder, value added products and industrial usage. Globally 67 per cent of maize is used for livestock feed, 25 per cent for human consumption and rest for industrial purposes. The components of the maize seed include starch, protein, oil, fat and sucrose, due to which it has assumed industrial importance. Maize and its byproducts are being used in diversified industries influencing alcohol production, textile industry, paper industry, pharmaceuticals, cosmetic industry, edible oil industry, poultry feed and many chemical industries.

Maize is an excellent source of carbohydrate and good quality oil, and normally consisting of 5 – 8 % protein, however deficient in two essential amino acids *viz.*, lysine and tryptophan. Whereas, Quality Protein Maize (QPM) consisting of 9 – 12 % protein, which is rich in lysine and tryptophan with balanced amino acid profile provides

improved nutrition diet to the poor. Thus, the protein of QPM has a nutritional value of nearly equivalent to cow's milk.

The oil content in maize varieties, grown commercially in India is about 2 to 4 per cent, while in USA the available high oil corn strains possess as high as 18 to 22 per cent of very good quality oil.

The germ, which accounts for 5 to 14% of the weight of maize kernel, contains about 85 % oil. It also has higher concentration of lysine and tryptophan than the endosperm. Increase in oil and quality protein is accompanied by increase in germ size and by decrease in grain and endosperm weight since higher per cent of oil is confined to the germ. Maize oil is of good quality both from a nutritional stand point for the health of human beings and also in terms of cooking quality. Maize oil is rich in polyunsaturated fatty acid and also contains high level of natural antioxidants, hence maize oil is ideal for heart patients (Godawat and Dwivedi, 1989).

Presently, research efforts are being made to develop QPM and high oil hybrids by utilizing released QPM (opaque 2) and high oil inbreds / populations of CIMMYT and other sources by converting normal elite maize lines through repeated back crosses and recurrent selection procedures.

In this direction, the present investigation entitled “**Studies on genetic divergence, combining ability and stability for protein, oil and grain yield in maize (*Zea mays* L.) genotypes**” was undertaken utilizing 196 Quality Protein Maize (QPM) and High Oil Lines (HOL) for genetic divergence studies. Selected 10 divergent, parents were

utilized for diallel crossing excluding reciprocals and 45 crosses generated. These resultant crosses along with parents and checks were evaluated for stability on yield, its components, protein and oil in maize genotypes and also to identify superior parents and crosses with quality protein coupled with high oil and grain yield which could be used in the future breeding programme to develop QPM / HOL hybrids for commercial cultivation with the following objectives:

1. To study the extent of variability for protein, oil and yield in Quality Protein Maize (QPM) genotypes
2. To study the correlations between protein, oil and yield characters
3. To study the combining ability for high protein coupled with high oil and grain yield
4. To study the stability of yield and its component characters

*REVIEW OF
LITERATURE*

CHAPTER II

REVIEW OF LITERATURE

Maize is one of the most intensively studied crops and hence, a wealth of information is available on genetics of several hereditary parameters. The literature available on genetic analysis of yield and its components in maize (*Zea mays* L.) is reviewed under the following sub heads.

- 2.1 Genetic Divergence
- 2.2 Heritability and genetic advance
- 2.3 Combining ability analysis
- 2.4 Heterosis
- 2.5 Correlation studies
- 2.6 Path coefficient analysis
- 2.7 Stability analysis

2.1 GENETIC DIVERGENCE

Genetic diversity is the basic for any crop improvement programme. The hybrids involving the parents with more diversity among them are expected to exhibit higher amount of heterotic expression and broad spectrum of variability in segregating generations.

The D^2 statistic is useful tool to assess the genetic divergence among population. It also provides a quantitative measure of association

between geographic and genetic diversity based on generalized distance (Mahalanobis, 1936).

Saxena and Sandhu (1989) studied one hundred and forty populations of maize for divergence using D^2 technique and observed wide diversity and these diverse population identified by multivariate analysis could be used in hybrid composite breeding programme.

Genetic divergence was studied by Singh *et al.* (1999) for yield and other related parameters for fifty five inbred lines of maize and the inbreds were grouped into 5 clusters. Based on mean performance, genetic distance and clustering pattern, the inbreds of cluster I, IV and III can be used as parents to develop single or double cross hybrids.

Teixeira *et al.* (2002) studied genetic divergence for 169 maize accessions using 15 characters. All the germplasm evaluated showed differences, making possible the identification of germplasm with special characters. The flint group was the most divergent followed by the semident, floury and dent groups.

Thirty elite maize inbred lines were evaluated for genetic divergence for 18 traits using Mahalanobis D^2 statistics by Khumkar and Singh (2002). Significant diversity was observed among the inbred lines grouped into six clusters. The greatest intracluster distance was recorded for cluster IV, whereas the greatest inter cluster distance was observed

between cluster III and V. Among the characters evaluated, panicle length, plant height, 100 kernel weight, ear diameter and number of kernels per row had the greatest contribution towards genetic divergence.

Miranda *et al.* (2003) assessed genetic divergence in nine tropical popcorn cultivars using multivariate analysis and cultivars were grouped into 4 clusters mainly for grain yield and cultivars showed significant genetic divergence.

2.2 HERITABILITY AND GENETIC ADVANCE

Heritability is the proportion of total genotypic variance to total phenotypic variance. Genetic advance is the gain obtained through selection of superior individuals, which can be evaluated from heritability values. Basic information on heritability and genetic advance controlling the yield and yield components is a prerequisite for planning any breeding programme. Though the heritable estimates give useful indication of relative values of selection based on phenotypic expression, heritability values along with the genetic gain has to be considered jointly to arrive at a more reliable conclusion (Johnson *et al.*, 1955).

Ramamurthy *et al.* (1970) reported high and low heritability estimates for days to silking and 100 grain weight respectively, while Singh and Sharma (1970) reported low heritability for silking days and

100 grain weight and high genetic advance for plant height, number of grains per ear and grain yield.

Khehra *et al.* (1985) presented information on the genetic variance and heritability on grain yield per plant and four selected traits following analysis of data from 64 half sib and 256 full sib families. The expected genetic advance per selection cycle was highest for full sib selection followed by half-sib and mass selection.

Kumar and Singh (1986) analyzed the data on grain yield per plant from forty diverse genotypes and recorded high heritability (90.62%) and genetic advance (73.14%). Heritability for plant height, panicle weight, internode length and 1000 grain weight varied from 85.3% to 93.9% indicating desirable selection of these traits for crop improvement.

Lamkey and Hallauer (1987) calculated heritability and other genetic parameters for yield using variances among progenies for 121 selection experiments. The estimates for heritability from pooled analysis were 68% (full-sib), 58.5% (half-sib), 54.9% (full-sib reciprocal recurrent selection), 79.8% (S1 *per se* progeny), 77.3% (S2 *per se* progeny), 53.3% (test cross with an inbred tester) and 62.7% (test cross with a broad based tested). The estimate of heritability was smaller for S2 than S1 selection due to the importance of dominance effects in the individual populations under going selection.

Gouesnard *et al.* (1989) showed high heritability for plant height and ear height, while moderate to high heritability values for rows per ear (23.5%) and grains per row (67%) were reported by Hosary (1989) in composite variety, cabo 1.

Reddy and Agarwal (1992) reported a genetic advance of 8.90% for plant height and high heritability for ear height. According to Saha and Mukherjee (1993) high genetic advance and heritability were recorded for number of grains per row and grain yield per plant.

Ayala Osuna and Churata (1995) reported heritability estimates for grain yield (33.7%), plant height (54.6%) and ear height (63.4%) which indicated good potential for grain yield improvement as well as reduction in plant height and ear height through recurrent selection.

High heritability along with high genetic advance was exhibited by days to silking, grain yield and ear height whereas for plant height, the values were moderate and low for rest of the characters *viz.*, days to maturity and 100 grain weight (Mani and Bisht, 1996).

Fountain and Hallauer (1996) based on their studies on nine different populations reported that the integration of two primary maize breeding methods *viz.*, pedigree selections within F_2 populations and

genetic improvement of broad-base, synthetic populations is appropriate for continued genetic advance.

Tusuz and Balabandi (1997) reported highest heritability in the broad sense for 50 per cent silking (0.93) and it was low for plant height (0.12), ear height (0.31) and yield (0.06).

Samanch *et al.* (1998) reported high heritability for characters viz., plant height (0.58), ear height (0.47) and days to 50 per cent tasseling (0.53).

Singha and Prodhan (2000) reported high heritability estimates along with high expected genetic advance for gross ear yield, ear height ear length and total soluble solids. The yield attributing characters viz., days to 50 per cent silking, ear length, ear height, number of seed rows per cob, 100 seed weight, protein content, oil content and grain yield had high heritability whereas days to 50 per cent tasseling recorded moderately high heritability coupled with low GCA indicating the predominance of non-additive gene action and hence improvement of such traits is possible through heterosis breeding programme (Krishnam Raju, 2001).

Yadav *et al.* (2002) concluded that the heritability values estimated on individual diallel sets revealed that test weight, plant

height and cob width were highly heritable under both irrigated and rainfed conditions.

Kabdal *et al.* (2003) reported that heritability estimates and genetic advance were high for grain yield, ear height, plant height and ear length.

Satyanarayana *et al.* (2003) recorded high heritability with moderate genetic advance as per cent of mean for plant height, oil and protein content. Oil yield exhibited relatively high heritability coupled with higher genetic advance indicating better scope for the improvement of this trait through direct selection.

Srinivasu (2004) reported that the characters grain yield, oil yield, protein yield, oil content, protein content, 100 seed weight, days to 50 per cent silking and number of seed rows / cob had higher heritability with genetic advance as per cent of mean.

2.3 COMBINING ABILITY ANALYSIS

Combining ability of the inbred lines is the ultimate factor for determining future usefulness of the lines. Combining ability is a general concept of classifying inbred lines relative to their cross performance.

Sprague and Tatum (1942) elaborated the concept of

general combining ability (GCA) as the “average performance of a line in hybrid combinations” while the specific combining ability (SCA) as the “deviation from performance predicted on the basis of GCA”. They revealed in their experiments using single crosses in maize that general combining ability (GCA) is primarily due to additive effect of genes and specific combining ability (SCA) is due to non additive effect of genes.

Griffing (1956 a, 1956 b) proposed a generalized concept and methodology for combining ability analysis of diallel crosses with two models and four methods in each model.

In model - I (Fixed Effect Model), parent materials are selected with some purpose and the results obtained are applicable to the materials investigated. The main interest lies in estimation of combining ability effects. In model – II (Random Effect Model), the parents are random samples from the populations about which the inferences are to be drawn. Here the interest lies in estimation of different genetic components of the population variance.

In maize, several workers have studied combining ability and gene action controlling traits as given below.

Summary of review of different types of combining ability variances in maize

Sl.No.	Character	General combining ability (GCA)	Specific combining ability (SCA)	Both GCA and SCA
1	Days to 50% tasseling	Russel and Stuber (1985), Singh <i>et al.</i> (1998), Choudhary <i>et al.</i> (2000), Kabdal <i>et al.</i> (2003)	Murthy <i>et al.</i> (1981), Lee (1983), Guo <i>et al.</i> (1986), Widstrom <i>et al.</i> (1993), Venugopal <i>et al.</i> (2002), Yadagiri (2004)	Hassaballa <i>et al.</i> (1980),Lee (1983), Pal and Proadhan (1994), Paul and Debnath (1999)
2	Days to 50% Silking	Ottaviano and Camussi (1981), Beck <i>et Murthy et al.</i> (1981), Ramesha (1988), <i>al.</i> (1990),Newton and Eagles (1991), Vasal Dodiya and Joshi (2003), Venugopal <i>et al.</i> (1992), Pandey <i>et al.</i> (1994), Altinbas <i>al.</i> (2002), Yadagiri (2004) (1995), Singh <i>et al.</i> (1998), Leta Tulu and Ramachandrappa (1998), Mathur <i>et al.</i> (1998), Geetha (2000)		Dhillon and Singh (1977b), Hassaballa <i>et al.</i> (1980),Vasal <i>et al.</i> (1993), Pal and Pdrodhan (1994), Singh and Mishra (1996), Paul and Debnath (1999)
3	Days to 50% brown husk	Ottaviano and Camussi (1981), Beck <i>et Murthy et al.</i> (1981), Ramesha (1988), <i>al.</i> (1990),Newton and Eagles (1991), Vasal Dodiya and Joshi (2003), Venugopal <i>et al.</i> (1992), Altinbas (1995), Singh <i>et al.</i> (2002), Yadagiri (2004) <i>al.</i> (1998), Leta Tulu and Ramachandrappa (1998), Mathur <i>et al.</i> (1998), Geetha (2000)		Dhillon and Singh (1977b), Vasal <i>et al.</i> (1993), Pal and Pdrodhan (1994), Singh and Mishra (1996), Paul and Debnath (1999)
4	Ear height	Zamberi <i>et al.</i> (1986), Salem <i>et al.</i> (1986), Pandey <i>et al.</i> (1994), Altinbas (1995), Singh <i>et al.</i> (1998),Leta Tulu and Ramachandrappa (1998), Zelleke (2000), Venkat Nagesh kumar (2001)	Dhillon and Singh (1977b), Widstrom <i>et al.</i> (1993), Venugopal <i>et al.</i> (2002), Srinivasu (2004)	Dhillon and Singh (1977c), Hassaballa <i>et al.</i> (1980), Qadri <i>et al.</i> (1983), El-Hosary and Sedhom (1990), Beck <i>et al.</i> (1990), Muralikrishna and Patil (1992), Lima <i>et al.</i> (1995), Paul and Debnath (1999), Kabdal <i>et al.</i> (2003), He <i>et al.</i> (2003), Aguiar <i>et al.</i> (2003)
5	Plant height	Salem <i>et al.</i> (1986), Beck <i>et al.</i> (1990), Vasal <i>et al.</i> (1992), Ajala(1993), Singh <i>et al.</i> (1998a), Leta Tulu and Ramachandrappa (1998), Zelleke (2000), Kabdal <i>et al.</i> (2003), Geetha (2000)	Pajic (1986), Herbert and Gallais (1986), Altinbas (1995), Singh and Singh (1998), Venugopal <i>et al.</i> (2002), Yadagiri (2004)	Hassaballa <i>et al.</i> (1980), Lin and Chen (1986), Vasal <i>et al.</i> (1993), Lima <i>et al.</i> (1995), Paul and Debnath (1999), Aguiar <i>et al.</i> (2003), Gautam (2003), He <i>et al.</i> (2003)

Sl.No.	Character	General combining ability (GCA)	Specific combining ability (SCA)	Both GCA and SCA
6	Ear length	Salem <i>et al.</i> (1986), Liao <i>et al.</i> (1987), Ivanov and Tomov (1995), Mathur <i>et al.</i> (1998), Singh and Singh (1998), Kabdal <i>et al.</i> (2003)	Pajic (1986), Muralikrishna and Patil (1992), Pal and Prodhan (1994), Choudhary <i>et al.</i> (2000), Venugopal <i>et al.</i> (2002), Yadagiri (2004)	Dhillon and Singh (1977b), Shen and Lai (1987), Alika(1994), Singh and Mishra (1996), Ivanov(1998), Gautam (2003), He <i>et al.</i> (2003)
7	Ear girth	Shahi and Singh (1986), Salem <i>et al.</i> (1986), Prasad <i>et al.</i> (1988), Pal and Prodhan (1994),Alika (1994), Mathur <i>et al.</i> (1998)	Debnath <i>et al.</i> (1983), Nagda <i>et al.</i> (1995), Singh and Singh (1998), Venugopal <i>et al.</i> (2002), Srinivasu (2004)	Qadri <i>et al.</i> (1983), Singh and Mishra (1996)
8	Number of Kernel rows per ear	Ottaviano and Camussi (1981), Pajic (1986), Mathur <i>et al.</i> (1998), Singh and Singh(1998), Choukan (1999), Kabdal <i>et al.</i> (2003)	Khristova <i>et al.</i> (1983), Ali and Topera (1986), Muthaiah <i>et al.</i> (1989), Pal and Prodhan (1994), Venugopal <i>et al.</i> (2002)	Ivanov and Tomov (1995), El Hosary and Sedhom (1990), Venkat Nagesh Kumar (2001), Aguiar <i>et al.</i> (2003), He <i>et al.</i> (2003)
9	Number of Kernels per Row	Salem <i>et al.</i> (1986), Prasad <i>et al.</i> (1988), Mathur <i>et al.</i> (1998), Choukan (1999), Geetha (2000)	Pal and Prodhan (1994), Nagda <i>et al.</i> (1995), Singh and Singh (1998), Venugopal <i>et al.</i> (2002), Yadagiri (2004)	Ottaviano and Camussi (1981), El-Hefnawy and El-Zeir (1991) Ivanov (1998), He <i>et al.</i> (2003)
10	Number of Kernels per Ear	Salem <i>et al.</i> (1986), Prasad <i>et al.</i> (1988), Mathur <i>et al.</i> (1998), Choukan (1999), Geetha (2000)	Pal and Prodhan (1994), Nagda <i>et al.</i> (1995), Singh and Singh (1998), Venugopal <i>et al.</i> (2002), Srinivasu (2004)	Ottaviano and Camussi (1981), El-Hefnawy and El-Zeir (1991) Ivanov (1998), He <i>et al.</i> (2003)
11	100 kernel weight	Salem <i>et al.</i> (1986), Pal and Prodhan (1994), Alika (1994), Joshi <i>et al.</i> (1998), Geetha (2000), He <i>et al.</i> (2003), Kabdal <i>et al.</i> (2003)	Pajic (1986), Liao <i>et al.</i> (1987), Debnath <i>et al.</i> (1988), Nagda <i>et al.</i> (1995), Zelleke (2000), Venugopal <i>et al.</i> (2002), Srinivasu (2004)	Lin and Chen (1986), Singh and Mishra(1996), El-Hosary and Sedhom (1990), Venkat Nagesh Kumar (2001), Gautam (2003)

Sl.No.	Character	General combining ability (GCA)	Specific combining ability (SCA)	Both GCA and SCA
12	Protein content		Venugopal <i>et al.</i> (2002), Shanthi <i>et al.</i> (2002) Yadagiri (2004)	
13	Oil content		Satyanarayana (1990), Pal and Prodhana (1994), Kumar (1997), Kumar <i>et al.</i> (1997), Shanthi <i>et al.</i> (2002) Venugopal <i>et al.</i> (2002), Yadagiri (2004)	
14	Grain yield per plot	Gerrish (1983), Lee (1983), Kimani (1984), Zamberi <i>et al.</i> (1986), Mungoma and Pollak (1988), Genova (1988), Beck <i>et al.</i> (1990), Vasal <i>et al.</i> (1992), Vasal <i>et al.</i> (1993), Ajala (1993), Ferrao <i>et al.</i> (1994), Pandey <i>et al.</i> (1994), Leta Tulu and Ramachandrappa (1988), Mathur <i>et al.</i> (1998), Singh <i>et al.</i> (2000), Aguiar <i>et al.</i> (2003), He <i>et al.</i> (2003), Kabdal <i>et al.</i> (2003)	Pajic (1986), Liao <i>et al.</i> (1987), Debnath and Sarkar (1987), Han <i>et al.</i> (1991), Jha and Khehra (1992), Widstrom <i>et al.</i> (1993), Ivanov and Tomov (1995), Altinbas (1995), Joshi <i>et al.</i> (1998), Singh and Singh (1998), Choudhary <i>et al.</i> (2000), Zelleke (2000), Singh <i>et al.</i> (2000), Shanthi <i>et al.</i> (2002) Srinivasu (2004) Yadagiri (2004)	Odongo (1983), Baktash <i>et al.</i> (1985), Salem <i>et al.</i> (1986), Lin and Chen (1986), Lee (1987), Ramesha (1988), El-Hosary and Sedhom (1990), Perez <i>et al.</i> (1991), Pixley and Bjarnasou (1993), Pal and Prodhana (1994), Lima <i>et al.</i> (1995), Gama <i>et al.</i> (1995), Singh and Mishra (1996), Veragara <i>et al.</i> (1998), Paul and Debnath (1999), Nass <i>et al.</i> (2000) Venkat Nagesh, Kumar (2000), Singh <i>et al.</i> (2000), Gautam (2003)

Summary of work done on gene action in maize

Sl.No.	Character	Additive	Non-additive	Both additive and non-additive
1	Days to 50% tasseling	Rood and Major (1980), Hassaballa <i>et al.</i> (1980), Murthy <i>et al.</i> (1981), Sanghi <i>et al.</i> (1983), Mungoma and Pollak (1988), Gouesnard <i>et al.</i> (1989), Pal and Prodhan (1994), Mathur and Bhatnagar (1995), Malvar <i>et al.</i> (1996), Singh <i>et al.</i> (1998), Choudary <i>et al.</i> (2000)	Nawar and E.I-Hosary (1984), Guo <i>et al.</i> (1986), Venugopal <i>et al.</i> (2002), Yadav <i>et al.</i> (2002), Yadagiri (2004)	Mukherjee <i>et al.</i> (1971), Hassaballa <i>et al.</i> (1980), Ramesha (1988)
2	Days to 50% silking	Dhillon and singh (1977c), Hassaballa <i>et al.</i> (1980), Murthy <i>et al.</i> (1981), Sanghi <i>et al.</i> (1983), pal <i>et al.</i> (1986), Mungoma and pollak (1998), Pal and Prodhan (1994), Altinbas (1995), Mathur and Bhatnagar (1995), Nagda etal. (1995), Malvar <i>et al.</i> (1996), Singh <i>et al.</i> (1998), Leta Tulu and Ramchandrappa (1998), Mathur <i>et al.</i> (1998), Krishanam Raju (2001)	Crossa <i>et al.</i> (1990), Paul and Duara (1991), Appunu (2002), Venugopal <i>et al.</i> (2002), Yadav <i>et al.</i> (2002), Srinivasu (2004)	Bhalla and Khehra (1980), Hassaballa <i>et al.</i> (1980), Ramesha (1988), Leon <i>et al.</i> (1989).
3	Days to 50% Brown husk	Dhillon and singh (1977c), Hassaballa <i>et al.</i> (1980), Murthy <i>et al.</i> (1981), Sanghi <i>et al.</i> (1983), Nagda <i>et al.</i> (1995), Malvar <i>et al.</i> (1996), Singh <i>et al.</i> (1998), Leta Tulu and Ramchandrappa (1998), Mathur <i>et al.</i> (1998), Krishanam Raju (2001)	Crossa <i>et al.</i> (1990), Paul and Duara (1991), Venugopal <i>et al.</i> (2002), Yadav <i>et al.</i> (2002), Srinivasu (2004)	Bhalla and Khehra (1980), Hassaballa <i>et al.</i> (1980), Ramesha (1988), Leon <i>et al.</i> (1989).

Sl.No.	Character	Additive	Non-additive	Both additive and non-additive
4	Ear height	Dhillon and singh (1977b), Harville and Josephson (1979), Qadri <i>et al.</i> (1983) Nawar (1986), Gouesnard <i>et al.</i> (1989), El-Hefnawy and El Zeir (1991), Lima <i>et al.</i> (1995), Altinbas (1995), Singh <i>et al.</i> (1998) Leta Tulu and Ramachandrappa (1998), Zelleke (2000), Krishnam Raju (2001), Aguiar <i>et al.</i> (2003)	Mukherjee <i>et al.</i> (1974), Dhillon and Singh (1977c), Mathur and Bhatnagar (1995), Malvar <i>et al.</i> (1996), Appunu (2002), Venugopal <i>et al.</i> (2002)	Mukherjee <i>et al.</i> (1974), Pal <i>et al.</i> (1986), Debnath and Sarkar (1987), Mungoma and Pollak (1988), Rao <i>et al.</i> (1991), Gribincea (2002)
5	Plant height	Salem <i>et al.</i> (1986), Nawar (1986), Hallauer and Miranda (1988), Crossa <i>et al.</i> (1990), El-Hefnawy and El-Zeir (1991), Lima <i>et al.</i> (1995), Singh <i>et al.</i> (1998), Leta Tulu and Ramachandrappa (1998), Zelleke (2000), Aguiar <i>et al.</i> (2003)	Ivanovic (1979), Mahmoud <i>et al.</i> (1990), Mathur and Bhatnagar (1995), Malvar <i>et al.</i> (1996), Venugopal <i>et al.</i> (2002), Yadav <i>et al.</i> (2002), Srinivasu (2004)	Mukherjee <i>et al.</i> (1974), Pal <i>et al.</i> (1986), Debnath and Sarkar (1987), Venkat Nagesh Kumar (2001), Gribincea (2002)
6	Ear length	Qadri <i>et al.</i> (1983), Pal <i>et al.</i> (1986), Nawar (1986), Hallauer and Miranda (1988), Mahmoud <i>et al.</i> (1990), El-Hefnawy and El Zeir (1991), Alike (1994), Mathur <i>et al.</i> (1998), Krishnam Raju (2000), Yu <i>et al.</i> (2003)	Mukherjee <i>et al.</i> (1974), Ivanovic (1979), Genova (1988), Pajic (1986), Stuber <i>et al.</i> (1987), Satyanarayana <i>et al.</i> (1990), Pal and Prodhan (1994), Mathur and Bhatnagar (1995), Nagda <i>et al.</i> (1995), Malvar <i>et al.</i> (1996), Choudary <i>et al.</i> (2000), Appunu (2002), Venugopal <i>et al.</i> (2002)	Kalsy and Sharma (1970), Mukherjee <i>et al.</i> (1974), Setty (1975), Mukherjee and Dhawan (1970), Saha (1981), Debnath and Sarkar (1990), Venkat Nagesh Kumar (2001)
7	Ear girth	Wright <i>et al.</i> (1971), Mukherjee <i>et al.</i> (1974), Dhillon and Singh (1977c), Qadri <i>et al.</i> (1983), Nawar (1986), Pal <i>et al.</i> (1986), Hallauer and Miranda (1988), El-Hefnawy and El Zeir (1991) Pal and Prodhan (1994), Alike (1994), Mathur <i>et al.</i> (1998)	Debnath <i>et al.</i> (1998), Satyanarayana <i>et al.</i> (1990), Debnath and Sarkar (1990), Nagda <i>et al.</i> (1995), Mathur and Bhatnagar (1995), Appunu (2002), Venugopal <i>et al.</i> (2002), Yadav <i>et al.</i> (2002), Yu <i>et al.</i> (2003), Srinivasu (2004)	Saha and Mukherjee (1979), Saha (1981), Ahuja <i>et al.</i> (1983)

Sl.No.	Character	Additive	Non-additive	Both additive and non-additive
8	Number of Kernel rows per ear	Wright <i>et al.</i> (1971), Mukherjee <i>et al.</i> (1974), Dhillon and Singh (1977), Qadri <i>et al.</i> (1983), Nawar (1986), Pal <i>et al.</i> (1986), Satmari (1988), Leon <i>et al.</i> (1989), El-Hefnawy and El Zeir (1991), Pal and Prodhan (1994), Nagda <i>et al.</i> (1995), Malvar <i>et al.</i> (1996), Mathur <i>et al.</i> (1998), Krishnam Raju (2001), Yu <i>et al.</i> (2003)	Khristova <i>et al.</i> (1983), Satyanarayana <i>et al.</i> (1990), El-Hosary and Sedhom (1990), Mathur and Bhatnagar (1995), Venugopal <i>et al.</i> (2002), Yadagiri (2004)	Singh <i>et al.</i> (1977b), Debnath <i>et al.</i> (1988), Debnath and Sarkar (1990), Choukan (1999), Venkat Nagesh Kumar (2001)
9	Number of Kernels per Row	Johnson (1973), Ottaviano and Camussi (1981), Salem <i>et al.</i> (1986), Mathur <i>et al.</i> (1998), Krishnam Raju (2001), Yu <i>et al.</i> (2003)	Nawar <i>et al.</i> (1980), El Hosary and Sedhom (1990), Pal and Prodhan (1994), Mathur and Bhatnagar (1995), Nagda <i>et al.</i> (1995), Appunu (2002), Venugopal <i>et al.</i> (2002), Srinivasu (2004)	Debnath <i>et al.</i> (1988), Debnath and Sarkar (1990), Choukan (1999)
10	Number of Kernels per Ear	Johnson (1973), Ottaviano and Camussi (1981), Mathur <i>et al.</i> (1998), Krishnam Raju (2001), Yu <i>et al.</i> (2003)	Nawar <i>et al.</i> (1980), El Hosary and Sedhom (1990), Pal and Prodhan (1994), Appunu (2002), Venugopal <i>et al.</i> (2002), Yadagiri (2004)	Debnath <i>et al.</i> (1988), Debnath and Sarkar (1990), Choukan (1999)
11	100 kernel weight	Kumar (1974), Ramamurthy (1978), Leon <i>et al.</i> (1989), Salem <i>et al.</i> (1986), El-Hefnawy and El-Zeir (1991), Pal and Prodhan(1994), Alike(1994), Malvar <i>et al.</i> (1996), Joshi <i>et al.</i> (1998), Krishnam Raju (2001)	Khristova <i>et al.</i> (1983), Kimani (1984), Pajic (1986), Liao <i>et al.</i> (1987), Debnath <i>et al.</i> (1988), Mahmoud <i>et al.</i> (1990), Debnath and Sarkar (1990), Nagda <i>et al.</i> (1995), Mathur and Bhatnagar (1995), Zelleke (2000), Appunu (2002), Venugopal <i>et al.</i> (2002), Yu <i>et al.</i> (2003), Srinivasu (2004)	Ramamurthy (1978), Singh <i>et al.</i> (1979), Pal <i>et al.</i> (1986), Ramesha (1988), Venkat Nagesh Kumar (2001), Yadav <i>et al.</i> (2002)

Sl.No.	Character	Additive	Non-additive	Both additive and non-additive
12	Protein content	Krishnam Raju (2001)	Legesse <i>et al.</i> (1998), Venugopal <i>et al.</i> (2002), Yadagiri (2004)	Zarkadas <i>et al.</i> (2000)
13	Oil content	Krishnam Raju (2001)	Arnel and Miranda (1989), Srinivasu (2004)	Lina and de Lima (2000)
14	Grain yield per plot	Robinson <i>et al.</i> (1955), Sprague and Russel (1957), Choudhary (1964), Stuber <i>et al.</i> (1966) Hallauer and Wright (1967), Hallauer (1968), Singh <i>et al.</i> (1971), Wright <i>et al.</i> (1971),Singh <i>et al.</i> (1977a), Singh <i>et al.</i> (1977b), Sanghi <i>et al.</i> (1983), Khamis (1983), Nawar (1986), Pal <i>et al.</i> (1986), Lee (1987), Cosmin <i>et al.</i> (1991), El-Hosary and Sedhom (1990), Paul and Duara (1991), Gama <i>et al.</i> (1995), Leta Tulu and Ramachandrappa (1998), Mathur <i>et al.</i> (1998),Krishnam Raju (2001), Yu <i>et al.</i> (2003)	Hull (1952), Matzinger <i>et al.</i> (1959), Stuber <i>et al.</i> (1966), Mukherjee and Dhawan (1970), Wright <i>et al.</i> (1971), Darrah and Hallauer (1972), Cornelius and Dudley (1976), Dhillon and Singh (1977a), Murthy <i>et al.</i> (1981), Khristova <i>et al.</i> (1983), Pajic (1986), Guo <i>et al.</i> (1986), Debnath <i>et al.</i> (1988), Mahmoud <i>et al.</i> (1990), Pal and Prodhan (1994), Mathur and Bhatnagar (1995), Nagda <i>et al.</i> (1995), Malvar <i>et al.</i> (1996), Joshi <i>et al.</i> (1998), Choudhary <i>et al.</i> (2000), Zelleke (2000) Appunu (2002), Venugopal <i>et al.</i> (2002), Srinivasu (2004), Yadagiri (2004)	Moll <i>et al.</i> (1960), Eberhart (1971) Mukherjee <i>et al.</i> (1971, 1974), Johnson (1973), Kumar (1974), Setty (1975), Singh <i>et al.</i> (1979) Saha and Mukherjee (1979), Pinto <i>et al.</i> (1988), Muthaiah, <i>et al.</i> (1989), Sharma and Bhalla (1993), Choukan (1999), Nass <i>et al.</i> (2000), Venkat Nagesh Kumar (2001), Gribincea (2002), Yadav <i>et al.</i> (2002), Aguiar <i>et al.</i> (2003)

It is usually necessary to assume that there is no epistasis when giving a genetic interpretation to diallel statistics. Gilbert (1958) concluded that such an assumption could be justified on an empirical basis.

Singh and Joshi (1966) from their studies on line x tester analysis reported that non additive effects were of greater importance and suggested to use single or double crosses as testers involving inbreds with high SCA and also indicated that parental performance itself was not necessarily a guarantee of its usefulness in breeding programmes.

Ottaviano *et al.* (1970) reported preponderance of additive gene action for ear weight, whereas for other yield components a complex of gene interactions along with additive effect was noticed.

Inone and Kaneko (1974) found that the genetic differences were closely associated with SCA effects in crosses involving the inbreds.

Arunachalam (1976) emphasized that combining ability analysis operated with feasible and practical assumptions and hence more realistic to plant breeding problems. This model operates under the sole assumption that parents of the diallel cross are inbreds and have an advantage of maintenance of genetic uniformity when the hybrids and the parents are raised in plots (usually one row or few rows) in the field.

The qualitative characters can be measured on a random sample of plants from a plot. The estimates of the variance due to GCA and SCA provide an apt diagnosis of the predominant role of the additive / non additive gene action. The GCA and SCA effects will help to locate the parents and crosses that are responsible in establishing a particular type of gene action.

Simmonds (1979) concluded that the attraction of combining abilities provide empirical survey of complex observations and a reasonable basis for forecasting the performance of untested crosses. They are statistically robust due to their dependence on first degree statistics (means) and they are equally applicable to in breeders and out breeders, whether seed propagated or clonal.

Pal and Prodhan (1994) reported that the mean square estimates for both GCA and SCA were significant for maturity, oil content and grain yield. SCA components were higher than GCA components for above characters indicating the importance of non additive gene effects in controlling these traits.

Combining ability studies for oil improvement in maize (Kumar *et al.*, 1999) at Rajendranagar revealed a preponderance of non-additive gene action for grain yield, yield attributing characters and oil content.

Studies were conducted (Nass *et al.*, 2000) in tropical areas to examine the combining abilities and their interaction with environments in ten selected maize inbred lines in diallel crosses for identifying promising hybrid combinations. The combining ability analysis of diallel data across environments showed highly significant ($P < 0.01$) effects for environment, GCA, SCA and GCA x environment interaction. The SCA x environment interaction was not significant.

Direction of combining ability effects provides useful inference to plant breeders, for example, probability of obtaining heterosis in a single cross, when the divergence in the direction of GCA effects of parents is ensured and found to be high when the SCA effect is not significant. The literature on combining ability and gene action since 1970's in maize have been summarized for yield and yield attributing characters.

2.4 HETEROSIS

Heterosis is expressed as percentage increase or decrease of F_1 hybrid over the mid parental value. The superiority of F_1 hybrid over the better of two parents is known as heterobeltiosis while F_1 superiority over the standard check is termed as standard heterosis.

Shull (1952) explained the heterosis concept in maize. Heterosis results in increased yield, early maturity, taller plants and seed weight.

Non-allelic interaction might be the cause of heterosis rather than the special relation between the genes at same locus (Jinks, 1955). Falconer (1960) explained heterosis as complementary to inbreeding depression. Heterosis is directly proportional to Σdy^2 where 'd' is the degree of dominance component of gene action and 'y' is the difference in the gene frequencies of the parents involved in the cross. The success of heterosis breeding depends on the amount of genetic diversity present in the material.

Ganguli *et al.* (1989) reported positive heterosis over the better parent for grain yield, ear height, plant height and days to silking. Beck *et al.* (1990) observed low and moderate heterosis over the better parent. Sharma and Bhalla (1991) found high heterosis for grain yield. Dubey *et al.* (2001) from their studies reported significant heterotic response for oil content.

The literature available on heterosis was summarized and presented below:

Summary of review of heterosis in maize

Characters with significant relative heterosis	References
Days to 50 per cent tasseling	Daniel and Bajbay (1976), Rama Murthy (1978), Hassaballa <i>et al.</i> (1980), Widstom <i>et al.</i> (1993), Mandal (1996) and Venkatesh (1997), Yadav <i>et al.</i> (2002), Venugopal <i>et al.</i> (2002), Kabdal <i>et al.</i> (2003), Yadagiri (2004)
Days to 50 per cent silking	Daniel and Bajbay (1976), Dhillon and Singh (1977a), Rama Murthy (1978), Crossa <i>et al.</i> (1990), Vasal <i>et al.</i> (1992 a, b), Altinbas (1995), Mandal (1996), Venkatesh (1997) and Vasal <i>et al.</i> (1999), Rama (2001), Yadav <i>et al.</i> (2002), Venugopal <i>et al.</i> (2002), Yadagiri (2004)
Days to 50 per cent brown husk	Altinbas (1995), Mandal (1996), Venkatesh (1997) and Vasal <i>et al.</i> (1999), Rama (2001), Yadav <i>et al.</i> (2002), Venugopal <i>et al.</i> (2002), Yadagiri (2004)
Ear Height	Dhillon and Singh (1977 a), Lin and Chen (1986), Beck <i>et al.</i> (1990), Bhatnagar <i>et al.</i> (1993), Pandey <i>et al.</i> (1994), Mandal (1996) and Venkatesh (1997), Rama (2001), Yadav <i>et al.</i> (2002), Venugopal <i>et al.</i> (2002), Kabdal <i>et al.</i> (2003), Srinivasu (2004)
Plant Height	Dhillon and Singh (1977 a), Mabo (1977), Rama Murthy (1978), Hassaballa <i>et al.</i> (1980), Todorov (1981), Crossa <i>et al.</i> (1987), Misevic (1989 c), Beck <i>et al.</i> (1990), El Hefnawy and El Zeir (1991), Bhatnagar <i>et al.</i> (1993), Mandal (1996) and Venkatesh (1997) Rama (2001), Yadav <i>et al.</i> (2002), Venugopal <i>et al.</i> (2002), Kabdal <i>et al.</i> (2003), Yadagiri (2004)

Characters with significant relative heterosis	References
Ear Length	Verma and Singh (1980), Nawar and Khamis (1983), Debnath (1984), Mukherjee and Saha (1984), Tomov and Min (1990), Mandal (1996), Venkatesh (1997), Yadav <i>et al.</i> (2002), Venugopal <i>et al.</i> (2002), Srinivasu (2004)
Ear girth	Yurankova <i>et al.</i> (1989), Mandal (1996) and Venkatesh (1997), Yadav <i>et al.</i> (2002), Venugopal <i>et al.</i> (2002), Yadagiri (2004)
Number of kernel rows per ear	Appadurai and Nagarajan (1975), Mabo (1977), Genova (1984), Tomov and Min (1990), Mandal (1996) and Venkatesh (1997), Geetha (2001), Venugopal <i>et al.</i> (2002), Kabdal <i>et al.</i> (2003), Srinivasu (2004)
Number of kernels per row	Tomov and Min (1990), Mandal (1996) and Venkatesh (1997), Geetha (2001), Venugopal <i>et al.</i> (2002), Kabdal <i>et al.</i> (2003), Srinivasu (2004)
Number of kernels per ear	Rama (2001), Venugopal (2002), Yadagiri (2004)

Characters with significant relative heterosis	References
100 kernel weight	Shakoor and Atullah (1979), Verma and Singh (1980), Mukherjee and Saha (1984), Mandal (1996) and Venkatesh (1997), Rama (2001), Yadav <i>et al.</i> (2002), Venugopal <i>et al.</i> (2002), Yadagiri (2004)
Protein content	Wang <i>et al.</i> (1998), Konak <i>et al.</i> (1999) and Venugopal <i>et al.</i> (2002), Srinivasu (2004), Yadagiri (2004)
Oil content	Venu Gopal (2000), Tagoor Verma (2002), Srinivasu (2004), Yadagiri (2004)
Grain Yield	Krolikowski (1971), Mabo (1977), Verma and Singh (1980), Akthar and Singh (1981), Debnath (1984), Younus <i>et al.</i> (1987), Mahmoud <i>et al.</i> (1990), Tomov and Min (1990), Muralikrishna and Patil (1992), Vasal <i>et al.</i> (1992 a, b), Widstrom <i>et al.</i> (1993), Bhatnagar <i>et al.</i> (1993), Pandey <i>et al.</i> (1994), Santos <i>et al.</i> (1994), Altinbas (1995), Mandal (1996), Venkatesh (1997), Wang <i>et al.</i> (1998), Appunu (2000), Venu Gopal (2000), Venkat Nagesh Kumar (2001), Geetha (2001), Yadav <i>et al.</i> (2002), Venugopal <i>et al.</i> (2002), Kabdal <i>et al.</i> (2003), Srinivasu (2004), Yadagiri (2004)

2.5 CORRELATION STUDIES

Knowledge about the correlations of yield and yield components of maize and also the chemical components of kernel will help in formulating selection criterion. Correlation forms the basis of selection index thereby helping the plant breeder in crop improvement.

Yield is a complex character, which depends upon a number of yield components. Correlation studies indicate the magnitude of association between any two characters.

Stuber *et al.* (1966) reported that there is strong genetic association between plant height and ear height since tall plants normally have high ear heights. Shakhov (1975) reported a close association between ear height, ear diameter and number of grains per row.

Geortz *et al.* (1978) noticed highly significant and positive correlation between grain yield and the number of ears per plant. Positive and significant correlation was also reported (Laptev, 1981) for grain yield, plant height and ear height.

A close correlation between grain yield, 100 grain weight and number of grains per ear was reported by Karavaer (1982). Days to maturity and grain yield of maize also showed positive correlation (Parth *et al.*, 1986).

Ivankhenko and Orlyanskii (1987) reported that high yielding inbred lines can be obtained through selection for ear diameter and number of grains per ear. Sharma and Kumar (1987) also reported that grain yield per plant was positively correlated with plant height, ear girth, grain number per row and kernel rows per ear.

According to Annapurna (1989), there was positive and significant correlation between grain yield, plant height, ear length, ear girth, number of seeds per ear and 100 seed weight where as days to 75 per cent tasseling and 75 per cent silking had a negative correlation.

Mahajan *et al.* (1990) found significant positive correlation among kernel yield, ear length, number of kernels per row and plant height. However, Malwar *et al.* (1996) did not find any significant correlation among yield attributing components viz., number of grains per row, ear length and kernel weight.

Mittal *et al.* (1997) reported that days to silking and days to pollen shed were important parameters for estimating maturity under Indian conditions.

Netaji (1998) found significant and positive correlation between grain yield and 50 per cent tasseling, silking and maturity. According to Reddy (1998) there was significant positive correlation

between plant height and ear height and negative correlation between 50 per cent silking, 50 per cent maturity and grain yield.

Gautam *et al.* (1999) studied 50 indigenous genotypes of maize collected from different agro-climatic situations and reported that the grain yield was positively correlated with plant height and ear height.

Umakanth *et al.* (2000) found negative correlation for grain yield and days to 50 per cent silking. However, plant height and ear height were positively correlated with grain yield.

Correlation studies were also worked out for yield attributing characters and chemical components of grain.

Zozulya (1971) found significant positive correlation between oil content and grain yield of maize. Raman *et al.* (1983) also reported significant positive correlation between grain oil content and grain weight and yield. Similar results were also reported by Pamin (1985).

Umakanth (1993) reported negative correlation of grain yield with per cent oil and protein.

Chmeleva *et al.* (1988) found significant positive correlation between protein and oil contents. Results of Proksza and Harmati (1988) revealed that oil yields were usually high in hybrids with moderate oil content coupled with high yielding capacity. Lambert *et al.* (1997)

reported that high oil hybrids with increased oil content were found to be inferior in grain yield than normal hybrids.

Cao *et al.* (1999) reported highly significant positive correlations between oil content and protein contents. However, these two chemical components were negatively correlated with ear weight, 100 grain weight and ear diameter.

According to Venu Gopal (2000), there was negative and non significant correlation between grain yield and oil content of maize kernels. Existence of positive correlation between oil and protein contents and negative correlation with grain yield indicates the possibility of simultaneous improvement of protein and oil but leading to reduction in grain yield (Krishnam Raju, 2001).

Ravindra Babu (2002) reported in his studies that oil and protein contents had significant positive correlation with each other and negative correlation with yield.

Kabdal *et al.* (2003) reported significant and positive genotypic and phenotypic association of plant height, ear height, 100 kernel weight, ear length and number of kernel rows per ear with grain yield.

Satyanarayana *et al.* (2003) recorded that the grain yield had significant and positive correlation with all the traits studied except oil

and protein content. Oil content was positively correlated with protein content and vice versa. Thus selection for grain yield in addition to oil and protein content should involve high yielding lines with average oil and protein content.

Srinivasu (2004) reported that protein yield, 100 seed weight, oil yield, number of seeds / row, plant height, ear height, ear length and number of seeds / cob had significant and positive correlation with grain yield.

2.6 PATH COEFFICIENT ANALYSIS

Direct effect of a character on yield may be found through the study of genetic correlation. But, path coefficient analysis helps to separate the direct effect and their indirect effects through other attributes by partitioning the correlation coefficients (Wright, 1921).

Panchanathan *et al.* (1978) reported that the 1000 grain weight had the maximum direct effect towards increase in grain yield.

Path coefficient studies of Rupak *et al.* (1979) revealed that there was maximum direct effect of plant height on yield followed by 100 seed weight, ear girth and ear length. Kang *et al.* (1983) reported positive effect of ear weight on grain yield at both phenotypic and genotypic levels. The direct effect of plant height on grain yield was also positive and highly desirable.

Swarnalatha Devi (1990) also reported that the 100 seed weight and total seeds per ear had maximum direct effect on yield. Dwivedi and Godawat (1994) observed that the total number of grains per ear, ear girth, shelling percentage and 100 kernel weight showed maximum positive direct effect on grain yield of maize. According to Netaji (1998) and Gautham *et al.* (1999) the maximum direct effects towards grain yield were contributed by ear length followed by shelling percentage.

Chandramohan (1999) reported that the number of seeds per row, 100 seed weight and ear girth had direct effect on grain yield while oil content and protein content had direct negative effects on yield.

Venu Gopal (2000) emphasized the need for selection based on plant type with greater number of seeds per row, 100 seed weight, plant height and number of seed rows per ear in addition to early duration since these characters found to be important and had direct effect on grain yield.

Krishnam Raju (2001) studied the path coefficient analysis and revealed that 100 seed weight, number of seeds per row, ear length, ear girth, number of seed rows per ear and protein yield were the major characters which had direct influence on grain yield.

Ravindra Babu (2002) also emphasized that number of seeds per row, 100 seed weight and number of seeds per cob were the best direct contributors to grain yield.

Srinivasu (2004) reported that 100 seed weight exhibited highest positive direct effect on grain yield followed by number of seed rows/cob, number of seeds/row, ear length, plant height, days to 50 per cent silking and days to 50 per cent maturity.

2.7 STABILITY ANALYSIS

Genotype x Environment (G x E) interactions which commonly occur in plant material are of considerable importance in developing improved varieties and rationalization of policy and procedure in breeding programmes aimed at further genetic improvement in crop plants. Hence, in recent years much emphasis has been laid on the nature of G x E interactions. Earlier Finlay and Wilkinson (1963) considered linear regression as a measure of stability.

Eberhart and Russell (1966) emphasized the need of considering both linear (b_i) and non linear (S^2d_i) components. In order to be of practical use, the variety should have desirable mean.

Gentinetta *et al.* (1988) evaluated 7 opaque 2 maize hybrids for grain yield, plant height, ear height, 100 seed weight and protein

content at 11 locations. Two hybrids maintained high yield and stability for the yield traits in different locations.

Vega and Vega (1992) evaluated 24 maize hybrids at 7 locations to obtain estimates of parameters describing yield stability over environments. The estimates were used for empirical comparisons and association study. The methods based on the effects or sum of squares of G x E interaction were useful.

Information on stability was also derived (Mahajan and Khehra, 1992) from data on 6 yield components in 28 F₁ hybrids from a diallel cross of 8 maize inbred lines grown at 2 locations in Punjab during winter. Deviation from regression appeared to be more important parameter than regression for measuring stability.

For evaluating maize top crosses for their potential use in breeding programme, Gomes-e-Gama *et al.* (1993) conducted experiments at three locations in Brazil. Both single cross hybrids and populations had longer environmental interactions than the top crosses.

Information on stability was derived based on grain yield of 11 genotypes when grown in temperate wet areas of Himachal Pradesh. Gautam *et al.* (1998) reported that the local check performed well by recording highest average yield.

In order to estimate the phenotypic stability of parameters of tropical maize hybrids, Castanon and Tosquy (1998) used two statistical techniques *viz.*, regression method adjusted by multiplicative model and principal component analysis. Results revealed that the genotype environment interaction sum of squares (GEISS) was better estimated by PC technique where only two components explained 54.4% of GEISS variation.

The effect of additive, dominant and epistatic gene action for oil content was investigated by Rosulj and Saratlic (1998) in two maize inbred lines differing in oil content. The additive gene effects were highly significant at two locations. Epistasis did not contribute significantly to the inheritance of oil content. A comparison of gene effects in the different environments did not show significant genotype x environment interaction.

The methods to be used to estimate stability of corn hybrids for grain yield depends on the characteristics of the experiment. Luquez and Jura (2000) used three methods to estimate stability, among which the test of relative yield (RY) that uses standard deviation as the measure of stability found to be the best in corn improvement programmes, as there is possibility to classify some materials as high yielding and stable, avoiding the bias that high yielding environments given to the general average.

Scapion *et al.* (2000) evaluated twenty maize cultivators at eight locations for two years using three procedures to analyse cultivar stability and adaptability. The level of association among the three parameters was assessed using Spearman's rank correlation. The results revealed that the most responsive cultivars tended to have smaller π and *did not correlate with Huehn's non parametric measurements* $S_i(2)$ and $S_i(3)$ but correlated positively with $S_i(1)$ indicating that superior genotypes with lower π could also be stable.

Aguiar *et al.* (2003) studied adaptability and stability of twenty five entries in seven environments and reported significant differences for entries and environments for all the traits studied *i.e.*, grain yield, plant height, ear height, ear placement, and prolificacy. The genotype x environment interaction was significant for all traits.

Dodiya and Joshi (2003) studied eighty six genotypes for genotype x environment (G x E) interaction and stability parameters with respect to yield and maturity over three locations. G x E interaction was is for both characters studied. More number of genotypes were found stable for maturity compared to grain yield.

*MATERIALS
AND METHODS*

CHAPTER III

MATERIAL AND METHODS

The present investigation entitled “Studies on genetic divergence, combining ability and stability for protein, oil and grain yield in maize (*Zea mays* L.) genotypes” was carried out during *kharif*, 2001; *rabi* 2001-2002 and *kharif*, 2002 at the College Farm, College of Agriculture, Rajendranagar, Hyderabad; Agricultural Research Station (ARS), Karimnagar; and Regional Agricultural Research Station (RARS), Palem, Mahaboobnagar district.

CROP GROWTH CONDITIONS

The weather during the growing season was in general favourable for crop growth at three locations and years. The geographical location of the three sites is given below :

Location	Altitude (meters)	Latitude	Longitude
Rajendranagar, Hyderabad	542	17° 19’N	79° 23’E
RARS, Palem (Mahaboobnagar)	532	17° 8’ N	79° 43’E
ARS, Karimnagar	259	18° 30’ N	79° 15’ E

The technique used in the present investigation to generate data and the statistical procedures followed for analyzing the data are described in the following sub-heads :

- 3.1 Selection of experimental material
- 3.2 Generation of breeding material
- 3.3 Observations recorded
- 3.4 Statistical procedures

3.1 SELECTION OF EXPERIMENTAL MATERIAL

The experimental material consisted of 196 maize genotypes which included 128 Quality Protein Maize (QPM) and 68 High Oil Lines (HOL) obtained from NATP – QPM Project, Agricultural Research Station (Maize), Amberpet, Hyderabad.

Experiment I :

One hundred and ninety six (196) maize lines were raised in 14 x 14 Simple Lattice Design replicated thrice in single 5 m row plot long with a spacing of 75 x 25 cm forming a plot size of 3.75 m², two seeds were dibbled and thinned later to a single seedling per hill to obtain a stand of 21 plants per plot. Other cultural practices were taken up as per the recommendations and evaluated for genetic divergence studies during *kharif*, 2001 at the College Farm, College of Agriculture, Rajendranagar, Hyderabad. The data were subjected to D² analysis of genetic divergence based on characters *viz.*, protein content, oil content and grain yield and ten divergent parents were selected. The details of the parental lines are given below :



Plate 1 : General appearance of the field stand for Genetic Divergence studies during *kharif*, 2001



Plate 2 : A view of crossing block during *rabi*, 2001-02

3.2 GENERATION OF BREEDING MATERIAL

Experiment II :

The experiment was carried out at College Farm, College of Agriculture, Rajendranagar, Hyderabad during *rabi*, 2001-02. The selected ten parents were crossed in a diallel fashion as per Griffing's Method II (excluding reciprocals) to generate 45 crosses.

Experiment III :

During *kharif* 2002, a diallel set of 45 crosses along with 10 parents and two checks *viz.*, Madhuri and BMH-1620 were sown in Randomized Block Design replicated thrice over three locations *viz.*, Rajendranagar (Hyderabad), Palem (Mahaboobnagar) and Karimnagar of Andhra Pradesh. Each entry was sown in a row of five meters length with a spacing of 75 cm between rows and 25 cm between the plants forming a plot size of 3.75 m². The recommended fertilizers of NPK were applied in the ratio of 120 : 80 : 60 kg ha⁻¹. The entire P and K and half dose of nitrogen was applied as basal, while remaining half dose of N in two equal split doses at knee height and tasseling stages. Other cultural practices were taken up as per the recommendations, so as to raise a healthy maize crop.

3.3 OBSERVATIONS RECORDED

The observations were recorded for the following characters

1. Days to 50 per cent tasseling
2. Days to 50 per cent silking
3. Days to 50 per cent brown husk

Location I : Raiendranagar



Location II : Palem



Location III : Karimnagar



Plate 3: Evaluation studies at three locations during *kharif*, 2002

4. Ear height (cm)
5. Plant height (cm)
6. Ear length (cm)
7. Ear girth (cm)
8. Number of kernel rows per ear
9. Number of kernels per row
10. Number of kernels per ear
11. 100 kernel weight (g)
12. Protein content (%)
13. Oil content (%)
14. Grain yield (kg per plot)

Observations on 14 different quantitative characteristics were recorded in each plot on five random plants except for days to 50 per cent tasseling, days to 50 per cent silking, days to 50 per cent brown husk and grain yield, which were recorded on plot basis.

3.3.1 Days to 50 per cent Tasseling

Number of days from date of sowing to date of 50 per cent plants shedding pollen were recorded.

3.3.2 Days to 50 per cent Silking

Number of days from the date of sowing to the date of 50 per cent of plants with silk emergence were recorded.

3.3.3 Days to 50 per cent Brown Husk

Number of days from the date of sowing to date of 50 per cent of the plants turned to brown husk.

3.3.4 Ear Height (cm)

Measurement was taken from the base of the plant to the node of the attachment of the upper most ear in centimeters.

3.3.5 Plant Height (cm)

Measurement was recorded from base of the plant to the tip of the tassel in centimeters.

3.3.6 Ear Length (cm)

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

3.3.7 Ear Girth (cm)

Ear girth was measured in centimeters at a point of maximum diameter after dehusking of the ear.

3.3.8 Number of Kernel Rows per Ear

Number of kernel rows per ear was recorded by counting the number of rows per ear at the middle of the ear for five randomly selected ears.

3.3.9 Number of Kernels per Row

The number of kernels per row were counted and recorded in each ear.

3.3.10 Number of Kernels per Ear

Number of kernels per ear was recorded by counting the number of kernels per ear for five randomly selected ears.

3.3.11 100 Kernel Weight (g)

One hundred kernels were counted and the weight was recorded with the help of electronic top pan balance.

3.3.12 Oil Content (%)

Oil content in grain was assessed using Nuclear Magnetic Resonance (NMR) Spectroscopy. Grains from each entry in each replication were dried in hot air to get moisture content of 4.5 per cent, 15 grams of seed sample was then used for assessing oil content, using NMR spectroscopy against a standard reference sample.

3.3.13 Protein Content (%)

The protein content in maize seeds was estimated by standard procedure given by Lowry *et al.* (1951).

3.3.14 Grain Yield per Plot (kg)

All the ears in a plot (entry) were harvested in each replication and after thorough drying their weight was recorded precisely, moisture percentage of the seeds was determined, later on the yield was adjusted to 15 per cent moisture level.

3.4 STATISTICAL PROCEDURES

3.4.1 Genetic Diversity

After testing the differences between genotypes for each character, a simultaneous test of significance of difference between the mean values of a number of correlated variables was done by using 'V' statistic, which in turn

utilizes Wilk's criterion. The sum of squares and sum of products of error and error + genotypes were used for this purpose. The estimation of Λ (Wilk's criterion) was done by using the following relationship:

$$\Lambda' = W/s$$

Where, Λ = Wilk's criterion

W = Determinant of error matrix

s = Determinant of (error + genotype) sum of squares and sum of product matrix

The genetic diversity in 196 genotypes for characters was estimated using Mahalanobis (1936) D^2 statistic technique. The D^2 value between i^{th} and j^{th} genotypes for P character was calculated as follows:

$$D_{ij}^2 = P_t = \sum (y_{it} - y_{jt})^2$$

Where,

D_{ij}^2 = D^2 between i^{th} and j^{th} genotypes

y_{it} = uncorrelated mean value of the i^{th} genotype for 't' character

y_{jt} = uncorrelated mean value of the j^{th} genotype for 't' character

The various types involved in estimation of D^2 values are given below:

$$V(\text{stat}) = -mg \log e' \Lambda'$$

Where,

m = $n - (P+Q+1)/2$

P = Number of characters or variable observations

Q = Number of genotypes-1 (or degree of freedom for population)

n = degree of freedom for error + genotypes at base of natural log i.e., 2.7183

'V' (stat) = is distributed as χ^2 with PQ degrees of freedom

3.4.1.1 Transformation of correlated variables

Computation of D^2 values was reduced to simple summation of differences in mean values of various characters of the two genotypes *i.e.*, D^2 . Therefore, the transformation of correlated variables to uncorrelated ones was done before working out the D^2 values. Transformation was done by using pivotal condensation mean.

3.4.1.2 Computation of D^2 values

For a given combination of i and j genotypes, the mean deviation *i.e.*, $y_{it} - y_{jt}$ for $t = 1, 2, \dots, P$ variables are computed and the D^2 values were calculated as sum of squares of the deviation *i.e.*,

$$P_{et} = \sum (Y_{ie} - Y_{je})^2$$

3.4.1.3 Testing the significance of D^2 values:

The D^2 values obtained for a pair of genotypes as the calculated value of χ^2 were tested against tabulated value of χ^2 at 'P' degrees of freedom. Where "P" is the number of variables or characters considered.

3.4.1.4 Contribution of individual characters towards divergence

In all the combinations each character was ranked on the basis of its contribution towards divergence between two entries ($d_i = y_{it} - y_{jt}$). Rank-I was given to the highest mean difference and rank-P to the lowest differences. P is the total number of characters considered. The number of cases where a particular character ranked first was counted and the proportion of this to the total number of combinations expressed in percentage had quantified the

contribution of character to the overall genetic divergence between the genotypes:

$$X = \frac{N \times 100}{M}$$

Where,

X = Per cent contribution of character

N = Number of genotype combinations where the character ranked first

M = All possible combinations of the genotypes considered

3.4.1.5 Clustering of genotypes

Clustering of genotypes into different clusters was done by using Euclidean method. The criterion used in clustering by this method was that any two genotypes belonging to the same cluster should atleast on an average show a smaller D^2 value among themselves than those belonging to different clusters.

The first step in grouping the genotypes into different clusters was to arrange the genotypes in the order of their relative distance from each other. For this purpose, D^2 values of all the combinations in each genotype were arranged in the increasing order of their magnitude. To start with two genotypes having the smallest distance from each other was considered first to which third population having the smallest average D^2 value from the first two genotypes and so on. At certain stage when it was felt that after adding a particular variety there was a disrupt increase in the average D^2 value, then that genotype was not considered for inclusion in that cluster. Similarly, a second



cluster was formed. Thus, the process was continued till all the genotypes were included in one or the other cluster.

3.4.1.6 Intra and inter cluster distances

Based on D^2 values, average intra and inter cluster distances were calculated as per Euclidean method.

3.4.1.7 Average intra cluster distance

For the measurement of intra cluster distances, the formula used was $\sum D^2/n$ where, $\sum D^2$ was the sum of distance between all possible combinations and 'n' is number of the genotypes included in a cluster.

3.4.1.8 Average inter cluster distance

Cluster is taken one by one and their distances from other clusters were calculated. The distance between the two clusters was calculated as the sum of D^2 value between the numbers of one cluster to each of the members of other clusters divided by the product of number of genotypes in both clusters under consideration. The square root of the average D^2 value gave the genetic distance 'D' between the clusters.

3.4.2 Analysis of Variance

The analysis of variance for each character was carried out by using the method described by Panse and Sukhatme (1985).

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

Where,

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

μ = general mean

b_i = true effect of i^{th} block

t_j = true effect of j^{th} genotype

e_{ij} = random error associated with i^{th} block and j^{th} genotype

The analysis of variance for each character was carried out as indicated below.

Source of variation	d.f.	SS	MSS	F-ratio
Replications	r-1	RSS	M'r	M'r/M'e
Treatments	t-1	TSS	M't	M't/M'e
Error	(r-1) (t-1)	ESS	M'e	
Total	rt-1			

Where,

r = number of replications

t = number of genotypes

d.f. = degrees of freedom

SS = sum of squares

MSS = mean sum of squares

M'r = mean squares due to replications

M't = mean squares due to treatments

M'e = mean squares due to error

The test of significance was carried out by referring to 'F' table values given by Fisher and Yates (1967)

3.4.3 Genotypic and Phenotypic Coefficient of Variation (GCV and PCV)

The coefficients of variation were worked out using the formulae given by Burton (1952):

$$GCV = \frac{\sqrt{\sigma^2 g}}{\bar{X}} \times 100$$

$\bar{X}$ = general mean

Where, $\sigma^2 g$ = genotypic variance

Where, $\sigma^2 p$ = phenotypic variance

$$PCV = \frac{\sqrt{\sigma^2 p}}{\bar{X}} \times 100$$

3.4.4 Heritability (broad sense) h^2

$\bar{X}$ = general mean

The heritability (h^2) in broad sense for the different characters were estimated by using the following formula.

$$\text{Heritability (Broad sense)} = \frac{\text{Genotypic variance}(\sigma^2 g)}{\text{Phenotypic variance}(\sigma^2 p)} \times 100$$

3.4.5 Expected Genetic Advance

Genetic advance was estimated as per Johnson *et al.* (1955)

$$\text{Genetic advance} = \frac{\sigma^2 g}{\sigma^2 p} \times k \cdot \sigma p$$

- Where, σ^2g = genotypic variance
- σ^2p = phenotypic variance
- k = Selection differential at 5 per cent selection intensity which accounts to a constant value 2.06.
- σp = phenotypic standard deviation

Expected Genetic advance as per cent of mean = $\frac{GA}{Grand\ Mean(\bar{X})} \times 100$

- Where, GA = genetic advance
- $\bar{X}$ = is the grand mean of the character

3.4.6 Combining Ability Analysis

The data obtained from F_1 s and parents were analyzed as per Method II (F_1 s + parents) and Model -I (fixed effect) of Griffing (1956a) for combining ability.

The mathematical model for combining ability is

$$X_{ij} = \mu + g_i + g_j + S_{ij} + \frac{1}{bc} \sum_k \sum_l e_{ijkl}$$

$i, j = 1, \dots, p$

$K = 1, \dots, b$

$L = 1, \dots, c$

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- Where,
- b = Number of blocks
- c = Number of observations on $(I,j)^{th}$ genotype in K^{th} block
- μ = Population mean
- g_i = gca effect of the i^{th} parent
- g_j = gca effect of the j^{th} parent

S_{ij} = sca effect of the cross between i^{th} and j^{th} parents such that

$s_{ij} = S_{ji}$ and

e_{ijkl} = Environment effect pertaining to the $ijkl^{th}$ observation

ij^{th} = individual in K^{th} block

With i^{th} female parent and j^{th} male parent

The restrictions imposed on this model are

$\sum e_{igi} = 0$

$e_{jsij} + s_{iij} = 0$ (for each i)

Analysis of variance

Source	Df	S. S.	M. S.	Expected mean square
General Combining Ability	$(P - 1)$	S_g	M_g	$\sigma^2e + (P+2) (1/P-1) \sum g_i^2$
Specific Combining Ability	$P (P - 1) / 2$	S_s	M_s	$\sigma^2e + \frac{2}{P(P-1)} \sum_i \sum_j s_{ij}^2$
Error	M	S_e	M_e	σ^2e

$$S_g = \frac{1}{(P + 2)} [\sum_i (x_i + x_{ii})^2 - \frac{4}{P} x^2 ..]$$

$$S_s = \sum_i \sum_{sj} x_{ij}^2 - \frac{1}{(P + 2)} \sum_i (x_i + x_{ii})^2 + \frac{2}{(P + 1)(P + 2)} x^2 ..$$

Where ,

S_g = Sum of square due to GCA

S_s = Sum of square due to SCA

P = Number of parents

x_i = Total of the array involving i^{th} parent

x_{ii} = Mean value of i^{th} parent

X = Grand total of $\frac{1}{2} (p) (p-1)$ progenies

X_{ij} = Progeny mean value in the diallel table



m = Degree of freedom for error

Mean square *gca* to *sca* variance ratio was calculated to know the type of gene action in the inheritance of that particular trait.

$$\sigma^2_{gca} = \frac{Mg - M'e}{n+2}$$

$$\sigma^2_{sca} = Ms - Me'$$

Estimation of *gca* and *sca* effects

i) General combining ability effects of i^{th} parent with restriction $g_i = 0$

$$\hat{g}_i = \frac{1}{(P+2)} \left[\sum (x_i + x_{ii}) - \frac{2}{P} x_{...} \right]$$

ii) Specific combining ability effects of ij^{th} cross:

with restriction $s_{ij} + s_{ii} = 0$

$$\hat{S}_{ij} = X_{ij} - \frac{1}{(P+2)} (x_i + x_{ii} + x_j + x_{jj}) + \frac{2}{(P+1)(P+2)} x_{...}$$

Where,

P , x_{ij} , x_i , x_{ii} and $x_{..}$ denotes the same term as mentioned earlier.

Standard Errors

$$S.E.\hat{g}_i = \sqrt{\frac{(P-1)}{(P+2)} \sigma^2_e}$$

$$S.E.\hat{S}_{ii} = \sqrt{\frac{P(P-1)}{(P+1)(P+2)} \sigma^2_e}$$

$$S.E.\hat{S}_{ij} = \sqrt{\frac{P^2 + P + 2}{(P+1)(P+2)} \sigma^2_{e(i\#j)}}$$

Each *gca* and *sca* value was tested against zero for its significance by

t' test.

$$t = (\hat{g} - e) / SE(\hat{g}_i) \text{ or } t = (S_{ij} - 0) / SE(s_{ij})$$

3.4.7 Estimation of Heterosis

Estimates of heterosis were calculated according to Fonseca and Patterson (1968) and Standard heterosis according to Virmani *et al.* (1982).

$$\text{Relative Heterosis}(H_1) = \frac{\overline{F_1} - \overline{M.P.}}{\overline{M.P.}} \times 100$$

$$\text{Heterobeltiosis}(H_2) = \frac{\overline{F_1} - \overline{B.P.}}{\overline{B.P.}} \times 100$$

$$\text{Standard Heterosis}(H_3) = \frac{\overline{F_1} - \overline{S.C.}}{\overline{S.C.}} \times 100$$

Where,

- $\bar{F}_1$ = Mean of F_1
- $\overline{M.P.}$ = Mid parental value
- $\overline{B.P.}$ = Better parental value
- $\overline{S.C.}$ = Standard Check Value

The significance of heterosis, was tested by using ‘t’ test as suggested by Snedecor and Cochran (1989) and Paschal and Wilcox (1975).

Where

$$= \frac{\overline{F_1} - \overline{M.P.}}{\sqrt{\frac{EMS}{r}}}$$
$$= \frac{\overline{F_1} - \overline{B.P.}}{\sqrt{\frac{EMS}{r}}}$$
$$= \frac{\overline{F_1} - \overline{S.C.}}{\sqrt{\frac{EMS}{r}}}$$

- EMS = Error Mean Square
- r = Number of replications

The calculated ‘t’ value was compared with table ‘t’ value at error degrees of freedom.

3.4.8 Stability Analysis

Data obtained from the three environments were subjected to pooled analysis of variance (Panse and Sukhatme, 1985). The genotype x environment interactions were significant for most of the characters

and hence the data were further analysed to determine the phenotypic stability of different hybrids.

(i) **Phenotypic stability analysis**

Following the methodology of Eberhart and Russell's model (1966), three parameters namely (i) overall mean of each genotype over a range of environments, (ii) the regression of each genotype on the environmental index and (iii) a function of the squared deviation from the regression were estimated. Eberhart and Russell (1966) used to study the stability of genotypes under different environments.

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

Where, Y_{ij} = Mean of i^{th} genotype in j^{th} environment.

μ_i = Mean of i^{th} genotype over all the environments

b_i = Regression coefficient of the i^{th} genotype on the environmental index which measures the response of this genotype to varying environments

I_j = Environmental index which is defined as the deviation of the mean of all the genotypes at a given location from overall mean with $E_j - I_j = 0$

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

(II) **Analysis of variance for stability**

The analysis of variance proposed by Eberhart and Russell (1966) is given below.

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ANOVA to estimate stability parameters (Eberhart and Russell, 1966)

Source	d. f	S. S	M. S. S
1. Total	(ge -1)	$\sum_{i,j} Y_{ij}^2 - C. F.$	
2. Genotype	(g-1)	$\frac{1}{e} \sum_i Y_i^2 - C. F.$	MS 1
3. Environment	g(e-1)	$(\sum_{i,j} Y_{ij}^2 - \sum_i Y_i^2 / e)$	
4. Environment (Linear)	1	$\frac{1}{g} \sum_j (Y_j I_j)^2 / I_j^2$	
5. Genotype x Environment (Linear)	(g-1)	$(\sum_{i,j} Y_{ij} I_j)^2 / I_j^2) -$ Environment (linear) S. S	MS 2
6. Pooled deviation	g(e-2)	σ_{ij}^2	MS 3
7. Deviation due to genotype 1	(e-2)	$\sum_{i,j} Y_{ij}^2 - \frac{(\sum_i Y_i)^2}{e} - (\sum_{i,j} Y_{ij} I_j)^2 / I_j^2 = \sigma_{ij}^2$	
Genotype g	(e-2)	$\sum_{j} Y_{gj}^2 - \frac{(\sum_e Y_g)^2}{e} - (\sum_{j} Y_{gj} I_j)^2 / I_j^2 = \sigma^2_{gj}$	
8. Pooled error	e(r-1) (g-1)		

g= genotype; e= environment; r= replications

(III) Computation of regression coefficient (b_i) for each genotype

$$b_i = \frac{\sum_j Y_{ij} l_j}{\sum_j l_j^2}$$

Where,

b_i = regression coefficient of i^{th} genotype

$\sum_j l_j^2$ = the sum of squares of environmental indices which are common to each value of b_i .

$\sum_j Y_{ij} l_j$ = (for each genotype) = the sum of products of environmental

(l_j) index and the corresponding means (X) of that variety at each location. These values may be obtained in the following manner.

$$\sum_j (X)(l_j) = \sum_j Y_{ij} l_j = (S)$$

(l_j) = Vector for environmental index, and

(S) = Vector for sum of products *i.e.*, $\sum_j Y_{ij} l_j$

(IV) Computation of S^2_{di} :

In a regression analysis, it is possible to partition the variance of dependent variable (Y) into two parts, the one which explains the linearity between dependent and independent variables (variance due to regression) and the other which explains the variance due to deviations from linearity symbolically.

$$\sigma_Y^2 = \sigma^2_{\text{regression}} + \sigma^2_{\text{deviation from regression}}$$

The variance of means over different locations with regard to individual genotypes may be obtained in the following way.

$$\sigma^2_{gi} = Y_{ij} - (Y^2_i / g)$$

The variance due to deviations from regression ($\sum_i \delta_{ij}^2$) for a genotype being:

$$\sum_j \delta_{ij} = [\sum_j Y^2_{ij} - Y^2_i / g] - \frac{(\sum_j Y_{ij} I_j)^2}{\sum_j I_j^2}$$

Where,

$\sum_j Y^2_{ij} - Y^2_i / g$ = The variance due to dependent variable

$(\sum_j Y_{ij} - ij)^2 / (\sum_j ij)^2$ = The variance due to regression

Because

$$\frac{(\sum_j Y_{ij} I_j)^2}{\sum_j I_j^2} = \frac{(\sum_j Y_{ij} I_j)(\sum_j Y_{ij} I_j)}{\sum_j I_j^2} = bi \sum_j Y_{ij} I_j$$

From

$\sum_j \delta^2_{ij}$ = Values, the stability parameter,

S^2_{di} for each genotype is computed as follows:

$$S^2_{di} = \sum_j \delta^2_{ij} / (e - 2) - (S^2_e / r)$$

$$\text{Mean square} = \frac{\text{Deviation from regression}}{\text{d.f. for environment}} - \frac{\text{Pooled error deviation}}{\text{Number of replications}}$$

The variance due to genotypes, environments and the pooled error were the same as those calculated in the pooled analysis of the data, except that the total sum of squares was mainly partitioned into three main components.

- i. Sum of squares due to genotypes
- ii. Sum of squares due to environments + (G x E) and
- iii. Pooled error

Again sum of squares due to G x E was further partitioned into two parts namely

- i. S.S due to G X E (linear) which is in fact S.S due to regression and
- ii. S.S due to deviation from linearity of response (i.e., due to pooled deviation).

The different computational steps involved were as follows.

$$\text{a) S.S. due to environment} + (\text{GxE}) = \sum_i \sum_j Y_{ij}^2 - (\sum_i Y_i^2 / e)$$

$$\text{b) S.S. due to environment (linear)} = \frac{1}{g} \sum_j Y_j I_j^2 / \sum_j I_j^2$$

$$\text{c) S.S. due to GxE (linear)} = S(\sum_j Y_j I_j / \sum_j I_j) - \text{environment (linear) S.S.}$$

$$(\sum_j Y_j I_j^2) / \sum_j I_j^2 = b_i \sum_j Y_{ij} I_j \text{ for each variety}$$

Test of Significance

The following tests of significance were carried out:

1. To test the significance of the difference among genotype means namely:

$$H_0 = \mu_1 = \mu_2 = \mu_3 = \dots \mu_n$$

$$F = \frac{\text{Mean square due to genotype}}{\text{Mean square due to pooled deviation}} = \frac{MS_1}{MS_3}$$

2. To test that the genotypes did not differ for their regression on environmental index

i.e.,

$$H_0 = b_1 = b_2 = b_3 \dots b_n$$

$$F = \frac{\text{M.S. due to G} \times \text{E (linear)}}{\text{M.S. due to pooled deviation}} = \frac{MS_2}{MS_3}$$

3. Individual deviation from linear regression was tested as follows:

$$F = [(\sum_j \delta^2 ij) / (S - 2)] / \text{pooled error}$$

Against F table value at $(e-2)(g-2)$, at 5% or 1% probability level.

4. The hypothesis that any regression coefficient did not differ from unity or zero was tested by appropriate 't' test *i.e.*,

$$\text{For } (b - 0), t = \frac{|b - 0|}{SE(b_i)} \text{ for } (g - 2) \text{ df at 5\% level of probability}$$

$$\text{For } (1 - b), t = \frac{|b - 1|}{SE(b_i)} \text{ for } (g - 2) \text{ df at 5\% level of probability}$$

Where,

$$SE \ b_i = \sqrt{\sum_j \delta^2 ij / (e - 2) / \sum_j I_j^2}$$

Stable genotypes

A genotype with unit regression coefficient ($b_i=1$) and deviation not significantly different from zero ($S^2 d_i = 0$) was taken to be a stable genotype with unit response.

Mean and standard error of 'b'

$$\text{Mean of } b = \bar{b} = \sum b_i / g$$

$$S.E.(b) = \sqrt{\frac{M.S. \text{ due to pooled deviation}}{\sum_j I_j^2}}$$

Population mean (μ) and standard error was calculated as

Population mean (μ) = Grand total / No. of observations

$$S.E.(\text{mean}) = \sqrt{\frac{M.S. \text{ due to pooled deviation}}{\text{Number of environments} - 1}}$$

3.4.9 Correlation coefficients

Simple correlation coefficients (r) for grain yield and its components of the hybrids and parents were calculated by using the method given by Johnson *et al.* (1955):

$$r_g(xy) = \frac{Cov(xy)}{\sqrt{var(x) \cdot var(y)}}$$

$$Cov(xy) = \frac{1}{n} \left[xy - \frac{(xy)}{n} \right]$$

$$Var(x) = \frac{1}{n} \left[x^2 - \frac{(x^2)}{n} \right]$$

where,

- $r(xy)$ = correlation between x and y
- $Cov(xy)$ = covariance for characters x and y
- $Var(x)$ = variance for x
- $Var(y)$ = variance for y
- r = correlation coefficient
- xy = two independent variables

3.4.10 Path Coefficient Analysis

The direct and indirect effects at genotypic level for genotypes were estimated by taking seed yield as dependent variable, using path coefficient analysis suggested by Wright (1921) and Dewey and Lu (1959). The following equations were formed and solved simultaneously for estimating the various direct and indirect effects.

$$\begin{aligned} r_{1y} &= P_{1y} r_{11} + P_{2y} r_{12} + P_{3y} r_{13} \dots\dots\dots + P_{ny} r_{1n} \\ r_{2y} &= P_{1y} r_{21} + P_{2y} r_{22} + P_{3y} r_{23} \dots\dots\dots + P_{ny} r_{2n} \\ r_{ny} &= P_{1y} r_{n1} + P_{2y} r_{n2} + P_{3y} r_{n3} \dots\dots\dots + P_{ny} r_{nn} \end{aligned}$$

Where,

- 1, 2 n = Independent variable
- y = Dependent variable (yield per plant)
- $r_{1y}, r_{2y} \dots\dots\dots r_{ny}$ = coefficient of correlation between causal factors '1' to 'n' on dependent character 1
- $P_{1y}, P_{2y} \dots\dots\dots P_{ny}$ = Direct effect of characters 1 to n on character Y

The above equations can be written in matrix form as:

A

C

B

$$\begin{pmatrix} r_{1y} \\ r_{2y} \\ \vdots \\ r_{ny} \end{pmatrix} = \begin{pmatrix} 1 & r_{12} & r_{13} & \dots & r_{1n} \\ r_{21} & 1 & r_{23} & \dots & r_{2n} \\ \vdots & \vdots & \vdots & & \vdots \\ r_{n1} & r_{n2} & r_{n3} & \dots & 1 \end{pmatrix} \begin{pmatrix} p_{1y} \\ p_{2y} \\ \vdots \\ p_{ny} \end{pmatrix}$$

Then

$B=[C]^{-1} A$ where $C^{-1} =$

$$\begin{pmatrix} c_{11} & c_{12} & c_{13} & \dots & c_{1n} \\ c_{21} & c_{22} & c_{23} & \dots & c_{2k} \\ \vdots & \vdots & \vdots & & \vdots \\ \vdots & \vdots & \vdots & & \vdots \\ c_{n1} & c_{n2} & c_{n3} & \dots & c_{nn} \end{pmatrix}$$

Direct effects were as follows:

$$p_{1y} = \sum_{i=1}^k c_{1i} r_{iy}$$

$$p_{2y} = \sum_{i=1}^k c_{2i} r_{iy}$$

$$p_{ny} = \sum_{i=1}^k c_{ni} r_{iy}$$

Residual effect, which measures the contribution of characters not considered, was obtained as:

$$p_{ry} = \sqrt{1 - (p_{1y} r_{1y} + p_{2y} r_{2y} + \dots + p_{ny} r_{ny})}$$

Where, p_{ny} = Direct effect of x_n on Y
 r_{iy} = Correlation coefficient of x_n on y.

RESULTS

CHAPTER IV

RESULTS

The results of the present investigation on “Studies on genetic divergence, combining ability and stability for protein, oil and grain yield in maize (*Zea mays* L.) genotypes” are presented under following heads:

- 4.1 Genetic divergence
- 4.2 Study of means
- 4.3 Variability studies
- 4.4 Combining ability
- 4.5 Heterosis
- 4.6 Correlations
- 4.7 Path coefficient analysis
- 4.8 Stability studies

4.1 GENETIC DIVERGENCE

The quantitative assessment of divergence was made by adopting Mahalanobis D^2 statistics for protein, oil and yield characters.

Grouping of genotypes into various clusters (D^2 analysis)

One hundred and ninety six genotypes, comprising 128 Quality Protein Maize (QPM) and 68 High Oil Lines (HOL) were

Table 1a : Grouping of 196 maize genotypes in different clusters on the basis of D² values

Cluster No.	No. of inbreds	No. of selected parents	Inbred
I	17	03	37, 95 , 164, 151, 145, 112, 193 , 196, 94, 23, 67, 177, 31, 92 , 144, 43, 65
II	18	03	91, 47, 110 , 191, 26, 41, 10, 39, 192 , 8, 60, 173, 158, 96, 118 , 52, 13, 131
III	28	02	93, 27, 33, 128 , 111, 76, 153, 21, 161, 143, 175, 168, 20, 160, 106, 5, 29, 100, 136, 90, 49, 46, 62 , 7, 73, 9, 119, 194
IV	104	01	16, 44, 157, 146, 171, 132, 141, 59, 102, 11, 38, 74, 130, 30, 54, 25, 42, 122, 81, 120, 64, 35, 3, 187, 113, 109, 17, 137, 86, 45, 12, 15, 77, 68, 134, 14, 1, 4, 124, 56, 50, 182, 116, 57, 88, 179, 155, 82, 51, 104, 22, 2, 79, 34, 40, 66, 107, 84, 58, 55, 121, 183, 142, 167, 114, 117 , 150, 18, 28, 48, 53, 63, 180, 181, 184, 188, 189, 195, 185, 69, 70, 6, 19, 75, 78, 85, 87, 89, 165, 176, 178, 98, 99, 105, 108, 126, 127, 133, 140, 143, 146, 152, 154, 159
V	29	01	139, 190, 24, 166, 97, 123, 80, 101, 149, 103, 36 , 147, 163, 32, 71, 135, 115, 61, 138, 186, 125, 83, 169, 174, 129, 170, 162, 72, 172

Values in the bold are accession numbers of selected parents

Table 1b : Means of clusters from 196 genotypes of maize for protein content, oil content and grain yield

Cluster No.	Protein content (%)	Oil content (%)	Grain yield (kg/plot)
I	10.89	7.99	1.96
II	11.28	8.37	1.88
III	9.15	7.06	2.95
IV	6.55	6.73	3.57
V	11.70	5.27	1.77

Table 1c : Average intra and inter cluster distances (D² values)

Cluster	I	II	III	IV	V
I	6.36 (C)	13.30 (C)	18.65 (M)	29.20 (M)	19.54 (M)
II		4.53 (C)	30.16 (H)	41.00 (H)	10.09 (C)
III			6.41 (C)	12.59 (C)	36.01 (H)
IV				5.98 (C)	46.69 (H)
V					5.51 (C)

H = Highly Divergent (above 25); M = Moderately Divergent (15-25);
C = Closely Related (below 15)

Table 1d : Contribution of different characters towards Genetic divergence
(D²) in 196 genotypes of maize

S. No.	Source	Times ranked first	Contribution percentage
1	Protein content	12	15.12
2	Oil content	16	19.21
3	Grain yield	28	65.67

evaluated during *kharif*, 2001 and the data were subjected to D^2 statistics analysis.

One hundred and ninety six genotypes were grouped into five clusters (Table 1a). Among the five clusters formed, cluster IV was the largest group comprising 104 genotypes followed by cluster V and III with 29 and 28 genotypes, respectively while cluster II had 18 and the cluster I comprised 17 genotypes.

Cluster means of characters

The data on character means are presented in Table 1b. From the data it was observed that considerable differences existed among the clusters for all the characters studied. The mean for the protein content was highest in cluster V (11.70 per cent) and least in cluster IV (6.55 per cent). Cluster II had the highest oil content (8.37 per cent), while cluster V had the least (5.27 per cent). The highest mean grain yield was recorded in cluster IV (3.57 kg/plot) and the lowest was recorded in cluster V (1.77 kg/plot)

Average intra and inter cluster distances

The average intra and inter cluster D^2 values are presented in Table 1c. Intra cluster values ranged from 4.53 (cluster V) to 6.41 (cluster IV).

Inter cluster distance ranged from 10.09 (between cluster II and V) to 46.69 (between IV and V).

Based on D^2 analysis, 10 parents were selected from various clusters *i.e.*, from cluster I – 3 parents, cluster II – 3 parents, cluster III – 2 parents, cluster IV – 1 parent and cluster V – 1 parent.

4.2 MEANS

The selected 10 parents were crossed in a diallel fashion and resulting 45 crosses along with 10 parents and 2 checks, *viz.*, Madhuri and BMH-1620 were evaluated in Randomized Block Design with three replications at three locations *viz.*, Rajendranagar, Palem and Karimnagar. The data were collected on 14 characters including grain yield, protein and oil content.

4.2.1 Analysis of Variance

The genotypic differences were significant for all the characters in all the three locations *viz.*, Rajendranagar, Palem and Karimnagar (*Table 2*).

4.2.2 Mean Performance of Parents, Hybrids and Checks

The mean values of parents and hybrids for 12 quantitative characters, oil and protein content at three locations *viz.*, Rajendranagar, Palem and Karimnagar are presented in Table 3a to 3e.

Table 2 : Analysis of variance for 14 characters in maize genotypes at three locations

Source	d.f.	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husk	Ear height (cm)	Plant height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernel rows / ear	No. of kernels / row	No. of kernels / ear	100 kernel weight (g)	Protein content (%)	Oil content (%)	Grain yield (kg/plot)
Location I : Rajendranagar															
Replications	2	2.89	2.91	3.49	22.59	358.25	15.58	6.81	0.89	7.37	245.67	1.62	1.13	0.03	0.09
Treatments	54	9.65**	10.70**	12.58**	327.66**	1255.03**	13.91**	23.72**	4.09**	63.22**	17387.85**	19.70**	1.93**	1.68**	1.44**
Error	108	1.12	1.00	1.32	10.41	120.46	7.18	7.85	0.45	2.56	556.78	2.15	1.06	0.57	0.08
Location II : Palem															
Replications	2	1.64	0.59	0.12	35.98	82.00	8.74	2.12	0.29	0.29	752.58	1.86	0.21	0.70	0.04
Treatments	54	4.02**	3.38**	3.89**	325.82**	1300.79**	21.02**	5.52**	3.32**	68.72**	20603.31**	25.60**	1.65**	1.75**	1.86**
Error	108	1.30	1.10	1.54	22.65	67.04	3.34	2.11	0.56	2.45	689.63	1.52	0.55	0.49	0.07
Location III : Karimnagar															
Replications	2	0.33	0.57	0.24	29.67	123.06	2.34	2.53	0.29	3.57	128.10	0.40	0.66	0.38	0.02
Treatments	54	5.36**	5.55**	6.90**	310.37**	1287.41**	17.92**	10.90**	4.04**	55.68**	17707.43**	27.12**	1.73**	1.57**	1.73**
Error	108	1.12	1.33	1.54	11.35	68.87	4.39	4.28	0.53	3.24	683.54	1.57	0.86	0.51	0.08

* Significant (P<0.05)

** Significant (P<0.01)

4.2.2.1 Days to 50 per cent tasseling

The mean number of days to 50 per cent tasseling was 55.51 days with a range of 52.33 to 60.00 days at Rajendranagar. The mean for parents ranged from 56.67 (P_3) to 60 days (P_2 , P_4 and P_7) and for crosses it varied from 52.33 ($P_3 \times P_5$) to 56.67 days ($P_1 \times P_6$, $P_1 \times P_8$ and $P_6 \times P_{10}$). The checks Madhuri and BMH-1620 recorded 55.33 and 60.00 days to 50 per cent tasseling, respectively.

At Palem, mean number of days to 50 per cent tasseling was 56.34 days with a range of 54.33 to 59.67 days. Parents showed a mean range of 56.33 (P_3) to 59.67 days (P_{10}). Hybrids ranged from 54.33 ($P_3 \times P_5$) to 58.00 days ($P_1 \times P_4$) while check BMH-1620 recorded 59.67 days and Madhuri recorded 55.67 days.

The average number of days to 50 per cent tasseling at Karimnagar location was 55.93 days with a range from 53.33 to 59.00 days. The mean days to 50 per cent tasseling for parents ranged from 56.33 (P_6) to 59.00 days (P_2 , P_7 and P_{10}) while for hybrids the range varied from 53.33 ($P_2 \times P_6$ and $P_3 \times P_5$) to 57.33 days ($P_1 \times P_5$). The checks, Madhuri and BMH-1620 recorded 55.67 and 59.00 days for 50 per cent tasseling, respectively (Table 3a).

Table 3a: Mean performance of parents and crosses for days to 50 per cent tasseling, 50 per cent silking and 50 per cent brown husk at three locations

Parents	Days to 50% tasseling			Days to 50% silking			Days to 50% brown husk		
	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar
P ₁	59.00	57.67	58.33	61.33	60.67	61.67	91.67	90.67	91.67
P ₂	60.00	59.00	59.00	63.00	61.67	62.67	93.67	91.67	92.67
P ₃	56.67	56.33	57.33	59.00	59.67	60.33	89.00	90.33	90.33
P ₄	60.00	58.67	59.00	62.67	61.67	62.33	93.33	92.00	92.67
P ₅	57.00	57.00	57.00	60.00	59.00	60.00	91.00	92.00	92.00
P ₆	57.67	56.67	56.33	60.67	59.67	60.67	91.00	90.33	91.33
P ₇	60.00	59.33	59.00	63.00	62.67	62.00	93.67	93.00	92.33
P ₈	57.00	57.33	57.67	59.67	60.33	60.67	90.33	91.33	90.67
P ₉	57.67	56.67	56.67	60.67	60.00	60.00	91.33	92.67	92.33
P ₁₀	59.67	59.67	59.00	62.67	62.67	62.00	93.33	90.33	90.67
Mean	58.47	57.83	57.93	61.27	60.80	61.23	91.83	91.43	91.67
P ₁ X P ₂	55.33	55.67	54.67	57.33	58.33	58.33	87.33	89.00	88.33
P ₁ X P ₃	54.33	54.67	55.00	57.33	57.67	58.00	87.33	89.67	88.67
P ₁ X P ₄	54.00	58.00	56.00	56.67	60.00	59.00	89.00	89.33	89.67
P ₁ X P ₅	54.00	56.67	57.33	57.33	59.33	60.33	87.33	90.00	91.00
P ₁ X P ₆	56.67	55.00	55.33	58.67	58.33	58.33	89.00	88.00	89.00
P ₁ X P ₇	55.00	55.00	56.00	57.00	58.00	59.00	88.33	89.00	90.33
P ₁ X P ₈	56.67	56.33	55.00	59.33	60.67	60.33	89.67	91.00	91.00
P ₁ X P ₉	56.00	57.33	56.33	59.00	60.00	59.67	89.67	89.33	90.67
P ₁ X P ₁₀	55.00	55.00	55.67	57.67	58.67	59.67	88.00	88.67	90.33
P ₂ X P ₃	54.00	57.00	56.00	57.00	60.00	58.33	88.00	90.33	91.00
P ₂ X P ₄	55.67	56.67	56.33	58.67	59.67	59.33	88.67	90.00	89.67
P ₂ X P ₅	53.00	55.33	54.33	55.67	58.67	57.33	85.00	88.67	87.33
P ₂ X P ₆	52.67	54.67	53.33	55.33	59.00	58.33	85.33	89.67	87.67
P ₂ X P ₇	53.67	57.33	56.00	56.33	60.00	59.00	88.33	92.00	91.33
P ₂ X P ₈	54.00	55.00	56.33	56.33	58.00	59.67	85.67	87.00	89.33
P ₂ X P ₉	54.00	56.00	54.67	56.33	59.33	58.67	87.67	89.67	88.67
P ₂ X P ₁₀	54.00	56.67	55.00	56.67	60.00	59.00	86.67	90.67	89.00
P ₃ X P ₄	55.33	55.67	55.33	57.67	59.33	58.67	84.33	89.33	89.00
P ₃ X P ₅	52.33	54.33	53.33	55.00	58.67	57.33	87.00	89.00	86.33
P ₃ X P ₆	54.00	57.00	56.00	56.00	60.00	58.00	89.67	92.00	90.00
P ₃ X P ₇	55.67	56.33	56.33	58.33	59.33	60.00	88.67	90.33	90.67
P ₃ X P ₈	54.33	55.00	55.33	57.33	58.33	58.67	87.67	89.67	88.33
P ₃ X P ₉	54.33	56.67	54.33	57.33	59.67	58.00	88.33	90.00	87.67
P ₃ X P ₁₀	55.00	55.33	54.67	56.67	58.33	57.33	87.33	89.00	87.00
P ₄ X P ₅	55.00	55.67	55.67	57.33	59.33	58.67	88.00	90.67	90.33
P ₄ X P ₆	54.00	55.33	54.67	57.00	59.33	58.67	88.33	90.00	89.00
P ₄ X P ₇	55.00	56.33	55.00	57.67	59.67	58.33	89.33	90.33	88.33
P ₄ X P ₈	55.67	56.33	56.67	57.67	59.67	59.67	87.67	89.67	91.33
P ₄ X P ₉	54.67	56.67	55.33	57.33	60.33	58.33	88.33	90.67	87.67
P ₄ X P ₁₀	54.00	56.00	54.00	56.67	58.33	56.00	88.67	90.00	90.00
P ₅ X P ₆	53.33	56.67	55.33	55.67	59.67	57.33	85.67	89.67	87.33
P ₅ X P ₇	54.67	57.33	54.67	57.33	60.33	58.67	87.67	90.33	88.67
P ₅ X P ₈	54.67	55.33	55.33	57.67	59.00	58.33	89.33	89.67	89.00
P ₅ X P ₉	56.33	56.00	56.67	59.33	59.00	59.33	90.33	91.67	92.00
P ₅ X P ₁₀	55.67	55.67	56.67	58.33	59.67	59.67	89.00	89.67	91.00
P ₆ X P ₇	56.00	56.33	56.67	59.00	59.33	58.67	90.00	89.33	88.67
P ₆ X P ₈	56.33	57.33	56.00	59.67	59.67	59.00	90.33	90.33	89.33
P ₆ X P ₉	54.33	56.00	54.00	57.00	58.00	57.33	89.00	90.33	89.00
P ₆ X P ₁₀	56.67	56.67	56.67	59.00	59.00	59.67	89.67	89.33	89.67
P ₇ X P ₈	56.00	56.00	56.00	58.00	58.33	58.33	90.67	91.00	90.33
P ₇ X P ₉	55.67	55.67	56.67	58.67	58.67	59.33	89.00	88.67	90.00
P ₇ X P ₁₀	55.00	56.33	55.33	57.00	59.67	59.33	86.67	90.67	89.33
P ₈ X P ₉	55.33	55.67	55.67	57.67	58.67	57.67	87.67	89.33	89.00
P ₈ X P ₁₀	55.67	55.00	55.67	58.00	59.67	58.67	89.33	89.67	88.67
P ₉ X P ₁₀	55.33	55.67	55.67	57.33	60.67	60.67	87.67	90.67	90.67
Hybrid Mean	54.85	56.02	55.49	57.43	59.23	58.71	88.14	89.84	89.36
Grand Mean	55.51	56.35	55.93	58.13	59.52	59.17	88.81	90.13	89.78
Madhuri	55.33	55.67	55.67	58.00	59.33	59.33	88.33	89.33	89.67
BMH -1620	60.00	59.67	59.00	63.33	62.67	62.00	94.67	92.67	91.67
S.E.m ±	0.61	0.66	0.61	0.58	0.61	0.67	0.66	0.72	0.71
CD 5%	1.70	1.82	1.70	1.60	1.68	1.84	1.84	1.98	1.98
CV %	1.91	2.02	1.90	1.72	1.76	1.95	1.29	1.37	1.38

4.2.2.2 Days to 50 per cent silking

At Rajendranagar, the number of days to 50 per cent silking ranged from 55.00 to 63.00 days with a mean of 58.13 days. For parents, the days to 50 per cent silking varied from 59.00 (P_3) to 63.00 days (P_2 and P_7) and for crosses it was from 55.00 ($P_3 \times P_5$) to 59.67 days ($P_6 \times P_8$). The checks, Madhuri and BMH-1620 recorded 58.00 and 63.33 days to 50 per cent silking (Table 3a).

At Palem, the mean number of days to 50 per cent silking was 59.51 with a range of 57.67 to 62.67 days, while the parents showed a mean range of 59.00 (P_5) to 62.67 days (P_7 and P_{10}). The hybrids ranged from 57.67 ($P_1 \times P_3$) to 60.67 days ($P_1 \times P_8$) and ($P_9 \times P_{10}$) and the checks, Madhuri and BMH-1620 recorded 59.33 and 62.67 days, respectively.

At Karimnagar, the average number of days to 50 per cent silking was 59.17 days with a range of 57.33 to 62.67 days. The mean days to 50 per cent silking for parents ranged from 60.00 days (P_5 and P_9) to 62.67 days (P_2), while for hybrids the range was from 57.33 to 60.67 days. The check, BMH-1620 recorded 62.00 days, while Madhuri recorded 59.33 days.

4.2.2.3 Days to 50 per cent brown husk

The average number of days to 50 per cent brown husk was 88.81 days with a range of 84.33 to 93.67 days at Rajendranagar. The mean for parents ranged from 89.00 (P_3) to 93.67 days (P_2 and P_7), while that of crosses varied from 84.33 ($P_3 \times P_4$) to 90.67 days ($P_7 \times P_8$) BMH-1620 recorded 94.67 days for 50 per cent brown husk, whereas Madhuri recorded 88.33 days.

At Palem, mean number of days to 50 per cent brown husk was 90.13 days with a range of 87.00 to 93.00 days. Parents showed a mean range of 90.33 (P_3 , P_7 and P_{10}) to 93.00 days (P_7), while the checks, Madhuri and BMH-1620 recorded 89.33 and 92.67 days to 50 per cent brown husk, respectively.

At Karimnagar, the number of days to 50 per cent brown husk varied from 86.33 to 92.67 days with a mean of 89.78 days. The mean days to 50 per cent brown husk for parents ranged from 90.33 (P_3) to 92.67 days (P_2 and P_4) while for hybrids the range varied from 86.33 ($P_3 \times P_5$) to 92.00 days ($P_5 \times P_9$), the checks, Madhuri and BMH-1620 recorded 89.67 and 91.67 days (Table 3a).

4.2.2.4 Ear height (cm)

The ear height at Rajendranagar ranged from 54.30 to 91.10 cm with a mean of 79.12 cm. The mean ear height for parents ranged from

Table 3b: Mean performance of parents and crosses for ear height, plant height and ear length at three locations

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Parents & crosses	Ear height (cm)			Plant height (cm)			Ear length (cm)		
	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar
P ₁	77.20	75.67	76.13	158.83	149.20	155.97	13.37	10.70	12.37
P ₂	74.93	75.60	74.40	194.77	184.47	185.23	12.90	12.50	13.80
P ₃	60.50	55.30	56.77	164.13	162.30	166.47	12.93	11.63	12.80
P ₄	83.33	72.67	80.00	198.27	180.70	185.73	13.23	13.80	13.60
P ₅	56.37	48.17	50.50	130.93	100.63	104.17	14.33	12.37	12.40
P ₆	54.30	54.17	54.47	167.60	156.90	164.93	11.93	10.63	12.27
P ₇	61.40	60.93	61.83	159.87	144.73	145.90	11.33	11.43	12.33
P ₈	64.43	63.07	67.83	170.97	171.13	171.77	14.57	10.40	11.40
P ₉	68.53	64.83	68.40	151.00	144.77	150.00	12.37	12.63	12.53
P ₁₀	68.40	67.93	70.30	180.27	164.90	174.93	14.43	12.53	12.37
Mean	66.94	63.83	66.06	167.66	155.97	160.51	13.14	11.86	12.59
P ₁ X									
P ₂	83.67	80.43	82.67	199.83	180.87	188.07	18.53	16.43	18.47
P ₃	80.50	81.90	80.17	203.60	190.43	192.17	16.83	17.57	17.43
P ₄	75.77	82.40	77.10	210.83	207.53	203.63	16.67	16.60	16.37
P ₅	89.23	80.60	88.23	215.27	208.97	216.47	17.53	18.60	17.63
P ₆	80.70	79.73	81.57	187.27	206.43	215.73	17.80	16.13	17.73
P ₇	91.10	86.83	89.53	200.77	195.73	198.43	19.13	18.47	19.27
P ₈	86.03	85.53	85.67	212.20	200.93	207.73	17.27	16.60	18.93
P ₉	86.03	79.77	86.67	216.13	209.80	205.17	20.00	17.27	16.97
P ₁₀	85.83	84.93	89.10	226.17	209.07	207.27	16.17	16.63	16.40
P ₂ X									
P ₃	80.57	75.37	81.90	174.83	158.53	179.50	15.47	17.37	16.83
P ₄	74.60	69.90	72.77	193.90	191.80	186.20	17.87	17.43	16.10
P ₅	66.73	63.73	65.13	179.97	181.93	186.73	17.33	17.27	17.90
P ₆	88.57	62.07	90.93	198.73	191.77	200.47	18.47	16.17	18.33
P ₇	88.87	82.37	86.63	214.50	199.50	211.30	18.17	17.40	17.27
P ₈	88.20	86.27	88.80	205.33	200.07	203.10	17.83	17.60	18.90
P ₉	68.77	70.30	74.27	192.43	186.87	186.03	17.37	18.73	17.90
P ₁₀	88.47	86.13	90.53	187.10	186.40	187.80	16.87	18.90	19.17
P ₃ X									
P ₄	86.40	76.50	82.07	206.50	195.33	197.83	18.17	16.27	18.67
P ₅	70.70	62.87	68.93	181.67	179.00	172.97	17.00	17.83	16.80
P ₆	87.63	84.07	89.47	211.17	202.47	198.97	15.40	11.87	12.83
P ₇	89.47	83.53	89.40	216.73	202.63	216.07	16.93	18.50	17.70
P ₈	85.03	83.60	86.10	210.93	211.23	213.17	17.07	17.30	18.10
P ₉	90.43	87.27	89.57	217.47	208.13	206.07	17.00	13.30	14.77
P ₁₀	87.10	91.07	86.10	188.07	189.90	188.13	17.70	16.60	16.77
P ₄ X									
P ₅	82.40	82.33	81.17	199.10	201.17	205.47	12.43	11.87	12.50
P ₆	91.07	85.87	89.70	199.37	200.23	205.50	16.57	19.13	19.30
P ₇	88.43	87.70	89.97	203.20	193.90	185.53	19.13	19.63	19.07
P ₈	83.27	76.03	77.83	206.03	199.10	196.47	18.00	16.10	17.60
P ₉	66.60	63.43	65.20	180.50	179.57	185.17	18.93	17.00	16.10
P ₁₀	62.90	65.27	68.83	159.80	194.40	193.50	17.57	17.80	18.13
P ₅ X									
P ₆	84.37	85.43	82.43	179.20	188.17	178.90	16.50	15.63	16.63
P ₇	60.47	64.57	65.67	168.73	179.73	181.17	16.47	16.17	17.00
P ₈	64.47	64.03	68.90	180.60	189.83	184.60	16.87	16.10	16.40
P ₉	70.87	74.97	73.97	178.23	185.33	185.63	17.90	18.23	19.30
P ₁₀	73.23	75.57	78.73	185.93	183.93	187.37	17.27	16.23	17.90
P ₆ X									
P ₇	85.17	79.73	86.10	205.00	201.60	194.00	17.37	19.07	19.30
P ₈	78.50	74.70	78.90	204.13	195.00	199.77	19.57	18.03	18.43
P ₉	90.73	91.93	88.37	200.50	195.50	205.73	16.20	15.30	18.40
P ₁₀	88.53	86.07	84.17	224.53	203.60	218.27	18.90	19.53	19.20
P ₇ X									
P ₈	73.87	69.93	71.73	211.13	204.83	211.33	18.07	17.47	18.23
P ₉	87.27	82.27	87.80	214.13	212.57	215.03	19.30	18.10	19.37
P ₁₀	89.13	86.97	87.83	216.77	206.70	214.57	18.27	19.03	19.53
P ₈ X									
P ₉	90.37	90.63	89.23	195.10	194.50	189.83	19.43	18.03	18.37
P ₁₀	86.97	85.77	85.60	215.03	205.07	210.60	18.13	19.10	18.50
P ₉ X									
P ₁₀	83.47	77.97	81.90	208.30	200.77	195.90	19.40	19.70	18.97
Hybrid Mean	81.83	79.07	81.94	199.71	195.80	198.07	17.57	17.20	17.68
Grand Mean	79.12	76.30	79.05	193.88	188.56	191.24	16.77	16.23	16.75
Madhuri	77.83	76.13	78.53	194.90	185.87	184.63	17.50	17.03	17.73
BMH-1620	83.67	82.43	83.57	203.60	206.33	207.23	17.00	17.77	18.83
S.E.m ±	1.86	2.75	1.94	6.34	4.72	4.79	1.55	1.05	1.21
CD 5%	5.16	7.61	5.39	17.56	13.10	13.28	4.29	2.92	3.35
CV %	4.07	6.23	4.26	5.66	4.34	4.33	15.98	11.26	12.51

54.30 (P_6) to 83.33 (P_4) cm. Among hybrids, the cross $P_5 \times P_7$ recorded the lowest value of 60.47 cm and highest value of 91.10 cm was recorded by cross $P_1 \times P_7$. The checks Madhuri and BMH-1620 recorded 77.83 and 83.67 cm for ear height (Table 3b).

At Palem, a general mean of 76.30 cm was recorded with a range of 48.17 to 91.93 cm. The ear height of parents ranged from 48.17 (P_5) to 75.67 cm (P_1), while that of hybrids ranged from 62.07 ($P_2 \times P_6$) to 91.93 cm ($P_6 \times P_9$). The checks, Madhuri and BMH-1620 recorded 76.13 and 82.43 cm of ear height.

At Karimnagar, the mean ear height ranged from 50.50 to 90.93 cm with a mean of 79.05 cm. The ear height of parents ranged from 50.50 (P_5) to 80.00 cm (P_4), whereas mean ear height in hybrids ranged from 65.13 ($P_2 \times P_5$) to 90.93 cm ($P_2 \times P_6$). The checks, Madhuri and BMH-1620 recorded an ear height of 78.53 and 83.57 cm, respectively (Table 3b).

4.2.2.5 Plant height (cm)

The plant height of genotypes at Rajendranagar ranged from 130.93 to 226.17 cm with a mean of 193.88 cm. The mean plant height for parents ranged from 130.93 (P_5) to 198.27 cm (P_4). In case of hybrids, the mean plant height ranged from 168.73 ($P_5 \times P_7$) to 226.17 cm

($P_1 \times P_{10}$). The plant height of checks, Madhuri and BMH-1620 found 194.90 and 203.60 cm, respectively (Table 3b).

At Palem, the mean plant height ranged from 100.63 to 212.57 cm with an average height of 188.55 cm. For parental lines, the plant height ranged from 100.63 (P_5) to 184.47 cm (P_2), whereas for hybrids the height ranged from 158.53 ($P_2 \times P_3$) to 212.57 cm ($P_7 \times P_9$). The checks, BMH-1620 showed a plant height of 206.33 cm whereas, Madhuri recorded 185.87 cm.

At Karimnagar, mean plant height of 191.24 cm was recorded, showing range from 104.17 to 218.27 cm. The parents were in the range of 104.17 (P_5) to 185.73 cm (P_4). In hybrids, the mean plant height ranged from 178.90 ($P_5 \times P_6$) to 218.27 cm ($P_6 \times P_{10}$). The check, BMH-1620 recorded a plant height of 207.23 cm while, Madhuri recorded 184.63 cm.

4.2.2.6 Ear length (cm)

The ear length at Rajendranagar ranged from 11.33 to 20.00 cm with a mean of 16.77 cm. The parents recorded an ear length ranging from 11.33 (P_7) to 14.57 cm (P_8). For hybrids, the mean ear length varied from 12.43 ($P_4 \times P_5$) to 20.00 cm ($P_1 \times P_9$). The checks, Madhuri and BMH-1620 recorded 17.50 and 17.00 cm ear length, respectively (Table 3b).

Ear length at Palem varied from 10.40 to 19.70 cm with a general mean of 16.23 cm. The ear length for parents ranged from 10.40 (P₈) to 13.80 cm (P₄). In case of hybrids, the mean ear length varied from 11.87 (P₃ x P₆ and P₄ x P₅) to 19.70 cm (P₉ x P₁₀). The checks, BMH-1620 recorded 17.77 cm while Madhuri recorded 17.03 cm.

An ear length of 11.40 to 19.53 cm was recorded at Karimnagar location with a mean of 16.75 cm. The parents recorded an ear length ranging from 11.40 (P₈) to 13.80 cm (P₂), while for hybrids the range was 12.50 (P₄ x P₅) to 19.53 cm (P₇ x P₁₀). The check, BMH-1620 recorded 18.83 cm of ear length, whereas Madhuri recorded 17.73 cm.

4.2.2.7 Ear girth (cm)

The ear girth of genotypes at Rajendranagar ranged from 11.40 to 18.87 cm with a general mean of 15.32 cm. The mean ear girth for parents ranged from 11.43 (P₁) to 17.20 cm (P₆). In case of hybrids the mean ear girth ranged from 11.40 (P₃ x P₆) to 18.87 cm (P₄ x P₆). The checks, Madhuri and BMH-1620 also recorded 13.80 and 17.83 cm of ear girth, respectively (Table 3c).

At Palem, mean ear girth ranged from 10.37 to 15.63 cm with a general mean of 13.78 cm. The parents had a range of 10.47 (P₁) to

Table 3c: Mean performance of parents and crosses for ear girth, No. of kernel rows per ear and No. of kernels per row at three locations

Parents	Ear girth (cm)			No. of kernel rows per ear			No. of kernels per row		
	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar
P ₁	11.43	10.47	12.37	12.00	12.00	12.00	27.33	25.00	26.00
P ₂	13.33	11.43	12.90	14.00	12.67	14.00	29.00	30.00	28.67
P ₃	11.73	11.13	11.17	14.00	12.67	13.33	24.67	21.33	23.33
P ₄	13.87	12.80	14.17	12.00	12.67	12.00	26.00	23.33	26.33
P ₅	14.53	12.37	13.40	13.33	13.33	13.33	27.33	24.33	25.67
P ₆	17.20	13.37	14.20	14.00	14.00	14.00	28.00	29.00	28.00
P ₇	15.90	12.70	12.37	18.00	16.00	16.00	24.67	25.00	27.67
P ₈	13.57	12.53	11.97	16.67	16.00	16.67	29.33	29.00	29.33
P ₉	13.97	11.40	12.30	14.67	14.00	14.67	23.33	25.00	25.33
P ₁₀	14.57	11.23	11.43	16.00	16.00	15.33	21.67	24.00	23.33
Mean	14.01	11.94	12.63	14.47	13.93	14.13	26.13	25.60	26.37
P ₁ X									
P ₂	13.17	14.57	15.40	14.00	14.00	14.00	36.33	36.67	36.00
P ₃	15.73	15.47	13.33	16.00	14.67	16.00	37.00	36.67	36.33
P ₄	14.23	14.80	15.67	16.00	16.00	16.00	38.33	38.00	38.00
P ₅	17.60	15.57	13.97	14.00	16.00	16.00	36.33	36.00	36.67
P ₆	14.70	14.60	14.73	14.00	14.67	14.00	40.00	40.33	37.67
P ₇	14.63	14.73	14.73	16.00	15.33	16.00	36.67	37.67	37.33
P ₈	14.53	14.30	14.97	14.67	14.67	14.00	37.00	37.33	35.00
P ₉	16.33	14.40	14.67	16.00	14.00	16.00	37.33	35.67	36.67
P ₁₀	14.60	13.67	14.03	15.33	14.00	16.00	38.33	36.00	36.33
P ₂ X									
P ₃	13.93	14.63	16.73	14.00	14.00	14.00	35.33	33.00	35.33
P ₄	15.87	13.23	15.70	17.33	14.67	14.67	37.00	36.00	35.00
P ₅	16.47	14.07	13.97	14.67	14.67	14.00	33.67	33.67	36.00
P ₆	14.97	15.57	16.13	15.33	14.00	14.67	36.67	35.33	35.33
P ₇	17.37	15.40	15.33	14.00	15.33	14.00	30.67	30.33	29.67
P ₈	15.37	14.87	15.57	14.00	15.33	16.00	36.00	38.33	35.33
P ₉	14.63	13.43	13.50	16.00	16.00	17.33	36.33	34.67	33.33
P ₁₀	16.13	15.47	16.60	16.00	16.00	16.00	35.67	36.33	36.33
P ₃ X									
P ₄	11.57	14.50	14.07	14.00	16.00	14.00	35.00	31.67	33.67
P ₅	14.53	14.87	14.77	14.00	14.00	14.00	30.33	28.33	27.67
P ₆	11.40	10.37	11.13	14.00	14.00	14.00	36.67	30.00	30.00
P ₇	15.73	14.00	17.03	14.00	14.00	14.00	35.33	36.00	35.33
P ₈	15.40	14.03	14.67	15.33	16.00	16.00	37.00	36.67	37.33
P ₉	15.20	14.23	14.90	15.33	14.67	14.67	35.00	33.33	32.00
P ₁₀	16.67	14.80	16.63	14.00	14.00	14.00	32.67	33.33	34.00
P ₄ X									
P ₅	11.63	11.07	12.00	14.67	14.67	14.67	29.00	28.67	28.33
P ₆	18.87	15.27	16.47	16.67	16.00	16.00	32.33	33.67	33.00
P ₇	16.73	14.03	15.00	14.67	14.67	15.33	34.33	36.67	36.00
P ₈	15.67	12.97	13.30	16.00	14.67	14.67	36.00	37.33	35.33
P ₉	16.80	15.23	16.13	15.33	16.00	14.67	29.00	28.67	28.67
P ₁₀	16.60	14.03	14.43	15.33	14.00	15.33	38.33	37.33	36.00
P ₅ X									
P ₆	18.17	13.47	13.83	16.00	14.00	14.67	37.67	37.67	36.00
P ₇	15.80	13.40	14.63	14.00	15.33	12.67	38.67	39.33	37.33
P ₈	16.97	12.60	13.97	14.00	13.33	14.00	36.67	36.33	35.00
P ₉	16.23	13.50	15.47	14.00	13.33	14.00	34.33	36.67	36.33
P ₁₀	14.73	14.30	14.77	15.33	16.00	15.33	36.00	31.67	33.67
P ₆ X									
P ₇	18.77	14.87	17.30	16.00	15.33	16.00	38.00	37.33	38.33
P ₈	17.00	13.43	12.97	14.00	14.00	14.00	37.33	37.00	36.00
P ₉	16.00	13.67	15.87	15.33	16.00	16.00	37.33	36.00	34.00
P ₁₀	15.63	14.57	15.83	14.00	14.00	14.00	37.33	38.00	38.00
P ₇ X									
P ₈	16.20	14.73	14.97	14.67	15.33	15.33	37.67	36.00	36.00
P ₉	15.50	14.13	15.90	14.67	14.67	12.67	39.00	37.67	40.00
P ₁₀	16.80	14.33	14.07	14.00	14.00	14.00	33.33	33.67	33.33
P ₈ X									
P ₉	16.37	13.27	15.00	14.00	14.00	14.00	37.33	34.33	34.00
P ₁₀	16.57	14.63	15.97	16.00	16.00	16.00	37.00	38.00	38.33
P ₉ X									
P ₁₀	14.53	15.63	15.47	14.00	15.33	14.00	40.00	39.67	39.00
Hybrid Mean	15.61	14.19	14.92	14.90	14.19	14.81	35.94	35.40	35.09
Grand Mean	15.32	13.78	14.51	14.82	14.65	14.69	34.16	33.62	33.50
Madhuri	13.80	13.50	13.25	15.33	14.67	14.67	22.33	27.00	27.00
BMH-1620	17.83	14.27	14.27	14.00	14.00	14.00	36.67	33.67	33.67
S.E.m ±	1.62	0.84	1.19	0.39	0.43	0.42	0.92	0.91	1.04
CD 5%	4.48	2.32	3.31	1.07	1.20	1.17	2.56	2.50	2.88
CV %	18.29	10.54	14.27	4.53	5.11	4.99	4.69	4.66	5.37

13.37 cm (P_6). The check, BMH-1620 recorded 14.27 cm of ear girth while Madhuri recorded 13.50 cm.

Karimnagar center recorded a mean of 14.51 cm with a range of 11.13 to 17.30 cm. Parents showed a range of 11.17 (P_3) to 14.20 cm (P_6). The ear girth in crosses ranged from 11.13 ($P_3 \times P_6$) to 17.30 cm ($P_6 \times P_7$), while that of checks, Madhuri and BMH-1620 recorded mean ear girth of 13.25 and 14.27 cm, respectively.

4.2.2.8 Number of kernel rows per ear

The mean number of kernel rows per ear at Rajendranagar location was 14.82 with a range of 12.00 to 18.00. The kernel rows of parents ranged from 12.00 (P_1 and P_4) to 18.00 (P_7), while that of crosses varied from 14.00 ($P_1 \times P_2$, $P_1 \times P_5$ and $P_1 \times P_6$) to 17.33 ($P_2 \times P_4$). The check, BMH-1620 was found to have 14.00 kernel rows per ear while, Madhuri recorded mean 15.33 rows (Table 3c).

The average number of kernel rows per ear at Palem was found 14.65 with a range of 12.00 to 16.00. The number of kernel rows per ear for the parents ranged from 12.00 (P_1) to 16.00 (P_7 , P_8 and P_{10}). The mean range of crosses ranged from 13.33 ($P_5 \times P_8$ and $P_5 \times P_9$) to 16.00 ($P_1 \times P_4$ and $P_5 \times P_6$). The checks, Madhuri and BMH-1620 recorded 14.67 and 14.00 kernel rows per ear, respectively.

At Karimnagar, the number of kernel rows per ear varied from 12.00 to 17.33 with a mean of 14.69. The parents had the values ranging from 12.00 (P_1 and P_4) to 16.67 (P_8). The crosses ranged from 12.67 ($P_5 \times P_7$ and $P_7 \times P_9$) to 17.33 ($P_2 \times P_9$). The checks, Madhuri and BMH-1620 recorded 14.67 and 14.00 kernel rows per ear, respectively.

4.2.2.9 Number of kernels per row

The mean number of kernels per row at Rajendranagar was 34.16 with a range of 21.67 to 40.00. The number of kernels per row of parents varied from 21.67 (P_{10}) to 29.33 (P_8). The range for crosses was from 29.00 ($P_4 \times P_5$) to 40.00 ($P_1 \times P_6$ and $P_9 \times P_{10}$), while the checks, Madhuri and BMH-1620 recorded 22.33 and 36.67 kernels per row, respectively.

The average number of kernels per row at Palem found 33.62 with a range of 21.33 to 40.33. The number of kernels per row in parents ranged from 21.33 (P_3) to 30.00 (P_2). The mean of crosses had a range from 28.33 ($P_2 \times P_5$) to 40.33 ($P_1 \times P_6$). The check, BMH-1620 recorded 33.67 kernels per row while Madhuri recorded 27.00.

At Karimnagar, the number of kernels per row varied from 23.33 to 40.00 with a mean of 33.60. The parents had the values ranging from 23.33 (P_3 and P_{10}) to 29.33 (P_8). The crosses ranged from 27.67

($P_3 \times P_5$) to 40.00 ($P_7 \times P_9$). The check, BMH-1620 recorded 33.67 kernels per row, while Madhuri recorded 27.00.

4.2.210 Number of kernels per ear

The mean number of kernels per ear at Rajendranagar was 503.45 with a range of 315.33 to 605.33. The kernels per ear of parents varied from 315.33 (P_4) to 485.67 (P_8) while the crosses ranged from 431.33 ($P_2 \times P_7$) to 605.33 ($P_6 \times P_7$). The checks, Madhuri and BMH-1620 found to have 344.00 and 513.00 kernels per ear, respectively (Table 3d).

At Palem, the number of kernels per ear varied from 285.00 to 604.67 with a mean of 488.32. The parents had the values ranging from 285.00 (P_3) to 463.67 (P_8). The crosses ranged from 398.00 ($P_3 \times P_5$) to 604.67 ($P_5 \times P_7$). The check, BMH-1620 recorded 472.67 kernels per ear while Madhuri recorded 377.33.

The average number of kernels per ear at Karimnagar found to be 489.94 with a range of 311.67 to 599.00. The number of kernels per ear in parents ranged from 311.67 (P_3) to 498.00 (P_7). The crosses had a range of 383.33 ($P_3 \times P_5$) to 599.00 ($P_6 \times P_7$). The check, BMH-1620 recorded 468.67 kernels per ear and Madhuri recorded 378.33.

Table 3d: Mean performance of parents and crosses for No. of kernels per ear, 100 kernel weight and protein content at three locations

Parents	No. of kernels per ear			100 grain weight (g)			Protein content (%)		
	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar
P ₁	325.67	310.00	330.00	30.97	26.87	28.37	11.17	10.47	11.11
P ₂	402.67	373.00	403.00	31.10	31.17	31.37	10.56	10.41	10.47
P ₃	351.33	285.00	311.67	34.07	30.70	29.57	11.40	11.41	11.41
P ₄	315.33	299.00	316.33	32.27	30.10	29.50	10.42	10.45	10.44
P ₅	365.67	310.00	328.33	33.23	28.43	30.20	11.33	11.32	11.32
P ₆	391.33	407.33	387.33	34.20	32.27	32.37	9.45	9.44	9.45
P ₇	443.67	398.00	498.00	34.60	30.97	30.93	9.30	10.22	9.25
P ₈	485.67	463.67	486.67	27.33	33.57	30.90	10.81	10.84	10.66
P ₉	347.67	354.33	355.33	28.23	28.07	26.43	10.53	10.27	10.53
P ₁₀	346.00	291.00	358.67	26.57	25.30	25.47	11.10	11.52	11.13
Mean	377.50	349.13	377.53	31.26	29.74	29.51	10.61	10.64	10.58
P ₁ X P ₂	509.33	515.00	505.33	35.70	34.70	34.27	11.26	11.66	11.88
P ₁ X P ₃	591.33	539.00	583.00	36.03	35.53	38.30	10.76	11.43	10.77
P ₁ X P ₄	580.33	580.33	573.67	37.33	37.33	36.67	10.43	10.97	10.98
P ₁ X P ₅	499.00	584.00	588.33	35.63	38.27	39.50	10.64	10.61	10.63
P ₁ X P ₆	560.00	559.67	529.33	38.23	39.67	32.93	10.77	11.60	11.47
P ₁ X P ₇	582.00	565.67	574.67	37.27	36.27	37.27	10.16	10.14	10.15
P ₁ X P ₈	520.00	544.33	490.67	36.13	35.13	32.83	11.65	11.06	10.62
P ₁ X P ₉	562.33	507.33	553.33	36.30	34.77	36.37	9.26	9.95	10.06
P ₁ X P ₁₀	558.00	489.00	505.33	36.27	32.27	37.20	9.21	10.97	10.52
P ₂ X P ₃	492.67	462.33	497.00	37.07	33.50	35.27	11.41	10.49	10.43
P ₂ X P ₄	603.33	525.00	543.33	35.40	34.60	35.57	10.61	10.87	10.23
P ₂ X P ₅	494.67	497.33	501.67	36.53	35.33	35.27	11.87	11.71	11.88
P ₂ X P ₆	560.67	495.67	522.33	35.47	33.43	36.77	10.41	10.69	10.83
P ₂ X P ₇	431.33	467.00	412.33	33.23	32.80	32.33	11.44	11.43	11.43
P ₂ X P ₈	501.00	576.00	568.00	36.20	36.30	37.37	11.24	10.25	10.24
P ₂ X P ₉	577.67	555.00	574.33	36.10	35.00	37.53	11.36	10.32	11.29
P ₂ X P ₁₀	566.67	585.67	564.67	39.50	36.50	38.27	9.70	9.35	9.40
P ₃ X P ₄	487.00	509.67	470.67	38.33	36.10	34.40	10.16	10.13	10.14
P ₃ X P ₅	438.67	398.00	383.33	34.27	32.63	32.33	9.61	9.53	9.52
P ₃ X P ₆	517.00	418.67	422.00	33.83	32.63	33.30	11.87	11.58	11.80
P ₃ X P ₇	497.00	505.00	494.67	34.97	36.20	34.67	10.18	10.14	10.15
P ₃ X P ₈	516.00	521.33	567.00	35.37	35.93	36.20	9.87	9.54	9.97
P ₃ X P ₉	552.67	479.00	470.33	35.50	34.13	31.80	10.09	10.45	10.30
P ₃ X P ₁₀	470.67	483.33	471.33	34.47	34.20	34.27	9.68	10.92	10.34
P ₄ X P ₅	452.00	399.00	415.00	32.03	31.03	31.23	11.10	8.89	9.25
P ₄ X P ₆	536.00	537.00	520.00	35.33	34.67	35.10	10.39	10.10	10.13
P ₄ X P ₇	506.33	537.33	552.67	34.10	34.63	35.17	10.16	10.15	10.20
P ₄ X P ₈	564.00	546.33	528.67	33.50	35.00	36.87	11.15	11.55	11.31
P ₄ X P ₉	446.00	492.67	400.00	33.23	32.23	32.27	11.15	10.54	10.16
P ₄ X P ₁₀	574.00	489.67	539.33	34.73	35.17	34.67	9.25	9.22	9.24
P ₅ X P ₆	582.33	526.67	528.67	34.33	34.20	34.60	11.82	11.71	11.74
P ₅ X P ₇	541.33	604.67	468.00	38.13	40.47	33.27	9.90	11.64	9.92
P ₅ X P ₈	508.00	486.67	489.33	34.73	36.27	34.57	11.17	10.85	10.85
P ₅ X P ₉	481.00	487.67	509.67	33.97	32.93	35.13	11.74	11.42	11.55
P ₅ X P ₁₀	553.67	507.00	516.33	31.97	32.20	35.57	9.51	10.54	9.66
P ₆ X P ₇	605.33	577.67	599.00	37.23	38.77	39.07	9.86	9.74	9.84
P ₆ X P ₈	526.67	519.33	507.67	36.53	35.40	35.40	11.47	11.57	11.44
P ₆ X P ₉	569.00	567.33	544.67	33.20	36.40	35.17	10.84	10.82	11.65
P ₆ X P ₁₀	551.00	534.00	540.33	35.23	34.60	35.17	10.68	10.88	10.59
P ₇ X P ₈	532.67	556.67	559.33	36.50	35.73	36.80	11.39	11.17	11.20
P ₇ X P ₉	579.67	554.00	507.00	37.60	34.10	34.67	10.92	10.91	10.91
P ₇ X P ₁₀	467.67	471.00	471.00	33.47	32.87	33.23	10.29	8.92	9.25
P ₈ X P ₉	523.00	483.00	476.67	36.00	34.70	33.17	10.42	10.55	10.54
P ₈ X P ₁₀	579.00	582.67	584.00	36.90	37.23	37.43	8.83	10.28	9.14
P ₉ X P ₁₀	567.00	542.67	547.33	36.20	35.30	37.27	9.17	10.13	10.15
Hybrid Mean	531.45	519.25	514.91	35.56	35.05	35.25	10.55	10.61	10.53
Grand Mean	503.45	488.32	489.94	34.78	34.08	34.21	10.56	10.61	10.54
Madhuri	344.00	377.33	378.33	27.77	29.27	27.87	12.78	13.04	12.80
BMH-1620	513.00	472.67	468.67	33.97	33.27	31.23	10.12	9.99	10.74
S.E.m ±	13.62	15.16	15.09	0.85	0.71	0.72	0.59	0.43	0.54
CD 5%	37.76	42.02	41.84	2.34	1.97	2.00	1.64	1.18	1.49
CV %	4.68	5.37	5.33	4.21	3.62	3.66	9.75	7.00	8.84

4.2.2.11 100 kernel weight (g)

At Rajendranagar, the mean 100 kernel weight was found to be 34.77 g with a range of 26.57 to 39.50 g. Among the parents, the highest and the lowest values were 34.60 g (P_7) and 26.57 g (P_{10}), respectively while the values of crosses varied from 32.03 ($P_4 \times P_5$) to 39.50 g ($P_2 \times P_{10}$). The check, BMH-1620 recorded 33.97 g for 100 kernel weight whereas Madhuri recorded 27.77 g (Table 3d).

The mean values at Palem ranged from 25.30 to 40.47 g with a mean of 34.08 g. the parents had a range from 25.30 g (P_{10}) to 33.57 g (P_8) while the crosses varied from 31.03 ($P_4 \times P_5$) to 40.47 g ($P_5 \times P_7$). The checks, Madhuri and BMH-1620 recorded 29.27 and 33.27 g for 100 kernel weight, respectively.

At Karimnagar, the general mean was 34.21 g with a range of 25.47 to 39.50 g. The parents had a range from 25.47 (P_{10}) to 32.37 g (P_6). The crosses ranged from 31.23 ($P_4 \times P_5$) to 39.50 g ($P_1 \times P_5$). The checks, Madhuri and BMH-1620 recorded 27.87 and 31.23 g for 100 kernel weight.

4.2.2.12 Protein content (%)

At Rajendranagar mean protein content found to be 10.56 per cent with a range of 8.83 to 11.87 per cent, whereas the protein content of the parents ranged from 9.30 (P_7) to 11.40 per cent (P_5) and crosses had a

range of 8.83 ($P_8 \times P_{10}$) to 11.87 ($P_2 \times P_5$ and $P_3 \times P_6$). The checks, Madhuri and BMH-1620 recorded 12.78 and 10.12 per cent of protein content, respectively (Table 3d).

At Palem, the mean protein content was found to be 10.61 per cent and ranged from 8.89 to 11.71 per cent, the parents showed a range of 9.44 (P_6) to 11.52 per cent (P_{10}). The crosses had a range from 8.89 ($P_4 \times P_5$) to 11.71 per cent ($P_2 \times P_5$ and $P_5 \times P_6$), while the checks, Madhuri and BMH-1620 recorded 13.04 and 9.99 per cent of protein, respectively.

Protein content at Karimnagar ranged from 9.14 to 11.88 per cent, with a mean of 10.54 per cent, whereas parents protein content ranged from 9.25 (P_7) to 11.41 per cent (P_3). The crosses ranged from 9.14 ($P_8 \times P_{10}$) to 11.88 per cent ($P_2 \times P_5$) and the checks, Madhuri and BMH-1620 recorded 12.80 and 10.74 per cent of protein, respectively.

4.2.2.13 Oil content (%)

The mean oil content in maize seeds was 7.19 per cent and the lowest and highest values were 5.79 and 8.85 per cent at Rajendranagar. The oil content in parents ranged from 6.91 (P_6) to 8.56 per cent (P_1) and for crosses it varied from 5.79 ($P_3 \times P_5$) to 8.85 per cent ($P_3 \times P_{10}$). The checks, Madhuri and BMH-1620 recorded 8.45 and 7.44 per cent oil, respectively (Table 3e).

Table 3c: Mean performance of parents and crosses for oil content and grain yield at three locations

Parents	Oil content (%)			Grain yield (kg per plot)		
	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar
P ₁	7.56	7.44	7.46	2.02	1.68	1.88
P ₂	7.35	6.35	7.34	2.51	2.37	2.53
P ₃	7.82	7.76	7.83	2.40	1.75	1.84
P ₄	7.11	7.25	7.16	2.25	1.81	1.87
P ₅	7.54	7.46	7.47	2.43	1.77	1.99
P ₆	6.91	6.83	6.89	2.68	2.63	2.51
P ₇	7.11	7.17	7.17	2.74	2.47	3.08
P ₈	7.07	7.41	7.03	2.67	3.10	3.03
P ₉	7.46	8.36	7.45	1.96	1.99	1.89
P ₁₀	8.04	8.04	8.04	1.84	1.48	1.83
Mean	7.50	7.41	7.38	2.35	2.10	2.25
P ₁ X P ₂	6.17	6.17	6.14	3.64	3.58	3.46
P ₁ X P ₃	6.07	6.35	6.09	4.28	3.84	4.48
P ₁ X P ₄	6.80	7.59	7.24	4.32	4.32	4.21
P ₁ X P ₅	7.54	7.15	7.56	3.51	4.47	4.65
P ₁ X P ₆	6.65	6.73	6.75	4.12	4.44	3.98
P ₁ X P ₇	7.75	7.74	7.06	4.34	4.11	4.28
P ₁ X P ₈	6.64	6.38	6.44	3.80	3.84	3.22
P ₁ X P ₉	7.73	8.11	7.82	4.08	3.54	4.02
P ₁ X P ₁₀	7.79	8.46	8.45	4.05	3.16	3.76
P ₂ X P ₃	5.83	5.83	6.14	3.47	3.10	3.51
P ₂ X P ₄	7.21	6.42	7.29	4.27	3.63	3.63
P ₂ X P ₅	7.45	7.37	7.36	3.49	3.52	3.54
P ₂ X P ₆	7.86	7.75	7.86	3.98	3.32	3.85
P ₂ X P ₇	7.25	6.20	6.34	2.87	3.41	2.68
P ₂ X P ₈	7.34	7.22	7.25	3.63	4.20	4.25
P ₂ X P ₉	6.31	6.70	6.21	4.17	3.89	4.31
P ₂ X P ₁₀	7.18	6.18	6.35	4.49	4.21	4.32
P ₃ X P ₄	6.91	7.08	7.04	3.66	3.68	3.24
P ₃ X P ₅	5.79	5.69	6.36	2.92	2.61	2.48
P ₃ X P ₆	7.83	7.75	7.81	3.50	2.74	2.81
P ₃ X P ₇	6.73	6.64	6.73	3.61	3.66	3.43
P ₃ X P ₈	8.84	8.63	8.53	3.64	3.75	4.10
P ₃ X P ₉	7.84	7.61	7.51	3.93	3.28	2.99
P ₃ X P ₁₀	8.85	8.50	7.75	3.25	3.31	3.24
P ₄ X P ₅	5.83	5.89	5.94	2.90	2.51	2.59
P ₄ X P ₆	7.34	7.26	7.24	3.79	3.73	3.65
P ₄ X P ₇	6.43	6.38	6.46	3.46	3.73	3.90
P ₄ X P ₈	7.13	6.83	6.89	3.78	3.79	3.93
P ₄ X P ₉	5.82	6.95	5.61	2.97	2.96	2.58
P ₄ X P ₁₀	6.85	6.86	6.77	4.07	3.68	3.74
P ₅ X P ₆	7.84	7.84	7.82	3.98	3.61	3.66
P ₅ X P ₇	6.74	6.30	6.72	4.13	3.56	3.11
P ₅ X P ₈	7.06	7.15	7.11	3.53	3.59	3.39
P ₅ X P ₉	6.54	6.45	6.47	3.26	3.21	3.58
P ₅ X P ₁₀	7.26	6.41	7.16	3.54	3.27	3.68
P ₆ X P ₇	6.86	6.65	6.77	4.52	4.49	4.48
P ₆ X P ₈	8.76	8.76	8.79	3.86	3.67	3.59
P ₆ X P ₉	7.74	7.58	7.64	3.81	4.13	3.84
P ₆ X P ₁₀	7.95	7.85	7.85	3.70	3.70	3.77
P ₇ X P ₈	8.12	8.13	8.02	3.89	4.05	4.13
P ₇ X P ₉	7.71	7.86	7.84	4.37	3.66	3.69
P ₇ X P ₁₀	6.44	6.23	5.37	3.14	3.10	3.13
P ₈ X P ₉	7.62	7.28	7.66	3.77	3.36	3.17
P ₈ X P ₁₀	7.18	7.17	7.56	4.27	4.27	4.25
P ₉ X P ₁₀	6.43	6.83	6.78	4.28	3.83	4.08
Hybrid Mean	7.13	7.09	7.08	3.78	3.66	3.64
Grand Mean	7.19	7.14	7.13	3.52	3.38	3.39
Madhuri	8.45	8.44	8.45	1.92	2.21	2.11
BMH-1620	7.44	6.52	6.49	3.48	3.18	2.93
S.E.m ±	0.44	0.41	0.42	0.17	0.16	0.17
CD 5%	1.21	1.12	1.14	0.46	0.43	0.47
CV %	10.54	9.85	10.06	8.24	8.01	8.77

At Palem, mean oil content was 7.14 per cent with a range of 5.69 to 8.76 per cent. The oil content of parents varied from 6.35 (P_2) to 8.36 per cent (P_9). The checks, Madhuri and BMH-1620 were found to have oil content of 8.44 and 6.52 per cent, respectively.

The mean oil content at Karimnagar location recorded 7.13 per cent with a range of 5.37 to 8.79 per cent. The mean of parents ranged from 6.89 (P_6) to 8.04 per cent (P_{10}) and for crosses, it varied from 5.37 ($P_7 \times P_{10}$) to 8.79 per cent ($P_6 \times P_8$), while checks, Madhuri and BMH-1620 had oil content of 7.47 and 6.49 per cent.

4.2.2.14 Grain yield

Grain yield at Rajendranagar showed a range of 1.84 to 4.52 kg per plot with a general mean of 3.52 kg per plot. The grain yield of parents ranged from 1.84 (P_{10}) to 2.74 kg (P_7). The crosses varied from 2.87 ($P_2 \times P_7$) to 4.52 kg ($P_6 \times P_7$). The checks, Madhuri and BMH-1620 recorded 1.92 and 3.48 kg per plot (Table 3e).

The average grain yield per plot at Palem was 3.38 kg, showing a range of 1.48 to 4.90 kg. The parents found to have the values ranging from 1.48 kg (P_{10}) to 3.10 (P_8) kg and crosses had a range of 2.51 ($P_4 \times P_5$) to 4.90 kg ($P_5 \times P_7$), while the checks, Madhuri and BMH-1620 recorded 2.21 and 3.18 kg of grain yield per plot, respectively.

At Karimnagar mean grain yield was 3.39 kg with a range of 1.83 to 4.48 kg per plot. The grain yield of parents at this center varied from 1.83 (P₁₀) to 3.08 kg (P₇) and crosses varied from 2.48 (P₃ x P₅) to 4.48 kg (P₆ x P₇ and P₃ x P₅). The checks, Madhuri and BMH-1620 recorded 2.11 and 2.93 kg for grain yield per plot.

4.3 VARIABILITY STUDIES

The estimates of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2) and genetic advance as per cent of mean were estimated for all the characters at three locations and presented in Table 4 and Fig. No. 1 to 3.

The differences between GCV and PCV were wider for the characters *viz.*, days to 50 per cent tasseling, days to 50 per cent silking, days to 50 per cent brown husk, ear length, ear girth, number of kernels per ear and oil content. These differences were narrow for ear height, plant height, number of kernel rows per ear, number of kernels per row, 100 kernel weight, protein content and grain yield.

High heritability was observed for the characters ear height, plant height, ear length, number of kernel rows per ear, number of kernels per row, number of kernels per ear, 100 kernel weight and grain yield. However, these estimates were moderate for days to 50 per cent

Table 4: Estimates of genotypic (GCV), phenotypic (PCV) coefficients of variation, heritability and Genetic advance as per cent of mean for 14 characters at three locations

	Days to 50% tasseling			Days to 50% silking			Days to 50% brown husk		
	Rajendranagar	Palem	Karimnagar	Rajendranagar	Palem	Karimnagar	Rajendranagar	Palem	Karimnagar
GCV	3.04	1.69	2.12	3.09	1.46	2.00	2.18	0.98	1.49
PCV	3.59	2.64	2.85	3.54	2.29	2.80	2.54	1.69	2.03
h ²	71.56	41.05	55.54	76.20	40.66	51.30	73.89	33.77	53.62
GA % of mean	5.29	2.23	3.26	5.56	1.92	2.96	3.86	1.18	2.25

Table 4 contd..

	Ear height (cm)			Plant height (cm)			Ear length (cm)		
	Rajendranagar	Palem	Karimnagar	Rajendranagar	Palem	Karimnagar	Rajendranagar	Palem	Karimnagar
GCV	12.99	13.17	12.63	10.03	10.75	10.54	8.92	14.96	12.68
PCV	13.62	14.58	13.33	11.52	11.60	11.40	18.31	18.72	17.81
h ²	91.03	81.69	89.77	75.84	85.98	85.50	23.77	63.82	50.64
GA % of mean	25.54	24.53	24.65	17.99	20.54	20.07	8.97	24.61	18.58

Table 4 contd..

	Ear girth (cm)			No. of kernel rows per ear			No. of kernels per row		
	Rajendranagar	Karim Nagar	Tandoor	Rajendranagar	Karim Nagar	Tandoor	Rajendranagar	Karim Nagar	Tandoor
GCV	4.32	7.73	6.45	7.43	6.56	7.36	13.16	13.98	12.48
PCV	18.80	13.07	15.66	8.71	8.32	8.89	13.97	14.73	13.59
h ²	05.30	34.99	16.94	72.86	62.14	68.51	88.73	89.99	84.33
GA % of mean	2.05	9.42	5.47	13.07	10.65	12.55	25.54	27.32	23.61

Table 4 contd..

	No. of kernels per ear		100 kernel weight (g)			Protein content (%)		
	Rajendranagar	Palem	Karimnagar	Rajendranagar	Palem	Karimnagar	Rajendranagar	Palem
GCV	14.87	16.68	15.38	6.92	8.31	8.53	5.11	5.71
PCV	15.59	17.53	16.28	8.13	9.07	9.28	11.01	9.04
h ²	90.97	90.59	89.25	73.13	84.01	84.44	21.54	39.95
GA % of mean	29.23	32.71	29.92	12.25	15.69	16.15	4.88	7.44

Table 4 contd..

	Oil content (%)		Grain yield (kg / plot)		
	Rajendranagar	Palem	Karimnagar	Rajendranagar	Palem
GCV	8.45	9.05	5.33	19.15	22.85
PCV	13.52	13.38	13.07	20.85	24.21
h ²	39.12	45.74	40.66	84.37	89.05
GA % of mean	10.89	12.61	10.94	36.24	44.42

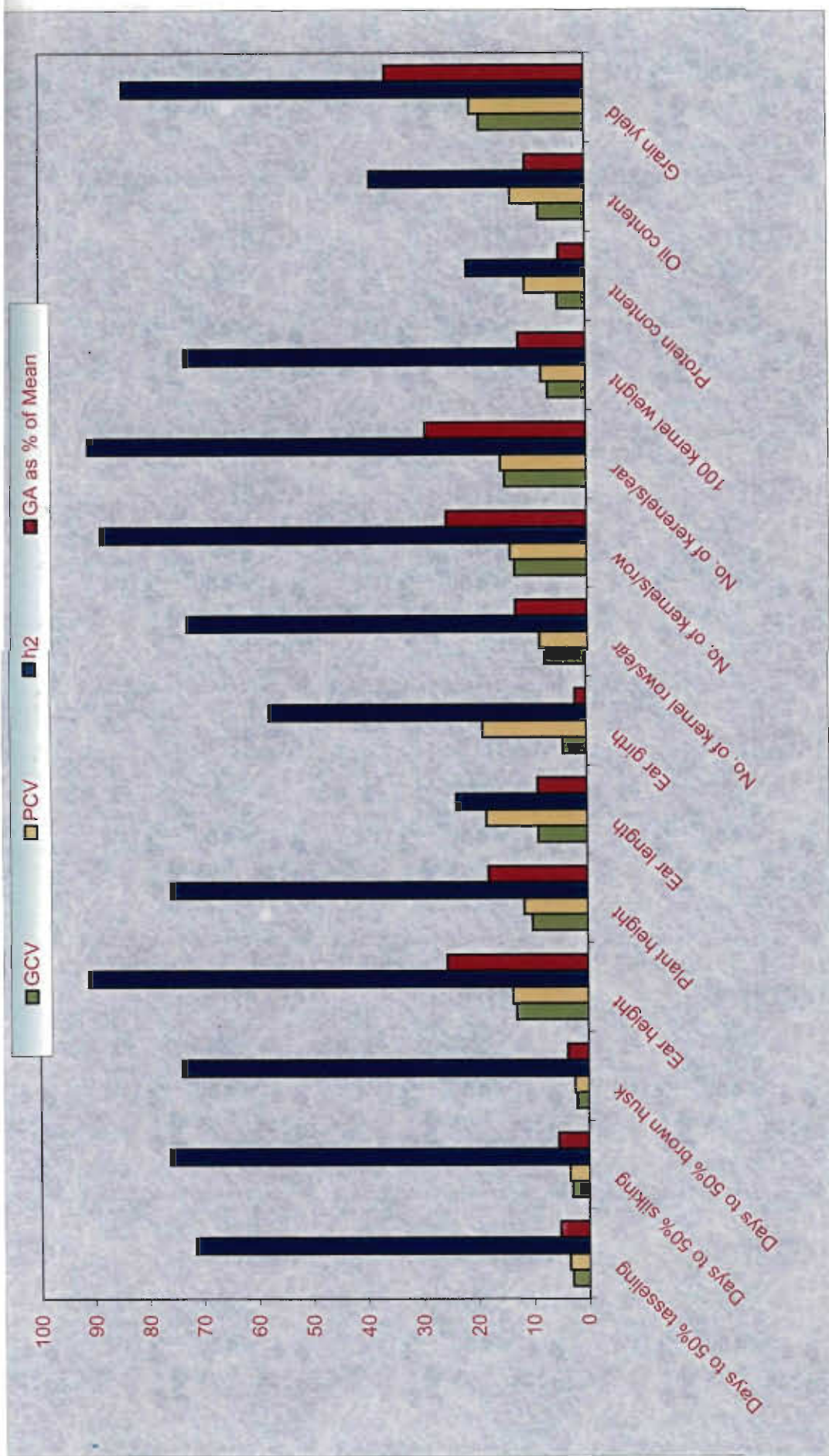


Fig. 1 : Variability parameters at Rajendranagar

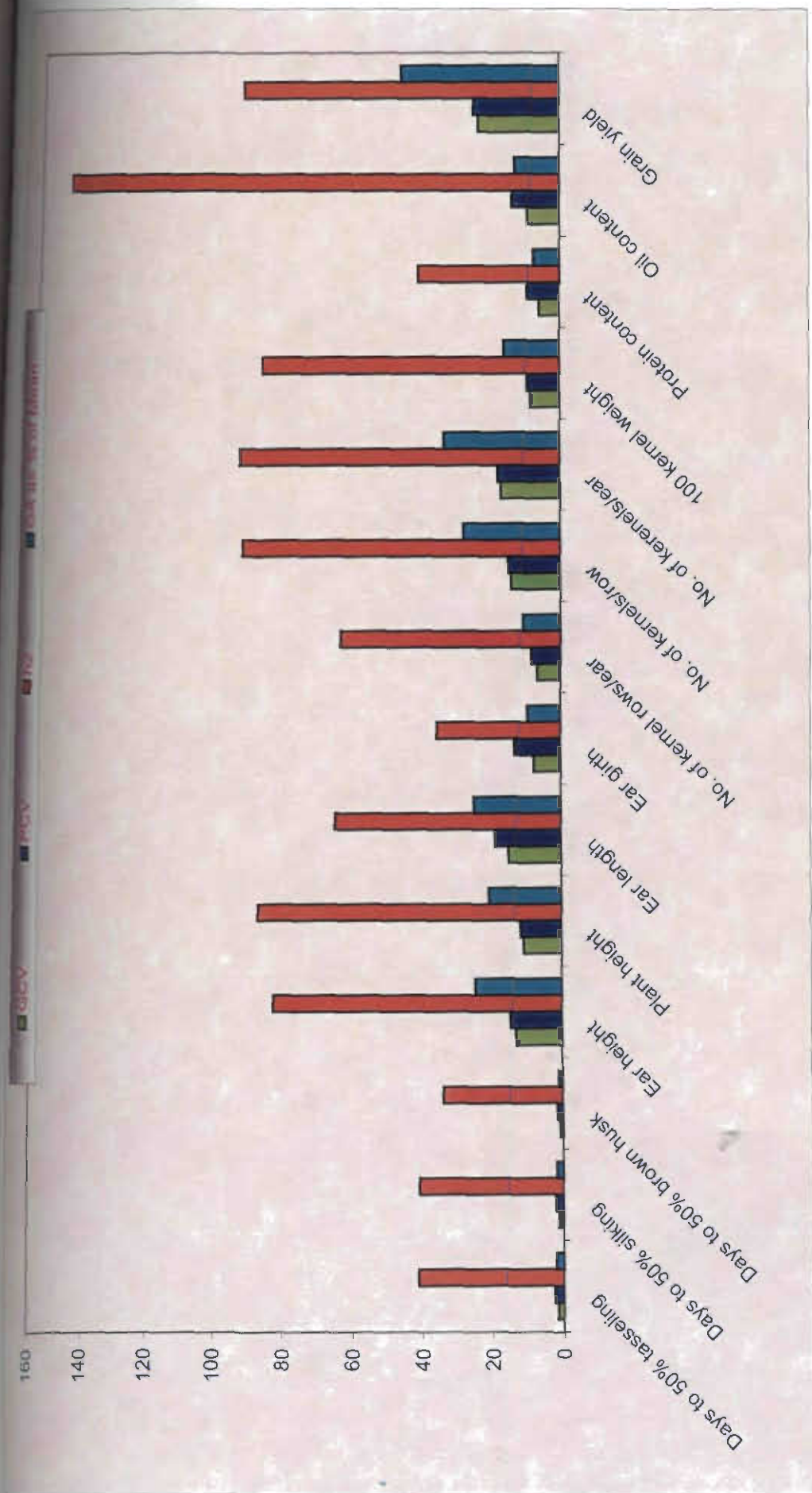


Fig. 2 : Variability parameters at Palem

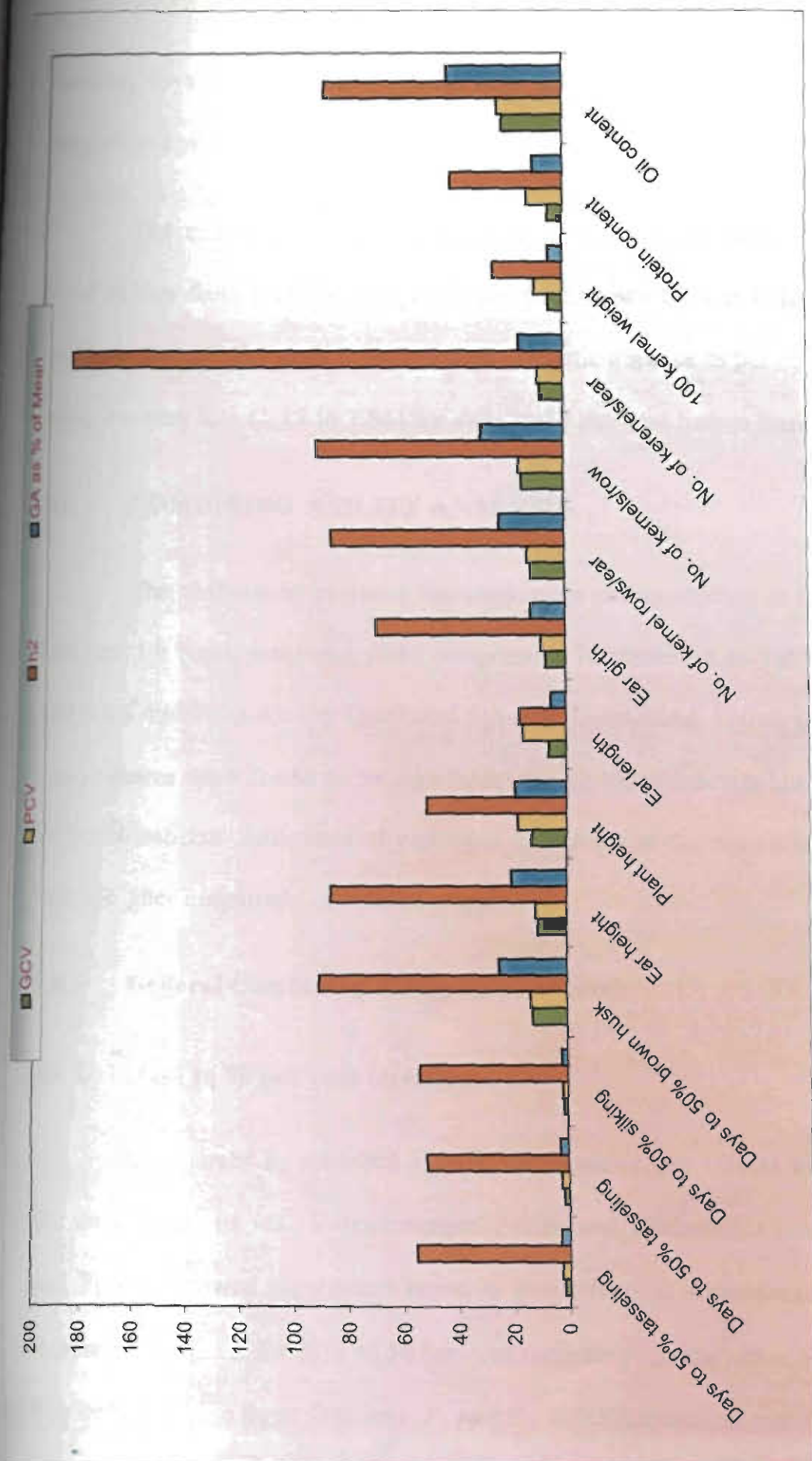


Fig. 3 : Variability parameters at Karimnagar

tasseling, days to 50 per cent silking, days to 50 per cent brown husk, ear girth and protein content.

The estimates of genetic advance as per cent of mean were found to vary from 1.18 for days to 50 per cent brown husk at Palem to 44.42 per cent per plot grain yield at Palem. Genetic advance as per cent of mean was very low (1.18 to 3.86) for days to 50 per cent brown husk.

4.4 COMBINING ABILITY ANALYSIS

The analysis of variance for combining ability studied at three locations for grain yield and yield components is presented in Table 5. General Combining Ability (*gca*) and Specific Combining Ability (*sca*) mean squares were found to be significant for all the characters studied at three locations. Estimates of variances revealed that the *sca* variance was of higher magnitude compared to *gca*.

4.4.1 General Combining Ability (*gca*) effects

4.4.1.1 Days to 50 per cent tasseling

The parent P_3 recorded significant negative *gca* effects at all the three locations *viz.*, Rajendranagar, Palem and Karimnagar and P_2 and P_5 also showed significant negative *gca* effects at Rajendranagar indicating earliness for days to 50 per cent tasselling. On the other hand P_7 parent at all the three locations, P_1 and P_{10} at Rajendranagar and P_4 at

Table 5 : Combining ability analysis for grain yield and its components, oil and protein contents at the 50% tasseling stage

Source	d.f	Days to 50% tasseling				Days to 50% Siking				Days to 50% brown husk			
		Rajendra-nagar	Palem	Karimnagar	Rajendra-nagar	Palem	Karimnagar	Rajendra-nagar	Palem	Karimnagar	Rajendra-nagar	Palem	Karimnagar
GCA	9	2.18**	0.98*	0.91*	1.81*	0.94*	1.18**	2.86**	1.09*			1.43**	
SCA	45	3.43**	1.41**	1.96*	3.92**	1.16**	1.98**	4.46**	1.34**			2.48**	
Error	108	0.38	0.43	0.38	0.34	0.37	0.44	0.44	0.51			0.51	
σ^2 gca		0.03	0.04	0.03	0.03	0.03	0.04	0.04	0.04			0.04	
σ^2 sca		0.36	0.41	0.36	0.32	0.35	0.42	0.42	0.49			0.49	
σ^2 gca / σ^2 sca		0.083	0.097	0.083	0.093	0.085	0.095	0.095	0.081			0.081	

Table 5 contd..

Source	d.f	Ear height (cm)			Plant height (cm)			Ear length (cm)		
		Rajendra-nagar	Palem	Karimnagar	Rajendra-nagar	Palem	Karimnagar	Rajendra-nagar	Palem	Karimnagar
GCA	9	106.31**	115.22**	110.81**	473.22**	388.90**	460.01**	5.06**	3.23**	5.23**
SCA	45	109.80**	107.29**	101.99**	407.39**	442.57**	422.98**	5.15**	7.76**	6.72**
Error	108	3.47	7.55	3.79	40.15	22.35	22.96	2.40	1.11	1.47
σ^2 gca		0.29	0.63	0.32	3.37	1.87	1.92	0.20	0.09	0.12
σ^2 sca		3.29	7.16	3.59	38.08	21.19	21.77	2.27	1.06	1.39
σ^2 gca / σ^2 sca		0.088	0.087	0.089	0.088	0.088	0.088	0.088	0.084	0.086

Table 5 contd..

Source	d.f	Ear girth (cm)			Number of kernel rows per ear			Number of kernels per row		
		Rajendra-nagar	Palem	Karimnagar	Rajendra-nagar	Palem	Karimnagar	Rajendra-nagar	Palem	Karimnagar
GCA	9	5.72*	2.38**	3.96**	0.97**	1.01**	0.96**	10.46**	18.69**	10.67**
SCA	45	6.32**	4.11**	4.20**	1.44**	1.13**	1.43**	23.20**	23.74**	20.14**
Error	108	2.62	0.70	1.43	0.15	0.19	0.18	0.86	0.82	1.08
Ó ² gca		0.21	0.06	0.11	0.01	0.01	0.01	0.07	0.067	0.09
Ó ² sca		2.48	0.67	1.35	0.14	0.17	0.17	0.81	0.78	1.03
Ó ² gca / Ó ² sca		0.084	0.089	0.081	0.071	0.058	0.058	0.086	0.076	0.087

Table 5 contd..

Source	d.f	Number of kernels per ear			100 kernel weight (g)			Protein content (%)		
		Rajendra-nagar	Palem	Karimnagar	Rajendra-nagar	Palem	Karimnagar	Rajendra-nagar	Palem	Karimnagar
GCA	9	2652.18**	5548.50**	5303.87**	4.47**	6.42**	3.63**	1.03**	0.39*	0.84**
SCA	45	6424.78**	7131.75**	6022.21**	6.99**	8.96**	10.12**	0.57*	0.58**	0.53**
Error	108	185.57	229.81	227.84	0.72	0.51	0.52	0.35	0.18	0.29
Ó ² gca		15.55	19.26	19.10	0.06	0.04	0.04	0.03	0.02	0.02
Ó ² sca		175.98	217.94	216.06	0.68	0.48	0.50	0.34	0.17	0.27
Ó ² gca / Ó ² sca		0.088	0.088	0.088	0.088	0.083	0.08	0.088	0.117	0.074

Table 5 contd..

Source	d.f	Oil content (%)			Grain yield (kg per plot)		
		Rajendra-nagar	Palem	Karimnagar	Rajendra-nagar	Palem	Karimnagar
GCA	9	0.56**	0.96**	0.59**	0.17**	0.48**	0.38**
SCA	45	0.56**	0.51**	0.51**	0.54**	0.65**	0.62**
Error	108	0.19	0.17	0.17	0.03	0.02	0.03
Ó ² gca		0.01	0.01	0.014	0.02	0.02	0.02
Ó ² sca		0.18	0.16	0.16	0.03	0.023	0.03
Ó ² gca / Ó ² sca		0.055	0.06	0.062	0.066	0.086	0.066

* Significant (P<0.05)

** Significant (P<0.01)

Palem were the poor combiners with significant positive *gca* effects indicating late in days to 50 per cent tasselling (Table 6).

4.4.1.2 Days to 50 per cent silking

Parents P₂, P₃ and P₅ at Rajendranagar, P₃ at Palem and P₃ and P₆ at Karimnagar recorded significant negative *gca* effects indicating earliness for days to 50 per cent silking. Parent P₇ at Rajendranagar, P₄, P₇ and P₁₀ at Palem and P₁ at Karimnagar were the poor combiners with significant positive *gca* effects for silking revealing their contribution for late maturity.

4.4.1.3 Days to 50 per cent brown husk

The parents P₂, P₃ and P₅ at Rajendranagar, P₁ at Palem and P₃ and P₆ at Karimnagar were the best combiners with significant negative *gca* effects indicating their contribution for earliness. Parent P₇ at all the three locations and P₁ at Karimnagar were the poor combiners with significant *gca* effects for days to 50 per cent brown husk revealing their contribution for late maturity.

4.4.1.4 Ear height

Parents P₁ and P₁₀ at all the three locations, P₆ at Rajendranagar and P₂ at Karimnagar were found as poor combiners with highly significant positive *gca* effects for ear height. Interestingly

Table 6: Estimates of general combining ability effects of the parents for various characters

Parent	Days to 50% tasseling			Days to 50% silking			Days to 50% brown husk		
	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar
P ₁	0.36*	-0.06	0.22	0.30	-0.19	0.42*	0.17	-0.51*	0.39*
P ₂	-0.35*	0.21	-0.05	-0.31*	0.13	0.20	-0.57**	-0.09	0.005
P ₃	-0.66**	-0.42*	-0.35*	-0.72**	-0.33*	-0.48**	-0.88**	-0.12	-0.68**
P ₄	0.22	0.35*	0.14	0.21	0.36*	0.03	0.17	0.21	0.22
P ₅	-0.63**	-0.23	-0.16	-0.47**	-0.25	-0.32	-0.46**	0.15	-0.05
P ₆	-0.10	-0.12	-0.38*	-0.06	-0.25	-0.35*	0.17	-0.17	-0.43*
P ₇	0.50**	0.46**	0.45**	0.49**	0.33*	0.31	0.75**	0.51*	0.39*
P ₈	0.17	-0.26	0.17	0.13	-0.16	0.06	0.14	-0.12	0.005
P ₉	0.06	-0.06	-0.21	0.16	-0.02	-0.15	0.28	0.35	0.20
P ₁₀	0.42*	0.15	0.17	0.27	0.38*	0.26	0.22	-0.20	-0.05
SE(gi)	0.16	0.17	0.16	0.15	0.16	0.18	0.18	0.19	0.19
SE(gi-gj)	0.25	0.26	0.25	0.23	0.24	0.27	0.27	0.29	0.25

Table 6 contd...

Parent	Ear height (cm)			Plant height (cm)			Ear length (cm)		
	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar
P ₁	3.57**	4.51**	3.61**	4.75**	2.83*	3.57*	0.18	-0.23	-0.02
P ₂	0.66	-0.96	1.07*	0.29	-2.28	-0.33	-0.06	0.31	0.35
P ₃	0.70	-0.21	-0.19	0.54	-0.98	-0.49	-0.58	-0.72*	-0.73*
P ₄	0.64	-0.38	-0.41	1.92	4.19**	2.25	-0.22	0.07	-0.26
P ₅	-7.93**	-7.40**	-7.95**	-16.84**	-14.56**	-16.33**	-0.54	-0.49	-0.61
P ₆	1.12*	-0.11	0.91	1.03	2.03	3.62*	-0.31	-0.53	0.03
P ₇	0.51	0.53	0.72	3.16	1.04	1.29	0.08	0.67*	0.59
P ₈	-0.40	0.27	-0.09	4.14*	5.72**	4.70*	-0.57	-0.11	0.16
P ₉	0.10	0.73	0.34	-2.32	-0.96	-2.42	0.98*	0.19	0.07
P ₁₀	1.00*	3.02**	1.98**	3.29	2.96*	4.13*	0.39	0.83**	0.41
SE(gi)	0.51	0.75	0.53	1.73	1.29	1.31	0.42	0.28	0.33
SE(gi-gj)	0.75	1.11	0.62	2.58	1.92	1.95	0.63	0.42	0.49

Table 6 contd..

Parent	Ear girth			No. of kernel rows per ear			No. of kernels per row		
	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar
P ₁	-0.84	0.11	-0.27	-0.25*	-0.32**	0.03	1.35**	1.21*	1.12**
P ₂	-0.32	0.20	0.43	0.02	-0.15	0.08	-0.005	0.37	0.09
P ₃	-1.23*	-0.20	-0.33	-0.36**	-0.37**	-0.35**	-1.00**	-2.34**	-1.68**
P ₄	-0.23	-0.07	-0.12	0.07	0.06	-0.18	-1.20**	-1.26**	-0.98**
P ₅	0.22	-0.33	-0.45	-0.47**	-0.26*	-0.46**	-0.70**	-1.06**	-0.85**
P ₆	0.95*	0.07	-0.25	0.02	-0.10	-0.02	1.13**	1.12**	0.48
P ₇	0.90*	1.28*	1.34*	0.41**	0.40**	0.03	-0.22	0.40	0.84**
P ₈	0.22	-0.64	-0.35	0.24*	0.34**	0.47**	1.24**	1.62**	1.03**
P ₉	0.08	-0.65	0.16	0.07	0.06	0.08	-0.28	-0.26	-0.32
P ₁₀	0.24	0.18	-0.51	0.24*	0.34**	0.31**	-0.31	0.18	0.26
SE(gi)	0.44	0.45	0.32	0.11	0.12	0.12	0.25	0.24	0.28
SE(gi-gj)	0.65	0.34	0.48	0.15	0.17	0.17	0.37	0.36	0.42

parent P₅ at all the three locations the best combiner with highly significant negative *gca* effects (Table 6).

4.4.1.5 Plant height

Parents P₁ and P₈ at Rajendranagar, P₁, P₈ and P₁₀ at Palem and P₁, P₆, P₈ and P₁₀ at Karimnagar were found as good combiners with significantly high positive *gca* effects for plant height. Significant negative *gca* effects were recorded in case of P₅ at all the three locations indicating their contribution for dwarfness. Among all the parents, P₁ and P₈ recorded significant positive *gca* effects at all the three locations (Table 6).

4.4.1.6 Ear length

The parents lines P₉ at Rajendranagar, P₇ and P₁₀ at Palem and P₃ at Karimnagar location were found to be best contributing parents for ear length with significant positive *gca* effects. Parent P₃ was the poor combiner at Palem and Karimnagar for this trait (Table 6).

4.4.1.7 Ear girth

The parent P₇ was found good general combiner for this character at all the three locations.

4.4.1.8 Number of kernel rows per ear

Parents P_7 , P_8 and P_{10} were found as good combiner with highly significant positive *gca* effects at all locations. On the other hand P_1 at Rajendranagar and Palem and P_3 and P_5 at all locations were the poor combiners with highly significant negative *gca* effects.

4.4.1.9 Number of kernels per row

Parents P_1 and P_8 at three locations and P_6 at Rajendranagar and Palem, P_7 at Karimnagar were found as best combiners with superior significant positive *gca* effects (Table 5).

4.4.1.10 Number of kernels per ear

For number of kernels per ear, parents P_1 , P_6 , P_7 and P_8 at all locations and P_2 at Karimnagar were found to be the good combiners and highly significant positive *gca* effects (Table 6).

4.4.1.11 100 kernel weight

The parents P_1 and P_7 were found as good general combiners at three locations (Table 6).

Table 6 contd...

Parent	No. of kernels per ear			100 kernel weight (g)			Protein content (%)		
	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar
P ₁	6.30	11.06**	14.52**	0.69**	0.52*	0.47*	-0.32*	0.31*	0.28*
P ₂	0.38	4.45	8.80*	0.40	-0.33	-0.39	0.35*	0.07	0.22
P ₃	-22.69**	-40.43**	-33.88**	0.45*	-0.22	-0.55**	0.01	0.02	0.02
P ₄	-13.19**	-13.04**	-17.77**	-0.33	-0.32	-0.44*	-0.07	-0.28*	-0.28*
P ₅	-21.33**	-21.71**	-27.69**	-0.37	-0.39*	-0.37	0.32*	0.23*	0.24*
P ₆	21.05**	14.92**	8.27*	0.43	0.78**	0.49*	0.06	0.06	0.20
P ₇	7.72*	21.95**	20.44**	0.76**	0.73**	0.46*	-0.27	-0.17	-0.36*
P ₈	16.97**	31.01**	29.61**	-0.49*	1.16**	0.51**	-0.09	0.04	0.06
P ₉	1.30	0.48	-7.94	-0.66**	-0.76**	-0.84**	-0.01	-0.09	0.14
P ₁₀	3.47	-8.71*	5.63	-0.88**	-1.16**	-0.19	-0.63**	-0.20	-0.44**
SE(g)	3.73	4.15	4.13	0.23	0.19	0.19	0.16	0.11	0.14
SE(gi-gj)	5.55	6.17	6.14	0.34	0.29	0.29	0.24	0.17	0.21

Table 6 contd...

Parent	Oil content (%)			Grain yield (kg per plot)		
	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar
P ₁	0.004	0.08	-0.00	0.12**	0.12**	0.17**
P ₂	-0.15	-0.50**	-0.23*	-0.07	0.03	0.11*
P ₃	0.09	0.08	0.09	-0.13**	-0.30**	-0.27**
P ₄	-0.38**	-0.23*	0.30**	-0.08	-0.12**	-0.17**
P ₅	-0.17	-0.28*	-0.08	-0.21**	-0.16**	-0.21**
P ₆	0.28*	0.27*	0.31**	0.15**	0.15**	0.17**
P ₇	-0.07	-0.17	-0.23*	0.09*	0.23**	0.14**
P ₈	0.30*	0.31**	0.31**	0.16**	0.29**	0.23**
P ₉	-0.04	0.29**	-0.003	-0.01	-0.11**	-0.10*
P ₁₀	0.15	0.16	0.13	-0.01	-0.14**	0.03
SE(gi)	0.12	0.11	0.11	0.04	0.03	0.04
SE(gi-gj)	0.17	0.16	0.16	0.07	0.05	0.07

4.4.1.12 Protein content

For this character, the parents P_1 and P_5 were good general combiners as they displayed significant and positive *gca* effects over three locations (Table 6).

4.4.1.13 Oil content

Among the parents, P_6 and P_8 at all locations and P_9 at Palem, P_4 at Karimnagar were the good combiners with highly significant positive *gca* effects for oil content.

4.4.1.14 Grain yield

Parents P_1 , P_6 , P_7 and P_8 were the good general combiners with highly significant and positive *gca* effects at all locations (Table 6).

4.4.2 Specific Combining Ability (*sca*) Effects

Specific combining ability effects of 45 hybrids for yield and its components, oil and protein contents at three locations are presented in Table 7a – 7e.

4.4.2.1 Days to 50 per cent tasseling

Out of 45 hybrids, 18 hybrids at Rajendranagar, 8 hybrids at Palem and 10 hybrids at Karimnagar recorded significant negative *sca*

Table 7 a : Estimates of specific combining ability effects of the 45 hybrids for days to 50 per cent tasseling, 50 per cent silking and 50 per brown husk

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Crosses	Days to 50% tasseling			Days to 50% silking			Days to 50% brown husk		
	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar
1x P2	-0.19	-0.82	-1.44*	-0.78	-1.13*	-1.47*	-1.07	-0.53	-1.85**
P3	-0.88**	-1.18	-0.81	-0.37	-1.32*	-1.11	-0.77	0.17	-0.82
P4	-2.10**	1.37*	-0.31	-1.98**	0.32	-0.64	-0.16	-0.50	-0.74
P5	-1.24*	0.62	1.33*	-0.62	0.26	1.06	-1.18	0.22	0.87
P6	0.90	-1.16	-0.44	0.30	-0.74	-0.91	-0.16	-1.44*	-0.74
P7	-1.38*	-1.74**	-0.61	-1.92**	-1.65**	-0.91	-1.41*	-1.14	-0.24
P8	0.62	0.32	-1.33*	0.77	1.51**	0.67	0.54	1.50*	0.82
P9	0.06	1.12	0.39	0.41	0.71	0.22	0.40	-0.64	0.29
P10	-1.30*	-1.43*	-0.67	-1.03	-1.04	-0.19	-1.21*	-0.75	0.21
2x P3	-0.49	0.87	0.47	-0.09	0.68	-0.55	0.65	0.42	1.90**
P4	0.29	-0.24	0.31	0.63	-0.35	-0.08	0.26	-0.25	-0.35
P5	-1.52**	-1.99**	-1.39*	-1.67**	-1.74**	-1.72**	-2.77**	-1.53*	-2.40**
P6	-2.38**	-1.77**	-2.17**	-2.42**	-0.40	-0.69	-3.07**	-0.19	-1.68*
P7	-1.99**	0.32	-0.33	-1.98**	0.01	-0.69	-0.66	1.44*	1.15
P8	-1.33*	-1.30*	0.28	-1.62**	-1.49**	0.22	-2.71**	-2.92**	-0.46
P9	-1.21*	-0.49	-1.00	-1.64**	-0.29	-0.55	-0.85	-0.72	-1.32*
P10	-1.58**	-0.05	-1.06	-1.42**	-0.04	-0.64	-1.80**	0.83	-0.74
3x P4	0.26	-0.60	-0.39	0.05	-0.21	-0.05	-3.77**	-0.89	-0.32
P5	-1.88**	-1.35*	-2.08**	-1.92**	-0.27	-1.03	-0.46	-1.17	-2.71**
P6	-0.74	1.20*	0.81	-1.34*	1.07	-0.33	1.57*	2.17**	1.35*
P7	0.31	-0.05	0.31	0.44	-0.18	1.00	-0.02	-0.19	1.18
P8	-0.69	-0.66	-0.42	-0.20	-0.68	-0.08	-0.41	-0.22	-0.77
P9	-0.58	0.82	-1.03	-0.23	0.51	-0.53	0.12	-0.36	-1.63*
P10	-0.27	-0.74	-1.08	-1.01	-1.24*	-1.61**	-0.82	-0.81	-2.04**
4x P5	-0.10	-0.80	-0.25	-0.53	-0.29	-0.22	-0.52	0.17	0.37
P6	-1.63**	-1.24*	-1.03	-1.28*	-0.29	-0.19	-0.82	-0.17	-0.57
P7	-1.24*	-1.82**	-1.53**	-1.17*	-1.54**	-1.79**	-1.41**	-1.53**	-2.07**
P8	-0.24	-0.10	0.42	-0.81	-0.04	0.39	-1.46*	-0.56	1.32*
P9	-1.13*	0.04	-0.53	-1.17*	0.48	-0.72	-0.93	-0.03	-2.54**
P10	-2.16**	-0.85	-2.25**	-1.95**	-1.93**	-3.47**	-0.55	-0.14	0.04
5x P6	-1.44*	0.68	-0.06	-1.92**	0.65	-1.16	-2.85**	-0.44	-1.96**
P7	-0.71	0.76	-1.56**	-0.81	0.73	-0.50	-1.43*	-0.47	-1.46*
P8	-0.38	-0.52	-0.61	-0.12	-0.10	-0.58	0.84	-0.50	-0.74
P9	1.40*	-0.05	1.11*	1.52**	-0.24	0.64	1.70**	1.03	2.07**
P10	0.37	-0.60	0.72	0.41	0.01	0.56	0.43	-0.42	1.32*
6x P7	0.09	-0.35	0.67	0.44	-0.27	-0.47	0.26	-1.14	-1.07
P8	0.76	1.37*	0.28	1.47**	0.57	0.11	1.20*	0.50	-0.02
P9	-1.13*	-0.16	-1.33*	-1.23*	-1.24*	-1.33*	-0.27	0.03	-0.54
P10	0.84	0.29	0.94	0.66	-0.65	0.59	0.45	-0.42	0.37
7x P8	-0.19	-0.55	-0.56	-0.76	-1.35*	-1.22*	0.95	0.47	0.15
P9	-0.41	-1.07	0.50	-0.12	-1.15*	0.00	-0.85	-2.33*	-0.38
P10	-1.44*	-0.63	-1.22*	-1.89**	-0.57	-0.41	-3.13**	0.22	-0.79
8x P9	-0.41	-0.35	-0.22	-0.76	-0.65	-1.41*	-1.57*	-1.03	-0.99
P10	-0.44	-1.24*	-0.61	-0.53	-0.07	-0.83	0.15	-0.14	-1.07
9x P10	-0.66	-0.77	-0.22	-1.23*	0.79	1.39*	-1.66**	0.39	0.73

effects. Two hybrids exhibited significant negative *sca* effects at all locations.

4.4.2.2 Days to 50 per cent silking

Significant negative *sca* effects for 50 per cent silking were recorded in 18 hybrids at Rajendranagar, 9 hybrids at Palem and 7 hybrids at Karimnagar and 12 hybrids exhibited significant negative *sca* effects at all locations.

Two hybrids at Rajendranagar, one at each Palem and Karimnagar recorded significant positive *sca* effects.

4.4.2.3 Days to 50 per cent brown husk

As many as 16 hybrids at Rajendranagar, 7 at Palem and 16 at Karimnagar recorded significant and negative *sca* effects. One hybrid $P_2 \times P_5$ recorded significant negative *sca* effect at all locations. Three hybrids each at Rajendranagar and Palem and five hybrids at Karimnagar exhibited significant positive *sca* effects (Table 7a).

4.4.2.4 Ear height

As many as 9 hybrids at Rajendranagar, 8 at Palem and 8 at Karimnagar exhibited significant negative *sca* effects, 6 hybrids recorded significant negative *sca* effects at all locations and 8 hybrids recorded significant positive *sca* effects at all locations.

Table 7 b : Estimates of specific combining ability effects of the 45 hybrids for ear height, plant height and ear length

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Crosses	Plant height			Ear height			Ear length		
	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar
P1x P2	0.31	0.58	-1.07	0.91	-8.24	-6.42	1.64	0.13	1.39
P3	-2.90	1.30	-2.31	4.42	0.03	-2.16	0.46	2.30*	1.44
P4	-7.58**	1.97	-5.16**	10.27	11.95**	6.56	-0.07	0.53	-0.09
P5	14.47**	7.19**	13.52**	33.47**	32.14**	37.98**	1.12	3.10**	1.53
P6	-3.12	-0.96	-2.02	-12.40*	13.00**	17.29**	1.16	0.67	0.97
P7	7.88**	5.48*	6.14**	-1.04	3.29	2.32	2.09	1.79	1.95
P8	3.73*	4.44	3.09	9.42	3.81	8.21	-0.26	0.72	2.04
P9	3.23	-1.79	3.65*	19.82**	19.37**	12.77**	2.56	1.07	0.17
P10	2.13	1.10	4.45*	24.24**	14.71**	8.31	-1.18	-0.20	-0.74
P2x P3	0.08	0.24	1.97	-19.88**	-26.75**	-10.92*	-0.65	1.55	0.46
P4	-5.83**	-5.06*	-6.94**	-2.19	1.34	-6.97	1.38	0.82	-0.73
P5	-5.12**	-4.20	-7.04**	2.64	10.23*	12.16**	1.17	1.21	1.42
P6	7.66**	-13.16**	9.89**	3.53	3.46	5.93	2.08	0.16	1.20
P7	8.57**	6.49*	5.78**	17.16**	12.19**	19.10**	1.37	0.18	-0.43
P8	8.82**	10.65**	8.77**	7.02	8.07	7.49	0.55	1.17	1.63
P9	-11.12**	-5.78*	-6.21**	0.59	1.56	-2.45	0.18	1.99*	0.72
P10	7.68**	7.77**	8.43**	-10.37	-2.83	-7.24	-0.23	1.52	1.65
P3x P4	5.93**	0.79	3.62*	10.15	3.57	4.82	2.20	0.68	2.92**
P5	-1.20	-5.81*	-1.97	4.08	6.00	-1.45	1.36	2.82**	1.40
P6	6.68**	8.09**	9.69**	15.71**	12.86**	4.59	-0.47	-3.11**	-3.22**
P7	9.12**	6.91**	9.81**	19.14**	14.02**	24.02**	0.66	2.31*	1.08
P8	5.60**	7.24**	7.34**	12.36*	17.94**	17.71**	0.31	1.91*	1.91
P9	10.50**	10.44**	10.36**	25.36**	21.53**	17.74**	0.33	-2.41*	-1.33
P10	6.27**	11.96**	5.26**	-9.66	-0.63	-6.75	1.13	0.25	0.33
P4x P5	10.56**	13.82**	10.48**	20.14**	22.98**	28.30**	-3.57*	-3.95**	-3.37**
P6	10.17**	10.06**	10.14**	2.53	5.45	8.37	0.34	3.36**	2.78*
P7	8.15**	11.24**	10.60**	4.23	0.10	-9.26*	3.50**	2.65**	2.99**
P8	3.90*	-0.16	-0.71	6.08	0.62	-1.74	0.88	-0.09	0.95
P9	-13.27**	-13.23**	-13.79**	-12.98*	-12.22**	-5.91	1.90	0.50	-0.46
P10	-17.87**	-13.68**	-11.79**	-39.30**	-1.31	-4.13	0.63	0.66	1.23
P5x P6	12.05**	16.66**	10.42**	1.13	12.14**	0.37	0.59	0.43	0.46
P7	-11.24**	-4.86	-6.16**	-11.47*	4.70	4.96	0.15	-0.25	0.27
P8	-6.33**	-5.14*	-2.11	-0.58	10.12*	4.99	0.06	0.48	0.10
P9	-0.43	5.33*	2.52	3.52	12.30**	13.15**	1.19	2.29*	3.09**
P10	1.03	3.65	5.65**	5.60	6.98	8.33	0.65	-0.35	1.35
P6x P7	4.40*	3.01	5.40**	6.92	9.96*	-2.17	0.83	2.69**	1.92
P8	-1.35	-1.76	-0.97	5.07	-1.32	0.19	3.54**	2.45*	2.88**
P9	10.38**	15.01**	8.05**	7.91	5.87	13.29**	-0.74	-0.60	1.53
P10	7.28**	6.86**	2.21	26.32**	10.05*	19.26**	2.06	3.00**	1.99
P7x P8	-5.37**	-7.18**	-7.95**	9.94	9.50*	14.09**	0.63	0.67	0.72
P9	7.52**	4.69	7.67**	19.41**	23.93**	24.92**	1.96	0.99	1.94
P10	8.49**	7.11**	6.07**	16.42**	14.14**	17.90**	1.02	1.28	1.77
P8x P9	11.54**	13.32**	9.93**	-0.60	1.18	-3.69	1.60	1.72	1.37
P10	7.24**	6.17*	4.66**	13.71*	7.82	10.52*	0.40	2.15*	1.16
P9x P10	3.23	-2.10	0.51	13.45*	10.21*	2.95	1.76	2.43*	1.72
SESj	1.71	2.53	1.79	5.83	4.35	4.41	1.42	0.97	1.11

Significant at (P<0.05)

** : Significant at (P<0.01)

4.4.2.5 Plant height

Significant and desirable positive significant *sca* effects were recorded in 14, 21 and 16 hybrids at Rajendranagar, Palem and Karimnagar, respectively. Ten hybrids recorded positive *sca* effects at all locations. Five hybrids at Rajendranagar and two each at Palem and Karimnagar recorded significant negative *sca* effects.

4.4.2.6 Ear length

Significant and desirable positive *sca* effects were recorded in 14 hybrids at Palem and 3 at Karimnagar. One hybrid at Rajendranagar, 3 at Palem and 2 at Karimnagar recorded significant negative *sca* effects. Only one hybrid ($P_4 \times P_5$) showed significant and negative *sca* effect at all locations (Table 7b).

4.4.2.7 Ear girth

As many as, 5 at Palem and 3 at Karimnagar exhibited significant positive *sca* effects. Two hybrids each at Rajendranagar, Palem and Karimnagar had significant and negative *sca* effects.

4.4.2.8 Number of kernel rows per ear

Thirteen hybrids at Rajendranagar and 10 at Palem and 15 at Karimnagar recorded significant positive *sca* effects. Five hybrids were recorded significant positive *sca* effect at all the locations. Eleven, 7 and 9

Table 1: Estimates of specific combining ability effects of the 45 hybrids for ear girth, number of kernel rows per ear, and number of kernels per row 103

Crosses	Ear girth			No. of kernel rows/ear			No. of kernels / ear		
	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar
P1x P2	-0.98	0.46	0.74	-0.59	-0.18	-0.81*	0.83	1.46	1.28
P3	2.49	1.77*	-0.56	1.80**	0.71	1.63**	2.49**	4.18**	3.39**
P4	-0.01	0.97	1.31	1.35**	1.60**	1.46**	4.02**	4.43**	4.36**
P5	2.90	2.00**	0.19	-0.09	1.93**	1.74**	1.52	2.24**	2.89**
P6	-0.73	0.62	0.25	-0.59	0.43	-0.70	3.35**	4.38**	2.56**
P7	-0.75	0.55	0.16	1.02**	0.60	1.24**	1.38	2.43**	1.86
P8	-0.17	0.54	1.09	-0.15	-0.01	-1.20**	0.24	0.88	-0.66
P9	1.77	0.61	0.28	1.35**	-0.40	1.19**	2.10*	1.10	2.36*
P10	-0.12	-0.42	-0.29	0.52	-0.68	0.96*	3.13**	0.99	1.45
P2x P3	0.18	0.85	2.13	-0.48	-0.12	-0.42	2.19*	1.35	3.42**
P4	1.11	-0.68	0.64	2.41**	0.10	0.08	4.05**	3.27**	2.39*
P5	1.25	0.41	-0.52	0.30	0.43	-0.31	0.21	0.74	3.25**
P6	-0.97	1.50	0.94	0.46	-0.40	-0.09	1.38	0.21	1.25
P7	1.47	1.13	0.05	-1.26**	0.43	-0.81*	-3.26**	-4.07**	-4.78**
P8	0.15	1.02	0.99	-1.09**	0.49	0.74	0.60	2.71**	0.70
P9	-0.44	-0.45	-1.60	1.08**	1.43**	2.46**	2.46**	0.93	0.06
P10	0.90	1.29	1.57	0.91*	1.16**	0.91*	1.83*	2.15**	2.47**
P3x P4	-2.28	1.00	-0.24	-0.54	1.66**	-0.15	3.05**	1.65*	2.84**
P5	0.23	1.63*	1.04	0.02	-0.01	0.13	-2.12*	-1.87*	-3.30**
P6	-3.63*	-3.29**	-3.30**	-0.48	-0.18	-0.31	2.38**	-2.40**	-2.30*
P7	0.75	0.14	2.51*	-0.87*	-0.68	-0.37	2.41**	4.32**	2.67**
P8	1.09	0.60	0.85	0.63	1.38**	1.19**	2.60**	3.77**	4.47**
P9	1.03	0.76	0.56	0.80*	0.32	0.24	2.13*	2.32**	0.50
P10	3.34*	2.03**	2.37*	-0.70*	-0.62	-0.65	-0.17	1.88*	1.92*
P4x P5	-3.68*	-2.30**	-2.18*	0.24	0.21	0.63	-3.26**	-2.62**	-3.33**
P6	2.83	1.48	1.57	1.74**	1.38**	1.52**	-1.76*	0.18	0.00
P7	0.74	0.04	0.02	-0.65	-0.45	0.80*	1.60	3.90**	2.64**
P8	0.36	-0.60	-0.98	0.85*	-0.40	-0.31	1.80*	3.35**	1.78
P9	3.63*	1.63*	2.34*	0.35	1.21**	0.08	-3.67**	-3.43**	-3.53**
P10	1.27	0.13	-0.29	0.19	-1.07**	0.52	5.69**	4.79**	3.22**
P5x P6	1.67	-0.05	-0.48	1.63**	-0.29	0.46	3.08**	3.99**	2.86**
P7	-0.65	-0.33	0.23	-0.76*	0.55	-1.59**	5.44**	6.38**	3.84**
P8	1.20	-0.70	0.27	-0.59	-1.40**	-0.70	1.96*	2.15**	1.31
P9	0.60	0.16	1.25	-0.42	-1.12**	-0.31	1.16	4.38**	4.00**
P10	-1.05	0.66	0.62	0.74*	1.27**	0.80*	2.85**	-1.07	0.75
P6x P7	1.59	0.72	2.19*	0.74*	0.38	1.30**	2.94**	2.18**	3.50**
P8	0.51	-0.28	-1.44	-1.09**	-0.90*	-1.15**	0.80	0.63	0.97
P9	-0.36	-0.08	0.94	0.41	1.38**	1.24**	2.33**	1.52	0.34
P10	-0.88	0.52	0.98	-1.09**	-0.90*	-0.98*	2.35**	3.07**	3.75**
P7x P8	-0.25	0.81	0.47	-0.81*	-0.07	0.13	2.49**	0.35	0.61
P9	-0.81	0.18	0.89	-0.65	-0.45	-2.15**	5.35**	3.90**	5.97**
P10	0.34	0.08	-0.88	-1.48**	-1.40**	-1.04**	-0.29	-0.54	-1.28
P8x P9	0.74	-0.26	0.69	-1.15**	-1.07**	-1.26**	2.21**	-0.65	-0.22
P10	0.78	0.80	1.72	0.69	0.66	0.52	1.91*	2.57**	3.53**
P9x P10	-1.11	1.77*	0.71	-1.15**	0.27	-1.09**	6.44**	6.13**	5.56**
SEs	1.49	0.77	1.10	0.35	0.40	0.39	0.85	0.83	0.95

* Significant at (P<0.05)

** Significant at (P<0.01)

hybrids at Rajendranagar, Palem and Karimnagar respectively registered significant negative *sca* effects (Table 7c).

4.4.2.9 Number of kernels per row

Out of 45 hybrids, 28 at Rajendranagar, 25 at Palem and 23 at Karimnagar recorded significant *sca* effects in desired direction. As many as 16 hybrids recorded significant positive *sca* effects at all locations. Five hybrids each at Rajendranagar, Palem and Karimnagar were found to have significant and negative *sca* effects.

4.4.2.10 Number of kernels per ear

Twenty two, 26 and 24 hybrids at Rajendranagar, Palem and Karimnagar recorded significant positive *sca* effects. Thirteen hybrids recorded significant positive *sca* effects at all locations. Three, six and eight hybrids at Rajendranagar, Palem and Karimnagar recorded significant and negative *sca* effects.

4.4.2.11 100 kernel weight

Thirteen hybrids at Rajendranagar, 17 at Palem and 18 at Karimnagar exhibited significant positive *sca* effects in the desirable direction. A total of five crosses recorded significant positive *sca* effects, while only two hybrids recorded significant negative *sca* effects



Table 7d: Estimates of specific combining ability effects of the 45 hybrids for number of kernels per ear, 100 hundred kernel weight and protein content

Crosses		Number of kernels / ear			100 kernel weight			Protein content (%)		
		Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar
P1x	P2	-0.82	11.16	-7.94	-0.17	0.42	-1.18	0.32	0.76	0.84
	P3	104.27**	80.05**	112.42**	0.11	1.44*	4.16**	0.15	0.58	-0.08
	P4	83.77**	93.99**	86.98**	2.20**	3.35**	2.43**	-0.08	0.43	0.44
	P5	10.57	106.32**	111.56**	0.54	4.35**	5.18**	-0.26	-0.45	-0.33
	P6	29.18*	45.35**	16.59	2.33**	4.57**	-2.25**	0.12	0.70	0.45
	P7	64.52**	44.32**	49.76**	1.03	1.22	2.41**	-0.16	-0.52	-0.30
	P8	-6.73	13.93	-43.41**	1.17	-0.34	-2.37**	0.84	0.09	-0.26
	P9	51.27**	7.46	56.81**	1.50	1.22	2.52**	-1.31*	-0.78*	-0.91
	P10	44.77**	-1.68	-4.77	1.69*	-0.88	2.70**	-0.74	0.35	0.14
P2x	P3	11.52	9.99	32.14*	1.43	-0.33	0.86	0.47	-0.22	-0.36
	P4	112.68**	45.27**	62.37**	0.55	0.88	1.05	-0.23	0.47	-0.24
	P5	12.16	26.27	30.62*	1.72*	1.68*	0.67	0.64	0.79*	0.98*
	P6	35.77**	-12.04	15.31	-0.15	-1.40*	1.31*	-0.58	-0.06	-0.13
	P7	-80.23**	-47.73**	-106.86**	-2.71**	-1.99**	-2.80**	0.80	0.92*	1.03*
	P8	-19.82	52.21**	39.64**	1.52	1.09	1.89**	0.11	-0.58	-0.58
	P9	72.52**	61.74**	83.53**	1.58*	1.72**	3.41**	0.46	-0.27	0.38
	P10	59.35**	101.60**	60.28**	5.21**	3.62**	3.49**	-0.58	-1.13**	-0.91
P3x	P4	19.43	74.82**	32.39*	3.44**	2.57**	1.19	-0.34	-0.23	-0.15
	P5	-20.76	-28.18*	-45.02**	-0.59	-0.84	-0.95	-1.29*	-1.34**	-1.19*
	P6	15.18	-44.15**	-42.33**	-1.83*	-2.01**	-0.85	1.22*	0.88*	1.03*
	P7	8.52	35.16*	18.17	-1.03	1.60*	0.84	-0.13	-0.32	-0.06
	P8	18.27	42.43**	81.34**	0.64	0.91	2.03**	-0.93	-1.24**	-0.66
	P9	70.60**	30.63*	22.23	0.93	1.04	-1.02	-0.48	-0.09	-0.41
	P10	-13.57	44.16**	9.64	0.13	1.50*	0.80	-0.27	0.49	0.22
P4x	P5	-16.93	-54.57**	-29.47*	-2.04**	-2.33**	-2.16**	0.30	-1.67**	-1.15*
	P6	24.68*	46.80**	39.56**	0.45	0.13	0.84	-0.16	-0.29	-0.33
	P7	8.35	40.10**	60.06**	-1.11	0.14	1.24	-0.05	-0.01	0.31
	P8	56.77**	40.05**	26.89	-0.44	0.09	2.59**	1.45**	1.08**	1.00*
	P9	-45.57**	16.91	-64.22**	-0.55	-0.75	-0.66	0.68	0.30	-0.24
	P10	80.27**	23.10	61.53**	1.18	2.58**	1.10	-0.60	-0.90*	-0.57
P5x	P6	79.16**	45.13**	58.14**	-0.51	-0.27	0.27	0.87	0.79*	0.85
	P7	51.49**	116.10**	-14.69	2.97**	6.04**	-0.74	-0.71	0.97*	-0.40
	P8	8.91	-10.95	-2.52	0.83	1.42*	0.22	0.07	-0.14	0.11
	P9	-2.43	20.57	55.37**	0.23	0.01	2.13**	0.87	0.67	0.73
	P10	68.07**	49.10**	48.45**	-1.55*	-0.33	1.92**	-0.73	-0.10	-0.58
P6x	P7	73.10**	52.46**	80.34**	1.25	3.16**	4.19**	-0.50	-0.77	-0.54
	P8	-14.82	-14.93	-20.16	1.82*	-0.63	0.19	0.62	0.74	0.64
	P9	43.18**	63.60**	54.39**	-1.35	2.30**	1.30	0.22	0.23	0.76
	P10	23.02	39.46**	36.48**	0.91	0.90	0.66	0.69	0.40	0.29
P7x	P8	4.52	15.38	19.34	1.46	-0.25	1.91**	0.88	0.58	0.97
	P9	67.18**	43.24**	4.56	2.72**	0.05	1.13	0.65	0.56	0.59
	P10	-46.98**	-30.57*	-45.02**	-1.18	-0.79	-0.95	0.64	-1.31**	-0.48
P8x	P9	1.27	-36.82**	-34.94*	2.39**	0.22	-0.71	-0.34	-0.12	-0.20
	P10	55.10**	72.05**	58.81**	3.51**	3.16**	2.91**	-1.31*	-0.27	-1.02*
P9x	P10	58.77**	62.57**	59.70**	2.98**	3.15**	4.09**	-0.74	-0.18	-0.09
SEs		12.54	13.96	13.90	0.78	0.65	0.66	0.54	0.39	0.49

*: Significant at (P<0.05) **: Significant at (P<0.01)



P₃



Plate 4 : Good general combiners over 3 locations

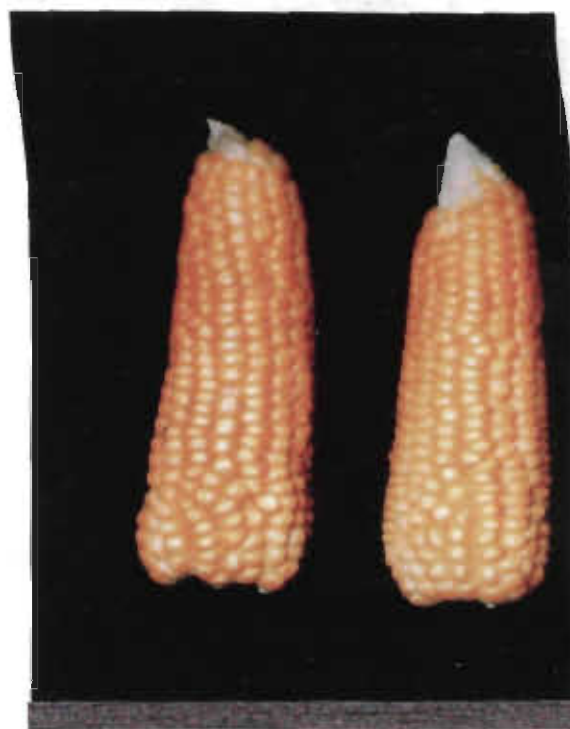


P₁



**P₆**

Plate 5 : Good general combiners over 3 locations

**P₇**

Estimates of specific combining ability effects of the 45 hybrids for oil content and grain yield

Crosses	Oil content (%)			Grain yield (kg/plot)		
	Rajendra-nagar	Palem	Karim-nagar	Rajendra-nagar	Palem	Karim-nagar
P1	-0.88*	-0.55	-0.75*	-0.03	0.04	-0.21
P2	-1.23**	-0.96*	-1.14**	0.78**	0.64**	1.19**
P3	-0.02	0.60	0.41	0.76**	0.94**	0.82**
P4	0.51	0.21	0.51	0.09	1.13**	1.31**
P5	-0.84*	-0.77*	-0.70	0.32*	0.77**	-0.14
P6	0.62	0.69	0.16	0.61**	0.37**	0.58**
P7	-0.86*	-1.16**	-1.02**	0.09	0.04	-0.57**
P8	0.57	0.59	0.69	0.45**	0.15	0.56**
P9	-0.57	1.07**	1.17**	0.42**	-0.20	0.17
P10						
P11						
P12						
P13	-1.31**	-0.89*	-0.85*	0.06	0.00	0.29
P14	0.56	0.02	0.70	0.80**	0.35*	0.30
P15	0.58	1.02**	0.55	0.16	0.26	0.26
P16	0.53	0.84*	0.64	0.28	-0.25	0.27
P17	0.29	-0.27	-0.32	-0.77**	-0.24	-0.97**
P18	-0.01	0.26	0.03	0.02	0.49**	0.51**
P19	-0.68	-0.23	-0.69	0.64**	0.59**	0.91**
P20	-0.01	-0.63	-0.68	0.97**	0.94**	0.79**
P21						
P22						
P23						
P24	0.01	0.09	0.12	0.36*	0.74**	0.30
P25	-1.33**	-1.25**	-0.79*	-0.25	-0.30*	-0.41**
P26	0.25	0.25	0.26	-0.04	-0.49**	-0.38*
P27	-0.49	-0.41	-0.26	0.14	0.35*	0.18
P28	1.24**	1.08**	0.98*	0.20	0.38**	0.76**
P29	0.59	0.09	0.29	0.56**	0.32*	-0.02
P30	1.41**	1.11**	0.39	-0.11	0.38**	0.09
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at all locations. Four hybrids each at Rajendranagar, Palem and Karimnagar, showed significant and negative *sca* effects (Table 7d).

4.4.2.12 Protein content

Only one hybrid at Rajendranagar, 6 at Palem and 4 at Karimnagar recorded significant positive *sca* effects. The hybrid $P_3 \times P_6$ recorded significant positive *sca* effects at all locations (Table 7d). Six hybrids recorded significant negative *sca* effects at all locations. The cross combination $P_3 \times P_5$ registered significant positive *sca* effect at all locations.

4.4.2.13 Oil content

As many as 3 hybrids at Rajendranagar, 7 at Palem and 5 at Karimnagar recorded significant positive *sca* effects. Six hybrids registered significant positive *sca* effects at all the three locations. Ten hybrids at Rajendranagar and eight each at Palem and Karimnagar recorded significant negative *sca* effects.

4.4.2.14 Grain yield

Out of 45 hybrids, 18 at Rajendranagar, 22 at Palem and 21 at Karimnagar recorded significant positive *sca* effects. Nine hybrids exhibited significant positive *sca* effects at all locations. Four each at Rajendranagar and Palem and eight hybrids at Karimnagar recorded

significant negative *sca* effects. Two hybrids exhibited significant negative effects at all the 3 locations (Table 7e).

4.5 HETEROSIS

Heterosis was estimated in 45 hybrids for 14 characters *viz.*, days to 50 per cent tasseling, days to 50 per cent silking, days to 50 per cent brown husk, ear height, plant height, ear length, ear girth, number of kernel rows per ear, number of kernels per row, number of kernels per ear, 100 kernel weight, protein content, oil content and grain yield per plot at three locations *viz.*, Rajendranagar, Palem and Karimnagar which is expressed as heterosis over the mid parent, heterobeltiosis and standard heterosis over checks Madhuri and BMH-1620.

The negative heterotic values for days to 50 per cent tasseling, days to 50 per cent silking and days to 50 per cent brown husk indicates earliness, which is desirable. For other characters positive estimates were considered as desirable. The character wise performance of hybrids is presented in Tables 8a to 8n and Figure 4. The values are expressed in per cent.

4.5.1 Days to 50 Per cent Tasseling

At Rajendranagar location all hybrids recorded negative heterosis and heterobeltiosis ranging from -10.56 ($P_2 \times P_7$) to -1.74 per cent ($P_5 \times P_9$ and $P_6 \times P_8$) and -10.56 ($P_2 \times P_7$) to -1.17 per cent

Table 8a: Estimates of heterosis, heterobeltiosis and standard heterosis at three locations for days to 50 per cent tasseling

Crosses	Days to 50 % tasseling											
	Rajendranagar				Palen				Karimnagar			
	Heterosis	Heterobe	Standard heterosis		Heterosis	Heterobe	Standard heterosis		Heterosis	Heterobe	Standard heterosis	
		-ltiosis	Check 1	Check 2		-ltiosis	Check 1	Check 2		-ltiosis	Check 1	Check 2
P ₁ X P ₂	-7.00**	-6.21**	0.00	-7.78**	-4.57**	-3.47**	0.00	-6.70**	-6.82**	-6.29**	-1.80*	-7.34**
P ₃	-6.05**	-4.12**	-1.81*	-9.44**	-4.09**	-2.96**	-1.80	-8.38**	-4.90**	-4.07**	-1.20	-6.78**
P ₄	-9.24**	-8.47**	-2.41**	-10.00**	-0.29	0.58	4.19**	-2.79**	-4.55**	-4.00**	0.60	-5.08**
P ₅	-6.90**	-5.26**	-2.41**	-10.00**	-1.16	-0.58	1.80	-5.03**	-0.58	0.58	2.99**	-2.82**
P ₆	-2.86**	-1.73*	2.41**	-5.56**	-3.79**	-2.94**	-1.20	-7.82**	-3.49**	-1.78*	-0.60	-6.21**
P ₇	-7.56**	-6.78**	-0.60	-8.33**	-5.98**	-4.62**	-1.20	-7.82**	-4.55**	-4.00**	0.60	-5.08**
P ₈	-2.30**	-0.58	2.41**	-5.56**	-2.03*	-1.74	1.20	-5.59**	-5.17**	-4.62**	-1.20	-6.78**
P ₉	-4.00**	-2.89**	1.20	-6.67**	0.29	1.18	2.99**	-3.91**	-2.03*	-0.59	1.20	-4.52**
P ₁₀	-7.30**	-6.78**	-0.60	-8.33**	-6.25**	-4.62**	-1.20	-7.82**	-5.11**	-4.57**	0.00	-5.65**
P ₁ X P ₃	-7.43**	-4.71**	-2.41**	-10.00**	-1.16	1.18	2.40*	-4.47**	-3.72**	-2.33**	0.60	-5.08**
P ₄	-7.22**	-7.22**	0.60	-7.22**	-3.68**	-3.41**	1.80	-5.03**	-4.52**	-4.52**	1.20	-4.52**
P ₅	-9.40**	-7.02**	-4.22**	-11.67**	-4.60**	-2.92**	-0.60	-7.26**	-6.32**	-4.68**	-2.40**	-7.91**
P ₆	-10.48**	-8.67**	-4.82**	-12.22**	-5.48**	-3.53**	-1.80	-8.38**	-7.51**	-5.33**	-4.19**	-9.60**
P ₇	-10.56**	-10.56**	-3.01**	-10.56**	-3.10**	-2.82**	2.99**	-3.91**	-5.08**	-5.08**	0.60	-5.08**
P ₈	-7.69**	-5.26**	-2.41**	-10.00**	-5.44**	-4.07**	-1.20	-7.82**	-3.43**	-2.31**	1.20	-4.52**
P ₉	-8.22**	-6.36**	-2.41**	-10.00**	-3.17**	-1.18	0.60	-6.15**	-5.48**	-3.53**	-1.80*	-7.34**
P ₁₀	-9.75**	-9.50**	-2.41**	-10.00**	-4.49**	-3.95**	1.80	-5.03**	-6.78**	-6.78**	-1.20	-6.78**
P ₂ X P ₄	-5.14**	-2.35**	0.00	-7.78**	-3.19**	-1.18	0.00	-6.70**	-4.87**	-3.49**	-0.60	-6.21**
P ₅	-7.92**	-7.65**	-5.42**	-12.78**	-4.12**	-3.55**	-2.40*	-8.94**	-6.71**	-6.43**	-4.19**	-9.60**
P ₆	-5.54**	-4.71**	-2.41**	-10.00**	0.88	1.18	2.40*	-4.47**	-1.47	-0.59	0.60	-5.08**
P ₇	-4.57**	-1.76*	0.60	-7.22**	-2.59**	0.00	1.20	-5.59**	-3.15**	-1.74*	1.20	-4.52**
P ₈	-4.40**	-4.12**	-1.81*	-9.44**	-3.23**	-2.37*	-1.20	-7.82**	-3.77**	-3.49**	-0.60	-6.21**
P ₉	-4.96**	-4.12**	-1.81*	-9.44**	0.29	0.59	1.80	-5.03**	-4.68**	-4.12**	-2.40**	-7.91**
P ₁₀	-5.44**	-2.94**	-0.60	-8.33**	-4.60**	-1.78	-0.60	-7.26**	-6.02**	-4.65**	-1.80*	-7.34**
P ₁ X P ₅	-5.98**	-3.51**	-0.60	-8.33**	-3.75**	-2.34*	0.00	-6.70**	-4.02**	-2.34**	0.00	-5.65**
P ₆	-8.22**	-6.36**	-2.41**	-10.00**	-4.05**	-2.35*	-0.60	-7.26**	-5.20**	-2.96**	-1.80*	-7.34**
P ₇	-8.33**	-8.33**	-0.60	-8.33**	-4.52**	-3.98**	1.20	-5.59**	-6.78**	-6.78**	-1.20	-6.78**
P ₈	-4.84**	-2.34**	0.60	-7.22**	-2.87**	-1.74	1.20	-5.59**	-2.86**	-1.73*	1.80*	-3.95**
P ₉	-7.08**	-5.20**	-1.20	-8.89**	-1.73	0.00	1.80	-5.03**	-4.32**	-2.35**	-0.60	-6.21**
P ₁₀	-9.75**	-9.50**	-2.41**	-10.00**	-5.35**	-4.55**	0.60	-6.15**	-8.47**	-8.47**	-2.99**	-8.47**
P ₂ X P ₆	-6.98**	-6.43**	-3.61**	-11.11**	-0.29	0.00	1.80	-5.03**	-2.35**	-1.78*	-0.60	-6.21**
P ₇	-6.55**	-4.09**	-1.20	-8.89**	-1.43	0.58	2.99**	-3.91**	-5.75**	-4.09**	-1.80*	-7.34**
P ₈	-4.09**	-4.09**	-1.20	-8.89**	-3.21**	-2.92**	-0.60	-7.26**	-3.49**	-2.92**	-0.60	-6.21**
P ₉	-1.74*	-1.17	1.81*	-6.11**	-1.47	-1.18	0.60	-6.15**	-0.29	0.00	1.80*	-3.95**
P ₁₀	-4.57**	-2.34**	0.60	-7.22**	-4.57**	-2.34*	0.00	-6.70**	-2.30**	-0.58	1.80*	-3.95**
P ₁ X P ₇	-4.82**	-2.89**	1.20	-6.67**	-2.87**	-0.59	1.20	-5.59**	-1.73*	0.59	1.80*	-3.95**
P ₈	-1.74*	-1.17	1.81*	-6.11**	0.58	1.18	2.99**	-3.91**	-1.75*	-0.59	0.60	-5.08**
P ₉	-5.78**	-5.78**	-1.81*	-9.44**	-1.18	-1.18	0.60	-6.15**	-4.42**	-4.14**	-2.99**	-8.47**
P ₁₀	-3.41**	-1.73*	2.41**	-5.56**	-2.58**	0.00	1.80	-5.03**	-1.73*	0.59	1.80*	-3.95**
P ₂ X P ₈	-4.27**	-1.75*	1.20	-6.67**	-4.00**	-2.33*	0.60	-6.15**	-4.00**	-2.89**	0.60	-5.08**
P ₉	-5.38**	-3.47**	0.60	-7.22**	-4.02**	-1.76	0.00	-6.70**	-2.02*	0.00	1.80*	-3.95**
P ₁₀	-8.08**	-7.82**	-0.60	-8.33**	-5.32**	-5.06**	1.20	-5.59**	-6.21**	-6.21**	-0.60	-6.21**
P ₃ X P ₉	-3.49**	-2.92**	0.00	-7.78**	-2.34*	-1.76	0.00	-6.70**	-2.62**	-1.76*	0.00	-5.65**
P ₁₀	-4.57**	-2.34**	0.60	-7.22**	-5.98**	-4.07**	-1.20	-7.82**	-4.57**	-3.47**	0.00	-5.65**
P ₁ X P ₁₀	-5.68**	-4.05**	0.00	-7.78**	-4.30**	-1.76	0.00	-6.70**	-3.75**	-1.75*	0.00	-5.65**

($P_5 \times P_9$ and $P_6 \times P_8$) respectively and standard heterosis for Madhuri and BMH-1620 ranged from -5.42 ($P_3 \times P_5$) to 2.40 per cent ($P_1 \times P_6$, $P_6 \times P_{10}$ and $P_1 \times P_8$) and -12.78 ($P_3 \times P_5$) to -5.56 per cent ($P_1 \times P_6$, $P_6 \times P_{10}$ and $P_1 \times P_8$) respectively (Table 8a).

Significant heterosis in negative direction was observed in all hybrids tested at Palem, which ranged from -6.25 ($P_1 \times P_{10}$) to 0.88 per cent ($P_3 \times P_6$) and heterobeltiosis varied from -5.06 ($P_7 \times P_{10}$) to 1.18 per cent ($P_1 \times P_9$, $P_3 \times P_6$ and $P_6 \times P_8$). Significant negative heterosis in 33 hybrids and heterobeltiosis in 22 hybrids were observed. Seven hybrids showed significant positive standard heterosis over Madhuri and over BMH-1620, standard heterosis ranged from -8.94 ($P_3 \times P_5$) to -2.79 per cent ($P_1 \times P_4$).

Forty two hybrids at Karimnagar showed significant negative heterosis which ranged from -8.47 ($P_4 \times P_{10}$) to -0.29 per cent ($P_5 \times P_9$) and heterobeltiosis ranged from -8.47 ($P_4 \times P_{10}$) to 0.59 per cent ($P_6 \times P_7$), standard heterosis ranged from 4.19 ($P_2 \times P_6$ and $P_3 \times P_5$) to 2.99 per cent ($P_1 \times P_5$) over Madhuri whereas standard heterosis over BMH-1620 ranged from -9.60 ($P_2 \times P_6$ and $P_3 \times P_5$) to -2.82 per cent ($P_1 \times P_5$).

4.5.2 Days to 50 Per cent Silking

Heterosis for days to 50 per cent silking ranged from -10.58 ($P_2 \times P_7$) to 0.83 per cent ($P_6 \times P_8$) at Rajendranagar, -6.17 ($P_4 \times P_{10}$) to

Table 8b: Estimates of heterosis, heterobeltiosis and standard heterosis at three locations for days to 50 per cent silking

		Days to 50 % silking											
Crosses		Rajendranagar				Palem				Karimnagar			
		Heterosis	Heterobe	Standard heterosis		Heterosis	Heterobe	Standard heterosis		Heterosis	Heterobe	Standard heterosis	
		-Itiosis		Check 1	Check 2	-Itiosis		Check 1	Check 2	-Itiosis		Check 1	Check 2
P ₁ X P ₂		-7.77**	-6.52**	-1.15	-9.47**	-4.63**	-3.85**	-1.69*	-6.91**	-6.17**	-5.41**	-1.69	-5.91**
P ₁		-4.71**	-2.82**	-1.15	-9.47**	-4.16**	-3.35**	-2.81**	-7.98**	-4.92**	-3.87**	-2.25*	-6.45**
P ₄		-8.60**	-7.61**	-2.30**	-10.53**	-1.91*	-1.10	1.12	-4.26**	-4.84**	-4.32**	-0.56	-4.84**
P ₅		-5.49**	-4.44**	-1.15	-9.47**	-0.84	0.56	0.00	-5.32**	-0.82	0.56	1.69	-2.69**
P ₆		-3.83**	-3.30**	1.15	-7.37**	-3.05**	-2.23**	-1.69*	-6.91**	-4.63**	-3.85**	-1.69	-5.91**
P ₇		-8.31**	-7.07**	-1.72*	-10.00**	-5.95**	-4.40**	-2.25**	-7.45**	-4.58**	-4.32**	-0.56	-4.84**
P ₈		-1.93*	-0.56	2.30**	-6.32**	0.28	0.55	2.25**	-3.19**	-1.36	-0.55	1.69	-2.69**
P ₉		-3.28**	-2.75**	1.72*	-6.84**	-0.55	0.00	1.12	-4.26**	-1.92*	-0.56	0.56	-3.76**
P ₁₀		-6.99**	-5.98**	-0.57	-8.95**	-4.86**	-3.30**	-1.12	-6.38**	-3.50**	-3.24**	0.56	-3.76**
P ₁ X P ₃		-6.56**	-3.39**	-1.72*	-10.00**	-1.10	0.56	1.12	-4.26**	-5.15**	-3.31**	-1.69	-5.91**
P ₄		-6.63**	-6.38**	1.15	-7.37**	-3.24**	-3.24**	0.56	-4.79**	-5.07**	-4.81**	0.00	-4.30**
P ₅		-9.49**	-7.22**	-4.02**	-12.11**	-2.76**	-0.56	-1.12	-6.38**	-6.52**	-4.44**	-3.37**	-7.53**
P ₆		-10.51**	-8.79**	-4.60**	-12.63**	-2.75**	-1.12	-0.56	-5.85**	-5.41**	-3.85**	-1.69	-5.91**
P ₇		-10.58**	-10.58**	-2.87**	-11.05**	-3.49**	-2.70**	1.12	-4.26**	-5.35**	-4.84**	-0.56	-4.84**
P ₈		-8.15**	-5.59**	-2.87**	-11.05**	-4.92**	-3.87**	-2.25**	-7.45**	-3.24**	-1.65	0.56	-3.76**
P ₉		-8.89**	-7.14**	-2.87**	-11.05**	-2.47**	-1.11	0.00	-5.32**	-4.35**	-2.22*	-1.12	-5.38**
P ₁₀		-9.81**	-9.57**	-2.30**	-10.53**	-3.49**	-2.70**	1.12	-4.26**	-5.35**	-4.84**	-0.56	-4.84**
P ₁ X P ₄		-5.21**	-2.26**	-0.57	-8.95**	-2.20**	-0.56	0.00	-5.32**	-4.35**	-2.76**	-1.12	-5.38**
P ₅		-7.56**	-6.78**	-5.17**	-13.16**	-1.12	-0.56	-1.12	-6.38**	-4.71**	-4.44**	-3.37**	-7.53**
P ₆		-6.41**	-5.08**	-3.45**	-11.58**	0.56	0.56	1.12	-4.26**	-4.13**	-3.87**	-2.25*	-6.45**
P ₇		-4.37**	-1.13	0.57	-7.89**	-3.00**	-0.56	0.00	-5.32**	-1.91*	-0.55	1.12	-3.23**
P ₈		-3.37**	-2.82**	-1.15	-9.47**	-2.78**	-2.23**	-1.69*	-6.91**	-3.03**	-2.76**	-1.12	-5.38**
P ₉		-4.18**	-2.82**	-1.15	-9.47**	-0.28	0.00	0.56	-4.79**	-3.60**	-3.33**	-2.25*	-6.45**
P ₁₀		-6.85**	-3.95**	-2.30**	-10.53**	-4.63**	-2.23**	-1.69*	-6.91**	-6.27**	-4.97**	-3.37**	-7.53**
P ₁ X P ₅		-6.52**	-4.44**	-1.15	-9.47**	-1.66*	0.56	0.00	-5.32**	-4.09**	-2.22*	-1.12	-5.38**
P ₆		-7.57**	-6.04**	-1.72*	-10.00**	-2.20**	-0.56	0.00	-5.32**	-4.61**	-3.30**	-1.12	-5.38**
P ₇		-8.22**	-7.98**	-0.57	-8.95**	-4.02**	-3.24**	0.56	-4.79**	-6.17**	-5.91**	-1.69	-5.91**
P ₈		-5.72**	-3.35**	-0.57	-8.95**	-2.19**	-1.10	0.56	-4.79**	-2.98**	-1.65	0.56	-3.76**
P ₉		-7.03**	-5.49**	-1.15	-9.47**	-0.82	0.56	1.69*	-3.72**	-4.63**	-2.78**	-1.69	-5.91**
P ₁₀		-9.57**	-9.57**	-2.30**	-10.53**	-6.17**	-5.41**	-1.69*	-6.91**	-9.92**	-9.68**	-5.62**	-9.68**
P ₁ X P ₆		-7.73**	-7.22**	-4.02**	-12.11**	0.56	1.13	0.56	-4.79**	-4.97**	-4.44**	-3.37**	-7.53**
P ₇		-6.78**	-4.44**	-1.15	-9.47**	-0.82	2.26**	1.69*	-3.72**	-3.83**	-2.22*	-1.12	-5.38**
P ₈		-3.62**	-3.35**	-0.57	-8.95**	-1.12	0.00	-0.56	-5.85**	-3.31**	-2.78**	-1.69	-5.91**
P ₉		-1.66*	-1.11	2.30**	-6.32**	-0.84	0.00	-0.56	-5.85**	-1.11	-1.11	0.00	-4.30**
P ₁₀		-4.89**	-2.78**	0.57	-7.89**	-1.92*	1.13	0.56	-4.79**	-2.19*	-0.56	0.56	-3.76**
P ₁ X P ₇		-4.58**	-2.75**	1.72*	-6.84**	-3.00**	-0.56	0.00	-5.32**	-4.35**	-3.30**	-1.12	-5.38**
P ₈		-0.83	0.00	2.87**	-5.79**	-0.56	0.00	0.56	-4.79**	-2.75**	-2.75**	-0.56	-4.84**
P ₉		-6.04**	-6.04**	-1.72*	-10.00**	-3.06**	-2.79**	-2.25**	-7.45**	-4.97**	-4.44**	-3.37**	-7.53**
P ₁₀		-4.32**	-2.75**	1.72*	-6.84**	-3.54**	-1.12	-0.56	-5.85**	-2.72**	-1.65	0.56	-3.76**
P ₁ X P ₈		-5.43**	-2.79**	0.00	-8.42**	-5.15**	-3.31**	-1.69*	-6.91**	-4.89**	-3.85**	-1.69	-5.91**
P ₉		-5.12**	-3.30**	1.15	-7.37**	-4.35**	-2.22**	-1.12	-6.38**	-2.73**	-1.11	0.00	-4.30**
P ₁₀		-9.28**	-9.04**	-1.72*	-10.00**	-4.79**	-4.79**	0.56	-4.79**	-4.30**	-4.30**	0.00	-4.30**
P ₁ X P ₉		-4.16**	-3.35**	-0.57	-8.95**	-2.49**	-2.22**	-1.12	-6.38**	-4.42**	-3.89**	-2.81**	-6.99**
P ₁₀		-5.18**	-2.79**	0.00	-8.42**	-2.98**	-1.10	0.56	-4.79**	-4.35**	-3.30**	-1.12	-5.38**
P ₁ X P ₁₀		-7.03**	-5.49**	-1.15	-9.47**	-1.09	1.11	2.25**	-3.19**	-0.55	1.11	2.25*	-2.15*

0.56 per cent ($P_3 \times P_6$ and $P_5 \times P_6$) at Palem and -9.92 ($P_4 \times P_{10}$) to -0.55 per cent ($P_9 \times P_{10}$) at Karimnagar. The heterobeltiosis ranged from -10.58 ($P_2 \times P_7$) to 0.00 per cent ($P_6 \times P_8$) at Rajendranagar, -5.41 ($P_4 \times P_{10}$) to 1.13 per cent ($P_5 \times P_{10}$) at Palem and -9.68 ($P_4 \times P_{10}$) to 1.11 per cent ($P_9 \times P_{10}$) at Karimnagar (Table 8b).

4.5.3 Days to 50 Per cent Brown Husk

Heterosis ranged from -7.94 ($P_2 \times P_5$) to -0.37 per cent ($P_3 \times P_6$ and $P_6 \times P_8$), heterobeltiosis from -7.14 ($P_2 \times P_{10}$ and $P_7 \times P_{10}$) to 0.75 per cent ($P_3 \times P_6$) and standard heterosis over Madhuri and BMH-1620 ranged from -4.53 ($P_3 \times P_4$) to 2.64 per cent ($P_7 \times P_8$) and -10.92 ($P_3 \times P_4$) to -4.23 per cent ($P_7 \times P_8$) respectively at Rajendranagar (Table 8c).

At Palem, heterosis ranged from -4.92 ($P_2 \times P_8$) to 1.84 per cent ($P_3 \times P_6$), heterobeltiosis -4.74 ($P_2 \times P_8$) to 1.85 ($P_3 \times P_6$) and standard heterosis over Madhuri and BMH-1620 ranged from -2.61 ($P_2 \times P_8$) to 2.99 per cent ($P_2 \times P_7$ and $P_3 \times P_6$) and -6.12 ($P_2 \times P_8$) to -0.72 per cent ($P_2 \times P_7$ and $P_3 \times P_6$), respectively.

At Karimnagar, heterosis ranged from -5.42 ($P_2 \times P_5$) to -0.18 per cent ($P_1 \times P_8$ and $P_5 \times P_9$), heterobeltiosis from -5.07 ($P_2 \times P_5$) to 0.74 per cent ($P_2 \times P_3$ and $P_4 \times P_8$) and standard heterosis over Madhuri and BMH-1620 ranged from -3.72 ($P_3 \times P_5$) to 2.60 per cent ($P_5 \times P_9$) and -5.82 ($P_3 \times P_5$) to 0.36 per cent ($P_5 \times P_9$) respectively.

Table 8c: Estimates of heterosis, heterobeltiosis and standard heterosis at three locations
for days to 50 per cent brown husk

Crosses	Days to 50 % brown husk											
	Rajendranagar				Palem				Karimnagar			
	Heterosis	Heterobe -ltiosis	Standard heterosis		Heterosis	Heterobe -ltiosis	Standard heterosis		Heterosis	Heterobe -ltiosis	Standard heterosis	
			Check 1	Check 2			Check 1	Check 2			Check 1	Check 2
P ₂	-5.76**	-4.73**	-1.13	-7.75**	-2.38**	-1.84**	-0.37	-3.96**	-4.16**	-3.64**	-1.49*	-3.64**
P ₃	-3.32**	-1.87**	-1.13	-7.75**	-0.92	-0.74	0.37	-3.24**	-2.56**	-1.85**	-1.12	-3.27**
P ₄	-3.78**	-2.91**	0.75	-5.99**	-2.19**	-1.47*	0.00	-3.60**	-2.71**	-2.18**	0.00	-2.18**
P ₅	-4.38**	-4.03**	-1.13	-7.75**	-1.46*	-0.74	0.75	-2.88**	-0.91	-0.73	1.49*	-0.73
P ₆	-2.55**	-2.20**	0.75	-5.99**	-2.76**	-2.58**	-1.49*	-5.04**	-2.73**	-2.55**	-0.74	-2.91**
P ₇	-4.68**	-3.64**	0.00	-6.69**	-3.09**	-1.84**	-0.37	-3.96**	-1.81**	-1.45*	0.74	-1.45*
P ₈	-1.47*	-0.74	1.51*	-5.28**	0.00	0.37	1.87**	-1.80**	-0.18	0.37	1.49*	-0.73
P ₉	-2.00**	-1.82**	1.51*	-5.28**	-2.55**	-1.47*	0.00	-3.60**	-1.45*	-1.09	1.12	-1.09
P ₁₀	-4.86**	-4.00**	-0.38	-7.04**	-2.03**	-1.85**	-0.75	-4.32**	-0.91	-0.37	0.74	-1.45*
P ₃ X P ₄	-3.65**	-1.12	-0.38	-7.04**	-0.73	0.00	1.12	-2.52**	-0.55	0.74	1.49*	-0.73
P ₄	-5.17**	-5.00**	0.38	-6.34**	-2.00**	-1.82**	0.75	-2.88**	-3.24**	-3.24**	0.00	-2.18**
P ₅	-7.94**	-6.59**	-3.77**	-10.21**	-3.45**	-3.27**	-0.75	-4.32**	-5.42**	-5.07**	-2.60**	-4.73**
P ₆	-7.58**	-6.23**	-3.40**	-9.86**	-1.47*	-0.74	0.37	-3.24**	-4.71**	-4.01**	-2.23**	-4.36**
P ₇	-5.69**	-5.69**	0.00	-6.69**	-0.36	0.36	2.99**	-0.72	-1.26*	-1.08	1.86**	-0.36
P ₈	-6.88**	-5.17**	-3.02**	-9.51**	-4.92**	-4.74**	-2.61**	-6.12**	-2.55**	-1.47*	-0.37	-2.55**
P ₉	-5.23**	-4.01**	-0.75	-7.39**	-2.71**	-2.18**	0.37	-3.24**	-4.14**	-3.97**	-1.12	-3.27**
P ₁₀	-7.31**	-7.14**	-1.89**	-8.45**	-0.37	0.37	1.49*	-2.16**	-2.91**	-1.84**	-0.74	-2.91**
P ₄ X P ₅	-7.50**	-5.24**	-4.53**	-10.92**	-2.01**	-1.11	0.00	-3.60**	-2.73**	-1.48*	-0.74	-2.91**
P ₅	-3.33**	-2.25**	-1.51*	-8.10**	-2.38**	-1.48*	-0.37	-3.96**	-5.30**	-4.43**	-3.72**	-5.82**
P ₆	-0.37	0.75	1.51*	-5.28**	1.85**	1.85**	2.99**	-0.72	-0.92	-0.37	0.37	-1.82**
P ₇	-2.92**	-0.37	0.38	-6.34**	-1.45*	0.00	1.12	-2.52**	-0.73	0.37	1.12	-1.09
P ₈	-2.23**	-1.50*	-0.75	-7.39**	-1.28*	-0.74	0.37	-3.24**	-2.39**	-2.21**	-1.49*	-3.64**
P ₉	-2.03**	-0.75	0.00	-6.69**	-1.64*	-0.37	0.75	-2.88**	-4.01**	-2.95**	-2.23**	-4.36**
P ₁₀	-4.20**	-1.87**	-1.13	-7.75**	-1.48*	-1.48*	-0.37	-3.96**	-3.87**	-3.69**	-2.97**	-5.09**
P ₅ X P ₆	-4.52**	-3.30**	-0.38	-7.04**	-1.45*	-1.45*	1.49*	-2.16**	-2.17**	-1.81**	0.74	-1.45*
P ₆	-4.16**	-2.93**	0.00	-6.69**	-1.28*	-0.37	0.75	-2.88**	-3.26**	-2.55**	-0.74	-2.91**
P ₇	-4.46**	-4.29**	1.13	-5.63**	-2.34**	-1.81**	1.12	-2.52**	-4.50**	-4.33**	-1.49*	-3.64**
P ₈	-4.54**	-2.95**	-0.75	-7.39**	-2.18**	-1.82**	0.37	-3.24**	-0.36	0.74	1.86**	-0.36
P ₉	-4.33**	-3.28**	0.00	-6.69**	-1.81**	-1.45*	1.49*	-2.16**	-5.23**	-5.05**	-2.23**	-4.36**
P ₁₀	-5.00**	-5.00**	0.38	-6.34**	-1.28*	-0.37	0.75	-2.88**	-1.82**	-0.74	0.37	-1.82**
P ₆ X P ₇	-5.86**	-5.86**	-3.02**	-9.51**	-1.65*	-0.74	0.37	-3.24**	-4.73**	-4.38**	-2.60**	-4.73**
P ₇	-5.05**	-3.66**	-0.75	-7.39**	-2.34**	-1.81**	1.12	-2.52**	-3.80**	-3.62**	-1.12	-3.27**
P ₈	-1.47*	-1.11	1.13	-5.63**	-2.18**	-1.82**	0.37	-3.24**	-2.55**	-1.84**	-0.74	-2.91**
P ₉	-0.91	-0.73	2.26**	-4.58**	-0.72	-0.36	2.61**	-1.08	-0.18	0.00	2.60**	0.36
P ₁₀	-3.44**	-2.20**	0.75	-5.99**	-1.65*	-0.74	0.37	-3.24**	-0.36	0.37	1.49*	-0.73
P ₇ X P ₈	-2.53**	-1.10	1.89**	-4.93**	-2.55**	-1.11	0.00	-3.60**	-3.45**	-2.92**	-1.12	-3.27**
P ₈	-0.37	0.00	2.26**	-4.58**	-0.55	0.00	1.12	-2.52**	-1.83**	-1.47*	-0.37	-2.55**
P ₉	-2.38**	-2.20**	0.75	-5.99**	-1.28*	0.00	1.12	-2.52**	-3.09**	-2.55**	-0.74	-2.91**
P ₁₀	-2.71**	-1.47*	1.51*	-5.28**	-1.11	-1.11	0.00	-3.60**	-1.47*	-1.10	0.00	-2.18**
P ₈ X P ₉	-1.45*	0.37	2.64**	-4.23**	-1.27*	-0.36	1.87**	-1.80**	-1.28*	-0.37	0.74	-1.45*
P ₉	-3.78**	-2.55**	0.75	-5.99**	-4.49**	-4.32**	-0.75	-4.32**	-2.53**	-2.53**	0.37	-1.82**
P ₁₀	-7.31**	-7.14**	-1.89**	-8.45**	-1.09	0.37	1.49*	-2.16**	-2.37**	-1.47*	-0.37	-2.55**
P ₉ X P ₁₀	-3.49**	-2.95**	-0.75	-7.39**	-2.90**	-2.19**	0.00	-3.60**	-2.73**	-1.84**	-0.74	-2.91**
P ₁₀	-2.72**	-1.11	1.13	-5.63**	-1.28*	-0.74	0.37	-3.24**	-2.21**	-2.21**	-1.12	-3.27**
P ₁₀ X P ₁₀	-5.05**	-4.01**	-0.75	-7.39**	-0.91	0.37	1.49*	-2.16**	-0.91	0.00	1.12	-1.09

4.5.4 Ear Height

Heterosis ranged from -17.09 ($P_4 \times P_{10}$) to 52.67 per cent ($P_3 \times P_6$), heterobeltiosis from -8.04 ($P_4 \times P_{10}$) to 67.71 per cent ($P_4 \times P_6$) and standard heterosis -22.31 ($P_5 \times P_7$) to 17.04 per cent ($P_1 \times P_7$) over Madhuri and -27.47 ($P_5 \times P_7$) to 9.28 per cent ($P_1 \times P_7$) (Table 8d).

At Palem, heterosis varied from -7.73 ($P_4 \times P_9$) to 66.97 per cent ($P_5 \times P_6$), heterobeltiosis, -3.93 ($P_4 \times P_{10}$) to 77.37 ($P_5 \times P_6$) and standard heterosis from -18.48 ($P_2 \times P_6$) to 20.75 per cent ($P_6 \times P_9$), over Madhuri and -24.71 ($P_2 \times P_6$) to 11.52 per cent ($P_6 \times P_9$) over BMH-1620.

At Karimnagar, heterosis ranged from -12.13 ($P_4 \times P_9$) to 60.86 per cent ($P_3 \times P_6$), heterobeltiosis -4.68 ($P_4 \times P_9$) to 74.72 per cent ($P_1 \times P_5$), standard heterosis over Madhuri and BMH-1620 ranged from -17.06 ($P_2 \times P_5$) to 15.79 per cent ($P_2 \times P_6$), -22.06 ($P_2 \times P_5$) to 8.82 per cent ($P_2 \times P_6$), respectively.

4.5.5 Plant Height

At Rajendranagar, heterosis for plant height ranged from -15.57 to 48.58 per cent, heterobeltiosis from -19.40 to 36.08 per cent and standard heterosis from -18.01 to 16.04 per cent and -34.40 to -7.16 per cent over Madhuri and BMH-1620, respectively.

4.5.4 Ear Height

Heterosis ranged from -17.09 ($P_4 \times P_{10}$) to 52.67 per cent ($P_3 \times P_6$), heterobeltiosis from -8.04 ($P_4 \times P_{10}$) to 67.71 per cent ($P_4 \times P_6$) and standard heterosis -22.31 ($P_5 \times P_7$) to 17.04 per cent ($P_1 \times P_7$) over Madhuri and -27.47 ($P_5 \times P_7$) to 9.28 per cent ($P_1 \times P_7$) (Table 8d).

At Palem, heterosis varied from -7.73 ($P_4 \times P_9$) to 66.97 per cent ($P_5 \times P_6$), heterobeltiosis, -3.93 ($P_4 \times P_{10}$) to 77.37 ($P_5 \times P_6$) and standard heterosis from -18.48 ($P_2 \times P_6$) to 20.75 per cent ($P_6 \times P_9$), over Madhuri and -24.71 ($P_2 \times P_6$) to 11.52 per cent ($P_6 \times P_9$) over BMH-1620.

At Karimnagar, heterosis ranged from -12.13 ($P_4 \times P_9$) to 60.86 per cent ($P_3 \times P_6$), heterobeltiosis -4.68 ($P_4 \times P_9$) to 74.72 per cent ($P_1 \times P_5$), standard heterosis over Madhuri and BMH-1620 ranged from -17.06 ($P_2 \times P_5$) to 15.79 per cent ($P_2 \times P_6$), -22.06 ($P_2 \times P_5$) to 8.82 per cent ($P_2 \times P_6$), respectively.

4.5.5 Plant Height

At Rajendranagar, heterosis for plant height ranged from -15.57 to 48.58 per cent, heterobeltiosis from -19.40 to 36.08 per cent and standard heterosis from -18.01 to 16.04 per cent and -34.40 to -7.16 per cent over Madhuri and BMH-1620, respectively (Table 8e).

Table 8d: Estimates of heterosis, heterobeliosis and standard heterosis at three locations for ear height

Crosses	Ear height (cm)											
	Rajendranagar				Palem				Karimnagar			
	Heterosis	Heterobe	Standard heterosis		Heterosis	Heterobe	Standard heterosis		Heterosis	Heterobe	Standard heterosis	
	-ltiosis		Check 1	Check 2	-ltiosis		Check 1	Check 2	-ltiosis		Check 1	Check 2
P ₁ X P ₂	9.99**	11.65**	7.49**	0.36	6.35*	6.39*	5.65	-2.43	9.83**	11.11**	5.26**	-1.08
P ₃	16.92**	33.06**	3.43	-3.44	25.07**	48.10**	7.57*	-0.65	20.64**	41.22**	2.08	-4.07*
P ₄	-5.61**	-1.86	-2.66	-9.12**	11.10**	13.39**	8.23**	-0.04	-1.24	1.27	-1.83	-7.74**
P ₅	33.62**	58.31**	14.65**	7.04**	30.17**	67.34**	5.87*	-2.22	39.35**	74.72**	12.35**	5.58**
P ₆	22.74**	48.62**	3.68	-3.20	22.82**	47.20**	4.73	-3.28	24.91**	49.76**	3.86	-2.39
P ₇	31.46**	48.37**	17.04**	9.28**	27.14**	42.51**	14.05**	5.34*	29.79**	44.80**	14.01**	7.14**
P ₈	21.49**	33.52**	10.54**	3.20	23.31**	35.62**	12.35**	3.76	19.01**	26.29**	9.08**	2.51
P ₉	18.07**	25.54**	10.54**	3.20	13.55**	23.03**	4.77	-3.23	19.93**	26.71**	10.36**	3.71
P ₁₀	17.90**	25.49**	10.28**	2.96	18.29**	25.02**	11.56**	3.03	21.69**	26.74**	13.45**	6.62**
P ₂ X P ₃	18.98**	33.17**	3.51	-3.36	15.15**	36.29**	-1.01	-8.57**	24.88**	44.27**	4.29*	-1.99
P ₄	-5.73**	-0.44	-4.15*	-10.52**	-5.71	-3.81	-8.19**	-15.20**	-5.74**	-2.20	-7.34**	-12.92**
P ₅	1.65	18.39**	-14.26**	-19.95**	2.99	32.32**	-16.29**	-22.68**	4.30	28.98**	-17.06**	-22.06**
P ₆	37.06**	63.11**	13.79**	6.24**	-4.34	14.58**	-18.48**	-24.71**	41.13**	66.95**	15.79**	8.82**
P ₇	30.37**	44.73**	14.18**	6.60**	20.65**	35.18**	8.19**	-0.08	27.18**	40.11**	10.31**	3.67
P ₈	26.57**	36.89**	13.32**	5.80**	24.42**	36.79**	13.31**	4.65	24.87**	30.91**	13.07**	6.26**
P ₉	-4.14	0.34	-11.65**	-17.51**	0.12	8.43*	-7.66**	-14.72**	4.01	8.58**	-5.43**	-11.13**
P ₁₀	23.44**	29.34**	13.66**	6.12**	20.02**	26.79**	13.13**	4.49	25.13**	28.78**	15.28**	8.34**
P ₃ X P ₄	20.14**	42.81**	11.01**	3.64*	19.56**	38.34**	0.48	-7.20**	20.01**	44.57**	4.50*	-1.79
P ₅	20.99**	25.43**	-9.16**	-15.19**	21.52**	30.52**	-17.43**	-23.74**	28.53**	36.50**	-12.22**	-17.51**
P ₆	52.67**	61.39**	12.59**	5.12**	53.59**	55.20**	10.42**	1.98	60.86**	64.26**	13.92**	7.06**
P ₇	46.79**	47.88**	14.95**	7.32**	43.73**	51.05**	9.72**	1.33	50.76**	57.49**	13.84**	6.98**
P ₈	36.13**	40.55**	9.25**	2.00	41.26**	51.18**	9.81**	1.42	38.20**	51.67**	9.63**	3.03
P ₉	40.17**	49.48**	16.19**	8.48**	45.28**	57.81**	14.62**	5.86*	43.12**	57.78**	14.05**	7.18**
P ₁₀	35.14**	43.97**	11.91**	4.48*	47.80**	64.68**	19.61**	10.47**	35.52**	51.67**	9.63**	3.03
P ₄ X P ₅	17.97**	46.19**	5.87**	-1.16	36.28**	70.93**	8.14**	-0.12	24.39**	60.73**	3.35	-2.87
P ₆	32.33**	67.71**	17.00**	9.24**	35.40**	58.52**	12.78**	4.16	33.42**	64.69**	14.22**	7.34**
P ₇	22.20**	44.03**	13.62**	6.08**	31.29**	43.93**	15.19**	6.39*	26.86**	45.50**	14.56**	7.66**
P ₈	12.70**	29.23**	6.98**	-0.12	12.03**	20.56**	-0.13	-7.76**	5.30*	14.74**	-0.89	-6.86**
P ₉	-12.29**	-2.82	-14.43**	-20.11**	-7.73*	-2.16	-16.68**	-23.05**	-12.13**	-4.68*	-16.98**	-21.98**
P ₁₀	-17.09**	-8.04**	-19.19**	-24.55**	-7.16*	-3.93	-14.27**	-20.82**	-8.41**	-2.09	-12.35**	-17.63**
P ₅ X P ₆	52.47**	55.37**	8.39**	1.20	66.97**	77.37**	12.22**	3.64	57.07**	63.23**	4.97*	-1.36
P ₇	2.69	7.27**	-22.31**	-27.47**	18.36**	34.05**	-15.19**	-21.67**	16.91**	30.03**	-16.38**	-21.42**
P ₈	6.73**	14.37**	-17.17**	-22.67**	15.13**	32.94**	-15.89**	-22.32**	16.45**	36.44**	-12.27**	-17.55**
P ₉	13.48**	25.72**	-8.95**	-14.99**	32.68**	55.64**	-1.53	-9.06**	24.42**	46.47**	-5.81**	-11.49**
P ₁₀	17.39**	29.92**	-5.91**	-12.16**	30.18**	56.89**	-0.74	-8.33**	30.35**	55.91**	0.25	-5.78**
P ₆ X P ₇	47.22**	56.84**	9.42**	2.16	38.55**	47.20**	4.73	-3.28	48.07**	58.08**	9.63**	3.03
P ₈	32.23**	44.57**	0.86	-5.84**	27.44**	37.91**	-1.88	-9.38**	29.03**	44.86**	0.47	-5.58**
P ₉	47.73**	67.10**	16.57**	8.84**	54.51**	69.72**	20.75**	11.52**	43.84**	62.24**	12.52**	5.74**
P ₁₀	44.31**	63.04**	13.75**	6.20**	40.98**	58.89**	13.05**	4.41	34.92**	54.53**	7.17**	0.72
P ₇ X P ₈	17.40**	20.30**	-5.10**	-11.40**	12.80**	14.77**	-8.14**	-15.16**	10.64**	16.01**	-8.66**	-14.16**
P ₉	34.33**	42.13**	12.12**	4.68*	30.82**	35.01**	8.06**	-0.20	34.83**	41.99**	11.80**	5.07**
P ₁₀	37.34**	45.17**	14.52**	6.92**	34.97**	42.72**	14.23**	5.50*	32.95**	42.05**	11.84**	5.11**
P ₈ X P ₉	35.92**	40.25**	16.10**	8.40**	41.73**	43.71**	19.05**	9.95**	31.00**	31.55**	13.62**	6.78**
P ₁₀	30.94**	34.97**	11.73**	4.32*	30.94**	35.99**	12.65**	4.04	23.94**	26.19**	9.00**	2.43
P ₉ X P ₁₀	21.91**	22.03**	7.24**	0.12	17.45**	20.26**	2.41	-5.42*	18.10**	19.74**	4.29*	-1.99

Table 8e: Estimates of heterosis, heterobelitosis and standard heterosis at three locations for plant height

Crosses	Plant height (cm)											
	Rajendranagar				Palem				Karimnagar			
	Heterosis	Heterobe	Standard heterosis		Heterosis	Heterobe	Standard heterosis		Heterosis	Heterobe	Standard heterosis	
	-ltiosis		Check 1	Check 2	-ltiosis		Check 1	Check 2	-ltiosis		Check 1	Check 2
P ₁ P ₂	13.03**	2.60	2.53	-17.97**	8.41**	-1.95	-2.69	-12.34**	10.24**	1.53	1.86	-9.25**
P ₃	26.08**	24.05**	4.46	-16.42**	22.27**	17.33**	2.46	-7.71**	23.21**	15.44**	4.08	-7.27**
P ₄	18.08**	6.34*	8.18**	-13.45**	25.82**	14.85**	11.66**	0.58	30.56**	9.64**	10.29**	-1.74
P ₅	48.58**	35.53**	10.45**	-11.63**	67.28**	40.06**	12.43**	1.28	107.81**	38.79**	17.24**	4.46*
P ₆	14.74**	11.73**	-3.92	-23.13**	34.88**	31.57**	11.07**	0.05	38.32**	30.80**	16.84**	4.10*
P ₇	25.99**	25.58**	3.01	-17.58**	33.18**	31.19**	5.31*	-5.14**	36.01**	27.23**	7.47**	-4.25*
P ₈	28.68**	24.12**	8.88**	-12.89**	25.45**	17.41**	8.11**	-2.62	33.19**	20.94**	12.51**	0.24
P ₉	39.52**	36.08**	10.89**	-11.28**	42.74**	40.62**	12.88**	1.68	36.78**	31.55**	11.12**	-1.00
P ₁₀	33.39**	25.46**	16.04**	-7.16**	33.12**	26.78**	12.48**	1.32	32.89**	18.48**	12.26**	0.02
P ₁ X P ₃	-2.57	-10.23**	-10.30**	-28.23**	-8.56**	-14.06**	-14.71**	-23.17**	7.83**	-3.10	-2.78	-13.38**
P ₄	-1.33	-2.20	-0.51	-20.40**	5.05*	3.98	3.19	-7.04**	0.52	0.25	0.85	-10.15**
P ₅	10.51**	-7.60**	-7.66**	-26.12**	27.63**	-1.37	-2.12	-11.83**	79.26**	0.81	1.14	-9.89**
P ₆	9.69**	2.04	1.97	-18.42**	12.35**	3.96	3.17	-7.06**	21.54**	8.22**	8.58**	-3.27
P ₇	20.97**	10.13**	10.06**	-11.95**	21.20**	8.15**	7.34**	-3.31	44.83**	14.07**	14.44**	1.96
P ₈	12.29**	5.43*	5.35*	-15.71**	12.52**	8.46**	7.64**	-3.04	18.24**	9.65**	10.00**	-1.99
P ₉	11.31**	-1.20	-1.27	-21.00**	13.52**	1.30	0.54	-9.43**	24.02**	0.43	0.76	-10.23**
P ₁₀	-0.22	-3.94	-4.00	-23.19**	6.71**	1.05	0.29	-9.66**	7.36**	1.39	1.72	-9.38**
P ₁ X P ₄	13.96**	4.15	5.95*	-15.23**	13.90**	8.10**	5.09*	-5.33**	18.84**	6.51**	7.15**	-4.54*
P ₅	23.14**	10.68**	-6.79*	-25.42**	36.16**	10.29**	-3.69	-13.25**	66.05**	3.90	-6.32**	-16.54**
P ₆	27.31**	25.99**	8.35**	-13.31**	26.86**	24.75**	8.93**	-1.87	20.63**	19.52**	7.76**	-3.99*
P ₇	33.79**	32.05**	11.20**	-11.03**	31.99**	24.85**	9.02**	-1.79	48.09**	29.80**	17.02**	4.26*
P ₈	25.89**	23.38**	8.23**	-13.41**	26.70**	23.43**	13.65**	2.37	28.05**	24.10**	15.45**	2.86
P ₉	38.02**	32.49**	11.58**	-10.73**	35.56**	28.24**	11.98**	0.87	37.38**	23.79**	11.61**	-0.56
P ₁₀	9.21**	4.33	-3.51	-22.80**	16.08**	15.16**	2.17	-7.96**	13.02**	7.55**	1.90	-9.22**
P ₄ X P ₅	20.96**	0.42	2.15	-18.27**	43.01**	11.33**	8.23**	-2.50	97.25**	10.62**	11.28**	-0.85
P ₆	8.98**	0.55	2.29	-18.16**	18.62**	10.81**	7.73**	-2.96	24.60**	10.64**	11.30**	-0.84
P ₇	13.48**	2.49	4.26	-16.58**	19.16**	7.30**	4.32*	-6.03**	27.16**	-0.11	0.49	-10.47**
P ₈	11.60**	3.92	5.71*	-15.42**	13.18**	10.18**	7.12**	-3.51	14.38**	5.78**	6.41**	-5.20**
P ₉	3.36	-8.96**	-7.39**	-25.90**	10.34**	-0.63	-3.39	-12.97**	23.44**	-0.31	0.29	-10.65**
P ₁₀	-15.57**	-19.40**	-18.01**	-34.40**	12.50**	7.58**	4.59*	-5.78**	10.61**	4.18*	4.80*	-6.63**
P ₅ X P ₆	20.05**	6.92*	-8.06**	-26.44**	46.13**	19.93**	1.24	-8.80**	71.74**	8.47**	-3.11	-13.67**
P ₇	16.05**	5.55	-13.43**	-30.73**	46.50**	24.18**	-3.30	-12.89**	73.92**	24.17**	-1.88	-12.58**
P ₈	19.64**	5.63	-7.34**	-25.86**	39.70**	10.93**	2.13	-8.00**	77.22**	7.47**	-0.02	-10.92**
P ₉	26.44**	18.04**	-8.55**	-26.83**	51.05**	28.02**	-0.29	-10.18**	78.21**	23.76**	0.54	-10.42**
P ₁₀	19.49**	3.14	-4.60	-23.67**	38.54**	11.54**	-1.04	-10.86**	79.87**	7.11**	1.48	-9.59**
P ₆ X P ₇	25.20**	22.32**	5.18	-15.85**	33.67**	28.49**	8.46**	-2.29	32.97**	17.62**	5.07*	-6.39**
P ₈	20.59**	19.40**	4.74	-16.20**	18.89**	13.95**	4.91*	-5.49**	21.12**	16.30**	8.20**	-3.60
P ₉	25.86**	19.63**	2.87	-17.69**	29.61**	24.60**	5.18*	-5.25**	37.16**	24.74**	11.43**	-0.72
P ₁₀	29.09**	24.56**	15.20**	-7.83**	26.54**	23.47**	9.54**	-1.32	32.34**	24.77**	18.22**	5.32**
P ₇ X P ₈	27.64**	23.49**	8.33**	-13.33**	29.70**	19.69**	10.20**	-0.73	44.85**	23.04**	14.46**	1.98
P ₉	37.77**	33.94**	9.87**	-12.10**	46.85**	46.83**	14.37**	3.02	47.38**	43.36**	16.47**	3.76*
P ₁₀	27.46**	20.25**	11.22**	-11.02**	33.51**	25.35**	11.21**	0.18	47.06**	22.66**	16.21**	3.54
P ₈ X P ₉	21.19**	14.12**	0.10	-19.91**	23.14**	13.65**	4.64*	-5.74**	26.56**	10.52**	2.82	-8.40**
P ₁₀	22.44**	19.29**	10.33**	-11.73**	22.05**	19.83**	10.33**	-0.61	22.61**	20.39**	14.06**	1.62
P ₉ X P ₁₀	25.76**	15.55**	6.88**	-14.49**	29.67**	21.75**	8.02**	-2.70	30.60**	11.99**	6.10**	-5.47**

Significant positive heterosis was recorded in 40 hybrids, heterobeltiosis in 27 and standard heterosis in 19 and 0 hybrids over Madhuri and BMH-1620, respectively.

Heterosis for plant height at Palem exhibited a range from -8.56 ($P_2 \times P_3$) to 67.28 ($P_1 \times P_5$) and heterobeltiosis from -14.06 ($P_2 \times P_3$) to 46.83 ($P_7 \times P_9$) and standard heterosis ranged from -14.71 ($P_2 \times P_3$) to 14.37 ($P_7 \times P_9$), over Madhuri and -23.17 ($P_2 \times P_3$) to 3.02 ($P_7 \times P_9$) over BMH-1620.

At Karimnagar, heterosis varied from 0.39 ($P_2 \times P_4$) to 66.43 ($P_1 \times P_5$). heterobeltiosis -3.10 ($P_4 \times P_{10}$) to 43.36 ($P_7 \times P_9$) and standard heterosis -6.32 ($P_3 \times P_5$) to 18.22 ($P_6 \times P_{10}$) and -16.54 ($P_3 \times P_5$) to 5.32 ($P_6 \times P_{10}$) over Madhuri and BMH-1620, respectively. Forty three hybrids exhibited positive significant heterosis and heterobeltiosis.

4.5.6 Ear Length

Many of the hybrids exhibited significant and positive heterosis at Rajendranagar (42), Palem (42) and Karimnagar (43) indicating their superior contribution for ear length.

Heterosis for ear length at Rajendranagar was ranged from -9.79 ($P_4 \times P_5$) to 62.87 per cent ($P_7 \times P_9$). Only one hybrid exhibited negative heterosis. Heterobeltiosis ranged from -13.26 ($P_4 \times P_5$) to 56.06 per cent ($P_7 \times P_9$). The standard heterosis ranged from -28.95

Table 8f: Estimates of heterosis, heterobeltiosis and standard heterosis at three locations for ear length

Crosses	Ear length (cm)											
	Rajendranagar				Palem				Karimnagar			
	Heterosis	Heterobe- llosis	Standard heterosis		Heterosis	Heterobe- llosis	Standard heterosis		Heterosis	Heterobe- llosis	Standard heterosis	
			Check 1	Check 2			Check 1	Check 2			Check 1	Check 2
P ₁ X P ₂	41.12**	38.65**	5.90	9.02	41.67**	31.47**	-3.52	-7.50	41.15**	32.82**	25.34**	-1.95
P ₃	28.01**	25.94**	-3.81	-0.98	57.31**	51.00**	3.13	-1.13	38.54**	36.20**	18.33**	-7.43
P ₄	25.31**	24.69**	-4.76	-1.96	35.51**	20.29**	-2.54	-6.57	26.06**	20.34**	11.09	-13.10*
P ₅	26.59**	22.33*	0.19	3.14	61.27**	50.40**	9.20	4.69	42.40**	42.20**	19.68**	-6.37
P ₆	40.71**	33.17**	1.71	4.71	51.25**	50.78**	-5.28	-9.19	43.98**	43.40**	20.36**	-5.84
P ₇	54.93**	43.14**	9.33	12.55	66.87**	61.52**	8.41	3.94	56.01**	55.80**	30.77**	2.30
P ₈	23.63**	18.54*	-1.33	1.57	57.35**	55.14**	-2.54	-6.57	59.33**	53.10**	28.51**	0.53
P ₉	55.44**	49.63**	14.29*	17.65*	48.00**	36.68**	1.37	-2.81	36.28**	35.37**	15.16*	-9.91
P ₁₀	16.31	12.01	-7.62	-4.90	43.19**	32.71**	-2.35	-6.38	32.61**	32.61**	11.31	-12.92*
P ₁ X P ₃	19.74*	19.59*	-11.62	-9.02	43.92**	38.93**	1.96	-2.25	26.57**	21.98**	14.25*	-10.62*
P ₄	36.73**	35.01**	2.10	5.10	32.57**	26.33**	2.35	-1.88	17.52*	16.67*	9.28	-14.51**
P ₅	27.29**	20.93*	-0.95	1.96	38.87**	38.13**	1.37	-2.81	36.64**	29.71**	21.49**	-4.96
P ₆	48.72**	43.15**	5.52	8.63	39.77**	29.33**	-5.09	-9.01	40.66**	32.85**	24.43**	-2.65
P ₇	49.93**	40.83**	3.81	6.86	45.40**	39.20**	2.15	-2.06	32.14**	25.12**	17.19*	-8.32
P ₈	29.85**	22.43**	1.90	4.90	53.71**	40.80**	3.33	-0.94	50.00**	36.96**	28.28**	0.35
P ₉	37.47**	34.63**	-0.76	2.16	49.07**	48.28**	9.98*	5.44	35.95**	29.71**	21.49**	-4.96
P ₁₀	23.41*	16.86	-3.62	-0.78	51.00**	50.80**	10.96*	6.38	46.50**	38.89**	30.09**	1.77
P ₁ X P ₄	38.85**	37.28**	3.81	6.86	27.92**	17.87**	-4.50	-8.44	41.41**	37.25**	26.70**	-0.88
P ₅	24.69**	18.60*	-2.86	0.00	48.61**	44.20**	4.70	0.38	33.33**	31.25**	14.03*	-10.80*
P ₆	23.86*	19.07	-12.00	-9.41	6.59	2.01	-30.33**	-33.21**	2.39	0.26	-12.90	-31.86**
P ₇	39.56**	30.93**	-3.24	-0.39	60.40**	59.03**	8.61	4.13	40.85**	38.28**	20.14**	-6.02
P ₈	24.12**	17.16*	-2.48	0.39	57.03**	48.71**	1.57	-2.63	49.59**	41.41**	22.85**	-3.89
P ₉	34.39**	31.44**	-2.86	0.00	9.62	5.28	-21.92**	-25.14**	16.58*	15.36*	0.23	-21.59**
P ₁₀	29.35**	22.63**	1.14	4.12	37.38**	32.45**	-2.54	-6.57	33.25**	30.99**	13.80*	-10.97*
P ₁ X P ₅	-9.79	-13.26	-28.95**	-26.86**	-9.30	-14.01*	-30.33**	-33.21**	-3.85	-8.09	-15.16*	-33.63**
P ₆	31.66**	25.19**	-5.33	-2.55	56.62**	38.65**	12.33*	7.69	49.23**	41.91**	31.00**	2.48
P ₇	55.77**	44.58**	9.33	12.55	55.61**	42.27**	15.26**	10.51*	47.04**	40.20**	29.41**	1.24
P ₈	29.50**	23.57**	2.86	5.88	33.06**	16.67**	-5.48	-9.38	40.80**	29.41**	19.46**	-6.55
P ₉	47.92**	43.07**	8.19	11.37	28.63**	23.19**	-0.20	-4.32	23.21**	18.38*	9.28	-14.51**
P ₁₀	26.99**	21.71*	0.38	3.33	35.19**	28.99**	4.50	0.19	39.67**	33.33**	23.08**	-3.72
P ₃ X P ₆	25.63**	15.12	-5.71	-2.94	35.94**	26.42**	-8.22	-12.01*	34.86**	34.14**	12.90	-11.68*
P ₇	28.31**	14.88	-5.90	-3.14	35.85**	30.73**	-5.09	-9.01	37.47**	37.10**	15.38*	-9.73
P ₈	16.72	15.79	-3.62	-0.78	41.43**	30.19**	-5.48	-9.38	37.82**	32.26**	11.31	-12.92*
P ₉	34.08**	24.88**	2.29	5.29	45.87**	44.33**	7.05	2.63	54.81**	53.99**	31.00**	2.48
P ₁₀	20.05*	19.63*	-1.33	1.57	30.39**	29.52**	-4.70	-8.63	44.55**	44.35**	21.49**	-4.96
P ₄ X P ₇	49.28**	45.53**	-0.76	2.16	72.81**	66.76**	11.94*	7.32	56.91**	56.49**	31.00**	2.48
P ₈	47.67**	34.32**	11.81	15.10*	71.47**	69.59**	5.87	1.50	55.77**	50.27**	25.11**	-2.12
P ₉	33.33**	31.00**	-7.43	-4.71	31.52**	21.11**	-10.18*	-13.88**	48.39**	46.81**	24.89**	-2.30
P ₁₀	43.36**	30.95**	8.00	11.18	68.63**	55.85**	14.68**	9.94*	55.89**	55.26**	30.32**	1.95
P ₇ X P ₈	39.51**	24.03**	3.24	6.27	60.00**	52.77**	2.54	-1.69	53.65**	47.84**	23.76**	-3.19
P ₉	62.87**	56.06**	10.29	13.53	50.42**	43.27**	6.26	1.88	55.76**	54.52**	31.45**	2.83
P ₁₀	41.79**	26.56**	4.38	7.45	58.83**	51.86**	11.74*	7.13	58.16**	57.95**	32.58**	3.72
P ₈ X P ₉	44.31**	33.41**	11.05	14.31	56.58**	42.74**	5.87	1.50	53.48**	46.54**	24.66**	-2.48
P ₁₀	25.06**	24.49**	3.62	6.67	66.57**	52.39**	12.13*	7.50	55.68**	49.60**	25.57**	-1.77
P ₉ X P ₁₀	44.78**	34.41**	10.86	14.12	56.56**	55.94**	15.66**	10.88*	52.34**	51.33**	28.73**	0.71

($P_3 \times P_6$) to 14.29 per cent ($P_1 \times P_9$) and -26.86 ($P_4 \times P_5$) to 17.65 per cent ($P_1 \times P_9$) over Madhuri and BMH-1620 respectively (Table 8f).

At Palem, heterosis ranged from -9.30 ($P_4 \times P_5$) to 72.81 per cent ($P_6 \times P_7$) and heterobeltiosis -14.01 ($P_4 \times P_5$) to 69.59 per cent ($P_6 \times P_8$) and standard heterosis ranged from -30.33 ($P_4 \times P_5$ and $P_3 \times P_6$) to 15.66 per cent ($P_9 \times P_{10}$) over Madhuri, -33.21 ($P_3 \times P_6$ and $P_4 \times P_5$) to 10.88 per cent ($P_9 \times P_{10}$) over BMH-1620.

Karimnagar location showed significant and positive heterosis with 43 hybrids in desired direction and it ranged from -3.85 ($P_4 \times P_5$) to 59.33 per cent ($P_1 \times P_8$) and heterobeltiosis -8.09 ($P_4 \times P_5$) to 57.95 per cent ($P_7 \times P_{10}$) and standard heterosis -15.16 ($P_4 \times P_5$) to 32.58 per cent ($P_7 \times P_{10}$) over Madhuri and -33.63 ($P_4 \times P_5$) to 3.72 per cent ($P_7 \times P_{10}$) over BMH-1620.

4.5.7 Ear Girth

Heterosis at Rajendranagar ranged from -21.20 ($P_3 \times P_6$) to 35.83 per cent ($P_1 \times P_3$). Heterobeltiosis ranged from -33.72 ($P_3 \times P_6$) to 34.09 per cent ($P_1 \times P_3$). Standard heterosis varied from -17.39 ($P_3 \times P_6$) to 36.71 per cent ($P_4 \times P_6$) over Madhuri and -36.07 ($P_3 \times P_6$) to 5.79 per cent ($P_4 \times P_6$) over BMH-1620 (Table 8g).

At Palem, heterosis varied from -15.37 ($P_3 \times P_6$) to 43.21 per cent ($P_1 \times P_3$), heterobeltiosis from -22.44 ($P_3 \times P_6$) to 38.92 per cent ($P_1 \times P_3$) and standard heterosis over Madhuri and BMH-1620 ranged from -23.21

8g: Estimates of heterosis, heterobeltiosis and standard heterosis at three locations for ear girth

	Ear girth (cm)											
	Rajendranagar				Palem				Karimnagar			
	Heterosis	Heterobe -ltiosis	Standard heterosis		Heterosis	Heterobe -ltiosis	Standard heterosis		Heterosis	Heterobe -ltiosis	Standard heterosis	
			Check 1	Check 2			Check 1	Check 2			Check 1	Check 2
AX P ₂	6.33	-1.25	-4.59	-26.17**	33.03**	27.41**	7.90	2.10	21.90**	19.38*	16.37*	7.94
P ₂	35.83**	34.09**	14.01	-11.78	43.21**	38.92**	14.57**	8.41	13.31	7.82	0.76	-6.54
P ₄	12.52	2.64	3.14	-20.19**	27.22**	15.63**	9.63	3.74	18.09*	10.59	18.39*	9.81
P ₅	35.56**	21.10*	27.54**	-1.31	36.35**	25.88**	15.31**	9.11	8.41	4.23	5.54	-2.10
P ₆	2.68	-14.53	6.52	-17.57*	22.52**	9.23	8.15	2.34	10.92	3.76	11.34	3.27
P ₇	7.07	-7.97	6.04	-17.94*	27.19**	16.01**	9.14	3.27	19.14*	19.14*	11.34	3.27
P ₈	16.27	7.13	5.31	-18.50*	24.35**	14.10**	5.93	0.23	23.01**	21.02**	13.10	4.91
P ₉	28.61**	16.95	18.36	-8.41	31.71**	26.32**	6.67	0.93	18.92*	18.60*	10.83	2.80
P ₁₀	12.31	0.23	5.80	-18.13*	25.96**	21.66**	1.23	-4.21	17.93*	13.48	6.05	-1.64
P ₂ X P ₃	11.17	4.50	0.97	-21.87**	29.69**	27.99**	8.40	2.57	39.06**	29.72**	26.45**	17.29*
P ₄	16.67	14.42	14.98	-11.03	9.22	3.39	-1.98	-7.24	16.01*	10.82	18.64*	10.05
P ₅	18.18	13.30	19.32*	-7.66	18.21**	13.75*	4.20	-1.40	6.21	4.23	5.54	-2.10
P ₆	-1.97	-12.98	8.45	-16.07*	25.54**	16.46**	15.31**	9.11	19.07**	13.62*	21.91**	13.08
P ₇	18.81*	9.22	25.85**	-2.62	27.62**	21.26**	14.07**	7.94	21.37**	18.86*	15.87*	7.48
P ₈	14.25	13.27	11.35	-13.83	24.06**	18.62**	10.12*	4.21	25.20**	20.67**	17.63*	9.11
P ₉	7.20	4.77	6.04	-17.94*	17.66**	17.49**	-0.49	-5.84	7.14	4.65	2.02	-5.37
P ₁₀	15.65	10.76	16.91	-9.53	36.47**	35.28**	14.57**	8.41	36.44**	28.68**	25.44**	16.36*
P ₂ X P ₄	-9.64	-16.59	-16.18	-35.14**	21.17**	13.28*	7.41	1.64	11.05	-0.71	6.30	-1.40
P ₅	10.66	0.00	5.31	-18.50*	26.52**	20.22**	10.12*	4.21	20.22*	10.20	11.59	3.50
P ₆	-21.20*	-33.72**	-17.39	-36.07**	-15.37**	-22.44**	-23.21**	-27.34**	-12.22	-21.60**	-15.87*	-21.96**
P ₇	13.87	-1.05	14.01	-11.78	17.48**	10.24	3.70	-1.87	44.76**	37.74**	28.72**	19.39**
P ₈	21.74*	13.51	11.59	-13.64	18.59**	11.97*	3.95	-1.64	26.80**	22.56**	10.83	2.80
P ₉	18.29	8.83	10.14	-14.77*	26.33**	24.85**	5.43	-0.23	26.99**	21.14**	12.59	4.44
P ₁₀	26.74**	14.42	20.77*	-6.54	32.34**	31.75**	9.63	3.74	47.20**	45.48**	25.69**	16.59*
P ₂ X P ₅	-18.08	-19.95*	-15.70	-34.77**	-12.05*	-13.54*	-18.02**	-22.43**	-12.94	-15.29*	-9.32	-15.89*
P ₆	21.46*	9.69	36.71**	5.79	16.69**	14.21**	13.09**	7.01	16.10*	15.96*	24.43**	15.42*
P ₇	12.43	5.24	21.26*	-6.17	10.07	9.64	3.95	-1.64	13.07	5.88	13.35	5.14
P ₈	14.22	12.98	13.53	-12.15	2.37	1.30	-3.95	-9.11	1.79	-6.12	0.50	-6.78
P ₉	20.72*	20.29*	21.74*	-5.79	25.90**	19.01**	12.84*	6.78	21.91**	13.88*	21.91**	13.08
P ₁₀	16.76	13.96	20.29*	-6.92	16.78**	9.64	3.95	-1.64	12.76	1.88	9.07	1.17
P ₂ X P ₆	14.50	5.62	31.64**	1.87	4.66	0.75	-0.25	-5.61	0.24	-2.58	4.53	-3.04
P ₇	3.83	-0.63	14.49	-11.40	6.91	5.51	-0.74	-6.07	13.58	9.20	10.58	2.57
P ₈	20.76*	16.74	22.95*	-4.86	1.20	0.53	-6.67	-11.68*	10.12	4.23	5.54	-2.10
P ₉	13.92	11.70	17.63	-8.97	13.60*	9.16	0.00	-5.37	20.36**	15.42*	16.88*	8.41
P ₁₀	1.26	1.14	6.76	-17.38*	21.19**	15.63**	5.93	0.23	18.93*	10.20	11.59	3.50
P ₂ X P ₇	13.39	9.11	35.99**	5.23	14.07**	11.22*	10.12*	4.21	30.24**	21.83**	30.73**	21.26**
P ₈	10.51	-1.16	23.19*	-4.67	3.73	0.50	-0.49	-5.84	-0.89	-8.69	-2.02	-9.11
P ₉	2.67	-6.98	15.94	-10.28	10.36	2.24	1.23	-4.21	19.75**	11.74	19.90**	11.21
P ₁₀	-1.57	-9.11	13.29	-12.34	18.43**	8.98	7.90	2.10	23.54**	11.50	19.65**	10.98
P ₂ X P ₈	9.95	1.89	17.39	-9.16	16.78**	16.01**	9.14	3.27	23.01**	21.02**	13.10	4.91
P ₉	3.79	-2.52	12.32	-13.08	17.29**	11.29*	4.69	-0.93	28.92**	28.57**	20.15**	11.45
P ₁₀	10.28	5.66	21.74*	-5.79	19.78**	12.86*	6.17	0.47	18.21*	13.75	6.30	-1.40
P ₂ X P ₉	18.89*	17.18	18.60	-8.22	10.86	5.85	-1.73	-7.01	23.63**	21.95**	13.35	5.14
P ₁₀	17.77	13.73	20.05*	-7.10	23.14**	16.76**	8.40	2.57	36.47**	33.43**	20.65**	11.92
P ₂ X P ₁₀	1.87	-0.23	5.31	-18.50*	38.14**	37.13**	15.80**	9.58*	30.34**	25.75**	16.88*	8.41

($P_3 \times P_6$) to 15.80 per cent ($P_9 \times P_{10}$) and -27.34 ($P_3 \times P_6$) to 9.58 per cent ($P_9 \times P_{10}$), respectively.

Heterosis ranged from -12.94 ($P_4 \times P_5$) to 47.20 per cent ($P_3 \times P_{10}$) at Karimnagar location while heterobeltiosis ranged from -21.60 ($P_3 \times P_6$) to 45.48 per cent ($P_3 \times P_{10}$). Standard heterosis over Madhuri ranged from -15.87 ($P_3 \times P_6$) to 30.73 per cent ($P_6 \times P_7$) and -21.96 ($P_3 \times P_6$) to 21.26 per cent ($P_6 \times P_7$) over BMH-1620.

4.5.8 Number of Kernel Rows per Ear

At Rajendranagar, a maximum of 23 hybrids exhibited significant positive heterosis, while the heterobeltiosis was in case of 14 hybrids. Heterosis ranged from -17.65 ($P_7 \times P_{10}$) to 33.33 per cent ($P_1 \times P_4$ and $P_2 \times P_4$), heterobeltiosis from -22.22 ($P_2 \times P_7$, $P_3 \times P_7$, $P_5 \times P_7$ and $P_7 \times P_{10}$) to 33.33 per cent ($P_1 \times P_4$) and standard heterosis over Madhuri ranged from -8.70 to 13.04 per cent and over BMH-1620 ranged from 0.00 to 23.81 per cent (Table 8h).

Heterosis at Palem ranged from -12.50 ($P_7 \times P_{10}$) to 29.73 per cent ($P_1 \times P_4$), heterobeltiosis -16.67 ($P_5 \times P_8$) to 26.32 per cent ($P_1 \times P_4$) and ($P_3 \times P_4$) standard heterosis over Madhuri ranged from -9.09 to 9.09 per cent and -4.76 to 14.29 per cent over BMH-1620.

At Karimnagar, heterosis varied from -17.39 ($P_6 \times P_7$) to 33.33 per cent ($P_1 \times P_4$), heterobeltiosis -20.83 ($P_5 \times P_7$, and $P_7 \times P_9$), to 33.33

Table 8b: Estimates of heterosis, heterobeltiosis and standard heterosis at three locations for number of kernel rows/ear

Cross	No. of kernel rows per ear											
	Rajendranagar				Palem				Karimnagar			
	Heterosis	Heterobeltiosis	Standard heterosis		Heterosis	Heterobeltiosis	Standard heterosis		Heterosis	Heterobeltiosis	Standard heterosis	
			Check 1	Check 2			Check 1	Check 2			Check 1	Check 2
P ₁ X P ₂	7.69**	0.00	-8.70**	0.00	13.51**	10.53**	-4.55	0.00	7.69**	0.00	-4.55	0.00
P ₂	23.08**	14.29**	4.35*	14.29**	18.92**	15.79**	0.00	4.76	26.32**	20.00**	9.09**	14.29**
P ₄	33.33**	33.33**	4.35*	14.29**	29.73**	26.32**	9.09**	14.29**	33.33**	33.33**	9.09**	14.29**
P ₅	10.53**	5.00*	-8.70**	0.00	26.32**	20.00**	9.09**	14.29**	26.32**	20.00**	9.09**	14.29**
P ₆	7.69**	0.00	-8.70**	0.00	12.82**	4.76	0.00	4.76	7.69**	0.00	-4.55	0.00
P ₇	6.67**	-11.11**	4.35*	14.29**	9.52**	-4.17	4.55	9.52**	14.29**	0.00	9.09**	14.29**
P ₈	2.33	-12.00**	-4.35*	4.76*	4.76	-8.33**	0.00	4.76	-2.33	-16.0**	-4.55	0.00
P ₉	20.00**	9.09**	4.35*	14.29**	7.69**	0.00	-4.55	0.00	20.00**	9.09**	9.09**	14.29**
P ₁₀	9.52**	-4.17*	0.00	9.52**	0.00	-12.50**	-4.55	0.00	17.07**	4.35	9.09**	14.29**
P ₁ X P ₃	0.00	0.00	-8.70**	0.00	10.53**	10.53**	-4.55	0.00	2.44	0.00	-4.55	0.00
P ₄	33.33**	23.81**	13.04**	23.81**	15.79**	15.79**	0.00	4.76	12.82**	4.76	0.00	4.76
P ₅	7.32**	4.76*	-4.35*	4.76*	12.82**	10.00**	0.00	4.76	2.44	0.00	-4.55	0.00
P ₆	9.52**	9.52**	0.00	9.52**	5.00	0.00	-4.55	0.00	4.76	4.76	0.00	4.76
P ₇	-12.50**	-22.22**	-8.70**	0.00	6.98**	-4.17	4.55	9.52**	-6.67**	-12.50**	-4.55	0.00
P ₈	-8.70**	-16.00**	-8.70**	0.00	6.98**	-4.17	4.55	9.52**	4.35	-4.00	9.09**	14.29**
P ₉	11.63**	9.09**	4.35*	14.29**	20.00**	14.29**	9.09**	14.29**	20.93**	18.18**	18.18**	23.81**
P ₁₀	6.67**	0.00	4.35*	14.29**	11.63**	0.00	9.09**	14.29**	9.09**	4.35	9.09**	14.29**
P ₁ X P ₄	7.69**	0.00	-8.70**	0.00	26.32**	26.32**	9.09**	14.29**	10.53**	5.00	-4.55	0.00
P ₅	2.44	0.00	-8.70**	0.00	7.69**	5.00	-4.55	0.00	5.00	5.00	-4.55	0.00
P ₆	0.00	0.00	-8.70**	0.00	5.00	0.00	-4.55	0.00	2.44	0.00	-4.55	0.00
P ₇	-12.50**	-22.22**	-8.70**	0.00	-2.33	-12.50**	-4.55	0.00	-4.55	-12.50**	-4.55	0.00
P ₈	0.00	-8.00**	0.00	9.52**	11.63**	0.00	9.09**	14.29**	6.67**	-4.00	9.09**	14.29**
P ₉	6.98**	4.55*	0.00	9.52**	10.00**	4.76	0.00	4.76	4.76	0.00	0.00	4.76
P ₁₀	-6.67**	-12.50**	-8.70**	0.00	-2.33	-12.50**	-4.55	0.00	-2.33	-8.70**	-4.55	0.00
P ₁ X P ₅	15.79**	10.00**	-4.35*	4.76*	12.82**	10.00**	0.00	4.76	15.79**	10.00**	0.00	4.76
P ₆	28.21**	19.05**	8.70**	19.05**	20.00**	14.29**	9.09**	14.29**	23.08**	14.29**	9.09**	14.29**
P ₇	-2.22	-18.52**	-4.35*	4.76*	2.33	-8.33**	0.00	4.76	9.52**	-4.17	4.55	9.52**
P ₈	11.63**	-4.00*	4.35*	14.29**	2.33	-8.33**	0.00	4.76	2.33	-12.00**	0.00	4.76
P ₉	15.00**	4.55*	0.00	9.52**	20.00**	14.29**	9.09**	14.29**	10.00**	0.00	0.00	4.76
P ₁₀	9.52**	-4.17*	0.00	9.52**	-2.33	-12.50**	-4.55	0.00	12.20**	0.00	4.55	9.52**
P ₁ X P ₆	17.07**	14.29**	4.35*	14.29**	2.44	0.00	-4.55	0.00	7.32**	4.76	0.00	4.76
P ₇	-10.64**	-22.22**	-8.70**	0.00	4.55	-4.17	4.55	9.52**	-13.64**	-20.83**	-13.64**	-9.52**
P ₈	-6.67**	-16.00**	-8.70**	0.00	-9.09**	-16.67**	-9.09**	-4.76	-6.67**	-16.00**	-4.55	0.00
P ₉	0.00	-4.55*	-8.70**	0.00	-2.44	-4.76	-9.09**	-4.76	0.00	-4.55	-4.55	0.00
P ₁₀	4.55*	-4.17*	0.00	9.52**	9.09**	0.00	9.09**	14.29**	6.98**	0.00	4.55	9.52**
P ₁ X P ₇	0.00	-11.11**	4.35*	14.29**	2.22	-4.17	4.55	9.52**	6.67**	0.00	9.09**	14.29**
P ₈	-8.70**	-16.00**	-8.70**	0.00	-6.67**	-12.50**	-4.55	0.00	-8.70**	-16.00**	-4.55	0.00
P ₉	6.98**	4.55*	0.00	9.52**	14.29**	14.29**	9.09**	14.29**	11.63**	9.09**	9.09**	14.29**
P ₁₀	-6.67**	-12.50**	-8.70**	0.00	-6.67**	-12.50**	-4.55	0.00	-4.55	-8.70**	-4.55	0.00
P ₁ X P ₈	-15.38**	-18.52**	-4.35*	4.76*	-4.17	-4.17	4.55	9.52**	-6.12**	-8.00**	4.55	9.52**
P ₉	-10.20**	-18.52**	-4.35*	4.76*	-2.22	-8.33**	0.00	4.76	-17.39**	-20.83**	-13.64**	-9.52**
P ₁₀	-17.65**	-22.22**	-8.70**	0.00	-12.50**	-12.50**	-4.55	0.00	-10.64**	-12.50**	-4.55	0.00
P ₁ X P ₉	-10.64**	-16.00**	-8.70**	0.00	-6.67**	-12.50**	-4.55	0.00	-10.64**	-16.00**	-4.55	0.00
P ₁₀	-2.04	-4.00*	4.35*	14.29**	0.00	0.00	9.09**	14.29**	0.00	-4.00	9.09**	14.29**

per cent ($P_1 \times P_4$). The standard heterosis over Madhuri ranged from -13.64 ($P_5 \times P_7$ and $P_7 \times P_8$) to 18.18 per cent ($P_2 \times P_9$) and over BMH-1620 from -9.52 ($P_5 \times P_7$ and $P_7 \times P_9$) to 23.81 per cent ($P_2 \times P_9$).

4.5.9 Number of Kernels per Row

Heterosis exhibited significant positive heterosis and heterobeltiosis at Rajendranagar and Palem and only heterosis at Karimnagar for all the crosses. Heterosis ranged from 8.75 ($P_4 \times P_5$) to 77.78 per cent ($P_9 \times P_{10}$) and heterobeltiosis from 5.74 ($P_2 \times P_7$) to 71.43 per cent ($P_9 \times P_{10}$) and standard heterosis over Madhuri from 29.85 ($P_4 \times P_5$ and $P_4 \times P_9$) to 79.10 per cent ($P_1 \times P_6$) and ($P_9 \times P_{10}$) and over BMH-1620 from -20.90 ($P_4 \times P_5$ and $P_4 \times P_9$) to 9.09 per cent ($P_1 \times P_5$ and $P_9 \times P_{10}$) at Rajendranagar (Table 8i).

At Palem, heterosis varied from 10.30 ($P_2 \times P_7$) to 61.90 per cent ($P_9 \times P_{10}$), heterobeltiosis from 1.11 ($P_2 \times P_7$) to 58.67 per cent ($P_9 \times P_{10}$) and standard heterosis over Madhuri from 4.94 ($P_4 \times P_5$) to 49.38 per cent ($P_1 \times P_6$) and over BMH-1620 from -15.84 ($P_3 \times P_5$) to 19.80 per cent ($P_1 \times P_6$).

Heterosis at Karimnagar varied from 5.33 ($P_2 \times P_7$) to 60.27 per cent ($P_9 \times P_{10}$), heterobeltiosis from -3.49 ($P_2 \times P_7$) to 53.95 ($P_9 \times P_{10}$). Standard heterosis over Madhuri ranged from 2.47 ($P_3 \times P_5$) to 48.15 per cent

Estimates of heterosis, heterobeltiosis and standard heterosis at three locations¹³¹
for number of kernels per row

		No. of kernels per row											
		Rajendranagar				Palem				Karimnagar			
		Heterosis	Heterobe	Standard heterosis		Heterosis	Heterobe	Standard heterosis		Heterosis	Heterobe	Standard heterosis	
			-ltiosis	Check 1	Check 2		-ltiosis	Check 1	Check 2		-ltiosis	Check 1	Check 2
P ₁ X P ₂	P ₁	28.99**	25.29**	62.69**	-0.91	33.33**	22.22**	35.80**	8.91**	31.71**	28.58**	33.33**	6.93**
	P ₂	42.31**	35.37**	65.67**	0.91	58.27**	46.67**	35.80**	8.91**	47.30**	39.74**	34.57**	7.92**
	P ₃	43.75**	40.24**	71.64**	4.55*	57.24**	52.00**	40.74**	12.87**	45.22**	44.30**	40.74**	12.87**
	P ₄	32.93**	32.93**	62.69**	-0.91	45.95**	44.00**	33.33**	6.93**	41.94**	41.03**	35.80**	8.91**
	P ₅	44.58**	42.86**	79.10**	9.09**	49.38**	39.08**	49.38**	19.80**	39.51**	34.52**	39.51**	11.88**
	P ₆	41.03**	34.15**	64.18**	0.00	50.67**	50.67**	39.51**	11.88**	39.13**	34.94**	38.27**	10.89**
	P ₇	30.59**	26.14**	65.67**	0.91	38.27**	28.74**	38.27**	10.89**	26.51**	19.32**	29.63**	3.96
	P ₈	47.37**	36.59**	67.16**	1.82	42.67**	42.67**	32.10**	5.94**	42.86**	41.03**	35.80**	8.91**
	P ₉	56.46**	40.24**	71.64**	4.55*	46.94**	44.00**	33.33**	6.93**	47.30**	39.74**	34.57**	7.92**
	P ₁₀												
P ₂ X P ₃	P ₂	31.68**	21.84**	58.21**	-3.64	28.57**	10.00**	22.22**	-1.98	35.90**	23.26**	30.86**	4.95*
	P ₄	34.55**	27.59**	65.67**	0.91	35.00**	20.00**	33.33**	6.93**	27.27**	22.09**	29.63**	3.96
	P ₅	19.53**	16.09**	50.75**	-8.18**	23.93**	12.22**	24.69**	0.00	32.52**	25.58**	33.33**	6.93**
	P ₆	28.65**	26.44**	64.18**	0.00	19.77**	17.78**	30.86**	4.95*	24.71**	23.26**	30.86**	4.95*
	P ₇	14.29**	5.75*	37.31**	-16.36**	10.30**	1.11	12.35**	-9.90**	5.33	3.49	9.88**	-11.88**
	P ₈	23.43**	22.73**	61.19**	-1.82	29.94**	27.78**	41.98**	13.86**	21.84**	20.45**	30.86**	4.95*
	P ₉	38.85**	25.29**	62.69**	-0.91	26.06**	15.56**	28.40**	2.97	23.46**	16.28**	23.46**	-0.99
	P ₁₀	40.79**	22.99**	59.70**	-2.73	34.57**	21.11**	34.57**	7.92**	39.74**	26.74**	34.57**	7.92**
P ₃ X P ₄	P ₃	38.16**	34.62**	56.72**	-4.55*	41.79**	35.71**	17.28**	-5.94**	35.57**	27.85**	24.69**	0.00
	P ₅	16.67**	10.98**	35.82**	-17.27**	24.09**	16.44**	4.94	-15.84**	12.93**	7.79*	2.47	-17.82**
	P ₆	39.24**	30.95**	64.18**	0.00	19.21**	3.45	11.11**	-10.89**	16.88**	7.14*	11.11**	-10.89**
	P ₇	43.24**	43.24**	58.21**	-3.64	55.40**	44.00**	33.33**	6.93**	38.56**	27.71**	30.86**	4.95*
	P ₈	37.04**	26.14**	65.67**	0.91	45.70**	26.44**	35.80**	8.91**	41.77**	27.27**	38.27**	10.89**
	P ₉	45.83**	41.89**	56.72**	-4.55*	43.88**	33.33**	23.46**	-0.99	31.51**	26.32**	18.52**	-4.95*
	P ₁₀	41.01**	32.43**	46.27**	-10.91**	47.06**	38.89**	23.46**	-0.99	45.71**	45.71**	25.93**	0.99
P ₄ X P ₅	P ₄	8.75**	6.10*	29.85**	-20.91**	20.28**	17.81**	6.17*	-14.85**	8.97**	7.59*	4.94	-15.84**
	P ₆	19.75**	15.48**	44.78**	-11.82**	28.66**	16.09**	24.69**	0.00	21.47**	17.86**	22.22**	-1.98
	P ₇	35.53**	32.05**	53.73**	-6.36**	51.72**	46.67**	35.80**	8.91**	33.33**	30.12**	33.33**	6.93**
	P ₈	30.12**	22.73**	61.19**	-1.82	42.68**	28.74**	38.27**	10.89**	26.95**	20.45**	30.86**	4.95*
	P ₉	17.57**	11.54**	29.85**	-20.91**	18.62**	14.67**	6.17*	-14.85**	10.97**	8.86**	6.17*	-14.85**
	P ₁₀	60.84**	47.44**	71.64**	4.55*	57.75**	55.56**	38.27**	10.89**	44.97**	36.71**	33.33**	6.93**
P ₅ X P ₆	P ₅	36.14**	34.52**	68.66**	2.73	41.25**	29.89**	39.51**	11.88**	34.16**	28.57**	33.33**	6.93**
	P ₇	48.72**	41.46**	73.13**	5.45**	59.46**	57.33**	45.68**	16.83**	40.00**	34.94**	38.27**	10.89**
	P ₈	29.41**	25.00**	64.18**	0.00	36.25**	25.29**	34.57**	7.92**	27.27**	19.32**	29.63**	3.96
	P ₉	35.53**	25.61**	53.73**	-6.36**	48.65**	46.67**	35.80**	8.91**	42.48**	41.56**	34.57**	7.92**
	P ₁₀	46.94**	31.71**	61.19**	-1.82	31.03**	30.14**	17.28**	-5.94**	37.41**	31.17**	24.69**	0.00
P ₆ X P ₇	P ₆	44.30**	35.71**	70.15**	3.64	38.27**	28.74**	38.27**	10.89**	37.72**	36.90**	41.98**	13.86**
	P ₈	30.23**	27.27**	67.16**	1.82	27.59**	27.59**	37.04**	9.90**	25.58**	22.73**	33.33**	6.93**
	P ₉	45.45**	33.33**	67.16**	1.82	33.33**	24.14**	33.33**	6.93**	27.50**	21.43**	25.93**	0.99
	P ₁₀	50.34**	33.33**	67.16**	1.82	43.40**	31.03**	40.74**	12.87**	48.05**	35.71**	40.74**	12.87**
P ₇ X P ₈	P ₇	39.51**	28.41**	68.66**	2.73	33.33**	24.14**	33.33**	6.93**	26.32**	22.73**	33.33**	6.93**
	P ₉	62.50**	58.11**	74.63**	6.36**	50.67**	50.67**	39.51**	11.88**	50.94**	44.58**	48.15**	18.81**
	P ₁₀	43.88**	35.14**	49.25**	-9.09**	37.41**	34.67**	24.69**	0.00	30.72**	20.48**	23.46**	-0.99
P ₈ X P ₉	P ₈	41.77**	27.27**	67.16**	1.82	27.16**	18.39**	27.16**	1.98	24.39**	15.91**	25.93**	0.99
	P ₁₀	45.10**	26.14**	65.67**	0.91	43.40**	31.03**	40.74**	12.87**	45.57**	30.68**	41.98**	13.86**
P ₉ X P ₁₀	P ₉	77.78**	71.43**	79.10**	9.09**	61.90**	58.67**	46.91**	17.82**	60.27**	53.95**	44.44**	15.84**

(P₇ x P₉) and over BMH-1620 from -17.82 (P₃ x P₅) to 18.81 per cent (P₇ x P₉).

4.5.10 Number of Kernels per Ear

At all the locations all the hybrids exhibited significant positive heterosis and heterobeltiosis at Rajendranagar and Palem except one (P₂ x P₇) at Rajendranagar. Heterosis at Rajendranagar ranged from 1.93 (P₂ x P₇) to 81.07 per cent (P₁ x P₄), heterobeltiosis -2.78 (P₂ x P₇) to 78.20 per cent (P₁ x P₄), standard heterosis ranged from 25.39 and -15.92 per cent (P₂ x P₇) to 75.97 per cent and 18.00 per cent (P₆ x P₇) over Madhuri and BMH-1620, respectively (Table 8j).

At Palem, heterosis ranged from 18.09 per cent (P₈ x P₉) to 90.59 per cent (P₁ x P₄), heterobeltiosis from 2.78 (P₃ x P₆) to 88.39 per cent (P₁ x P₅), whereas standard heterosis ranged from 5.48 and -15.80 (P₃ x P₅) to 60.25 and 27.93 per cent (P₅ x P₇) over Madhuri and BMH-1620, respectively.

Heterosis at Karimnagar location had a range from -8.47 (P₂ x P₇) to 81.77 per cent (P₁ x P₄), heterobeltiosis from -17.20 (P₂ x P₇) to 78.28 per cent (P₁ x P₄).

($P_7 \times P_9$) and over BMH-1620 from -17.82 ($P_3 \times P_5$) to 18.81 per cent ($P_7 \times P_9$).

4.5.10 Number of Kernels per Ear

At all the locations all the hybrids exhibited significant positive heterosis and heterobeltiosis at Rajendranagar and Palem except one ($P_2 \times P_7$) at Rajendranagar. Heterosis at Rajendranagar ranged from 1.93 ($P_2 \times P_7$) to 81.07 per cent ($P_1 \times P_4$), heterobeltiosis -2.78 ($P_2 \times P_7$) to 78.20 per cent ($P_1 \times P_4$), standard heterosis ranged from 25.39 and -15.92 per cent ($P_2 \times P_7$) to 75.97 per cent and 18.00 per cent ($P_6 \times P_7$) over Madhuri and BMH-1620, respectively (Table 8j).

At Palem, heterosis ranged from 18.09 per cent ($P_8 \times P_9$) to 90.59 per cent ($P_1 \times P_4$), heterobeltiosis from 2.78 ($P_3 \times P_6$) to 88.39 per cent ($P_1 \times P_5$), whereas standard heterosis ranged from 5.48 and -15.80 ($P_3 \times P_5$) to 60.25 and 27.93 per cent ($P_5 \times P_7$) over Madhuri and BMH-1620, respectively.

Heterosis at Karimnagar location had a range from -8.47 ($P_2 \times P_7$) to 81.71 per cent ($P_1 \times P_3$), heterobeltiosis from -17.20 ($P_2 \times P_7$) to 78.28 per cent ($P_1 \times P_5$) and standard heterosis ranged from 1.32 ($P_3 \times P_5$) and -18.21 ($P_3 \times P_5$) to 58.33 and 27.81 per cent ($P_6 \times P_7$) over Madhuri and BMH-1620 respectively.

Table 8j: Estimates of heterosis, heterobeltiosis and standard heterosis at three locations for number of kernels per ear

Crosses	No. of kernels per ear											
	Rajendranagar				Palem				Karimnagar			
	Heterosis	Heterobe -ltiosis	Standard heterosis		Heterosis	Heterobe -ltiosis	Standard heterosis		Heterosis	Heterobe -ltiosis	Standard heterosis	
			Check 1	Check 2			Check 1	Check 2			Check 1	Check 2
AX P ₂	39.86**	26.49**	48.06**	-0.71	50.81**	30.07**	36.48**	8.96**	37.88**	25.39**	33.57**	7.82**
P ₃	74.69**	68.31**	71.90**	15.27**	81.18**	73.87**	42.84**	14.03**	81.71**	76.67**	54.10**	24.40**
P ₄	81.07**	78.20**	68.70**	13.13**	90.59**	87.20**	53.80**	22.78**	77.51**	73.84**	51.63**	22.40**
P ₅	44.36**	36.46**	45.06**	-2.73	88.39**	88.39**	54.77**	23.55**	78.73**	78.28**	55.51**	25.53**
P ₆	56.21**	43.10**	62.79**	9.16**	56.04**	37.40**	48.32**	18.41**	47.58**	36.66**	39.91**	12.94**
P ₇	51.30**	31.18**	69.19**	13.45**	59.79**	42.13**	49.91**	19.68**	38.81**	15.39**	51.89**	22.62**
P ₈	28.18**	7.07**	51.16**	1.36	40.72**	17.40**	44.26**	15.16**	20.16**	0.82	29.69**	4.69
P ₉	67.03**	61.74**	63.47**	9.62**	52.73**	43.18**	34.45**	7.33**	61.48**	55.72**	46.26**	18.07**
P ₁₀	66.15**	61.27**	62.21**	8.77**	62.73**	57.74**	29.59**	3.46	46.76**	40.89**	33.57**	7.82**
P ₂ X P ₃	30.68**	22.35**	43.22**	-3.96	40.53**	23.95**	22.53**	-2.19	39.09**	23.33**	31.37**	6.05*
P ₄	68.06**	49.83**	75.39**	17.61**	56.25**	40.75**	39.13**	11.07**	51.07**	34.82**	43.61**	15.93**
P ₅	28.76**	22.85**	43.80**	-3.57	45.63**	33.33**	31.80**	5.22*	37.19**	24.48**	32.60**	7.04**
P ₆	41.23**	39.24**	62.98**	9.29**	27.04**	21.69**	31.36**	4.87	32.18**	29.61**	38.06**	11.45**
P ₇	1.93	-2.78	25.39**	-15.92**	21.14**	17.34**	23.76**	-1.20	-8.47**	-17.20**	8.99**	-12.02**
P ₈	12.80**	3.16	45.64**	-2.34	37.69**	24.23**	52.65**	21.86**	27.69**	16.71**	50.13**	21.19**
P ₉	53.98**	43.46**	67.93**	12.61**	52.61**	48.79**	47.08**	17.42**	51.47**	42.51**	51.81**	22.55**
P ₁₀	51.38**	40.73**	64.73**	10.46**	76.41**	57.02**	55.21**	23.91**	48.27**	40.12**	49.25**	20.48**
P ₂ X P ₄	46.10**	38.61**	41.57**	-5.07*	74.54**	70.46**	35.07**	7.83**	49.89**	48.79**	24.41**	0.43
P ₅	22.36**	19.96**	27.52**	-14.49**	33.78**	28.39**	5.48	-15.80**	19.79**	16.75**	1.32	-18.21**
P ₆	39.23**	32.11**	50.29**	0.78	20.94**	2.78	10.95**	-11.42**	20.74**	8.95**	11.54**	-9.96**
P ₇	25.03**	12.02**	44.48**	-3.12	47.88**	26.88**	33.83**	6.84**	22.19**	-0.67	30.75**	5.55*
P ₈	23.30**	6.25**	50.00**	0.58	39.27**	12.44**	38.16**	10.30**	42.05**	16.51**	49.87**	20.98**
P ₉	58.13**	57.31**	60.66**	7.73**	49.84**	35.18**	26.94**	1.34	41.03**	32.36**	24.32**	0.36
P ₁₀	34.99**	33.97**	36.82**	-8.25**	67.82**	66.09**	28.09**	2.26	40.63**	31.41**	24.58**	0.57
P ₂ X P ₅	32.75**	23.61**	31.40**	-11.89**	31.03**	28.71**	5.74	-15.59**	28.75**	26.40**	9.69**	-11.45**
P ₆	51.70**	36.97**	55.81**	4.48*	52.05**	31.83**	42.31**	13.61**	47.80**	34.25**	37.44**	10.95**
P ₇	33.42**	14.12**	47.19**	-1.30	54.18**	35.01**	42.40**	13.68**	35.73**	10.98**	46.08**	17.92**
P ₈	40.82**	16.13**	63.95**	9.94**	43.27**	17.83**	44.79**	15.59**	31.67**	8.63**	39.74**	12.80**
P ₉	34.54**	28.28**	29.65**	-13.06**	50.82**	39.04**	30.57**	4.23	19.11**	12.57**	5.73	-14.65**
P ₁₀	73.59**	65.90**	66.86**	11.89**	65.99**	63.77**	29.77**	3.60	59.80**	50.37**	42.56**	15.08**
P ₂ X P ₆	53.85**	48.81**	69.28**	13.52**	46.84**	29.30**	39.58**	11.42**	47.74**	36.49**	39.74**	12.80**
P ₇	33.77**	22.01**	57.36**	5.52*	70.81**	51.93**	60.25**	27.93**	13.27**	-6.02*	23.70**	-0.14
P ₈	19.34**	4.60*	47.67**	-0.97	25.81**	4.96	28.98**	2.96	20.08**	0.55	29.34**	4.41
P ₉	34.86**	31.54**	39.83**	-6.24**	46.81**	37.63**	29.24**	3.17	49.10**	43.43**	34.71**	8.75**
P ₁₀	55.60**	51.41**	60.95**	7.93**	68.72**	63.55**	34.36**	7.26**	50.32**	43.96**	36.48**	10.17**
P ₂ X P ₇	44.99**	36.44**	75.97**	18.00**	43.46**	41.82**	53.09**	22.21**	35.32**	20.28**	58.33**	27.81**
P ₈	20.11**	8.44**	53.10**	2.66	19.25**	12.01**	37.63**	9.87**	16.17**	4.32	34.19**	8.32**
P ₉	53.99**	45.40**	65.41**	10.92**	48.97**	39.28**	50.35**	20.03**	46.68**	40.62**	43.96**	16.22**
P ₁₀	49.46**	40.80**	60.17**	7.41**	52.94**	31.10**	41.52**	12.98**	44.86**	39.50**	42.82**	15.29**
P ₇ X P ₈	14.63**	9.68**	54.84**	3.83	29.21**	20.06**	47.53**	17.77**	13.61**	12.32**	47.84**	19.35**
P ₉	46.50**	30.65**	68.51**	13.00**	47.28**	39.20**	46.82**	17.21**	18.83**	1.81	34.01**	8.18**
P ₁₀	18.45**	5.41*	35.95**	-8.84**	36.72**	18.34**	24.82**	-0.35	9.96**	-5.42*	24.49**	0.50
P ₈ X P ₉	25.52**	7.69**	52.03**	1.95	18.09**	4.17	28.00**	2.19	13.22**	-2.05	25.99**	1.71
P ₁₀	39.24**	19.22**	68.31**	12.87**	54.42**	25.66**	54.42**	23.27**	38.17**	20.00**	54.36**	24.61**
P ₉ X P ₁₀	63.48**	63.09**	64.83**	10.53**	68.18**	53.15**	43.82**	14.81**	53.31**	52.60**	44.67**	16.79**

4.5.11 100 kernel Weight

At Rajendranagar, heterosis varied from -2.19 ($P_4 \times P_5$) to 36.99 per cent ($P_2 \times P_{10}$), heterobeltiosis from -3.95 ($P_2 \times P_7$) to 35.00 per cent ($P_8 \times P_{10}$) and the standard heterosis over Madhuri and BMH-1620 ranged from 15.13 and -5.89 ($P_5 \times P_{10}$) to 42.26 and 16.29 per cent ($P_2 \times P_{10}$), respectively (Table 8k).

Heterosis and heterobeltiosis for most of the hybrids were significant and positive for Palem location and varied from 3.65 and 1.14 ($P_3 \times P_6$) to 38.40 and 34.58 per cent ($P_1 \times P_5$) respectively. Standard heterosis ranged from 6.04 ($P_4 \times P_5$) to 38.27 per cent ($P_5 \times P_7$) over Madhuri and -6.71 ($P_4 \times P_5$) to 21.64 per cent ($P_5 \times P_7$) over BMH-1620.

Majority of the hybrids showed significant and positive heterosis and heterobeltiosis at Karimnagar and range of heterosis was from 3.80 ($P_2 \times P_7$) to 43.61 per cent ($P_9 \times P_{10}$) and heterobeltiosis from 1.75 ($P_1 \times P_6$) to 40.98 per cent ($P_9 \times P_{10}$) and standard heterosis ranged from 12.08 to 41.75 and 0.00 to 26.47 per cent over Madhuri and BMH-1620, respectively.

4.5.12 Protein Content

Heterosis at Rajendranagar location varied from -19.41 ($P_8 \times P_{10}$) to 15.22 ($P_2 \times P_7$), heterobeltiosis from -20.47 ($P_8 \times P_{10}$) to 8.36 per cent ($P_2 \times P_7$) and standard heterosis from -30.94 ($P_8 \times P_{10}$) to -7.14 per cent

Table 8k: Estimates of heterosis, heterobeltiosis and locations for 100 kernel weight		100 kernel weight (g)
		Palem
		Standard

Table 8k: Estimates of heterosis, heterobeltiosis and standard heterosis for 100 kernel weight												
Rajendranagar					Palem				Karimnagar			
100 kernel weight (g)					100 kernel weight (g)				100 kernel weight (g)			
Heterosis					Heterosis				Heterosis			
Heterobeltiosis					Heterobeltiosis				Heterobeltiosis			
Standard heterosis					Standard heterosis				Standard heterosis			
Check 1					Check 1				Check 1			
Check 2					Check 2				Check 2			
P ₁	15.04**	14.79**	28.57**	5.10*	19.59**	11.34**	18.56**	4.31*	14.73**	9.25**	22.97**	9.71**
P ₂	10.81**	5.77**	29.77**	6.08**	23.45**	15.74**	21.41**	6.81**	32.22**	29.54**	37.44**	22.63**
P ₃	18.08**	15.70**	34.45**	9.91**	31.07**	24.03**	27.56**	12.22**	26.73**	24.29**	31.58**	17.40**
P ₄	11.01**	7.22**	28.33**	4.91*	38.40**	34.58**	30.75**	15.03**	34.89**	30.79**	41.75**	26.47**
P ₅	17.34**	11.79**	37.70**	12.56**	34.16**	22.93**	35.54**	19.24**	8.45**	1.75	18.18**	5.44**
P ₆	13.68**	7.71**	34.21**	9.72**	25.42**	17.12**	23.92**	9.02**	25.69**	20.47**	33.73**	19.32**
P ₇	23.96**	16.68**	30.13**	6.38**	16.27**	4.67**	20.05**	5.61**	10.80**	6.26**	17.82**	5.12**
P ₈	22.64**	17.22**	30.73**	6.87**	26.58**	23.87**	18.79**	4.51*	32.73**	28.20**	30.50**	16.44**
P ₉	26.07**	17.12**	30.61**	6.77**	23.71**	20.10**	10.25**	-3.01	38.20**	31.14**	33.49**	19.10**
P ₁₀												
P ₁ X P ₂	13.76**	8.81**	33.49**	9.13**	8.30**	7.49**	14.46**	0.70	15.75**	12.43**	26.56**	12.91**
P ₁ X P ₃	11.73**	9.71**	27.49**	4.22*	12.95**	11.02**	18.22**	4.01*	16.87**	13.39**	27.63**	13.87**
P ₁ X P ₄	13.58**	9.93**	31.57**	7.56**	18.57**	13.37**	20.73**	6.21**	14.56**	12.43**	26.56**	12.91**
P ₁ X P ₅	8.63**	3.70	27.73**	4.42*	5.41**	3.62*	14.24**	0.50	15.38**	13.59**	31.94**	17.72**
P ₁ X P ₆	1.17	-3.95*	19.69**	-2.16	5.58**	5.24**	12.07**	-1.40	3.80*	3.08	16.03**	3.52
P ₁ X P ₇	23.90**	16.40**	30.37**	6.58**	12.15**	8.14**	24.03**	9.12**	20.02**	19.13**	34.09**	19.64**
P ₁ X P ₈	21.69**	16.08**	30.01**	6.28**	18.18**	12.30**	19.59**	5.21**	29.87**	19.66**	34.69**	20.17**
P ₁ X P ₉	36.99**	27.01**	42.26**	16.29**	29.28**	17.11**	24.72**	9.72**	34.66**	22.00**	37.32**	22.52**
P ₁ X P ₁₀												
P ₂ X P ₃	15.58**	12.52**	38.06**	12.86**	18.75**	17.59**	23.35**	8.52**	16.48**	16.35**	23.44**	10.14**
P ₂ X P ₄	1.83	0.59	23.41**	0.88	10.37**	6.30**	11.50**	-1.90	8.20**	7.06**	16.03**	3.52
P ₂ X P ₅	-0.88	-1.07	21.85**	-0.39	3.65*	1.14	11.50**	-1.90	7.53**	2.88	19.50**	6.62**
P ₂ X P ₆	1.84	1.06	25.93**	2.94	17.41**	16.90**	23.69**	8.82**	14.60**	12.07**	24.40**	10.99**
P ₂ X P ₇	15.20**	3.82	27.37**	4.12*	11.83**	7.05**	22.78**	8.02**	19.74**	17.15**	29.90**	15.90**
P ₂ X P ₈	13.96**	4.21*	27.85**	4.51*	16.17**	11.18**	16.63**	2.61	13.57**	7.55**	14.11**	1.81
P ₂ X P ₉	13.69**	1.17	24.13**	1.47	22.14**	11.40**	16.86**	2.81	24.53**	15.90**	22.97**	9.71**
P ₂ X P ₁₀												
P ₃ X P ₄												
P ₃ X P ₅	-2.19	-3.61	15.37**	-5.69**	6.04**	3.10	6.04**	-6.71**	4.63*	3.42	12.08**	0.00
P ₃ X P ₆	6.32**	3.31	27.25**	4.02*	11.17**	7.44**	18.45**	4.21*	13.47**	8.44**	25.96**	12.38**
P ₃ X P ₇	1.99	-1.45	22.81**	0.39	13.43**	11.84**	18.34**	4.11*	16.38**	13.69**	26.20**	12.59**
P ₃ X P ₈	12.42**	3.82	20.65**	-1.37	9.95**	4.27*	19.59**	5.21**	22.08**	19.31**	32.30**	18.04**
P ₃ X P ₉	9.86**	3.00	19.69**	-2.16	10.83**	7.09**	10.14**	-3.11	15.38**	9.38**	15.79**	3.31
P ₃ X P ₁₀	18.07**	7.64**	25.09**	2.26	26.96**	16.83**	20.16**	5.71**	26.14**	17.51**	24.40**	10.99**
P ₄ X P ₅												
P ₄ X P ₆	1.83	0.39	23.65**	1.08	12.69**	5.99**	16.86**	2.81	10.60**	6.90**	24.16**	10.78**
P ₄ X P ₇	12.43**	10.21**	37.33**	12.27**	36.25**	30.68**	38.27**	21.64**	8.83**	7.54**	19.38**	6.51**
P ₄ X P ₈	14.69**	4.51*	25.09**	2.26	16.99**	8.04**	23.92**	9.02**	13.15**	11.87**	24.04**	10.67**
P ₄ X P ₉	10.52**	2.21	22.33**	0.00	16.58**	15.83**	12.53**	-1.00	24.07**	16.34**	26.08**	12.49**
P ₄ X P ₁₀	6.91**	-3.81	15.13**	-5.89**	19.85**	13.25**	10.02**	-3.21	27.78**	17.77**	27.63**	13.87**
P ₅ X P ₆												
P ₅ X P ₇	8.24**	7.61**	34.09**	9.62**	22.61**	20.14**	32.46**	16.53**	23.43**	20.70**	40.19**	25.08**
P ₅ X P ₈	18.74**	6.82**	31.57**	7.56**	7.54**	5.46**	20.96**	6.41**	11.91**	9.37**	27.03**	13.34**
P ₅ X P ₉	6.35**	-2.92	19.57**	-2.26	20.66**	12.81**	24.37**	9.42**	19.61**	8.65**	26.20**	12.59**
P ₅ X P ₁₀	15.96**	3.02	26.89**	3.73	20.21**	7.23**	18.22**	4.01*	21.61**	8.65**	26.20**	12.59**
P ₆ X P ₇												
P ₆ X P ₈	8.24**	7.61**	34.09**	9.62**	22.61**	20.14**	32.46**	16.53**	23.43**	20.70**	40.19**	25.08**
P ₆ X P ₉	18.74**	6.82**	31.57**	7.56**	7.54**	5.46**	20.96**	6.41**	11.91**	9.37**	27.03**	13.34**
P ₆ X P ₁₀	6.35**	-2.92	19.57**	-2.26	20.66**	12.81**	24.37**	9.42**	19.61**	8.65**	26.20**	12.59**
P ₇ X P ₈	15.96**	3.02	26.89**	3.73	20.21**	7.23**	18.22**	4.01*	21.61**	8.65**	26.20**	12.59**
P ₇ X P ₉	17.87**	5.49**	31.45**	7.46**	10.74**	6.45**	22.10**	7.41**	19.03**	18.97**	32.06**	17.82**
P ₇ X P ₁₀	19.68**	8.67**	35.41**	10.70**	15.53**	10.12**	16.51**	2.51	20.86**	12.07**	24.40**	10.99**
P ₈ X P ₉	9.43**	-3.28	20.53**	-1.47	16.82**	6.14**	12.30**	-1.20	17.85**	7.44**	19.26**	6.40**
P ₈ X P ₁₀												
P ₉ X P ₁₀												

Protein content (%)					Protein content (%)					Protein content (%)				
Rajendranagar					Palem					Karimnagar				
	Heterosis	Heterobiosis	Standard heterosis		Heterosis	Heterobiosis	Standard heterosis		Heterosis	Heterobiosis	Standard heterosis			
			Check 1	Check 2			Check 1	Check 2			Check 1	Check 2		
P ₁	3.65	0.81	-11.91**	11.30*	11.65**	11.33**	-10.61**	16.64**	10.12*	6.96	-7.19*	10.61**		
P ₂	4.67	-5.61	-15.85**	6.32	4.45	0.15	-12.37**	14.34**	-4.35	-5.64	-15.86**	0.28		
P ₃	3.44	-6.68	-18.46**	3.03	4.86	4.74	-15.90**	9.74**	1.90	-1.17	-14.24**	2.20		
P ₄	-5.42	-6.09	-16.76**	5.17	-2.62	-6.24*	-18.66**	6.14	-5.19	-6.07	-16.95**	-1.02		
P ₅	4.46	-3.61	-15.77**	6.42	16.45**	10.73**	-11.09**	16.01**	11.64**	3.30	-10.36**	6.83		
P ₆	-0.80	-9.10*	-20.57**	0.36	-2.03	-3.21	-22.28**	1.40	-0.26	-8.58*	-20.68**	-5.46		
P ₇	5.96	4.24	-8.92*	15.09**	3.78	2.03	-15.21**	10.64**	-2.42	-4.38	-17.03**	-1.12		
P ₈	-14.65**	-17.09**	-27.55**	-8.47	-4.05	-4.96	-23.69**	-0.43	-7.01	-9.42*	-21.41**	-6.33		
P ₉	-17.28**	-17.54**	-27.95**	-8.96	-0.23	-4.75	-15.90**	9.74**	-5.43	-5.54	-17.84**	-2.08		
P ₁₀														
P ₁	3.89	0.06	-10.79**	12.71**	-3.91	-8.12**	-19.60**	4.90	-4.71	-8.64*	-18.54**	-2.92		
P ₂	1.13	0.47	-17.02**	4.84	4.17	3.99	-16.69**	8.70*	-2.14	-2.29	-20.08**	-4.75		
P ₃	8.47	4.76	-7.14	17.33**	7.75*	3.45	-10.25**	17.11**	9.06*	4.98	-7.19*	10.61**		
P ₄	4.03	-1.45	-18.61**	2.83	7.71*	2.69	-18.02**	6.97*	8.79*	3.47	-15.36**	0.87		
P ₅	15.22**	8.36	-10.51**	13.08**	10.79**	9.76**	-12.37**	14.34**	15.87**	9.14*	-10.73**	6.39		
P ₆	5.23	4.01	-12.07**	11.10*	-3.54	-5.44	-21.42**	2.53	-3.08	-3.94	-20.00**	-4.66		
P ₇	7.74	7.61	-11.13**	12.29*	-0.23	-0.90	-20.88**	3.23	7.49	7.19	-11.82**	5.09		
P ₈	-10.45*	-12.64**	-24.14**	-4.15	-14.73**	-18.81**	-28.32**	-6.47	-12.95**	-15.54**	-26.54**	-12.45**		
P ₉														
P ₁₀														
P ₁	-6.89	-10.88*	-20.54**	0.40	-7.36*	-11.27**	-22.36**	1.30	-7.22	-11.19**	-20.81**	-5.62		
P ₂	-15.43**	-15.67**	-24.82**	-5.01	-16.12**	-16.47**	-26.91**	-4.63	-16.26**	-16.62**	-25.65**	-11.39**		
P ₃	13.85**	4.09	-7.20	17.26**	11.08**	1.49	-11.19**	15.87**	13.17**	3.42	-7.79*	9.90*		
P ₄	-1.69	-10.73*	-20.41**	0.56	-6.22	-11.13**	-22.23**	1.47	-1.81	-11.10**	-20.73**	-5.52		
P ₅	-11.15*	-13.45**	-22.84**	-2.50	-14.26**	-16.41**	-26.86**	-4.57	-9.69*	-12.68**	-22.14**	-7.20		
P ₆	-7.96	-11.46**	-21.06**	-0.26	-3.60	-8.41**	-19.86**	4.57	-6.09	-9.73*	-19.51**	-4.07		
P ₇	-14.00**	-15.12**	-24.32**	-4.38	-4.72	-5.15	-16.25**	9.27**	-8.25*	-9.38*	-19.19**	-3.69		
P ₈														
P ₉														
P ₁₀														
P ₁	2.07	-2.03	-13.16**	9.72*	-18.35**	-21.47**	-31.87**	-11.10**	-14.96**	-18.26**	-27.73**	-13.87**		
P ₂	4.58	-0.32	-18.74**	2.67	1.58	-3.32	-22.54**	1.07	1.93	-2.91	-20.83**	-5.65		
P ₃	2.97	-2.56	-20.57**	0.36	-1.82	-2.90	-22.21**	1.50	3.64	-2.24	-20.29**	-5.00		
P ₄	5.05	3.18	-12.77**	10.21*	8.53**	6.58*	-11.42**	15.57**	7.22	6.10	-11.64**	5.31		
P ₅	6.44	5.89	-12.77**	10.21*	1.72	0.86	-19.19**	5.44	-3.12	-3.55	-20.65**	-5.43		
P ₆	-14.09**	-16.72**	-27.69**	-8.63	-16.02**	-19.91**	-29.29**	-7.74*	-14.29**	-16.98**	-27.79**	-13.94**		
P ₇														
P ₈														
P ₉														
P ₁₀														
P ₁	13.80**	4.32	-7.53*	16.83**	12.78**	3.45	-10.25**	17.11**	13.05**	3.71	-8.31*	9.28*		
P ₂	-4.09	-12.68**	-22.60**	-2.21	8.09*	2.86	-10.76**	16.44**	-3.55	-12.34**	-22.50**	-7.64		
P ₃	0.86	-1.47	-12.67**	10.34*	-2.09	-4.15	-16.84**	8.50*	-1.23	-4.09	-15.21**	1.06		
P ₄	7.35	3.56	-8.21*	15.97**	5.82	0.94	-12.42**	14.27**	5.77	2.09	-9.74**	7.57		
P ₅	-15.23**	-16.09**	-25.63**	-6.03	-7.71*	-8.51**	-19.22**	5.40	-13.97**	-14.67**	-24.56**	-10.09*		
P ₆														
P ₇														
P ₈														
P ₉														
P ₁₀														
P ₁	5.14	4.34	-22.91**	-2.60	-0.93	-4.70	-25.33**	-2.57	5.28	4.20	-23.10**	-8.35*		
P ₂	13.21**	6.07	-10.32**	13.31**	14.08**	6.73*	-11.30**	15.74**	13.83**	7.35	-10.60**	6.55		
P ₃	8.51	2.91	-15.22**	7.11	9.79**	5.35	-17.02**	8.27*	16.64**	10.64*	-8.98**	8.47*		
P ₄	3.94	-3.81	-16.48**	5.53	3.78	-5.56	-16.61**	8.80*	2.95	-4.85	-17.24**	-1.37		
P ₅														
P ₆														
P ₇														
P ₈														
P ₉														
P ₁₀														
P ₁	13.26**	5.37	-10.92**	12.55**	6.08	3.04	-14.36**	11.74**	12.52**	5.10	-12.47**	4.31		
P ₂	10.13*	3.70	-14.57**	7.94	6.44	6.16	-16.38**	9.10**	10.26*	3.58	-14.79**	1.55		
P ₃	0.82	-7.36	-19.55**	1.65	-17.90**	-22.52**	-31.59**	-10.74**	-9.29*	-16.95**	-27.76**	-13.90**		
P ₄														
P ₅														
P ₆														
P ₇														
P ₈														
P ₉														
P ₁₀														
P ₁	-2.33	-3.58	-18.48**	3.00	-0.06	-2.68	-19.12**	5.54	-0.52	-1.13	-17.66**	-1.86		
P ₂	-19.41**	-20.47**	-30.94**	-12.75**	-8.07*	-10.77**	-21.21**	2.80	-16.15**	-17.93**	-28.62**	-14.93**		
P ₃														
P ₄														
P ₅														
P ₆														
P ₇														
P ₈														
P ₉														
P ₁₀														
P ₁	-15.24**	-17.41**	-28.28**	-9.39	-7.02*	-12.04**	-22.34**	1.33	-6.26	-8.80*	-20.68**	-5.46		

($P_2 \times P_5$) over Madhuri and -12.75 ($P_8 \times P_{10}$) to 17.33 per cent ($P_2 \times P_5$) over BMH-1620. As many as 6 hybrids for heterosis performed well with significant positive values. All hybrids showed negative value for Madhuri and 13 hybrids for BMH-1620 (Table 8I).

At, Palem, heterosis for protein varied from -18.35 ($P_4 \times P_5$) to 16.45 per cent ($P_1 \times P_6$), heterobeltiosis -22.52 ($P_7 \times P_{10}$) to 11.33 per cent ($P_1 \times P_2$) and standard heterosis from -31.87 ($P_4 \times P_5$) to -10.25 per cent ($P_2 \times P_5$ and $P_5 \times P_6$) over Madhuri and -11.10 ($P_4 \times P_5$) to -17.11 per cent ($P_4 \times P_5$ and $P_5 \times P_6$) over BMH-1620.

Heterosis at Karimnagar varied from -16.26 ($P_3 \times P_5$) to 16.64 per cent ($P_6 \times P_9$), heterobeltiosis from -18.26 ($P_4 \times P_5$) to 10.64 per cent ($P_6 \times P_9$) and standard heterosis from -28.62 ($P_8 \times P_{10}$) to -7.19 per cent ($P_1 \times P_2$ and $P_2 \times P_5$) for Madhuri and -14.93 ($P_8 \times P_{10}$) to 10.61 per cent ($P_1 \times P_2$ and $P_2 \times P_5$) over BMH-1620. Eleven hybrids for heterosis and two for heterobeltiosis registered significant positive values.

4.5.13 Oil Content

At Rajendranagar, 5 hybrids exhibited significant positive heterosis, while it was in the negative direction in case of 28 hybrids. The heterobeltiosis was significant positive in case of 4 hybrids and 24 hybrids recorded significant negative heterobeltiosis.

Table 8m: Estimates of heterosis, heterobeltiosis and standard heterosis at three locations for oil content

Crosses	Oil content (%)											
	Rajendranagar				Palem				Karimnagar			
	Heterosis	Heterobe -ltiosis	Standard heterosis		Heterosis	Heterobe -ltiosis	Standard heterosis		Heterosis	Heterobe -ltiosis	Standard heterosis	
			Check 1	Check 2			Check 1	Check 2			Check 1	Check 2
P ₁ X P ₂	-22.42**	-27.89**	-26.98**	-17.11**	-10.56*	-17.11**	-26.94**	-5.42	-16.96**	-17.65**	-27.30**	-5.34
P ₃	-25.89**	-29.06**	-28.17**	-18.45**	-16.43**	-18.13**	-24.76**	-2.61	-20.28**	-22.15**	-27.89**	-6.11
P ₄	-13.22**	-20.57**	-19.57**	-8.69	3.40	2.06	-10.03*	16.46**	-0.93	-2.95	-14.32**	11.56*
P ₅	-6.27	-11.84**	-10.73*	1.34	-4.01	-4.11	-15.28**	9.66	1.21	1.12	-10.57**	16.44**
P ₆	-14.03**	-22.32**	-21.34**	-10.70*	-5.70	-9.54*	-20.26**	3.22	-5.90	-9.52*	-20.12**	4.01
P ₇	-1.13	-9.47*	-8.32*	4.08	5.98	4.08	-8.25*	18.76**	-3.49	-5.36	-16.45**	8.78
P ₈	-15.00**	-22.40**	-21.42**	-10.79*	-14.14**	-14.29**	-24.45**	-2.20	-11.18*	-13.72**	-23.83**	-0.82
P ₉	-3.50	-9.70*	-8.56*	3.81	2.66	-2.99	-3.91	24.39**	4.96	4.87	-7.42	20.54**
P ₁₀	-18.20**	-20.69**	-19.68**	-8.82	9.35*	5.27	0.28	29.81**	8.97*	5.01	-0.04	30.15**
P ₁ X P ₃	-23.11**	-25.44**	-30.97**	-21.63**	-17.34**	-24.84**	-30.92**	-10.58*	-19.06**	-21.59**	-27.38**	-5.44
P ₄	-0.21	-1.86	-14.64**	-3.09	-5.52	-11.36*	-23.89**	-1.48	0.64	-0.59	-13.69**	12.38*
P ₅	0.02	-1.24	-11.87**	0.04	6.81	-1.12	-12.64**	13.09*	-0.56	-1.47	-12.86**	13.46**
P ₆	10.26*	6.94	-6.98	5.60	17.57**	13.41**	-8.18*	18.87**	10.48*	7.09	-7.02	21.06**
P ₇	0.25	-1.36	-14.20**	-2.60	-8.36	-13.62**	-26.58**	-4.96	-12.59**	-13.58**	-24.97**	-2.31
P ₈	1.78	-0.18	-13.18**	-1.43	4.87	-2.65	-14.49**	10.69*	0.86	-1.23	-14.24**	11.66*
P ₉	-14.72**	-15.33**	-25.29**	-15.18**	-8.91*	-19.86**	-20.62**	2.76	-16.03**	-16.65**	-26.55**	-4.37
P ₁₀	-6.67	-10.66*	-15.03**	-3.54	-14.15**	-23.18**	-26.82**	-5.27	-17.38**	-21.01**	-24.81**	-2.11
P ₃ X P ₄	-7.39	-11.63*	-18.19**	-7.12	-5.62	-8.72*	-16.11**	8.59	-6.03	-10.05*	-16.69**	8.47
P ₅	-24.58**	-25.95**	-31.44**	-22.17**	-25.15**	-26.60**	-32.54**	-12.68*	-16.91**	-18.78**	-24.77**	-2.05
P ₆	6.36	0.13	-7.30	5.24	6.28	-0.04	-8.14*	18.92**	6.12	-0.26	-7.61	20.29**
P ₇	-9.89*	-13.98**	-20.36**	-9.58*	-11.01*	-14.35**	-21.29**	1.89	-10.25*	-14.01**	-20.36**	3.70
P ₈	18.74**	13.00**	4.62	18.76**	13.73**	11.22**	2.21	32.31**	14.80**	8.99*	0.95	31.43**
P ₉	2.62	0.21	-7.22	5.33	-5.56	-8.97*	-9.83*	16.72**	-1.62	-4.00	-11.08**	15.77**
P ₁₀	11.64**	10.16*	4.77	18.94**	7.66	5.76	0.75	30.42**	-2.29	-3.61	-8.24*	19.47**
P ₄ X P ₅	-20.44**	-22.72**	-31.05**	-21.72**	-19.93**	-21.05**	-30.25**	-9.71	-18.80**	-20.52**	-29.70**	-8.47
P ₆	4.80	3.33	-13.10**	-1.34	3.17	0.23	-13.94**	11.40*	3.11	1.16	-14.32**	11.56*
P ₇	-9.56	-9.61	-23.91**	-13.61**	-11.51*	-11.96**	-24.41**	-2.15	-9.82*	-9.90*	-23.55**	-0.46
P ₈	0.61	0.33	-15.62**	-4.21	-6.78	-7.82	-19.04**	4.81	-2.89	-3.73	-18.46**	6.16
P ₉	-20.07**	-21.95**	-31.12**	-21.81**	-10.98**	-16.91**	-17.69**	6.54	-23.21**	-24.71**	-33.65**	-13.61**
P ₁₀	-9.58*	-14.81**	-18.97**	-8.02	-10.20*	-14.64**	-18.68**	5.27	-10.88*	-15.79**	-19.84**	4.37
P ₆ X P ₇	8.49	3.93	-7.26	5.28	9.77*	5.19	-7.07	20.30**	8.91	4.64	-7.46	20.49**
P ₈	-8.01	-10.61*	-20.24**	-9.45*	-13.83**	-15.47**	-25.32**	-3.32	-8.26	-10.12*	-20.51**	3.49
P ₉	-3.38	-6.41	-16.49**	-5.19	-3.88	-4.16	-15.32**	9.61	-1.98	-4.86	-15.86**	9.55
P ₁₀	-12.78**	-13.26**	-22.60**	-12.14*	-18.44**	-22.85**	-23.58**	-1.07	-13.27**	-13.43**	-23.43**	-0.31
P ₇ X P ₈	-6.83	-9.71*	-14.12**	-2.51	-17.27**	-20.27**	-24.05**	-1.69	-7.67	-10.94**	-15.23**	10.37*
P ₉ X P ₁₀	-2.19	-3.61	-18.86**	-7.88	-5.05	-7.30	-21.21**	1.99	-3.72	-5.63	-19.92**	4.26
P ₁₀ X P ₁₁	25.33**	23.92**	3.63	17.64**	22.93**	18.12**	3.75	34.30**	26.25**	24.93**	3.98	35.39**
P ₁₁ X P ₁₂	7.73	3.76	-8.44*	3.94	-0.22	-9.33*	-10.19**	16.26**	6.60	2.60	-9.59*	17.72**
P ₁₂ X P ₁₃	6.40	-1.08	-5.92	6.81	5.56	-2.36	-6.99	20.40**	5.16	-2.40	-7.10	20.96**
P ₁₃ X P ₁₄	14.48**	14.10**	-3.94	9.05	11.52*	9.71*	-3.63	24.74**	12.98**	11.90*	-5.05	23.63**
P ₁₄ X P ₁₅	5.88	3.44	-8.72*	3.63	1.16	-6.02	-6.91	20.50**	7.27	5.28	-7.22	20.80**
P ₁₅ X P ₁₆	-14.98**	-19.87**	-23.79**	-13.48**	-18.10**	-22.51**	-26.18**	-4.45	-29.40**	-33.24**	-36.45**	-17.26**
P ₁₆ X P ₁₇	4.93	2.19	-9.82*	2.37	-7.73	-12.96**	-13.78**	11.61*	5.76	2.82	-9.39*	17.98**
P ₁₇ X P ₁₈	-4.92	-10.66*	-15.03**	-3.54	-7.25	-10.86**	-15.09**	9.92	0.33	-5.97	-10.49**	16.54**
P ₁₈ X P ₁₉	-16.95**	-19.95**	-23.87**	-13.57**	-16.75**	-18.34**	-19.12**	4.70	-12.42**	-15.67**	-19.72**	4.52

Heterosis ranged from -25.89 ($P_1 \times P_3$) to 25.33 per cent ($P_6 \times P_8$), heterobeltiosis from -29.06 ($P_1 \times P_3$) to 23.92 per cent ($P_6 \times P_8$) and standard heterosis from -31.43 ($P_3 \times P_5$) to 4.77 per cent ($P_3 \times P_{10}$) over Madhuri and from -22.17 ($P_3 \times P_5$) to 18.94 per cent ($P_3 \times P_{10}$) over BMH-1620 (Table 8m).

At Palem, heterosis varied from -25.15 ($P_3 \times P_5$) to 22.93 per cent ($P_6 \times P_8$), heterobeltiosis from -26.60 ($P_3 \times P_5$) to 18.12 per cent ($P_6 \times P_8$) and standard heterosis from -32.54 ($P_3 \times P_5$) to 3.75 per cent ($P_6 \times P_8$) over Madhuri and from -12.68 ($P_3 \times P_5$) to 34.30 per cent ($P_6 \times P_8$) over BMH-1620. Only 6 hybrids for heterosis, 4 hybrids for heterobeltiosis recorded significant positive values.

Heterosis at Karimnagar varied from -29.40 ($P_7 \times P_{10}$) to 26.25 per cent ($P_6 \times P_8$), heterobeltiosis from -33.24 ($P_7 \times P_{10}$) to 24.93 per cent ($P_6 \times P_8$) and standard heterosis from -36.45 ($P_7 \times P_{10}$) to 3.98 per cent ($P_6 \times P_8$) over Madhuri and from -17.26 ($P_7 \times P_{10}$) to 35.39 per cent ($P_6 \times P_8$) over BMH-1620.

4.5.14 Grain Yield (kg/plot)

Most of the hybrids exhibited significant positive heterosis and heterobeltiosis at all the three locations viz., Rajendranagar, Palem and Karimnagar.

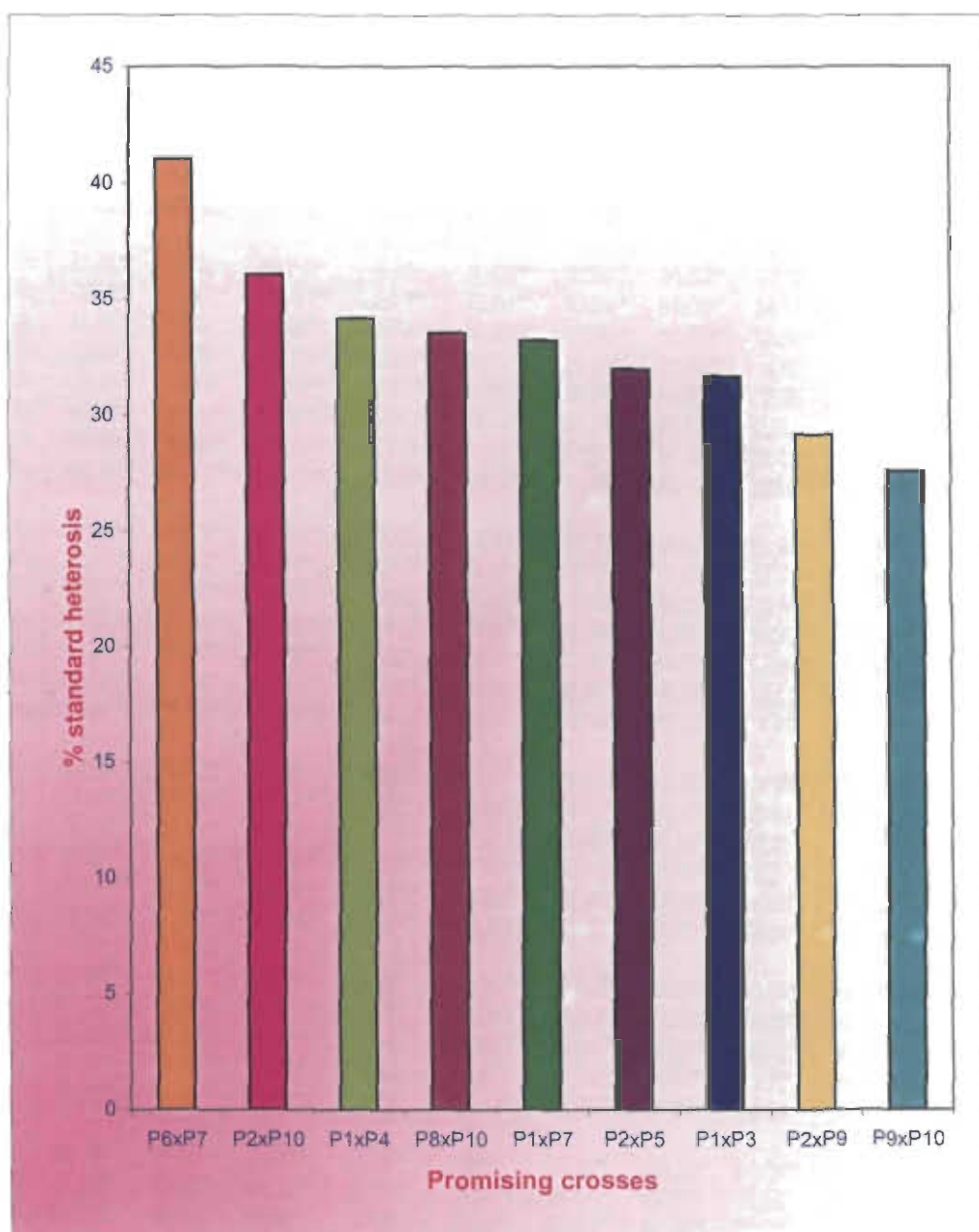


Fig. 4 : Superior crosses for standard heterosis for grain yield over BMH 1620 at three locations

Table 8n: Estimates of heterosis, heterobeltiosis and standard heterosis at three locations for grain yield

Crosses	Grain yield per plot (kg)											
	Rajendranagar				Palem				Karimnagar			
	Heterosis	Heterobe	Standard heterosis		Heterosis	Heterobe	Standard heterosis		Heterosis	Heterobe	Standard heterosis	
	-Itiosis		Check 1	Check 2	-Itiosis		Check 1	Check 2	-Itiosis		Check 1	Check 2
P ₁ X P ₂	61.09**	45.35**	90.09**	4.59	76.79**	51.05**	62.24**	12.70**	57.19**	36.89**	64.14**	18.20**
P ₃	93.96**	78.58**	123.30**	22.87**	123.71**	119.24**	73.87**	20.78**	140.68**	138.54**	112.16**	52.79**
P ₄	102.66**	92.28**	125.39**	24.02**	147.80**	139.11**	95.77**	35.99**	124.76**	124.16**	99.37**	43.57**
P ₅	57.90**	44.38**	83.30**	0.86	159.32**	152.73**	102.72**	40.82**	140.90**	134.23**	120.54**	58.82**
P ₆	75.30**	53.61**	114.78**	18.18**	105.88**	68.69**	101.06**	39.66**	59.27**	39.18**	65.56**	19.23**
P ₇	82.48**	58.39**	126.43**	24.59**	98.39**	66.76**	86.40**	29.49**	72.72**	38.92**	103.00**	46.19**
P ₈	62.28**	42.50**	98.26**	9.09*	60.92**	24.11**	74.17**	20.99**	31.39**	6.38	52.76**	10.01*
P ₉	105.19**	102.48**	113.04**	17.22**	93.09**	78.19**	60.42**	11.44**	113.63**	112.87**	90.68**	37.32**
P ₁₀	109.85**	100.66**	111.13**	16.17**	100.00**	87.90**	43.05**	-0.63	102.88**	100.53**	78.36**	28.44**
P ₁ X P ₃	41.40**	38.30**	80.87**	-0.48	50.65**	30.94**	40.63**	-2.31	60.67**	38.87**	66.51**	19.91**
P ₄	79.52**	70.21**	122.61**	22.49**	73.98**	53.31**	64.65**	14.38**	65.28**	43.61**	72.20**	24.00**
P ₅	41.30**	39.23**	82.09**	0.19	69.89**	48.38**	59.37**	10.70**	56.90**	40.05**	67.93**	20.93**
P ₆	53.60**	48.63**	107.83**	14.35**	32.93**	26.36**	50.60**	4.62	52.78**	52.17**	82.46**	31.40**
P ₇	9.40	4.74	49.74**	-17.61**	41.01**	38.24**	54.53**	7.35	-4.63	-13.19**	26.86**	-8.65
P ₈	40.46**	36.25**	89.57**	4.31	53.78**	35.74**	90.48**	32.32**	52.88**	40.26**	101.42**	45.05**
P ₉	86.58**	66.36**	117.57**	19.71**	78.58**	64.14**	76.28**	22.46**	95.17**	70.49**	104.42**	47.21**
P ₁₀	106.75**	79.26**	134.43**	29.00**	118.89**	77.64**	90.79**	32.53**	98.17**	70.88**	104.90**	47.55**
P ₁ X P ₄	57.65**	52.71**	90.96**	5.07	107.12**	103.87**	66.92**	15.95**	74.84**	73.75**	53.71**	10.69*
P ₅	20.77**	19.86**	52.17**	-16.27**	48.48**	47.65**	18.43**	-17.73**	29.68**	25.00**	17.69**	-15.24**
P ₆	37.89**	30.60**	82.61**	0.48	24.96**	4.06	24.02**	-13.85**	29.25**	12.08*	33.33**	-3.98
P ₇	40.43**	31.63**	88.17**	3.54	73.60**	48.38**	65.86**	15.22**	39.38**	11.35*	62.72**	17.18**
P ₈	43.91**	36.63**	90.09**	4.59	54.61**	20.99**	69.79**	17.94**	68.40**	35.42**	94.47**	40.05**
P ₉	80.12**	63.84**	104.87**	12.73**	75.38**	64.93**	48.49**	3.15	60.36**	58.38**	41.86**	2.16
P ₁₀	53.42**	35.61**	69.57**	-6.70	105.17**	89.14**	50.00**	4.20	76.07**	75.59**	53.40**	10.47*
P ₅	23.79**	19.04**	51.13**	-16.84**	40.17**	38.75**	13.60*	-21.09**	34.60**	30.54**	22.91**	-11.49*
P ₆	53.86**	41.42**	97.74**	8.80*	68.29**	41.95**	69.18**	17.52**	66.95**	45.55**	73.14**	24.69**
P ₇	38.64**	26.16**	80.35**	-0.77	74.41**	51.08**	68.88**	17.31**	57.44**	26.38**	84.68**	32.99**
P ₈	53.87**	41.75**	97.22**	8.52*	54.59**	22.39**	71.75**	19.31**	60.52**	29.70**	86.26**	34.13**
P ₉	41.09**	32.20**	54.96**	-14.74**	56.06**	48.99**	34.14**	-6.82	37.53**	36.68**	22.43**	-11.83*
P ₁₀	99.18**	81.16**	112.35**	16.84**	124.16**	103.69**	66.77**	15.84**	102.34**	100.54**	77.41**	27.76**
P ₆	55.67**	48.51**	107.65**	14.26**	63.94**	37.14**	63.44**	13.54**	62.94**	45.95**	73.62**	25.03**
P ₇	59.79**	50.85**	115.65**	18.66**	131.31**	98.65**	122.05**	54.25**	22.81**	0.97	47.55**	6.26
P ₈	38.43**	32.37**	84.17**	1.34	47.67**	16.04**	62.84**	13.12**	35.02**	11.77*	60.51**	15.59**
P ₉	48.29**	33.97**	70.09**	-6.41	71.07**	61.74**	45.62**	1.15	84.87**	80.37**	69.83**	22.30**
P ₁₀	65.83**	45.62**	84.87**	1.72	101.44**	84.75**	48.19**	2.94	92.67**	85.23**	74.41**	25.60**
P ₇	66.79**	64.96**	135.83**	29.76**	76.06**	70.60**	103.32**	41.24**	60.19**	45.30**	112.32**	52.90**
P ₈	44.26**	43.91**	101.22**	10.72**	28.17**	18.51**	66.31**	15.53**	29.72**	18.59**	70.30**	22.64**
P ₉	64.25**	42.29**	98.96**	9.47*	78.92**	57.03**	87.16**	30.01**	74.70**	53.12**	82.15**	31.17**
P ₁₀	63.57**	37.94**	92.87**	6.12	80.03**	40.56**	67.52**	16.37**	73.60**	50.20**	78.67**	28.67**
P ₈	43.77**	41.85**	102.78**	11.58**	45.60**	30.79**	83.53**	27.49**	35.01**	33.84**	95.58**	40.84**
P ₉	85.83**	59.49**	128.00**	25.45**	64.52**	48.51**	66.01**	15.32**	48.26**	19.57**	74.72**	25.82**
P ₁₀	36.97**	14.48**	63.65**	-9.95*	57.06**	25.54**	40.33**	-2.52	27.46**	1.62	48.50**	6.94
P ₉	62.71**	41.25**	96.52**	8.13*	32.33**	8.61*	52.42**	5.88	28.73**	4.51	50.08**	8.08
P ₁₀	89.50**	60.12**	122.78**	22.58**	86.73**	37.89**	93.50**	34.42**	74.64**	40.15**	101.26**	44.94**
P ₁₀	125.24**	118.17**	123.48**	22.97**	121.37**	92.95**	73.72**	20.67**	119.16**	115.87**	93.36**	39.25**

At Rajendranagar, all hybrids over Madhuri and 25 hybrids over BMH-1620 showed significant positive standard heterosis. Heterosis varied from 9.40 ($P_2 \times P_7$) to 125.24 per cent ($P_9 \times P_{10}$), heterobeltiosis from 4.74 ($P_2 \times P_7$) to 118.17 per cent ($P_9 \times P_{10}$) and standard heterosis from 49.74 ($P_2 \times P_7$) to 135.83 per cent ($P_6 \times P_7$) over Madhuri and -17.61 ($P_2 \times P_7$) to 29.76 per cent ($P_6 \times P_7$) over BMH-1620 (Table 8n).

At Palem, all hybrids over Madhuri and 31 hybrids over BMH-1620 showed significant performance in positive direction for standard heterosis range of variation was 24.96 ($P_3 \times P_6$) to 159.32 per cent ($P_1 \times P_5$) for heterosis, 4.06 ($P_3 \times P_6$) to 152.73 per cent ($P_1 \times P_5$) for heterobeltiosis and 13.60 ($P_4 \times P_5$) to 122.05 per cent ($P_5 \times P_7$) and -21.09 to 54.25 per cent ($P_5 \times P_7$) over Madhuri and BMH-1620, respectively for standard heterosis.

Heterosis at Karimnagar varied from -4.63 ($P_2 \times P_7$) to 140.90 per cent ($P_1 \times P_5$), heterobeltiosis from -13.19 to 138.54 per cent ($P_1 \times P_3$) and standard heterosis from 17.69 ($P_3 \times P_5$) to 120.54 per cent ($P_1 \times P_5$) over Madhuri and -15.24 ($P_3 \times P_5$) to 58.82 per cent ($P_1 \times P_5$) over BMH-1620. All forty five and 36 hybrids recorded significant positive standard heterosis over Madhuri and BMH-1620, respectively.

4.6 CORRELATION STUDIES

In general, correlation studies reveal the direction and magnitude of the association between any two characters. Correlation coefficient refers to the measure of the relationship of two variables for two characters. Correlation coefficients serve as a tool to determine the superior lines.

Phenotypic and genotypic correlations

Phenotypic and genotypic correlation coefficients were estimated between yield, its components and oil and protein contents. In 45 hybrids at Rajendranagar, Palem and Karimnagar and the same are presented in Table 9a, 9b and 9c respectively. In general, genotypic correlations were of higher magnitude than the corresponding phenotypic values and hence only the genotypic correlations are discussed hereunder.

4.6.1 Days to 50 Per cent Tasseling

Days to 50 per cent tasseling was significantly and positively correlated with days to 50 per cent silking, and days to per cent brown husk, while it had negative association with remaining characters except protein and oil content at Rajendranagar (Table 9a). Similar association of characters was found at Palem and Karimnagar locations.

Table 9a: Phenotypic and genotypic correlations for 14 characters at Rajendranagar location													
Variables	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husk	Plant height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernel rows / ear	No. of kernels / row	No. of kernels / ear	100 kernel weight (g)	Protein content (%)	Oil content (%)	Grain yield (kg/plot)
Days to 50% tasseling	P 1.0000	0.9539**	0.7780**	-0.2266	-0.4127**	-0.2007	-0.1228	-0.4930**	-0.4924**	-0.3909**	0.0086	0.1347	-0.4809**
	G 1.0000	0.9956**	0.9029**	-0.3276*	-0.7461**	-0.6291**	-0.1571	-0.6284**	-0.6289**	-0.5417**	-0.1181	0.2413	-0.6427**
Days to 50% silking	P 1.0000	1.0000	0.8148**	-0.2592	-0.3899**	-0.1364	-0.0748	-0.5167**	-0.4974**	-0.4061**	-0.0033	0.1312	-0.4883**
	G 1.0000	1.0000	0.9160**	-0.3386*	-0.8118**	-0.4791**	-0.1117	-0.6283**	-0.6137**	-0.5275**	-0.1182	0.2311	-0.6295**
Days to 50% brown husk	P 1.0000	1.0000	1.0000	-0.3231*	-0.4114**	-0.0923	-0.0349	-0.4511**	-0.4195**	-0.4190**	0.0281	0.1445	-0.4387**
	G 1.0000	1.0000	1.0000	-0.3994**	-0.7451**	-0.2941*	-0.0591	-0.5750**	-0.5373**	-0.5858**	-0.0838	0.206	-0.5854**
Ear height (cm)	P 1.0000			1.0000	0.6972**	0.342*	-0.012	0.4351**	0.3892**	0.2918*	-0.0773	0.1301	0.4038**
	G 1.0000			1.0000	0.8375**	0.7420**	-0.0232	0.4905**	0.4309**	0.3402*	-0.0818	0.1785	0.4630**
Plant height (cm)	P 1.0000			1.0000	0.3351*	0.1324	0.0636	0.4970**	0.4606**	0.2796*	-0.056	0.0269	0.4639**
	G 1.0000			1.0000	0.8769**	0.2698*	0.0816	0.6027**	0.5428**	0.4473**	-0.197	0.0366	0.5720**
Ear length (cm)	P 1.0000			1.0000	0.1777		0.0924	0.4968**	0.4780**	0.3801**	-0.0458	-0.0345	0.4929**
	G 1.0000			1.0000	1.5312**		0.0534	1.0977**	0.9549**	0.7806**	-0.0561	0.0845	0.9950**
Ear girth (cm)	P 1.0000			1.0000			0.1959	0.1494	0.2188	0.112	-0.0769	0.0272	0.2149
	G 1.0000			1.0000			0.8297**	0.8297**	1.0224**	0.7848**	-0.7345**	0.2412	0.9765**
No. of kernel rows per ear	P 1.0000			1.0000			1.0000	0.0658	0.4875**	0.0886	-0.1882	-0.0497	0.3619**
	G 1.0000			1.0000			1.0000	0.1607	0.5409**	0.0326	-0.3568**	-0.049	0.3976**
No. of kernels per row	P 1.0000			1.0000			1.0000	1.0000	0.8777**	0.6785**	-0.0929	-0.0562	0.8875**
	G 1.0000			1.0000			1.0000	1.0000	0.9096**	0.7604**	-0.1462	-0.0289	0.9444**
No. of kernels per ear	P 1.0000			1.0000			1.0000	1.0000	1.0000	0.6223**	-0.154	-0.0877	0.9444**
	G 1.0000			1.0000			1.0000	1.0000	1.0000	0.6555**	-0.2774*	-0.0829	0.9695**
100 kernel weight (g)	P 1.0000			1.0000			1.0000	1.0000	1.0000	1.0000	-0.1405	-0.097	0.7833**
	G 1.0000			1.0000			1.0000	1.0000	1.0000	1.0000	-0.2574	-0.1275	0.8206**
Protein content (%)	P 1.0000			1.0000			1.0000	1.0000	1.0000	1.0000	1.0000	0.2552	-0.1655
	G 1.0000			1.0000			1.0000	1.0000	1.0000	1.0000	1.0000	-0.2680*	-0.3245*
Oil content (%)	P 1.0000			1.0000			1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	-0.0983
	G 1.0000			1.0000			1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	-0.0865
Grain yield (kg)/plot	P 1.0000			1.0000			1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	G 1.0000			1.0000			1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
P-Phenotypic	G-Genotypic												

** : Significant (P<0.01)

* : Significant (P<0.05)

Table 9c: Phenotypic and genotypic correlations for 14 characters at Karimnagar location

	50% tasseling	50% silking	50% brown husk	Plant height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernel rows / ear	No. of kernels / row	No. of kernels / ear	weight (g)	content (%)	oil content (%)	grain yield (kg/ plot)	
Days to 50% tasseling	P	1.0000	0.8189**	0.7300**	-0.2525	-0.3521**	-0.1701	-0.1061	-0.3810**	-0.3249*	-0.3556**	0.0460	0.1676	-0.3274*
Days to 50% silking	G	1.0000	0.8928**	0.8103**	-0.3807**	-0.7259**	-0.9195**	-0.1907	-0.4981**	-0.4126**	-0.4815**	0.0333	0.2741*	-0.4327**
Days to 50% brown husk	P	1.0000	0.7487**	0.7487**	-0.2259	-0.2842*	-0.0846	-0.1100	-0.3693**	-0.3333*	-0.3393*	-0.0317	0.0641	-0.3286*
Plant height (cm)	G	1.0000	0.7572**	0.7572**	-0.3337*	-0.6813**	-0.8860**	-0.2201	-0.5212**	-0.4540**	-0.4829**	-0.1280	0.1666	-0.4571**
Ear length (cm)	P	1.0000	1.0000	1.0000	-0.2228	-0.2316	-0.0847	-0.1177	-0.2930*	-0.2805*	-0.2631	-0.0044	0.0301	-0.2604
Ear girth (cm)	G	1.0000	1.0000	1.0000	-0.3285*	-0.6255**	-0.8547**	-0.2175	-0.4271**	-0.3916**	-0.4183**	0.0229	0.0483	-0.3973**
No. of kernel rows per ear	P	1.0000	1.0000	1.0000	0.6613**	0.4458**	0.2935*	0.1699	0.4930**	0.4650**	0.4345**	-0.0317	0.0369	0.4655**
No. of kernels per ear	G	1.0000	1.0000	1.0000	0.7828**	0.6915**	0.7459**	0.2431	0.5699**	0.5322**	0.5126**	-0.0856	0.0855	0.5478**
No. of kernels per row	P	1.0000	1.0000	1.0000	1.0000	0.4817**	0.2362	0.1695	0.5734**	0.5175**	0.4821**	-0.0218	0.0208	0.5155**
100 kernel weight (g)	G	1.0000	1.0000	1.0000	1.0000	0.7555**	0.7272**	0.2367	0.6743**	0.5981**	0.5815**	-0.0938	0.0513	0.6054**
Protein content (%)	P	1.0000	1.0000	1.0000	1.0000	1.0000	0.6195**	0.1319	0.6795**	0.6001**	0.6290**	-0.0874	-0.1181	0.6229**
Oil content (%)	G	1.0000	1.0000	1.0000	1.0000	1.0000	0.9107**	0.2477	0.9480**	0.8332**	0.8522**	0.0096	-0.1526	0.8631**
Grain yield (kg)/plot	P	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0516	0.3749**	0.3129*	0.3555**	-0.2221	-0.1872	0.3164*
	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1511	1.0543**	0.8469**	0.9332**	-0.2438	-0.2069	0.8838**
	P	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1801	0.5922**	0.4663**	-0.1038	0.0611	0.5690**
	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3101*	0.6782**	0.4996**	-0.3546**	-0.0078	0.6404**
	P	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8589**	0.8113**	-0.0177	0.0273	0.8610**
	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8932**	0.8932**	0.8674**	-0.0331	0.0425	0.9016**
	P	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8732**	-0.0605	0.0319	0.9740**
	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8871**	-0.1613	-0.0033	0.9853**
	P	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	-0.0589	0.0016	0.9450**
	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	-0.1263	-0.0328	0.9502**
	P	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3458**	-0.0504
	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1869	-0.1284
	P	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0311	0.0018
	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	P	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	G	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

* : Significant (P<0.05) ** : Significant (P<0.01)

4.6.2 Days to 50 Per cent Silking

Days to 50 per cent silking showed significant positive association with days to 50 per cent tasseling, days to 50 per cent brown husk. On the other hand it showed significant negative association with plant height, ear length, ear girth, number of kernels per row, number of kernels per ear, 100 kernel weight and grain yield at all locations.

4.6.3 Days to 50 Per cent Brown Husk

Days to 50 per cent brown husk showed significant positive association with days to 50 per cent tasseling and days to 50 per cent brown husk and it had significant negative association with ear height, plant height, ear length, ear girth, number of kernels per row, number of kernels per ear, 100 kernel weight and grain yield in all the three locations.

4.6.4 Ear Height

Ear height revealed significant positive association with plant height, ear length, ear girth, number of kernels per row, number of kernels per ear, 100 kernel weight and grain yield in all the three locations. It had significant negative association with days to 50 per cent tasseling, days to 50 per cent silking and days to 50 per cent brown husk at all three locations.

4.6.5 Plant Height

The association of plant height was significant and positive with ear height, ear length, number of kernels per row, number of kernels per ear, 100 kernel weight and grain yield. Days to 50 per cent tasseling, days to 50 per cent silking and days to 50 per cent brown husk had negative and significant correlation with plant height.

4.6.6 Ear Length

Ear length showed positive and significant association with ear height, plant height, ear girth, number of kernel rows per ear, number of kernels per ear, 100 kernel weight and grain yield at Rajendranagar, Palem and Karimnagar locations. Days to 50 per cent tasseling, days to 50 per cent silking and days to 50 per cent brown husk had significant and negative correlation with ear length (Table 9a to 9c).

4.6.7 Ear Girth

Ear girth had significant positive association with ear height, plant height, ear length, number of kernel rows per ear, number of kernels per row, number of kernels per ear, 100 kernel weight and grain yield at Rajendranagar, Palem and Karimnagar. Days to 50 per cent tasseling, days to 50 per cent silking and days to 50 per cent brown husk registered significant and negative association with ear girth. It had also

significant and negative association with protein and oil content at Rajendranagar and Palem, respectively.

4.6.8 Number of Kernel Rows per Ear

The association of number of kernel rows per ear was significant and positive with ear girth, number of kernels per ear and grain yield and significant and negative with protein content at Rajendranagar. At Palem location, it showed significant and positive association with plant height, ear length, ear girth, number of kernels per row, number of kernels per ear, 100 kernel weight and grain yield, whereas at Karimnagar it had significant and positive association with number of kernels per row, number of kernels per ear, 100 kernel weight and grain yield and it had significant and negative association with protein content.

4.6.9 Number of Kernels per Row

Number of kernels per row revealed positive and significant association with ear height, plant height, ear length, ear girth, number of kernel rows per ear, number of kernels per ear, 100 kernel weight and grain yield. It had significant negative association with days to 50 per cent tasseling, days to 50 per cent silking and days to 50 per cent brown husk at all the three locations.

4.6.10 Number of Kernels per Ear

Number of kernels per ear, an important yield contributing character showed significant positive correlation with ear height, plant height, ear length, ear girth, number of kernel rows per ear, number of kernels per row, 100 kernel weight and grain yield, while it had significant negative association with days to 50 per cent tasseling, days to 50 per cent silking and days to 50 per cent brown husk at all the three locations *viz.*, Rajendranagar, Palem and Karimnagar (Table 9a to 9c).

4.6.11 100 Kernel Weight

It had shown significant positive association with ear height, plant height, ear length, ear girth, number of kernels per row, number of kernels per ear and grain yield and significant negative association with days to 50 per cent tasseling, days to 50 per cent silking and days to 50 per cent brown husk at all the three locations. In addition, it had significant positive association with number of kernel rows per ear at Palem and Karimnagar locations.

4.6.12 Protein Content

It had significant negative association with ear girth, number of kernel rows per ear and number of kernels per ear. At Rajendranagar location it registered negative and significant association with oil

content and grain yield, while at Palem and Karimnagar, it had positive and significant correlation with oil content.

4.6.13 Oil Content

Oil content recorded significant and negative correlation with protein content at Rajendranagar, while it registered significant and positive association with oil content at both Palem and Karimnagar locations.

4.6.14 Grain Yield

Showed significant and positive association with ear height, plant height, ear length, ear girth, number of kernel rows per ear, number of kernels per row, number of kernels per ear, 100 kernel weight and had significant negative association with days to 50 per cent tasseling, days to 50 per cent silking and days to 50 per cent brown husk at all the three locations *viz.*, Rajendranagar, Palem and Karimnagar.

4.7 PATH COEFFICIENT ANALYSIS

Direct and indirect phenotypic and genotypic path coefficients are presented in Table 10a, 10b and 10c. Genotypic path coefficients were of higher magnitude than the phenotypic coefficients demonstrating that the observed relationships among various characters were due to genetic causes. The relationship between the characters with

Variables	Days to	Days to Ear height	Plant	Ear length	Ear girth	No. of lower
Days to	0.98	0.00	0.00	0.00	0.00	0.00
Days to Ear height	0.00	0.98	0.00	0.00	0.00	0.00
Plant	0.00	0.00	0.98	0.00	0.00	0.00
Ear length	0.00	0.00	0.00	0.98	0.00	0.00
Ear girth	0.00	0.00	0.00	0.00	0.98	0.00
No. of lower	0.00	0.00	0.00	0.00	0.00	0.98

		50% tasselling	50% silking	50% brown husk	Plant height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernel rows / ear	100 kernel weight (g)	Protein content (%)	Oil content (%)	Correlation with grain yield	
												r _r	
Days to 50% tasselling	P	0.025	-0.016	0.014	0.000	-0.003	-0.003	-0.005	-0.044	-0.182	0.001	0.000	-0.362**
	G	3.784	-2.926	-0.695	0.095	-0.096	-1.519	-0.168	-2.080	3.502	-0.073	-0.053	-0.515**
Days to 50% silking	P	0.021	-0.020	0.015	0.000	-0.003	-0.003	-0.002	-0.048	-0.188	0.001	0.000	-0.394**
	G	3.311	-3.344	-0.577	0.086	-0.085	-1.270	0.057	-2.195	3.580	0.023	0.159	-0.564**
Days to 50% brown husk	P	0.015	-0.014	0.023	0.000	-0.003	-0.003	-0.007	-0.052	-0.193	0.001	0.000	-0.404**
	G	2.352	-1.727	-1.118	0.128	-0.093	-1.391	-0.306	-2.530	4.159	0.027	0.201	-0.639**
Ear height (cm)	P	-0.004	0.004	-0.005	0.000	0.004	0.002	0.008	0.054	0.210	-0.001	0.000	0.401**
	G	-1.091	1.052	0.501	-0.152	0.083	0.941	0.411	2.047	-3.547	0.044	-0.022	0.509**
Plant height (cm)	P	-0.007	0.005	-0.008	0.001	0.000	0.003	0.012	0.077	0.294	-0.001	0.000	0.615**
	G	-1.786	1.424	0.707	-0.202	0.100	1.401	0.611	2.586	-4.555	0.060	-0.026	0.692**
Ear length (cm)	P	-0.009	0.006	-0.008	0.000	0.000	0.006	0.013	0.075	0.297	-0.002	0.001	0.617**
	G	-2.401	1.879	0.684	-0.133	0.151	1.849	0.622	2.896	-5.327	0.042	0.140	0.779**
Ear girth (cm)	P	-0.008	0.006	-0.007	0.000	0.007	0.009	0.016	0.056	0.245	-0.001	0.000	0.518**
	G	-2.589	1.914	0.700	-0.127	0.126	2.220	1.150	2.745	-6.010	0.428	0.246	0.876**
No. of kernel rows per ear	P	-0.002	0.001	-0.003	0.000	0.002	0.003	0.054	0.023	0.241	-0.001	0.000	0.486**
	G	-0.350	-0.106	0.188	-0.068	0.052	1.408	1.814	0.1219	-3.945	0.226	0.044	0.558**
No. of kernels / row	P	-0.009	0.008	-0.010	0.000	0.006	0.004	0.011	0.118	0.418	0.001	0.000	0.881**
	G	-2.211	2.062	0.794	-0.147	0.123	1.712	0.621	3.561	-6.091	-0.033	0.063	0.925**
No. of kernels / ear	P	-0.010	0.008	-0.009	0.000	0.006	0.005	0.028	0.105	0.471	0.000	0.000	0.967**
	G	-2.026	1.830	0.710	-0.140	0.123	2.039	1.094	3.315	-6.543	-0.008	0.096	0.984**
100 kernel weight (g)	P	-0.009	0.008	-0.009	0.000	0.006	0.004	0.022	0.095	0.413	0.000	0.000	0.944**
	G	-1.983	1.892	0.696	-0.134	0.104	1.768	0.763	3.055	-5.891	-0.009	0.154	0.959**
Protein content (%)	P	0.002	-0.001	0.001	0.000	-0.001	-0.001	-0.003	0.004	0.008	0.015	-0.002	0.026
	G	0.784	0.219	0.085	-0.002	-0.018	-0.418	-0.362	0.330	-0.146	-0.354	-0.129	0.036
Oil content (%)	P	0.001	0.000	0.001	0.000	-0.002	-0.001	0.000	-0.005	0.005	-0.005	-0.077	-0.077
	G	0.239	0.632	0.266	-0.006	-0.025	-0.647	-0.095	-0.267	0.746	-0.054	-0.843	-0.152

* : Significant (P<0.05) ** : Significant (P<0.01)

Genotypic residual effect: -0.166

P-Phenotypic	G-Genotypic
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Phenotypic residual effect: 0.042

G-Genotypic

Table 10c: Phenotypic and genotypic path coefficients for various characters at Karimnagar

Variables	Days to 50% tasseling	Days to 50% silking	Days to 50% brown husk	Ear height (cm)	Plant height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernels / row	No. of kernels / ear	100 kernel weight (g)	Protein content (%)	Oil content (%)	Correlation with grain yield r_1
Days to 50% tasseling	P 0.014	-0.001	0.012	-0.003	0.002	-0.008	0.006	-0.006	-0.032	-0.171	0.000	0.000	-0.327*
	G -0.017	0.040	-0.003	-0.009	0.014	-0.045	0.042	-0.012	-0.035	-0.229	0.001	0.001	-0.433**
Days to 50% silking	P 0.012	-0.001	0.012	-0.002	0.002	-0.006	0.003	-0.007	-0.031	-0.176	0.000	0.000	-0.329*
	G -0.015	0.045	-0.003	-0.008	0.012	-0.042	0.040	-0.014	-0.037	-0.252	-0.003	0.001	-0.457**
Days to 50% brown husk	P 0.011	-0.001	0.016	-0.002	0.002	-0.005	0.003	-0.007	-0.024	-0.148	0.000	0.000	-0.260
	G -0.014	0.034	-0.004	-0.009	0.012	-0.039	0.039	-0.014	-0.030	-0.217	0.001	0.000	-0.397**
Ear height (cm)	P -0.004	0.000	-0.004	0.010	-0.006	0.010	-0.010	0.010	0.041	0.245	0.000	0.000	0.466**
	G 0.005	-0.012	0.001	0.031	-0.028	0.043	-0.034	0.015	0.040	0.295	-0.002	0.000	0.548**
Plant height (cm)	P -0.004	0.000	-0.004	0.007	-0.009	0.011	-0.008	0.010	0.048	0.273	0.000	0.000	0.516**
	G 0.007	-0.015	0.001	0.025	-0.036	0.047	-0.033	0.015	0.047	0.332	-0.002	0.000	0.605**
Ear length (cm)	P -0.005	0.000	-0.004	0.004	-0.004	0.022	-0.021	0.008	0.057	0.316	-0.001	0.000	0.623**
	G 0.012	-0.031	0.002	0.022	-0.027	0.062	-0.041	0.015	0.066	0.462	0.000	-0.001	0.863**
Ear girth (cm)	P -0.002	0.000	-0.001	0.003	-0.002	0.014	-0.033	0.003	0.031	0.165	-0.002	0.000	0.316*
	G 0.016	-0.040	0.003	0.023	-0.026	0.056	-0.045	0.009	0.074	0.470	-0.006	-0.001	0.884**
No. of kernel. rows per ear	P -0.002	0.000	-0.002	0.002	-0.001	0.003	-0.002	0.060	0.015	0.312	-0.001	0.000	0.569**
	G 0.003	-0.010	0.001	0.008	-0.009	0.015	-0.007	0.062	0.022	0.376	-0.009	0.000	0.640**
No. of kernels / row	P -0.006	0.000	-0.005	0.005	-0.005	0.015	-0.013	0.011	0.083	0.453	0.000	0.000	0.861**
	G 0.009	-0.024	0.002	0.018	-0.024	0.058	-0.048	0.019	0.070	0.496	0.000	0.000	0.902**
No. of kernels / ear	P -0.005	0.000	-0.005	0.005	-0.004	0.013	-0.010	0.035	0.072	0.527	0.000	0.000	0.974**
	G 0.007	-0.021	0.001	0.017	-0.021	0.051	-0.038	0.042	0.063	0.555	0.000	0.000	0.985**
100 kernel weight (g)	P -0.005	0.000	-0.004	0.004	-0.004	0.014	-0.012	0.028	0.068	0.460	0.000	0.000	0.945**
	G 0.008	-0.022	0.002	0.016	-0.021	0.053	-0.042	0.031	0.061	0.376	-0.003	0.000	0.950**
Protein content (%)	P 0.001	0.000	0.000	0.000	0.000	-0.002	0.007	-0.006	-0.002	-0.032	0.007	-0.001	-0.050
	G -0.001	-0.006	0.000	-0.003	0.003	0.001	0.011	-0.022	-0.002	-0.023	0.026	0.001	-0.128
Oil content (%)	P 0.002	0.000	0.001	0.000	0.000	-0.003	0.006	0.004	0.002	0.001	0.002	-0.001	0.031
	G -0.005	0.008	0.000	0.003	-0.002	-0.009	0.009	-0.001	0.003	-0.012	0.005	0.005	0.002

* : Significant (P<0.05) ** : Significant (P<0.01)

Genotypic residual effect : -0.001

G-Genotypic

Phenotypic residual effect : 0.023

grain yield, oil content, and protein content were mainly discussed over three locations.

At Rajendranagar location, days to 50 per cent tasseling showed a positive direct effect on grain yield. The indirect negative contribution was through 100 kernel weight, oil content, number of kernels per ear and number of kernels per row resulted in negative correlation with grain yield. Days to 50 per cent silking recorded negative direct effect but the character showed negative indirect contribution through oil content, 100 kernel weight, number of kernels per ear, number of kernels per row and ear height resulted in negative significant correlation with yield. Days to 50 per cent brown husk had direct positive effect on grain yield. The indirect negative influence on grain yield was through 100 kernel weight, number of kernel rows per ear, number of kernels per row, number of kernels per ear, ear height and days to 50 per cent silking resulted in significant and negative correlation with grain yield.

Ear height showed positive direct effect on grain yield. It had indirect positive contribution through 100 kernel weight, number of kernels per ear, number of kernels per row and days to 50 per cent silking resulted in that the net effect of the character on yield was significant and positive. Plant height had negative direct effect. On the other hand it had positive indirect contribution through protein content,

100 grain weight, number of kernels per ear, number of kernels per row, ear height and days to 50 per cent silking resulting in significant and positive correlation with grain yield.

Ear length indicated direct negative effect and on the other hand it had positive indirect effect through traits *viz.*, protein content, 100 kernel weight, number of kernels per ear, number of kernels per row and days to 50 per cent silking resulting in that the net effect of the character on grain yield was significant and positive. Ear girth had direct negative effect conversely it had positive indirect effect through protein content, 100 kernel weight, number of kernels per row, number of kernels per ear, ear height and days to 50 per cent silking resulted in positive and significant correlation with grain yield. Number of kernel rows per ear had positive direct effect. The character had indirect positive effect through protein content, 100 kernel weight, number of kernels per ear, number of kernels per row and days to 50 per cent silking, resulting in significant and positive correlation with grain yield. Number of kernels per row recorded positive direct effect. It showed positive indirect contribution through protein content, 100 kernel weight, number of kernels per ear, number of kernel rows per ear, ear height and days to 50 per cent silking and resulted in significant positive correlation with yield. Number of kernels per ear had positive direct effect and on the other hand, it had positive indirect effect through

oil content, protein content, 100 kernel weight, number of kernels per row, number of kernel rows per ear, ear height, days to 50 per cent silking resulted in positive and significant correlations with grain yield. Hundred kernel weight had positive direct effect and it had positive indirect contribution through ear height, number of days to 50 per cent silking, number of kernel rows per ear, number of kernels per row, number of kernels per ear, protein content and oil content resulted in significant and positive correlation with grain yield.

Protein content had direct negative effect and had negative indirect effect through 100 kernel weight, number of kernel rows per ear, number of kernels per ear, number of kernels per row, ear height, number of days to 50 per cent brown husk and number of days to 50 per cent tasseling resulting in that the net effect of the character on grain yield was negative and significant. Oil content had recorded a negative direct effect and on the other hand it had negative indirect effect through 100 kernel weight, number of kernels per ear, number of kernels per row, number of kernel rows per ear, ear girth, ear length, plant height and number of days to 50 per cent silking resulting in significant and negative correlation with grain yield.

At Palem location, days to 50 per cent tasseling had direct positive effect and it had indirect negative effect through oil content, protein content, 100 kernel weight, number of kernels per row, number

of kernels rows per ear, ear girth, ear length, ear height, days to 50 per cent brown husk and days to 50 per cent silking resulting in negative and significant correlations with grain yield (Table 10b). Days to 50 per cent silking had direct negative effect. This character had indirect negative contribution through 100 kernel weight, number of kernels per row, ear girth, ear length, ear height and days to 50 per cent brown husk resulted in negative correlation with yield. Days to 50 per cent brown husk showed direct and negative effect. It had indirect negative influence through the traits viz., 100 kernel weight, number of kernels per row, number of kernel rows per ear, ear girth, ear length, ear height and days to 50 per cent silking resulted in negative and significant correlation with grain yield. Ear height had direct and positive effect where as it had indirect positive influence through protein content, 100 kernel weight, number of kernels per row, number of kernel rows per ear, ear girth, ear length, days to 50 per cent brown husk and days to 50 per cent silking resulting in positive and significant correlations with grain yield.

Plant height had direct negative effect and it showed the indirect positive influence through protein content, 100 kernel weight, number of kernels per row, number of kernel rows per ear, ear girth, ear length, ear height and days to 50 per cent silking resulted in positive correlation with grain yield. Ear length had direct positive effect,

of kernels rows per ear, ear girth, ear length, ear height, days to 50 per cent brown husk and days to 50 per cent silking resulting in negative and significant correlations with grain yield (Table 10b). Days to 50 per cent silking had direct negative effect. This character had indirect negative contribution through 100 kernel weight, number of kernels per row, ear girth, ear length, ear height and days to 50 per cent brown husk resulted in negative correlation with yield. Days to 50 per cent brown husk showed direct and negative effect. It had indirect negative influence through the traits viz., 100 kernel weight, number of kernels per row, number of kernel rows per ear, ear girth, ear length, ear height and days to 50 per cent silking resulted in negative and significant correlation with grain yield. Ear height had direct and positive effect where as it had indirect positive influence through protein content, 100 kernel weight, number of kernels per row, number of kernel rows per ear, ear girth, ear length, days to 50 per cent brown husk and days to 50 per cent silking resulting in positive and significant correlations with grain yield.

Plant height had direct negative effect and it showed the indirect positive influence through protein content, 100 kernel weight, number of kernels per row, number of kernel rows per ear, ear girth, ear length, ear height and days to 50 per cent silking resulted in positive correlation with grain yield. Ear length had direct positive effect,

it showed indirect positive contribution through oil content, protein content, 100 kernel weight, number of kernels per row, number of kernel rows per ear, ear girth, ear height, days to 50 per cent brown husk and days to 50 per cent silking resulted in positive and significant correlations with yield. Ear girth had direct positive effect on yield and this character showed indirect positive influence through protein content, oil content, 100 kernel weight, number of kernels per row, number of kernel rows per ear, ear length, ear height, days to 50 per cent brown husk and days to 50 per cent silking resulted in significant positive effect on yield.

Number of kernel rows per ear had direct positive effect on yield. It had indirect positive effect through the characters viz., protein content, oil content, 100 kernel weight, number of kernels per row, ear girth, ear length, ear height and days to 50 per cent brown husk resulted in positive and significant influence on yield. Number of kernels per row also had direct positive effect on yield. It had indirect positive influence through oil content, 100 kernel weight, number of kernel rows per ear, ear girth, ear length, ear height, days to 50 per cent brown husk and days to 50 per cent silking resulted in positive correlation effect with yield. Number of kernels per ear had direct negative effect. It had indirect positive influence through oil content, 100 kernel weight, number of kernels per row, number of kernel rows per ear, ear girth, ear

length, ear height, days to 50 per cent brown husk and days to 50 per cent silking resulted in positive and significant correlation with yield. Hundred grain weight had direct positive effect. It had indirect positive influence through number of kernels per row, number of kernel rows per ear, ear girth, ear length, ear height, days to 50 per cent brown husk and days to 50 per cent silking resulted in positive and significant correlation with yield.

Protein content had direct negative effect on yield. This character had indirect and negative influence through oil content, number of kernels per ear, number of kernel rows per ear, ear girth, ear length and ear height, on the other hand it showed positive indirect effect through 100 kernel weight, number of kernels per row, plant height, days to 50 per cent brown husk, silking and tasseling. Oil content showed direct negative effect. It showed indirect negative influence through characters viz., protein content, 100 kernel weight, number of kernels per row, number of kernel rows per ear, ear girth, ear length and plant height resulted in negative correlation with yield.

At Karimnagar, days to 50 per cent tasseling showed direct and negative effect. It had indirect negative influence through the traits viz., 100 kernel weight, number of kernels per ear, number of kernels per row, number of kernel rows per ear, ear length, ear height and days to 50 per cent brown husk resulting in significant negative correlation

with grain yield. Days to 50 per cent silking and positive direct effect and the positive indirect effect through oil content, ear girth and plant height and on the other hand it had negative direct effect through protein content, 100 kernel weight, number of kernels per ear, number of kernels per row, number of kernel rows per ear, ear length, ear height, number of days to 50 per cent brown husk and number of days to 50 per cent tasseling resulting in negative and significant correlations with yield. Number of days to 50 per cent brown husk had direct negative effect and it showed indirect negative effect through 100 kernel weight, number of kernels per ear, number of kernels per row, number of kernel rows per ear, ear length, ear height and days to 50 per cent tasseling resulting in negative and significant correlations with yield.

Ear height had direct positive effect and it showed positive and indirect influence through 100 kernel weight, number of kernels per ear, number of kernels per row, number of kernel rows per ear, ear length and days to 50 per cent silking resulting in positive and significant correlations with yield. Plant height showed direct and negative effect and it had indirect positive effect through characters viz., 100 kernel weight, number of kernels per ear, number of kernels per row, number of kernel rows per ear, ear length, ear height, days to 50 per cent brown husk and days to 50 per cent silking. Ear length had direct and positive effect and it had indirect positive influence through 100 kernel weight,

number of kernels per ear, number of kernels per row, number of kernel rows per ear, ear height, days to 50 per cent brown husk and days to 50 per cent tasseling resulting in positive and significant correlation with yield. Ear girth had direct and negative effect and it showed positive influence through 100 kernel weight, number of kernels per ear, number of kernels per row, number of rows per ear, ear length, ear height, days to 50 per cent brown husk and days to 50 per cent tasseling resulted in significant and positive correlations with yield.

Number of kernel rows per ear had direct positive effect. It showed indirect and positive influence through 100 kernel weight, number of kernels per ear, number of kernels per row, ear length, ear height, days to 50 per cent brown husk and days to 50 per cent tasseling resulting in positive and significant correlations with yield. Number of kernels per row had, direct positive effect and it had positive and indirect contribution through characters *viz.*, 100 kernel weight, number of kernels per ear, number of kernel rows per ear, ear length, ear height, days to 50 per cent brown husk and days to 50 per cent tasseling resulting in positive and significant correlation with yield. Number of kernels per ear had direct poor effect. It showed positive and indirect contribution through 100 kernel weight, number of kernels per row, number of kernel rows per ear, ear length, ear height, days to 50 per cent brown husk and days to 50 per cent tasseling resulting in positive

correlations with yield. Hundred kernel weight had direct positive effect and it had indirect and positive influence through number of kernels per ear, number of kernels per row, number of kernel rows per ear, ear length, ear height, days to 50 per cent brown husk and days to 50 per cent tasseling resulting in significant and positive correlation with yield.

Protein content had direct positive effect and it had negative indirect influence through 100 kernel weight, number of kernels per ear, number of kernels per row, number of kernel rows per ear, ear height, days to 50 per cent silking and days to 50 per cent tasseling resulting in negative and significant correlations with yield. Oil content had direct effect positive effect and it showed indirect positive influence through protein content, number of kernels per row, ear girth, ear height and days to 50 per cent silking. On the other hand it had indirect negative *effect through 100 kernel weight, number of kernels per ear, number of kernel rows per ear, ear length, plant height and days to 50 per cent tasseling.*

1.8 STABILITY PARAMETERS FOR GRAIN YIELD AND YIELD COMPONENTS

Grading of Environments

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correlations with yield. Hundred kernel weight had direct positive effect and it had indirect and positive influence through number of kernels per ear, number of kernels per row, number of kernel rows per ear, ear length, ear height, days to 50 per cent brown husk and days to 50 per cent tasseling resulting in significant and positive correlation with yield.

Protein content had direct positive effect and it had negative indirect influence through 100 kernel weight, number of kernels per ear, number of kernels per row, number of kernel rows per ear, ear height, days to 50 per cent silking and days to 50 per cent tasseling resulting in negative and significant correlations with yield. Oil content had direct effect positive effect and it showed indirect positive influence through protein content, number of kernels per row, ear girth, ear height and days to 50 per cent silking. On the other hand it had indirect negative effect through 100 kernel weight, number of kernels per ear, number of kernel rows per ear, ear length, plant height and days to 50 per cent tasseling.

4.8 STABILITY PARAMETERS FOR GRAIN YIELD AND YIELD COMPONENTS

4.8.1 Grading of Environments

The pooled analysis of variance for 14 characters over three locations viz., Rajendranagar, Palem and Karimnagar revealed

Table 11 : Pooled analysis of variance for Grain Yield and its components involving 55 maize Genotypes over three environments

Source	Df	Days to 50 % tasseling	Days to 50% silking	Days to 50% brown husk	Ear height (cm)	Plant height (cm)
Genotypes	54	5.086**	5.131**	5.625**	303.665**	1201.259**
Environment (Linear)	1	19.245**	57.430**	51.425**	284.355**	788.492**
Envi. + (Geno. X Envi.)	110	0.795	1.221	1.522	0.8912	46.345
Genotype x Envi (Linear)	54	0.915**	1.048**	1.419*	14.148**	51.316*
Pooled deviation	55	0.336	0.361	0.735*	3.408	27.975
Pooled error	330	0.414	0.386	0.500	5.071	29.105
SE(b) ±		0.980	0.588	0.886	0.811	1.405

Source	df	Ear length (cm)	Ear girth (cm)	No. of kernel rows/ear	No. of kernels / row	No. of kernels / ear
Genotypes	54	16.000**	5.233**	3.024**	59.886**	17170.371**
Environment (Linear)	1	10.295**	64.662**	0.879**	13.437**	7595.322**
Envi. + (Geno. X Envi.)	110	0.888	1.554	0.401	1.427	754.303
Genotype x Env(Linear)	54	0.779	1.196	0.438	1.664*	749.457
Pooled deviation	55	0.824	0.757	0.356	0.974	634.741**
Pooled error	330	1.695	1.655	0.172	0.924	212.581
SE(b) ±		2.105	0.802	4.724	1.997	2.143

Source	df	100 kernel weight (g)	Protein content (%)	Oil content (%)	Grain yield (kg/plot)
Genotypes	54	19.957**	1.455**	1.479**	1.529**
Environment (Linear)	1	15.045*	0.199	0.139	0.661**
Envi. + (Geno. X Envi.)	110	2.192	0.160	0.094	0.080
Genotype x Env(Linear)	54	2.010	0.124	0.104	0.071
Pooled deviation	55	2.138**	0.194	0.085	0.078**
Pooled error	330	0.578	0.274	0.175	0.027
SE(b) ±		2.806	8.014	5.941	2.554

* Significant (P<0.05) ** : Significant (P<0.01)

significant differences among genotypes (Table 11). Environment (linear) was also significant for all characters except protein and oil content. The magnitude of environment (linear) was higher for all characters. The genotype x environment interaction was significant for days to 50 per cent tasseling, days to 50 per cent silking, days to 50 per cent brown husk, ear height, plant height and number of kernels per row. Pooled deviations were significant for days to 50 per cent brown husk, number of kernels per ear, 100 kernel weight and grain yield.

The mean values and environmental index for grain yield and its components under each environment in the present study at Rajendranagar, Palem and Karimnagar were presented in Table 12.

A comparative study of environmental mean with grand mean helped to grade the environments. For grain yield the location Rajendranagar was favourable as indicated by highest positive environmental index value and was followed by Karimnagar and Palem. Similar trend was observed for oil content. However, for protein content Palem was found to be favourable environment. For other characters viz., ear height, plant height, ear length, ear girth, number of kernel rows per ear, number of kernels per row, number of kernels per ear and 100 kernel weight at Rajendranagar location was most favourable. Palem location was found to be favourable for days to

Table 12: Mean and the environmental indices for grain yield and its components for each environment

Characters		Environments			
		Rajendranagar	Palem	Karimnagar	Grand mean
1.Days to 50% tasseling	$\overline{X}$	55.51	56.35	55.93	55.92
	ij	-0.420	0.416	0.004	
2.Days to 50% silking	$\overline{X}$	58.13	59.52	59.17	58.93
	ij	-0.810	0.577	0.232	
3.Days to 50% brown husk	$\overline{X}$	88.81	90.13	89.78	89.57
	ij	-0.763	0.557	0.206	
4. Ear height	$\overline{X}$	79.12	76.30	79.05	78.16
	ij	0.964	-1.857	0.893	
5.Plant height	$\overline{X}$	193.88	188.56	191.24	191.22
	ij	2.653	-2.670	0.017	
6.Ear length	$\overline{X}$	16.77	16.23	16.75	16.58
	ij	0.184	-0.352	0.167	
7.Ear girth	$\overline{X}$	15.32	13.78	14.51	14.53
	ij	0.781	-0.751	-0.029	
8.Number of kernel rows per ear	$\overline{X}$	14.82	14.65	14.69	14.72
	ij	0.101	-0.068	-0.032	
9.Number of kernels per ear	$\overline{X}$	34.16	33.62	33.50	33.75
	ij	0.398	-0.141	-0.256	
10.No. of kernels per ear	$\overline{X}$	503.45	488.32	489.94	493.90
	ij	9.549	-5.583	-3.965	
11. 100 kernel weight	$\overline{X}$	34.78	34.08	34.41	34.35
	ij	0.419	-0.273	-0.145	
12. Protein content (%)	$\overline{X}$	10.56	10.61	10.54	10.57
	ij	-0.008	0.042	-0.034	
13.Oil content (%)	$\overline{X}$	7.20	7.15	7.13	7.15
	ij	0.039	-0.014	-0.025	
14. Grain yield (kg/plot)	$\overline{X}$	3.52	3.38	3.43	3.42
	ij	0.089	-0.049	-0.040	
	Total ij	13.176	-10.167	-3.009	

$\overline{X}$ = Mean ij = Environmental index

50 per cent tasseling, days to 50 per cent silking, days to 50 per cent brown husk and protein content.

4.8.2 Estimates of Stability Parameters of Ten Parents

The estimates of the stability parameters *viz.*, mean, regression coefficient (b_i) and deviation from regression (S^2d_i) of the parental lines from various characters are presented below (Table 13a – 13e).

4.8.2.1 Days to 50 per cent tasseling

In the parental lines the estimates of deviation from regression (S^2d_i) were non-significant. The parental lines P_3 , P_5 and P_8 had unit regression coefficient. Parental lines P_1 , P_2 , P_4 and P_9 recorded regression coefficient less than unity.

4.8.2.2 Days to 50 per cent silking

The parental lines P_3 , P_8 and P_{10} had unit regression coefficient. The values of deviation from regression were non-significant for all the parental lines, indicating their suitability for wider environments. Parental lines P_1 , P_2 , P_4 , P_5 , P_6 , P_7 and P_9 with regression coefficient significantly less than unity, were suitable for poor environments.

Parent	Days to 50% Tasseling			Days to 50% Silking			Days to 50% Brown husk		
	Mean	bi	s ² di	Mean	bi	s ² di	Mean	bi	s ² di
P ₁	58.330	-1.594*	-0.413	61.220	-0.295*	0.042	91.330	-0.596	-0.170
P ₂	59.330	-1.201*	-0.252	62.440	-0.812**	-0.111	92.670	-1.412**	-0.366
P ₃	56.780	-0.389	0.052	59.670	0.666	0.040	89.890	1.086	-0.418
P ₄	59.220	-1.598*	-0.344	62.220	-0.628**	-0.279	92.670	-0.941*	-0.439
P ₅	57.000	0.000	-0.414	59.670	-0.553*	-0.040	91.670	0.815	-0.453
P ₆	56.890	-1.205*	0.041	60.330	-0.553*	-0.039	90.890	-0.324	-0.078
P ₇	59.440	-0.805	-0.121	62.560	-0.407*	-0.041	93.000	-0.691	-0.057
P ₈	57.330	0.405	-0.249	60.220	0.592	-0.232	90.780	0.668	-0.401
P ₉	57.000	-1.201*	-0.252	60.220	-0.517*	-0.369	92.110	1.013	-0.499
P ₁₀	59.440	-0.008	-0.117	62.440	-0.148	-0.112	91.440	-2.374**	-0.369
Mean of bi		1.000			1.000			0.999	
SE of bi		0.980			0.588			0.886	

Table 13 contd...

Parent	Ear height (cm)			Plant height (cm)			Ear length (cm)		
	Mean	bi	s ² di	Mean	bi	s ² di	Mean	bi	s ² di
P ₁	76.330	0.365	-4.524	154.670	1.817	-26.930	12.140	4.145	-1.263
P ₂	74.980	-0.332	-4.919	188.160	1.935	-16.292	13.070	1.571	-1.268
P ₃	57.520	1.221	1.588	164.300	0.353	-22.153	12.460	2.341	-1.692
P ₄	78.670	3.251**	-0.227	188.230	3.301	-19.825	13.540	-0.739	-1.632
P ₅	51.680	1.929	11.363	111.910	5.680	62.684	13.030	1.979	0.112
P ₆	54.310	0.076	-5.056	163.140	2.018	-24.773	11.610	2.762	-1.625
P ₇	61.390	0.242	-4.968	150.170	2.839	-1.526	11.700	0.715	-1.183
P ₈	65.110	1.076	0.981	171.290	-0.025	-28.755	12.120	5.029	3.061
P ₉	67.260	1.304	-5.059	148.590	1.178	-26.348	12.510	-0.352	-1.682
P ₁₀	68.880	0.495	-3.194	173.370	2.895	-26.097	13.110	1.733	0.383
Mean of bi		0.999			1.005			1.002	
SE of bi		0.811			1.405			2.105	

4.8.2.3 Days to 50 per cent brown husk

Deviation from regression (S^2_{di}) was non-significant for days to 50 per cent brown husk in all the parental lines. Parental lines P_3 , P_6 and P_8 with low mean, unit regression and non-significant S^2_{di} appeared to be early maturing. Parental lines P_2 , P_4 and P_{10} recorded regression coefficient less than unity.

4.8.2.4 Ear height

The parental lines P_3 , P_5 , P_6 and P_7 recorded low ear height (which is desirable) b_i estimates were around unity and non-significant S^2_{di} were suitable for different environments. Parental lines P_4 recorded regression coefficient significantly greater than unity indicated its suitability for favourable environments.

4.8.2.5 Plant height

All the parental lines had non-significant deviation from regression (S^2_{di}) and b_i estimates equal to one. The parental lines P_2 , P_4 , P_8 and P_{10} had high plant height and were tall growing among all the parental lines.

4.8.2.6 Ear length

Parental lines P_2 , P_4 , P_5 and P_{10} recorded higher mean values for ear length while P_6 and P_7 had smaller ear size. The estimates of b_i and S^2_{di} were non-significant for all the genotypes.

4.8.2.7 Ear girth

All the parental lines recorded non-significant deviation from regression for ear girth. The parental lines P_2 , P_4 , P_5 , P_6 and P_7 recorded regression coefficient (b_i) equal to unity with more ear girth indicated stability of ear girth across environments.

4.8.2.8 Number of kernel rows per ear

All the parental lines had non-significant deviation from regression (S^2_{di}) for number of kernel rows per ear. Parental lines P_6 , P_8 , P_9 and P_{10} recorded regression coefficient equal to unity and more number of kernel rows per ear. The parental lines P_7 with regression coefficient significantly more than unity appeared suitable for better environment.

4.8.2.6 Ear length

Parental lines P_2 , P_4 , P_5 and P_{10} recorded higher mean values for ear length while P_6 and P_7 had smaller ear size. The estimates of b_i and S^2d_i were non-significant for all the genotypes.

4.8.2.7 Ear girth

All the parental lines recorded non-significant deviation from regression for ear girth. The parental lines P_2 , P_4 , P_5 , P_6 and P_7 recorded regression coefficient (b_i) equal to unity with more ear girth indicated stability of ear girth across environments.

4.8.2.8 Number of kernel rows per ear

All the parental lines had non-significant deviation from regression (S^2d_i) for number of kernel rows per ear. Parental lines P_6 , P_8 , P_9 and P_{10} recorded regression coefficient equal to unity and more number of kernel rows per ear. The parental lines P_7 with regression coefficient significantly more than unity appeared suitable for better environment.

4.8.2.9 Number of kernels per row

The deviation from regression (S^2d_i) values were non-significant for all the parental lines for P_4 . The parental lines P_2 , P_6 and P_8 with regression coefficient equal to unit and more number of

Table 13 contd....

Parent	Ear girth (cm)			No. of kernel rows per ear			No. of kernels per row		
	Mean	bi	s ² di	Mean	bi	s ² di	Mean	bi	s ² di
P ₁	11.420	0.594	-0.265	12.000	0.001	-0.172	26.110	2.752	-1.804
P ₂	12.560	1.225	-1.437	13.560	5.737	0.488	29.220	-0.229	0.026
P ₃	11.340	0.398	-1.614	13.330	7.087	-0.085	23.110	3.331	1.996
P ₄	13.610	0.674	-1.157	12.220	-2.868	-0.007	25.220	1.194	4.135*
P ₅	13.430	1.413	-1.655	13.330	0.001	-0.172	25.780	3.488	0.623
P ₆	14.920	2.525	-1.025	14.000	0.001	-0.172	28.330	-0.579	-0.339
P ₇	13.660	2.134	0.601	16.670	12.654*	-0.062	25.780	-3.345*	1.751
P ₈	12.690	0.701	-0.916	16.440	2.869	-0.007	29.220	0.193	-0.859
P ₉	12.560	1.682	-1.591	14.440	2.869	-0.007	24.560	-3.066*	-0.924
P ₁₀	12.410	2.209	-0.405	15.780	1.351	0.095	23.000	-3.102*	-0.385
Mean of bi		0.999			1.000			1.000	
SE of bi		0.802			4.724			1.997	

Table 13 contd....

Parent	No. of kernels per ear			100 kernel weight (g)			Protein content (%)		
	Mean	bi	s ² di	Mean	bi	s ² di	Mean	bi	s ² di
P ₁	321.890	0.509	-26.923	28.730	5.526	-0.260	10.920	-8.963	-0.219
P ₂	390.890	1.190	185.281	31.210	-0.207	-0.552	10.480	-0.950	-0.266
P ₃	316.00	3.821	-0.791	31.440	5.810	1.217	11.410	0.138	-0.274
P ₄	310.220	0.632	-78.276	30.620	3.671	0.002	10.440	0.317	-0.274
P ₅	334.670	3.323	-127.801	30.620	6.464	-0.130	11.320	0.055	-0.275
P ₆	395.330	-0.532	-27.692	32.940	2.934	-0.545	9.450	0.037	-0.272
P ₇	446.560	0.286	478.67**	32.170	5.630	-0.300	9.590	13.494	-233
P ₈	478.670	0.861	23.096	30.600	-8.186**	0.798	10.770	2.203	-0.27
P ₉	352.440	-0.490	210.989	27.580	1.138	1.049	10.450	-3.513	-0.267
P ₁₀	331.890	1.860	1897.67**	25.780	1.869	-0.578	11.250	5.555	-0.261
Mean of bi		0.999			1.003			1.093	
SE of bi		2.143			2.806			8.014	

kernels per row and were stable over environments. The parental lines P_7 , P_9 and P_{10} recorded regression coefficient less than unity indicating their suitability for poor environments.

4.8.2.10 Number of kernels per ear

Deviation from regression coefficient for all the parental lines recorded as non-significant except P_7 and P_{10} parents. The parental line P_2 , P_6 , P_7 and P_8 had regression coefficient equal to unity and recorded more number of kernels per ear and they were stable.

4.8.2.11 100 kernel weight

The parental lines P_2 , P_3 , P_6 and P_7 with non-significant S^2_{di} estimates, equal to unity and had more 100 kernel weight and were found stable even wider environments. The parental lines P_8 with regression coefficient significantly less than unity was specifically suitable for poor environments.

4.8.2.12 Protein content

All the parental lines had non-significant deviation of regression for protein content. The parental lines P_1 , P_3 , P_5 and P_{10} recorded regression coefficient equal to unity having higher mean values indicated stability of protein content over different environments.

Table 13 contd....

Parent	Oil content (%)			Grain yield (kg) per plot		
	Mean	bi	s ² di	Mean	bi	s ² di
P ₁	7.820	18.141*	-0.153	1.860	1.847	-0.011
P ₂	7.010	6.097	0.393	2.470	0.483	-0.015
P ₃	7.800	0.388	-0.172	2.000	4.495	-0.026
P ₄	7.170	-1.329	-0.169	1.970	3.070	-0.026
P ₅	7.490	1.219	-0.175	2.060	4.208	-0.011
P ₆	6.880	0.669	-0.173	2.610	0.771	-0.019
P ₇	7.150	-0.924	-0.175	2.760	-0.022	0.164
P ₈	7.170	-1.682	-0.093	2.930	-2.973	-0.026
P ₉	7.750	-5.227	0.309	1.950	0.149	-0.022
P ₁₀	8.040	-0.061	-0.175	1.720	1.512	0.032
Mean of bi		1.025			1.000	
SE of bi		5.941			2.554	

4.8.2.13 Oil content

All the parental lines recorded non-significant deviation from regression (S^2_{di}) for oil content. The parental lines P_3 , P_9 and P_{10} recorded regression coefficient (b_i) equal to unity possess high oil content and indicated stability of the character over wider environments. The parental line P_1 had regression coefficient (b_i) more than unity and hence suitable for better environment with below average adoptability.

4.8.2.14 Grain yield

The parental lines P_2 , P_6 , P_7 and P_8 with high grain yield per plot, non-significant deviation from regression (S^2_{di}) and regression coefficient (b_i) equal to unity were stable over wider environments.

4.8.3 Estimates of Stability Parameters of Crosses

The data on mean of three locations and stability parameters of 45 crosses for the various characters are given in Table 14 a to 14e.

4.8.3.1 Days to 50 per cent tasseling

The cross $P_3 \times P_5$ was earliest for days to 50 per cent tasseling (53.33 days). Thirty one crosses were earlier in tasseling than the general mean. Thirty six crosses did not significantly deviate from unity ($b_i=1$) while forty three crosses showed non-significant deviation from regression. Two crosses recorded significant deviation from regression

Table 14a : Estimates of stability parameters of 45 crosses of maize for days to 50 per cent tasseling, days to 50 per cent silking and days to 50 per cent brown husk

Cross	Days to 50% Tasseling			Days to 50% Silking			Days to 50% Brown husk		
	Mean	bi	s ² di	Mean	bi	s ² di	Mean	bi	s ² di
P ₁ x P ₂	55.220	0.389	0.052	58.000	0.776	-0.349	88.220	1.212	-0.467
P ₁ x P ₃	54.670	0.405	0.249	57.670	0.333	-0.280	88.560	1.682	-0.411
P ₁ x P ₄	56.000	4.783**	-0.414	58.560	2.364*	-0.369	89.330	0.344	-0.389
P ₁ x P ₅	56.000	3.212*	2.201*	59.000	1.774	0.993	89.440	2.394	1.320
P ₁ x P ₆	55.670	-1.998**	-0.256	57.440	-0.259*	-0.382	88.670	-0.596	0.165
P ₁ x P ₇	55.330	0.012	0.253	58.000	0.999	0.573	89.220	0.836	0.921
P ₁ x P ₈	56.000	-0.416	1.081	60.110	0.960	-0.386	90.560	1.086	-0.421
P ₁ x P ₉	56.560	1.590	-0.337	59.560	0.702	-0.382	89.890	0.021	0.464
P ₁ x P ₁₀	55.220	0.008	-0.117	58.670	0.999	0.573	89.000	0.910	1.614
P ₂ x P ₃	55.670	3.593*	-0.262	58.440	1.957	0.134	89.780	2.049	0.533
P ₂ x P ₄	56.220	1.198	-0.397	59.220	0.702	-0.382	89.440	1.013	-0.498
P ₂ x P ₅	54.220	2.792	-0.399	57.220	2.031	-0.174	87.000	2.696	-0.417
P ₂ x P ₆	53.560	2.388	-0.334	57.560	2.697**	-0.351	87.550	3.093*	-0.052
P ₂ x P ₇	55.670	4.390**	-0.265	58.440	2.623**	-0.381	90.560	2.842*	-0.436
P ₂ x P ₈	55.110	1.217	1.8088*	58.000	1.664	2.2784*	87.330	1.600	3.991**
P ₂ x P ₉	54.890	2.388	-0.334	58.110	2.179*	-0.382	88.670	1.410	-0.362
P ₂ x P ₁₀	55.220	3.185*	-0.331	58.560	2.364*	-0.369	88.780	2.894*	-0.272
P ₃ x P ₄	55.440	0.397	-0.395	58.560	1.145	-0.347	87.560	4.003**	0.124
P ₃ x P ₅	53.330	2.391	-0.414	57.000	2.548	-0.278	87.440	1.043	2.3342*
P ₃ x P ₆	55.670	3.593*	-0.262	58.000	2.659	-0.234	90.560	1.462	0.683
P ₃ x P ₇	56.110	0.801	-0.343	59.220	0.924	-0.129	89.890	1.432	-0.123
P ₃ x P ₈	54.890	0.805	-0.123	58.110	0.850	-0.177	88.560	1.337	-0.101
P ₃ x P ₉	55.110	2.776	0.519	58.330	1.440	0.340	88.670	0.845	1.722
P ₃ x P ₁₀	55.000	0.393	-0.245	57.440	1.071	-0.175	87.780	0.918	1.007
P ₄ x P ₅	55.440	0.801	-0.342	58.440	1.404	-0.368	89.670	2.100	-0.407
P ₄ x P ₆	54.670	1.594	-0.414	58.330	1.662	-0.381	89.110	1.138	-0.308
P ₄ x P ₇	55.440	1.587	-0.109	58.560	1.255	0.042	89.330	0.375	1.368
P ₄ x P ₈	56.220	0.805	-0.122	59.000	1.552	-0.234	89.560	1.997	2.505*
P ₄ x P ₉	55.560	2.388	-0.335	58.670	1.883	0.579	88.890	1.242	3.020*
P ₄ x P ₁₀	54.670	2.380	0.271	57.000*	0.774	1.877	89.560	1.086	-0.422
P ₅ x P ₆	55.110	3.989**	-0.351	57.560	2.585**	0.714	87.560	2.748	0.504
P ₅ x P ₇	55.560	3.173*	0.805	58.780	1.957	0.134	88.890	1.807	0.072
P ₅ x P ₈	55.110	0.801	-0.342	58.330	0.886	-0.317	89.330	0.124	-0.295
P ₅ x P ₉	56.330	-0.393	-0.245	59.220	-0.184*	-0.347	91.330	1.160	-0.206
P ₅ x P ₁₀	56.000	0.012	0.253	59.220	1.035	-0.318	89.890	0.836	0.919
P ₆ x P ₇	56.330	0.405	-0.249	59.000	0.110	-0.176	89.380	-0.691	-0.059
P ₆ x P ₈	56.560	1.186	0.055	59.440	-0.148	-0.112	90.000	-0.221	0.122
P ₆ x P ₉	54.780	1.979	0.512	57.440	0.628	-0.278	89.440	0.793	0.097
P ₆ x P ₁₀	56.670	0.000	-0.414	59.220	0.148	-0.112	89.560	-0.199	-0.465
P ₇ x P ₈	56.000	0.000	-0.414	58.220	0.259	-0.381	90.670	0.124	-0.290
P ₇ x P ₉	56.000	0.012	0.253	58.890	0.148	-0.113	89.220	0.021	0.463
P ₇ x P ₁₀	55.560	1.590	-0.337	58.670	1.995	-0.319	88.890	2.968*	-0.449
P ₈ x P ₉	55.560	0.401	-0.396	58.000	0.554	-0.039	88.670	1.285	-0.489
P ₈ x P ₁₀	55.440	-0.793	-0.337	58.780	1.071	-0.175	89.220	0.051	0.015
P ₉ x P ₁₀	55.560	0.401	-0.396	59.560	2.586**	0.036	89.670	2.446	-0.101
Mean of bi		1.000			1.000			0.999	
SE of bi		0.980			0.588			0.886	

coefficient of unity. Based on mean, regression coefficient and deviation from regression and considering less number of days to 50 per cent tasseling desirable criteria, twenty four crosses were considered as stable.

4.8.3.2 Days to 50 per cent silking

The two crosses $P_3 \times P_5$ and $P_4 \times P_{10}$ were the earliest in silking (57.00 days). Thirty three crosses were earlier in number of days to 50 per cent silking than the general mean (58.93 days). Thirty four crosses did not significantly deviate from unit regression ($b_i = 1$), while forty four crosses showed non significant deviation from regression. Eleven crosses recorded significant deviation from regression coefficient of unity. Based on mean, regression coefficient and deviation from regression and considering less number of days to 50 per cent silking as a desirable criteria, twenty four crosses are considered as stable.

4.8.3.3 Days to 50 per cent brown husk

The lowest mean was recorded by $P_2 \times P_5$ (87.00 days) and it was earliest in days to 50 per cent brown husk. Thirty five crosses were earlier in number of days to 50 per cent brown husk than the general mean (89.57). Based on mean, regression coefficient and deviation from regression and considering less number of days to 50 per cent brown husk as a desirable criteria twenty eight crosses are considered as stable (Table 14a).

4.8.3.4 Ear height

The mean over locations ranged from 63.57 ($P_4 \times P_7$) to 90.34 cm ($P_6 \times P_9$). The estimates of b_i and S^2d_i indicated thirty seven hybrids as stable. The crosses, $P_2 \times P_3$, $P_4 \times P_8$ and $P_1 \times P_6$ had intermediate ear height with desired parameters.

4.8.3.5 Plant height

Average plant height of the hybrids ranged from 170.96 ($P_2 \times P_3$) to 215.47 cm ($P_6 \times P_{10}$). Forty one crosses exhibited non significant unit regression and S^2d_i estimates. The crosses $P_1 \times P_{10}$, $P_3 \times P_7$, $P_3 \times P_8$, $P_7 \times P_9$ and $P_7 \times P_{10}$ were tall and stable. The grand mean of crosses was 191.22 cm.

4.8.3.6 Ear length

The length of the ear ranged from 12.27 ($P_3 \times P_{10}$) to 19.36 cm ($P_9 \times P_{10}$). Thirty six crosses recorded higher mean ear length than the grand mean (16.58 cm) and recorded non significant unit regression and deviation from regression (Table 14b).

4.8.3.7 Ear girth

The mean range for ear girth ranged from 10.97 ($P_3 \times P_6$) to 16.98 cm ($P_5 \times P_7$). Forty crosses showed unit regression and non-significant S^2d_i estimates.

Table 14b : Estimates of stability parameters of 45 crosses of maize for ear height, plant height and ear length

Cross		Ear height (cm)			Plant height (cm)			Ear length (cm)		
		Mean	bi	s ² di	Mean	bi	s ² di	Mean	bi	s ² di
P ₁ X	P ₂	82.260	0.987	-4.629	189.590	3.566	-25.912	17.810	3.916	-1.700
	P ₃	80.860	-0.561	-5.005	195.400	2.473	-13.386	17.280	-0.843	-1.522
	P ₄	78.420	-2.150**	-4.390	207.330	0.619	-8.572	16.540	-0.142	-1.649
	P ₅	86.020	2.924*	-4.730	213.570	1.195	-16.893	17.920	-1.925	-1.691
	P ₆	80.670	0.495	-4.661	203.140	-3.570**	211.6**	17.220	3.096	-1.698
	P ₇	89.160	1.259	-3.968	198.310	0.952	-29.237	18.960	1.385	-1.685
	P ₈	85.740	0.115	-5.007	206.960	2.124	-28.643	17.600	2.768	-0.232
	P ₉	84.160	2.356	-4.732	210.370	1.186	11.580	18.080	2.438	2.785
	P ₁₀	86.620	0.886	0.484	214.170	3.206	42.898	16.400	-0.670	-1.670
	P ₃	79.280	2.095	-3.959	170.960	3.083	78.565	16.560	-2.359	-0.810
P ₂ X	P ₄	72.420	1.369	-3.553	190.630	0.392	0.408	17.130	-0.771	-0.110
	P ₅	65.200	0.800	-3.874	182.880	-0.357	-6.690	17.500	0.640	-1.529
	P ₆	80.520	9.913**	-0.272	196.990	1.321	-11.410	17.660	4.234	-1.698
	P ₇	85.960	1.946	-2.859	208.430	2.829	-17.717	17.610	0.642	-1.300
	P ₈	87.760	0.796	-4.844	202.830	0.996	-29.183	18.110	1.407	-1.103
	P ₉	71.110	0.398	10.218	188.440	1.047	-20.425	18.000	-2.101	-1.568
	P ₁₀	88.380	1.193	-2.745	187.100	0.139	-28.411	18.310	-1.769	0.888
	P ₄	81.660	2.803*	3.505	199.890	2.100	-22.916	17.700	4.049	-1.539
	P ₅	67.500	2.505	-3.794	177.880	0.497	7.133	17.210	-1.754	-1.668
	P ₆	87.060	1.595	-3.162	204.200	1.631	12.137	13.370	4.372	1.416
P ₃ X	P ₇	87.470	2.116	-5.043	211.810	2.663	-3.009	17.710	-2.269	-1.426
	P ₈	84.910	0.697	4.441	211.780	-0.047	-26.188	17.490	0.494	-1.153
	P ₉	89.090	0.986	-4.746	210.560	1.751	1.234	15.020	4.988	0.617
	P ₁₀	88.090	-1.596**	-4.463	188.700	-0.340	-28.582	17.020	1.242	-1.279
	P ₅	81.970	-0.190	-4.295	201.910	-0.375	-9.994	12.270	1.134	-1.692
	P ₆	88.880	1.629	-4.270	201.700	-0.150	-7.396	18.330	-2.387	1.940
	P ₇	88.700	0.527	-3.832	194.210	1.736	84.359	19.280	-1.003	-1.690
	P ₈	79.040	1.657	9.080	200.530	1.301	-4.249	17.230	3.237	-1.638
	P ₉	65.080	0.894	-4.173	181.740	0.187	-11.600	17.340	1.105	2.270
	P ₁₀	65.670	0.171	12.615	182.570	-6.473**	155.01*	17.830	0.073	-1.534
P ₅ X	P ₆	84.080	-0.717*	-3.110	182.090	-1.685	-13.863	16.260	1.763	-1.684
	P ₇	63.570	-0.574	8.241	176.540	-2.052*	3.750	16.540	1.052	1.544
	P ₈	65.800	0.920	5.058	185.010	-1.730	-28.637	16.460	1.032	-1.595
	P ₉	73.270	-0.937*	-0.473	183.070	-1.323	-18.825	18.480	0.635	-0.700
	P ₁₀	75.840	0.111	10.101	185.740	0.384	-25.259	17.130	2.529	-1.470
P ₆ X	P ₇	83.670	2.109	-4.463	200.200	0.633	28.670	18.580	-1.469	0.131
	P ₈	77.370	1.431	-4.937	199.630	1.722	-29.391	18.680	1.882	-1.089
	P ₉	90.340	-0.840*	-2.134	200.580	0.955	10.326	16.630	3.690	0.857
	P ₁₀	86.260	0.131	4.433	215.470	3.944*	-18.667	19.210	-0.924	-1.653
P ₇ X	P ₈	71.840	1.042	-2.940	209.100	1.194	-21.977	17.920	1.289	-1.679
	P ₉	85.780	1.885	-4.832	213.910	0.303	-27.269	18.920	2.334	-1.692
	P ₁₀	87.980	0.552	-4.268	212.680	1.901	-24.294	18.940	-0.305	-0.898
P ₈ X	P ₉	90.080	-0.292	4.410	193.140	0.112	-12.664	18.610	1.690	-1.157
	P ₁₀	86.110	0.194	-4.151	210.230	1.879	29.300	18.580	-1.495	-1.635
P ₉ X	P ₁₀	81.110	1.702	-4.012	201.660	1.410	20.745	19.360	-0.955	-1.593
Mean of bi			0.999			1.005			1.002	
SE of bi			0.811			1.405			2.105	

4.8.3.8 Number of kernel rows per ear

The number of kernel rows ranged from 13.78 ($P_5 \times P_8$ and $P_5 \times P_9$) to 16.44 ($P_2 \times P_9$). Fifteen crosses recorded mean higher than general mean (14.72) for number of kernel rows per ear with non-significant regression and S^2_{di} estimates.

4.8.3.9 Number of kernels per row

The number of kernels per row mean ranged from 28.67 ($P_4 \times P_5$) to 39.56 ($P_9 \times P_{10}$). Thirty two crosses recorded higher mean values than the general mean (33.75) and with non significant unit regression and deviation from regression.

4.8.3.10 Number of kernels per ear

The average number of kernels per ear ranged from 406.67 ($P_3 \times P_5$) to 594.00 ($P_6 \times P_7$). Thirty five crosses were found to be stable over environments with non significant unit regression and deviation from regression. The cross $P_6 \times P_7$ recorded highest number of kernels per row followed by $P_8 \times P_{10}$, $P_1 \times P_4$, $P_1 \times P_7$ and $P_2 \times P_{10}$ and were found stable.

4.8.3.11 100 kernel weight

Mean, regression coefficient (bi) and deviation from regression (S^2_{di}) for 100 kernel weight are presented in Table 14d.

Table 14c : Estimates of stability parameters of 45 crosses of maize for ear girth, number of kernel row per ear and number of kernels per row

Cross		Ear girth (cm)			No. of kernel rows per ear			No. of kernels per row		
		Mean	bi	s ² di	Mean	bi	s ² di	Mean	Bi	s ² di
P ₁ x	P ₂	14.380	-0.951	-0.172	14.000	0.001	-0.172	36.330	0.157	-0.708
	P ₃	14.840	0.231	1.743	15.560	5.737	0.488	38.670	0.894	-0.897
	P ₄	14.900	-0.399	-0.770	16.000	0.001	-0.172	38.110	0.544	-0.922
	P ₅	15.710	1.391	2.701	15.330	-12.653**	-0.061	36.030	-0.157	-0.708
	P ₆	14.680	0.063	-1.650	14.220	-2.867	-0.007	39.330	2.259	2.053
	P ₇	14.700	-0.067	-1.654	15.780	2.869	-0.007	37.220	-1.279	-0.805
	P ₈	14.600	0.138	-1.449	14.440	1.350	0.095	36.440	1.908	1.372
	P ₉	15.130	1.278	-1.379	15.330	8.605	1.313**	36.560	1.666	-0.194
	P ₁₀	14.100	0.611	-1.651	15.110	4.387	1.595**	36.890	3.453	-0.650
	P ₁₀	14.100	0.611	-1.651	15.110	4.387	1.595**	36.890	3.453	-0.650
P ₂ x	P ₃	15.100	-0.518	2.276	14.000	0.001	-0.172	34.660	1.351	2.259
	P ₄	14.930	1.687	-0.653	15.560	16.272**	0.024	36.000	2.681	-0.679
	P ₅	14.830	1.597	-0.647	14.440	1.350	0.095	34.440	-2.451	1.239
	P ₆	15.560	-0.413	-1.175	14.670	7.087	-0.085	35.780	2.173	-0.892
	P ₇	16.030	1.308	-0.998	14.440	-5.736	0.488	30.220	1.244	-0.783
	P ₈	15.270	0.314	-1.511	15.110	-9.785*	0.374	36.560	-0.651	3.935*
	P ₉	13.860	0.795	-1.489	16.440	-2.699	0.897	34.780	4.117	-0.545
	P ₁₀	16.070	0.414	-1.208	16.000	0.001	-0.172	36.110	-1.086	-0.916
	P ₁₀	16.070	0.414	-1.208	16.000	0.001	-0.172	36.110	-1.086	-0.916
	P ₁₀	16.070	0.414	-1.208	16.000	0.001	-0.172	36.110	-1.086	-0.916
P ₃ x	P ₄	13.380	-1.938**	-1.057	14.670	-8.604*	1.313**	33.440	3.331	1.996
	P ₅	14.720	-0.219	-1.653	14.000	0.001	-0.172	28.780	3.860	-0.902
	P ₆	10.970	0.667	-1.603	14.000	0.001	-0.172	32.220	10.865**	-0.120
	P ₇	15.590	1.075	1.618	14.000	0.001	-0.172	35.660	-0.386	-0.665
	P ₈	14.700	0.892	-1.655	15.780	-4.217	-0.160	37.000	0.457	-0.708
	P ₉	14.780	0.625	-1.625	14.890	4.219	-0.160	33.440	-1.117	-0.545
	P ₁₀	16.030	1.194	-1.048	14.000	0.001	-0.172	33.330	-1.787	-0.814
	P ₁₀	16.030	1.194	-1.048	14.000	0.001	-0.172	33.330	-1.787	-0.814
	P ₁₀	16.030	1.194	-1.048	14.000	0.001	-0.172	33.330	-1.787	-0.814
	P ₁₀	16.030	1.194	-1.048	14.000	0.001	-0.172	33.330	-1.787	-0.814
P ₄ x	P ₅	11.570	0.353	-1.359	14.670	0.001	-0.172	28.670	0.894	-0.897
	P ₆	16.870	2.361	-1.491	16.220	4.219	-0.160	33.000	-1.472	-0.564
	P ₇	15.260	1.769	-1.593	14.890	-1.349	0.095	35.670	-3.102*	-0.385
	P ₈	13.980	1.785	-1.068	15.110	8.436	-0.123	36.220	-0.071	1.149
	P ₉	16.060	1.018	-1.637	15.330	-1.518	0.680*	28.780	0.543	-0.922
	P ₁₀	15.020	1.695	-1.219	14.890	5.737	0.488	37.220	3.031	-0.427
	P ₁₀	15.020	1.695	-1.219	14.890	5.737	0.488	37.220	3.031	-0.427
	P ₁₀	15.020	1.695	-1.219	14.890	5.737	0.488	37.220	3.031	-0.427
	P ₁₀	15.020	1.695	-1.219	14.890	5.737	0.488	37.220	3.031	-0.427
	P ₁₀	15.020	1.695	-1.219	14.890	5.737	0.488	37.220	3.031	-0.427
P ₅ x	P ₆	15.160	3.113*	0.617	14.890	11.304*	-0.138	37.110	1.751	0.179
	P ₇	14.6410	1.563	-1.647	14.000	-3.036	3.236**	38.440	1.015	0.899
	P ₈	14.510	2.866*	-1.337	13.780	2.869	-0.007	36.000	1.944	-0.292
	P ₉	15.070	1.766	-1.347	13.780	2.869	-0.007	35.780	-3.452*	-0.649
	P ₁₀	14.600	0.276	-1.609	15.560	-2.867	-0.007	33.780	4.961	2.473
	P ₁₀	14.600	0.276	-1.609	15.560	-2.867	-0.007	33.780	4.961	2.473
	P ₁₀	14.600	0.276	-1.609	15.560	-2.867	-0.007	33.780	4.961	2.473
	P ₁₀	14.600	0.276	-1.609	15.560	-2.867	-0.007	33.780	4.961	2.473
	P ₁₀	14.600	0.276	-1.609	15.560	-2.867	-0.007	33.780	4.961	2.473
	P ₁₀	14.600	0.276	-1.609	15.560	-2.867	-0.007	33.780	4.961	2.473
P ₆ x	P ₇	16.980	2.529	-1.417	15.780	2.869	-0.007	37.890	0.036	-0.406
	P ₈	14.470	2.381	1.413	14.000	0.001	-0.172	36.780	1.594	-0.582
	P ₉	15.180	1.494	-0.847	15.780	-4.217	-0.160	35.780	4.274	0.244
	P ₁₀	15.340	0.677	-1.266	14.000	0.001	-0.172	37.780	-1.086	-0.916
P ₇ x	P ₈	15.300	0.968	-1.516	15.110	-4.217	-0.160	36.860	2.16	-0.874
	P ₉	15.180	0.863	-0.814	14.000	4.050	2.234**	38.890	-0.278	1.798
	P ₁₀	15.070	1.645	-0.296	14.000	0.001	-0.172	33.440	-0.193	-0.859
P ₈ x	P ₉	14.880	2.016	-1.605	14.000	0.001	-0.172	35.220	5.239*	-0.887
	P ₁₀	15.720	1.251	-1.536	16.000	0.001	-0.172	37.780	-1.980	-0.918
P ₉ x	P ₁₀	15.210	-0.727*	-1.573	14.440	-5.736	0.488	39.560	1.244	-0.784
Mean of bi			0.999			1.000			1.000	
SE of bi			0.802			4.724			1.997	

Table 14d : Estimates of stability parameters of 45 crosses of maize for number of kernels per ear, 100 kernel weight and protein content

Cross		No. of kernels per ear			100 kernel weight (g)			Protein content (%)		
		Mean	bi	s ² di	Mean	bi	s ² di	Mean	bi	s ² di
P ₁ x	P ₂	509.890	-0.114	-167.16	34.890	1.781	-0.358	11.600	-1.271	-0.083
	P ₃	571.110	2.355	602.824	36.620	-0.711	3.6311*	10.990	9.375	-0.245
	P ₄	578.110	0.191	-187.98	37.110	0.363	-0.317	10.790	1.527	-0.082
	P ₅	557.110	-6.002**	-112.96	37.800	-4.723*	1.168	10.630	-0.223	-0.274
	P ₆	549.670	0.894	-297.18	36.940	1.410	24.04**	11.280	3.778	0.081
	P ₇	574.110	0.871	-183.33	36.930	1.011	-0.189	10.150	-0.153	-0.274
	P ₈	518.330	-0.142	1228.8*	34.700	2.784	3.0459*	11.110	0.420	0.221
	P ₉	541.000	2.482	677.11	35.810	1.511	0.441	9.760	0.800	0.098
	P ₁₀	517.440	4.302	-168.24	35.240	3.528	9.781**	10.230	10.056	1.083*
	P ₁₁	517.440	4.302	-168.24	35.240	3.528	9.781**	10.230	10.056	1.083*
P ₂ x	P ₃	484.000	1.102	333.16	35.280	4.560	0.139	10.770	-1.779	0.32
	P ₄	557.220	4.890	-157.82	35.190	0.719	-0.185	10.570	7.963	-0.261
	P ₅	497.890	-0.309	-200.78	35.710	1.892	-0.533	11.820	-2.306	-0.271
	P ₆	526.220	3.729	2.248	35.220	1.352	4.572**	10.640	-0.685	-0.181
	P ₇	436.890	-0.897	1216.9*	32.790	0.923	-0.405	11.430	0.102	-0.274
	P ₈	548.330	-4.957**	-212.5	36.620	-0.723	0.116	10.580	-2.546	0.371
	P ₉	569.00	1.012	-54.510	36.210	0.341	2.6180*	10.990	-13.662	-0.162
	P ₁₀	572.330	-0.711	-13.621	38.090	3.686	0.283	9.480	-1.485	-0.209
	P ₁₁	572.330	-0.711	-13.621	38.090	3.686	0.283	9.480	-1.485	-0.209
	P ₁₂	572.330	-0.711	-13.621	38.090	3.686	0.283	9.480	-1.485	-0.209
P ₃ x	P ₄	489.110	-0.448	526.907	36.280	4.365	2.034	10.140	-0.115	-0.273
	P ₅	406.670	3.233	-12.690	33.080	2.686	-0.372	9.560	0.051	-0.269
	P ₆	452.560	6.704*	-184.05	33.260	1.498	-0.464	11.750	-3.154	-0.26
	P ₇	498.890	-0.257	-207.90	35.280	-1.076	0.429	10.160	-0.040	-0.273
	P ₈	534.780	-1.680	969.21*	35.830	-1.014	-0.495	9.700	-5.615	-0.27
	P ₉	500.670	5.343*	-61.193	33.810	3.367	3.3449*	10.280	2.776	-0.232
	P ₁₀	475.110	-0.531	-149.96	34.310	0.380	-0.579	10.310	10.067	0.198
	P ₁₁	475.110	-0.531	-149.96	34.310	0.380	-0.579	10.310	10.067	0.198
	P ₁₂	475.110	-0.531	-149.96	34.310	0.380	-0.579	10.310	10.067	0.198
	P ₁₃	475.110	-0.531	-149.96	34.310	0.380	-0.579	10.310	10.067	0.198
P ₄ x	P ₅	422.000	3.206	-153.55	31.430	1.440	-0.581	9.750	-10.141	2.242**
	P ₆	531.000	0.419	-54.827	35.030	0.800	-0.523	10.210	-1.041	-0.228
	P ₇	532.110	-2.584	-20.266	34.630	-1.106	-0.341	10.170	-0.574	-0.273
	P ₈	546.330	1.729	-1.166	35.120	-3.315	2.130	11.340	3.945	-0.24
	P ₉	446.220	-0.566	4035**	32.580	1.529	-0.568	10.620	2.705	0.209
	P ₁₀	534.330	4.405	700.877	34.860	-0.396	-0.473	9.240	-0.207	-0.274
	P ₁₁	534.330	4.405	700.877	34.860	-0.396	-0.473	9.240	-0.207	-0.274
	P ₁₂	534.330	4.405	700.877	34.860	-0.396	-0.473	9.240	-0.207	-0.274
	P ₁₃	534.330	4.405	700.877	34.860	-0.396	-0.473	9.240	-0.207	-0.274
	P ₁₄	534.330	4.405	700.877	34.860	-0.396	-0.473	9.240	-0.207	-0.274
P ₅ x	P ₆	545.890	3.792	-204.04	34.380	-0.005	-0.496	11.760	-0.556	-0.268
	P ₇	538.000	-0.455	9114**	37.290	0.272	26.39**	10.490	24.263**	-0.056
	P ₈	494.670	1.399	-212.95	35.190	-1.449	0.608	10.960	-0.864	-0.209
	P ₉	492.780	-1.093	72.593	34.010	0.417	1.798	11.570	2.227	-0.239
	P ₁₀	525.670	2.959	-202.22	33.240	-2.166	6.26**	9.900	12.827	-0.155
	P ₁₁	525.670	2.959	-202.22	33.240	-2.166	6.26**	9.900	12.827	-0.155
	P ₁₂	525.670	2.959	-202.22	33.240	-2.166	6.26**	9.900	12.827	-0.155
	P ₁₃	525.670	2.959	-202.22	33.240	-2.166	6.26**	9.900	12.827	-0.155
	P ₁₄	525.670	2.959	-202.22	33.240	-2.166	6.26**	9.900	12.827	-0.155
	P ₁₅	525.670	2.959	-202.22	33.240	-2.166	6.26**	9.900	12.827	-0.155
P ₆ x	P ₇	594.000	1.301	-193.90	38.360	-2.524	-0.372	9.510	-1.398	-0.272
	P ₈	517.890	0.842	-126.99	35.780	1.754	-0.557	11.490	1.813	-0.275
	P ₉	560.330	0.766	75.970	34.920	-4.273	-0.324	11.100	-9.242	-0.086
	P ₁₀	541.780	0.994	-201.33	35.000	0.677	-0.460	10.720	3.826	-0.276
	P ₁₁	541.780	0.994	-201.33	35.000	0.677	-0.460	10.720	3.826	-0.276
	P ₁₂	541.780	0.994	-201.33	35.000	0.677	-0.460	10.720	3.826	-0.276
	P ₁₃	541.780	0.994	-201.33	35.000	0.677	-0.460	10.720	3.826	-0.276
	P ₁₄	541.780	0.994	-201.33	35.000	0.677	-0.460	10.720	3.826	-0.276
	P ₁₅	541.780	0.994	-201.33	35.000	0.677	-0.460	10.720	3.826	-0.276
	P ₁₆	541.780	0.994	-201.33	35.000	0.677	-0.460	10.720	3.826	-0.276
P ₇ x	P ₈	549.560	-1.736	-197.36	36.340	0.614	-0.075	11.250	-0.884	-0.248
	P ₉	546.890	3.125	1155.2*	35.460	5.102	-0.543	10.910	0.051	-0.274
	P ₁₀	469.890	-0.231	-212.48	33.190	0.733	-0.541	9.490	-7.329	0.579
	P ₁₁	469.890	-0.231	-212.48	33.190	0.733	-0.541	9.490	-7.329	0.579
	P ₁₂	469.890	-0.231	-212.48	33.190	0.733	-0.541	9.490	-7.329	0.579
	P ₁₃	469.890	-0.231	-212.48	33.190	0.733	-0.541	9.490	-7.329	0.579
	P ₁₄	469.890	-0.231	-212.48	33.190	0.733	-0.541	9.490	-7.329	0.579
	P ₁₅	469.890	-0.231	-212.48	33.190	0.733	-0.541	9.490	-7.329	0.579
	P ₁₆	469.890	-0.231	-212.48	33.190	0.733	-0.541	9.490	-7.329	0.579
	P ₁₇	469.890	-0.231	-212.48	33.190	0.733	-0.541	9.490	-7.329	0.579
P ₈ x	P ₉	494.220	2.948	-150.34	34.620	2.835	1.264	10.500	0.557	-0.265
	P ₁₀	581.890	-0.292	-211.03	37.190	-0.618	-0.536	9.410	16.910	0.023
	P ₁₁	581.890	-0.292	-211.03	37.190	-0.618	-0.536	9.410	16.910	0.023
	P ₁₂	581.890	-0.292	-211.03	37.190	-0.618	-0.536	9.410	16.910	0.023
	P ₁₃	581.890	-0.292	-211.03	37.190	-0.618	-0.536	9.410	16.910	0.023
	P ₁₄	581.890	-0.292	-211.03	37.190	-0.618	-0.536	9.410	16.910	0.023
	P ₁₅	581.890	-0.292	-211.03	37.190	-0.618	-0.536	9.410	16.910	0.023
	P ₁₆	581.890	-0.292	-211.03	37.190	-0.618	-0.536	9.410	16.910	0.023
	P ₁₇	581.890	-0.292	-211.03	37.190	-0.618	-0.536	9.410	16.910	0.023
	P ₁₈	581.890	-0.292	-211.03	37.190	-0.618	-0.536	9.410	16.910	0.023
P ₉ x	P ₁₀	552.330	1.59	-210.16	34.260	0.337	1.330	9.820	2.485	0.337
	P ₁₁	552.330	1.59	-210.16	34.260	0.337	1.330	9.820	2.485	0.337
	P ₁₂	552.330	1.59	-210.16	34.260	0.337	1.330	9.820	2.485	0.337
	P ₁₃	552.330	1.59	-210.16	34.260	0.337	1.330	9.820	2.485	0.337
	P ₁₄	552.330	1.59	-210.16	34.260	0.337	1.330	9.820	2.485	0.337
	P ₁₅	552.330	1.59	-210.16	34.260	0.337	1.330	9.820	2.485	0.337
	P ₁₆	552.330	1.59	-210.16	34.260	0.337	1.330	9.820	2.485	0.337
	P ₁₇	552.330	1.59	-210.16	34.260	0.337	1.330	9.820	2.485	0.337
	P ₁₈	552.330	1.59	-210.16	34.260	0.337	1.330	9.820	2.485	0.337
	P ₁₉	552.330	1.59	-210.16	34.260	0.337	1.330	9.820	2.485	0.337
Mean of bi			0.999			1.003			1.093	
SE of bi			2.143			2.806			8.014	

Among the crosses studied, $P_6 \times P_7$ recorded highest 100 kernel weight 38.36 g. Thirty four crosses were recorded with mean values above general mean. Taking into consideration mean, regression coefficient and deviation from regression, twenty six crosses were found stable for 100 kernel weight.

4.8.3.12 Protein content

Protein content ranged from 9.24 ($P_4 \times P_{10}$) to 11.82 per cent ($P_2 \times P_5$). Twenty four crosses recorded higher mean values for protein content above the general mean (10.57). Forty three crosses showed non significant unit regression (bi) and deviation from regression (S^2di) for protein content (Table 14d).

4.8.3.13 Oil content

The oil content ranged from 5.88 ($P_4 \times P_5$) to 8.77 per cent ($P_6 \times P_8$). The regression estimates of stability parameter were non significant for forty one crosses whereas S^2di found to be non significant for all crosses except one. The cross combinations $P_6 \times P_8$, $P_3 \times P_8$, $P_7 \times P_8$, $P_6 \times P_{10}$, $P_5 \times P_6$, $P_3 \times P_6$, $P_2 \times P_6$ and $P_1 \times P_9$ possessed higher mean oil content and were stable over locations.

Table 14e : Estimates of stability parameters of 45 crosses of maize for oil content and grain yield

Cross		Oil content (%)			Grain yield (kg / plot)		
		Mean	bi	s ² di	Mean	bi	s ² di
P ₁ x	P ₂	6.160	0.321	-0.175	3.560	0.859	-0.019
	P ₃	6.170	-1.884	-0.135	4.200	1.163	0.172
	P ₄	7.210	-9.345	-0.067	4.280	0.377	-0.02
	P ₅	7.420	2.220	-0.08	4.210	-7.733*	0.005
	P ₆	6.710	-1.553	-0.175	4.020	0.763	0.426
	P ₇	7.520	7.240	0.11	4.250	1.118	-0.014
	P ₈	6.480	3.715	-0.171	3.620	1.743	0.176
	P ₉	7.890	-3.259	-0.121	3.880	2.428	0.08
	P ₁₀	7.900	-27.309**	-0.12	3.660	4.593	0.153
P ₂ x	P ₃	5.930	-3.137	-0.137	3.360	1.335	0.052
	P ₄	6.980	3.873	0.251	3.840	4.706	-0.026
	P ₅	7.390	1.334	-0.175	3.520	-0.287	-0.027
	P ₆	7.820	0.715	-0.168	3.720	3.151	0.097
	P ₇	6.600	15.805*	-0.125	2.990	-1.571	0.232
	P ₈	7.270	1.680	-0.174	4.030	-4.391*	-0.023
	P ₉	6.410	-1.154	-0.043	4.120	0.671	0.06
	P ₁₀	6.570	14.635*	-0.118	4.340	1.728	-0.022
P ₃ x	P ₄	7.010	-2.291	-0.172	3.530	1.292	0.076
	P ₅	5.950	-5.287	0.013	2.670	2.687	-0.015
	P ₆	7.800	0.782	-0.173	3.020	5.417	-0.027
	P ₇	6.700	0.538	-0.171	3.570	0.359	0
	P ₈	8.670	4.544	-0.174	3.830	-1.956	0.044
	P ₉	7.650	4.814	-0.174	3.400	5.774	-0.03
	P ₁₀	8.370	13.630*	0.008	3.270	-0.202	-0.024
P ₄ x	P ₅	5.880	-1.522	-0.174	2.670	2.610	-0.025
	P ₆	7.280	1.583	-0.175	3.730	0.688	-0.023
	P ₇	6.420	0.005	-0.172	3.690	-2.573	-0.008
	P ₈	6.950	4.299	-0.17	3.830	-0.541	-0.016
	P ₉	6.120	-4.427	.815*	2.840	1.329	0.049
	P ₁₀	6.830	0.694	-0.172	3.830	2.687	-0.026
P ₅ x	P ₆	7.830	0.163	-0.175	3.750	2.586	-0.026
	P ₇	6.590	2.858	-0.074	4.050	0.253	1.579
	P ₈	7.100	-1.068	-0.174	3.500	0.218	0.005
	P ₉	6.490	1.290	-0.174	3.350	-0.885	0.045
	P ₁₀	6.940	6.025	0.168	3.500	0.666	0.055
P ₆ x	P ₇	6.760	2.193	-0.165	4.500	0.270	-0.027
	P ₈	8.770	-0.283	-0.175	3.710	1.642	-0.023
	P ₉	7.650	1.969	-0.172	3.930	-1.399	0.011
	P ₁₀	7.880	1.669	-0.175	3.720	-0.244	-0.024
P ₇ x	P ₈	8.090	0.908	-0.17	4.020	-1.469	-0.023
	P ₉	7.800	-2.150	-0.174	3.910	5.174	-0.027
	P ₁₀	6.010	12.476	0.089	3.120	0.175	-0.026
P ₈ x	P ₉	7.520	1.679	-0.094	3.430	3.652	0
	P ₁₀	7.300	-3.911	-0.11	4.260	0.078	-0.027
P ₉ x	P ₁₀	6.680	-5.976	-0.168	4.070	2.523	-0.002
Mean of bi			1.025			1.00	
SE of bi			5.941			2.554	

4.8.3.14 Grain yield

The average grain yield of the crosses across the locations ranged from 2.67 ($P_3 \times P_5$ and $P_4 \times P_5$) to 4.50 kg per plot ($P_6 \times P_7$). Thirty three crosses recorded higher mean values for grain yield above the general mean (3.42 kg) and were stable over locations. The crosses $P_1 \times P_5$ and $P_2 \times P_8$ were suitable for un-favourable locations (Table 14e).

DISCUSSION

CHAPTER V

DISCUSSION

Maize is an important crop from the plant breeder's point of view, due to fact that many of the important concepts that had revolutionized the breeding methodologies are the outcome of research carried out on maize. Yield improvement in maize was mainly due to development of high yielding varieties, single cross hybrids, double cross hybrids, synthetics and composites. There was a continuous thrust on population improvement. Though double cross hybrids have shown higher yield levels but theoretically maximum exploitation of heterosis was possible through single cross hybrids only (Hallauer and Mirinda, 1988; Vasal, 1995). Hence the focus of maize breeders has shifted to develop high yielding single cross hybrids. For the production of commercially viable hybrids suitable inbreds need to be developed.

Though extensive research has been carried out on the crop for many quantitative characters but potential aspects like breeding for high protein content, oil content coupled with higher grain yields, remain relatively unemphasized. Keeping this in view, the present investigation was undertaken to identify suitable parents and hybrids. With this objective, 196 maize genotypes comprising 128 Quality Protein Maize (QPM) and 68 High Oil Lines (HOL) were evaluated. Based on the clustering pattern, ten divergent parents were selected. These parents

were crossed in diallel fashion (excluding reciprocals). The resulting 45 hybrids along with parents and two popular checks were evaluated at three locations *viz.*, Rajendranagar, Palem and Karimnagar. The results obtained are discussed cogently under different heads.

5.1 GENETIC DIVERGENCE

Selection of suitable and genetically divergent parents for the successful breeding programme is a difficult task for the plant breeder. Hence, it is necessary to study genetic diversity, variability and heritability present in the available germplasm lines. Diversity of parents is very much emphasized in breeding programmes, because the cross between the genotypes with maximum genetic divergence is likely to yield desirable types. The populations from diversified environments are expected to accumulate high genetic variability as compared to population inhabiting a similar ecological region. Generally, phenotypic or genotypic diversity could be considered as a measure of genetic diversity. Further, the multivariate analysis using Mahalanobis D^2 statistics provides a useful statistical tool for measuring the amount of genetic diversity present in a population in respect of characteristics considered. The success and usefulness of Mahalanobis analysis in quantifying the genetic divergence had been followed in maize (Saxena and Sandhu, 1989).

In the present investigation based on D^2 analysis, one hundred and ninety six genotypes comprising 128 quality protein maize and 68 high oil lines were grouped into five clusters. The magnitude of D^2 values suggests that there was a considerable amount of diversity in the material used in present investigation.

Intra cluster distance ranged from 4.53 (cluster II) and 6.41 (cluster III), which indicated that the genotypes of cluster II had less divergence among themselves. However, the genotypes in cluster III exhibited more divergence indicating comparative dissimilarity of the genotypes of this cluster. The maximum inter cluster distance was recorded in between cluster IV and V (46.69) followed by cluster III and V (36.01) and this might be due to limited gene exchange or selection practice among the genotypes for different characters. The genotypes from the cluster with high divergence could be isolated / selected for utilization in breeding programmes for obtaining desirable segregants. This may be explained on the basis that yield being a complex character of polygenic inheritance, similar genotypes could be produced by different combinations of genes. Such combinations may have selective advantage when constant selection is practiced in the population. It can be inferred that highest divergence occurred between cluster IV and V values (46.69), while it was least between I and II (13.30). The present findings were in agreement with the earlier findings of Singh *et al.* (1999), Khumkar and Singh (2002) and Mirinda *et al.* (2003).

Based on mean performance and genetic diversity, selection in cluster grouping appear to serve as a potential tool for choosing the parents for crossing for exploiting hybrid vigour and to improve productivity among the maize genotypes. Based on D^2 analysis, 10 parents were selected from different clusters *i.e.*, cluster I – 3 parents; cluster II – 3 parents; cluster III – 2 parents; cluster IV – 1 parent and cluster V – 1 parent.

5.2 NATURE OF GENE ACTION AND COMBINING ABILITY FOR GRAIN YIELD, YIELD COMPONENTS, OIL AND PROTEIN CONTENT

Knowledge of genetic architecture of yield and yield components enable a breeder to identify superior crosses. Ever since Sprague and Tatum (1942) had given the concept of combining ability in crop breeding, it has attained paramount importance in breeding experiments for isolating potential parental lines and superior performing hybrids. These concepts facilitate in determining the type of gene action controlling particular character which ultimately helps the breeder to formulate suitable breeding programme in exploiting, higher yields.

Average performance of parental line in series of cross combinations is generally referred to as general combining ability and is mainly attributed to additive and additive x additive gene effects which is mainly inter allelic interaction and indicate part of inter allelic

interaction also. However, deviation in the performance of a cross expected on the basis of average performance of parental lines is mainly attributed to dominant and epistatic effects and is termed as specific combining ability *i.e.*, non-additive part. Additive component of genetic variance is fixable through normal selection procedures, whereas non-additive component is not fixable and its presence for the controlling traits necessitates exploitation of hybrid vigor through heterosis breeding.

In the present investigation, genotypic differences were significant for all the 14 characters studied at Rajendranagar, Palem and Karimnagar. Cross (1977) and Han *et al.* (1991) observed additive and dominance gene effects depending on either parents are open pollinated or inbred lines. The combining ability analysis revealed significant mean squares due to general and specific combining ability indicating that both additive and non-additive gene actions were important in the inheritance of these characters. Alika (1994) reported predominant role of additive genetic variance for ear length, ear girth and 100 kernel weight except shelling per cent. The relative importance of additive and non-additive gene actions was reported by Nawar and Hosary (1984) and Muthaiah *et al.* (1989). They also observed predominant role of specific combining ability for plant height, height upto ear, ear length, ear girth, number of seeds per ear and number of seeds per row.

The magnitude of *gca* to *sca* variance was less than unity for all the characters studied, indicating predominant role of non-additive gene action in governing these characters. These results are in conformity with earlier investigations carried out by Appunu (2002) and Narasimha Reddy (2003) for earliness, Malwar *et al.* (1996) for ear height. In respect of plant height, primary action of non-additive gene action was reported by Mahamoud *et al.* (1990) and for ear length Mathur and Bhatnagar (1995). For 100 kernel weight Debnath and Sarkar (1990), Nagda *et al.* (1995), for grain yield Zelleke (2000) and Appunu (2002). Under these circumstances, for exploiting non-additive gene action and to improve these characters, one has to resort to recurrent selection and heterosis breeding procedures which lead to non-homozygous end products. Male sterility has been reported in maize, which may provide an opportunity for adopting these procedures.

The parental line P₃ possessed low *per se* means and turned out to be good general combiner for days to 50 per cent tasseling, silking and brown husk and contributed maximum favourable genes for earliness at all the three locations. Thus, it can be used as potential donor for inducing earliness.

The crosses P₂ x P₅ and P₄ x P₇ were the best specific combiners with significant negative *sca* effects for earliness. The

parents involved in these crosses were not good general combiners and are resultant of non-additive gene action, which can be improved through population improvement in addition to utilizing them in heterosis breeding.

In respect of plant height, P_1 and P_8 parents found to be taller at all the three locations. The parents possessed significant *gca* effects and recorded as good general combiners. An examination of *sca* effects of the crosses at all the locations indicated that, $P_1 \times P_5$, $P_6 \times P_{10}$ and $P_3 \times P_9$ were best specific crosses. First two crosses possess one of the parents as good combiner and gene action is of primarily non-additive type. The relative importance of additive gene action was reported by Hallauer and Mirinda (1988), Lima *et al.* (1995) and Zelleke (2000).

For ear height, P_5 was good general combiner. Thus, this parent can be used in breeding programmes aimed at improving the ear height. The best specific crosses are $P_4 \times P_9$, $P_4 \times P_{10}$ and $P_2 \times P_9$. None of these crosses have additive gene action and therefore heterosis breeding and recurrent selection are practiced.

Number of kernel rows per ear and number of kernels per ear had performed significant positive correlations with grain yield. For number of kernel rows per ear, P_8 and P_{10} parents were good general combiners and $P_2 \times P_9$, $P_1 \times P_4$, $P_4 \times P_6$ and $P_2 \times P_{10}$ were the best specific cross combinations. For number of kernels per ear P_6 , P_7 and P_8

turned to be good combiners and $P_1 \times P_3$, $P_2 \times P_4$ and $P_1 \times P_4$ were the best specific crosses.

The parents, P_7 and P_1 were good combiners for 100 kernel weight at all the locations. Many crosses exhibited significant *sca* effects but the crosses, $P_2 \times P_{10}$, $P_1 \times P_4$ and $P_9 \times P_{10}$ were the best specific cross combinations.

With global acceptance of maize endosperm oil, it can be considered as a rich source of nutritive oil with least detrimental affect on human health. Attention has been diverted to high oil rate of maize (Pal and Prodhan, 1994). Therefore, to identify potential parents and best crosses for oil content were evaluated. Among the parents, the best combiners for oil content were P_6 and P_8 at all the locations. The crosses, $P_3 \times P_8$ and $P_6 \times P_8$ were the best specific crosses. However the cross $P_6 \times P_8$ has both the parents as good general combiners and *sca* effects are significant at all the three locations. The gene action is mainly additive x additive type, which is fixable in nature. Desirable segregants can be identified from segregating progeny of this cross following pedigree selection.

The protein content of maize has nutritional value and it was demonstrated that protein content can be increased by breeding (Woodworth *et al.*, 1952). In the present investigation, it was interesting to note that the parents P_3 , P_5 and P_{10} possessed higher

protein content but P_5 and P_1 contributed maximum favourable genes for protein content. Considering, three locations, $P_3 \times P_6$ and $P_4 \times P_8$ were the best specific cross combinations. In these crosses, no parent is good general combiner and these were resultant of non-additive gene action. In such situations improvement can be achieved through population improvement in addition to utilizing them in heterosis breeding.

Grain yield is complex character and is influenced by number of its components apart from biotic and abiotic stresses. Among the ten parental lines P_1 , P_6 , P_7 and P_8 were identified as good general combiners at all the three locations. As many as, nine crosses exhibited significant *sca* effects at all the locations. The best specific combinations for grain yield are $P_1 \times P_7$, $P_1 \times P_6$, $P_2 \times P_{10}$, $P_1 \times P_3$ and $P_4 \times P_{10}$. Therefore, these hybrids are of considerable practical importance as they proved to be superior to popular commercial hybrids.

The cross, $P_1 \times P_7$ is derivative of high x high combiners and expected to throw transgressive segregants in the future generations.

Yield improvement can be sought from this cross by pedigree or simple selection procedure.

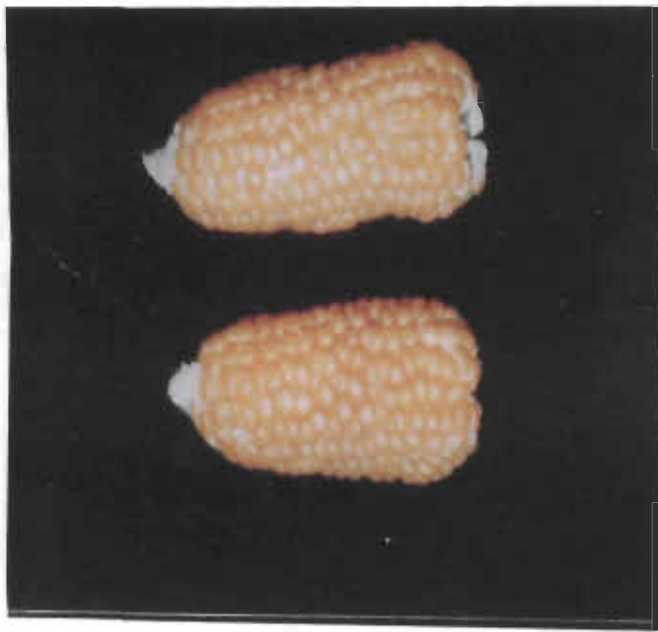
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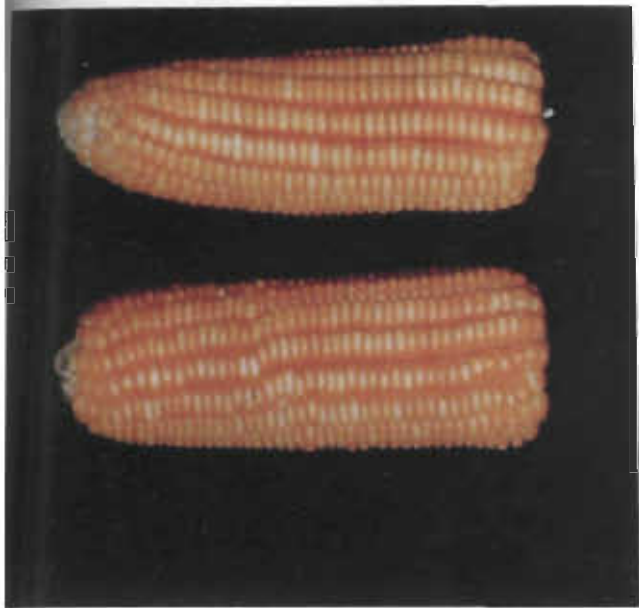
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The cross, $P_1 \times P_7$ is derivative of high x high combiners and expected to throw transgressive segregants in the future generations. Yield improvement can be sought from this cross by pedigree or simple selection procedure.

The other hybrids viz., $P_2 \times P_{10}$, $P_1 \times P_3$ and $P_1 \times P_4$ can be exploited by production of single cross hybrids in realizing their high yielding potential.



P₁



P₁ x P₄



P₄

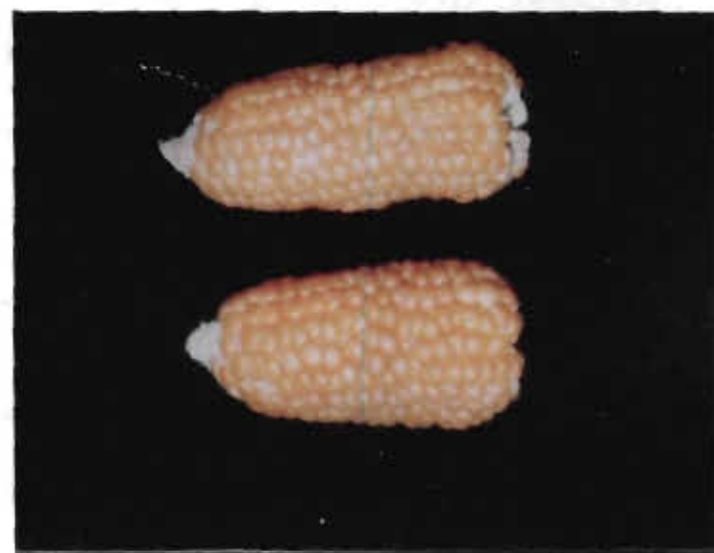
Plate 6 : Promising single cross P₁ x P₄



P₈



P₆ x P₈



P₆

Plate 7 : Promising single cross P₆ x P₈

The final selection of parents is mostly influenced by results on grain yield and other characters, which have direct bearing on yield (Venkatesh *et al.*, 2001). Venkatesh *et al.* (2001) suggested that the general picture of the combining ability of parents over all the characters is useful to decide the combining ability status of parents. Considering all the locations and yield contributing characters, P₁, P₆ and P₈ can be given the status of good general combiners and genetically worthy parents, as they contributed maximum favourable genes for grain yield and yield components. The parental line P₁ was good general combiner for plant height, number of kernels per row, number of kernels per ear and grain yield, 100 kernel weight, protein content and grain yield. Whereas P₈ was good general combiner for plant height, number of kernel rows per ear, number of kernels per row, number of kernels per ear, 100 kernel weight, oil content and grain yield. Hence, these high yielding parents with good attributes for different yield components may be inter crossed to pool the genes in desirable direction to improve the yield potential. Prasad *et al.* (1988) also suggested that grain yield in maize can be improved by improving component characters viz., kernel weight, kernel rows per ear and ear girth.

5.3 HETEROSIS

Shull (1952) gave the method of producing hybrid maize and with this, a new era was started. He outlined a plan using inbreeding to

establish inbred lines and crossing these to produce uniformly productive hybrids. The hybrid maize became extensively popular in United States corn belt during 1930's. This documented phenomenon of heterosis was widely used by maize breeders and thereafter many workers reported varying levels of heterosis in relation to mid parent, superior parent and standard check. In the present investigation also heterosis behaviour of 45 hybrids was estimated as heterosis (over the mean of the parents), heterobeltiosis (over superior parent) and standard heterosis (over high yielding check) in three locations viz., Rajendranagar, Palem and Karimnagar.

Maximum range of heterosis was observed for grain yield, number of kernels per ear, number of kernel rows per ear, ear length and plant height. The extent of heterosis was less for days to 50 per cent brown husk. The same trend of results was observed in all the locations.

Days to 50 per cent tasseling, days to 50 per cent silking and days to 50 per cent brown husk indicate the earliness of a genotype in maize. Earliness is a desirable character as it requires less moisture that too for a short period. Heterosis for earliness was reported by Daniel and Bajbay (1976), Dhillon and Singh (1977a), Hassaballa *et.al.* (1980), Crossa *et. al.* (1990), Mandal (1996), Satyanarayana and Sai Kumar (1996) and Venkatesh (1997). In the present investigation also many crosses exhibited heterosis for days to 50 per cent tasseling, silking and

brown husk but were not consistent and so also significant. However, the cross combinations, $P_2 \times P_5$, $P_2 \times P_6$, $P_2 \times P_7$ and $P_4 \times P_{10}$ registered significant level of heterosis and heterobeltiosis. These hybrids were earlier than the early parent and will be useful under rainfed cultivation.

Heterosis and heterobeltiosis for plant height was found to be positively significant in many crosses. The cross combinations, $P_1 \times P_9$ and $P_1 \times P_5$ were the best, recording a mean height of 214.10 and 213.51 cm, respectively over the locations. They were also superior for plant height over standard checks. Todorov (1981), Beck *et al.* (1990), Bhatnagar *et.al.* (1993) and Venkatesh (1997) also reported similar results.

Bhatnagar *et al.* (1993), Pandey *et al.* (1994) and Mandal (1996) reported heterosis for ear length. In the present study most of the hybrids possessed higher ear length when compared to better parent. Increase in ear length is useful to have higher number of kernels per ear resulting in higher yield as it has got significant genotypic correlation of 0.46**, 0.50** and 0.54** at Rajendranagar Palem and Karimnagar respectively.

Ear girth is an important character, which accommodates more number of rows on the ear and more number of grains per ear. This is also evident from the significant correlation at genotypic and phenotypic level at all the three locations.

The hybrids exhibited heterosis in positive direction for number of kernel rows per ear and number of kernels per ear, which are important components of grain yield. Among the crosses, $P_2 \times P_9$, $P_4 \times P_6$ and $P_1 \times P_4$ recorded more number of kernel rows per ear *i.e.*, 16.43, 16.22 and 16.00, respectively over all the locations. The average number of kernels per ear ranged from 531 to 578. Shah and Mukherjee (1985) also reported similar results.

The mean weight of 100 kernels ranged from 30.03 to 39.50 g at Rajendranagar, 31.03 to 40.47 grams at Palem and 31.23 to 39.50 g at Karimnagar. The hybrids, $P_5 \times P_7$, $P_6 \times P_7$, $P_2 \times P_{10}$ and $P_1 \times P_5$ had higher *per se* performance at all the locations ranging from 33.27 to 40.47 g. Heterosis, heterobeltiosis and standard heterosis were in positive direction for many hybrids. The above four hybrids registered significant heterosis and exceeded better parent and standard checks over the locations. Heterotic crosses for 100 kernel weight had also been reported by Verma and Singh (1980), Mukherjee and Saha (1984) and Mandal (1996).

The cross combinations, $P_2 \times P_{10}$, $P_6 \times P_7$, $P_2 \times P_9$, $P_1 \times P_7$, $P_1 \times P_3$, $P_1 \times P_4$ and $P_1 \times P_5$ recorded higher yield *per se* performance ranging from 3.51 to 4.52 kg per plot at Rajendranagar, 3.84 to 4.49 kg per plot at Palem and 4.21 to 4.48 kg per plot at Karimnagar, respectively. Most of the hybrids exhibited superiority over the mean of

their parents, better parent and standard checks. The crosses, $P_9 \times P_{10}$ at Rajendranagar, $P_1 \times P_5$ at Palem and Karimnagar recorded maximum heterosis. Varying levels of heterosis were recorded by Akhtar and Singh (1981), Murali Krishna and Patil (1992), Pandey *et al.* (1994), Wang *et al.* (1998) and Appunu (2002).

The oil content in maize normally ranges from 4.0 to 5.0 per cent (Kumar *et al.*, 1997). However in the present experimental material, the hybrids exhibited wide range of oil content varying from 5.79 to 8.76 per cent at Rajendranagar, 5.69 to 8.76 per cent at Palem and 5.37 to 8.79 per cent at Karimnagar. Heterosis in both positive and negative directions were observed in the crosses. The cross combinations, $P_6 \times P_8$, $P_3 \times P_{10}$ and $P_3 \times P_8$ recorded higher oil *per se* performance than standard checks and identified as superior crosses.

The performance of hybrid in relation to standard check is essential to identify superior hybrids. Kumar *et al.* (1997) reported standard heterosis ranging from 13.4 to 21.6 per cent for oil content.

Breeding for higher protein content improves the nutritional value of maize and this possibility was demonstrated by Woodworth (1952). Thereafter many workers reported heterotic performance of hybrids for protein content. Heterosis for protein content was reported by Wang (1998), Konak *et al.* (1999) and Venu Gopal (2000). Generally protein content ranges from 7.2 to 10.1 per cent (Singh,

2000). In the present study, the Quality Protein Maize (QPM) lines were used and in hybrids developed the range was from 8.83 to 11.87 per cent at Rajendranagar, 8.89 to 11.71 per cent at Palem and 9.14 to 11.88 per cent at Karimnagar. The cross combinations, $P_3 \times P_6$, $P_6 \times P_8$ and $P_2 \times P_7$ were identified as superior specific crosses. Hybrids with higher protein content are useful and essential to overcome the problem of malnutrition.

Across the locations, $P_2 \times P_{10}$, $P_6 \times P_7$, $P_2 \times P_9$, $P_1 \times P_{10}$, $P_1 \times P_3$, $P_1 \times P_4$ and $P_1 \times P_5$ were high yielders and recorded high level of heterosis, heterobeltiosis and standard heterosis for grain yield per plot. A critical analysis of heterotic performance for other characters revealed that heterosis for yield accomplished with heterosis for 100 kernel weight, number of kernels per ear, number of kernels per row and ear girth for $P_6 \times P_7$ and $P_2 \times P_9$. High yield with high protein and oil content was observed in $P_6 \times P_8$.

5.4 GENETIC PARAMETERS AND CHARACTER ASSOCIATION

The variance component derived from further partitioning of genotypic differences into phenotypic, genotypic and environmental coefficients of variation and heritability is a good index of transmission of characters from parents to their offsprings (Falconer, 1960). The estimates of heritability along with expected genetic advance are

more useful in predicting the resultant effects in selecting the best individuals.

Singh *et al.* (1998) observed high to moderate estimates of heritability and genetic advance for plant height, ear height, ear length, number of kernels per row, 100 kernel weight and grain yield. Shimpiger *et al.* (1996) observed high heritability estimates for yield components except yield, while Satyanarayana (1995) reported high heritability estimates per yield and suggested recurrent selection for yield improvement.

In the present study, heritability and genetic advance were low for ear girth and protein content, estimates were low to average for days to 50 per cent tasseling, days to 50 per cent silking, days to 50 per cent brown husk and oil content indicating predominant role of non-additive gene action and environment in governing these characters as a consequence, selection for these characters will not be effective.

Grain yield and its component characters *viz.*, ear height, plant height, ear length, number of kernels per row and number of kernels per ear had high heritability and genetic advance, therefore selection pressure may be imposed for improving these characters. Heritability was high for number of kernel rows per ear and 100 kernel weight, but genetic advance was average which indicated that selection would be effective with higher selection intensity.

In the present investigation phenotypic, genotypic correlations and path analysis were studied. Satyanarayana (1995) observed significant positive association of number of kernels per row, number of kernel rows per ear, ear length, ear girth, 100 kernel weight with grain yield.

Grain yield was significantly and positively associated with number of kernels per ear, 100 kernel weight, number of kernels per row, ear girth, ear length, plant height and number of kernel rows per ear at Rajendranagar, Palem and Karimnagar both at phenotypic and genotypic level. These results confirm the finding of Jadhav *et al.* (1995).

The concept of path analysis was originally developed by Wright (1921), but the technique was first used in plant selection by Dewey and Lu (1959). Thereafter many workers reported and utilized these techniques in crop improvement through selection. Kumar *et al.* (1998) in maize hybrids of 12 parental diallel suggested selection for number of kernels per row, number of kernel rows per ear, ear diameter, ear length and days to 50 per cent maturity. Mathur *et al.* (1997) observed least influence of environment on phenological characters and the pattern of association on number of kernel rows, number of kernels per ear and 100 kernel weight with grain yield remained consistent over environments.

The direct and indirect association through other characters by path analysis, revealed that number of kernels per ear, 100 kernel weight, number of kernels per row, number of kernel rows per ear and ear length directly influenced grain yield. Number of kernels per ear, number of kernels per row and number of kernel rows per ear indirectly contributed for 100 kernel weight, while 100 kernel weight, number of kernels per row, number of kernel rows per ear, ear girth, ear length and plant height positively contributed for number of kernels per ear. Geetha and Jayaraman (2000) advocated selection for number of grains per row to improve the grain yield. Hence, these characters could be exploited in selection for increasing yield the maize yield. Annapurna *et al.* (1998) also made similar recommendation, while Satyanarayana *et al.* (1990) reported the role of test weight via ear length and ear girth.

Oil content is one of the important characters and was found negatively and significantly correlated at genotypic level with protein content at Rajendranagar, while significantly and positively correlated at phenotypic level with protein content at Palem and Karimnagar. Direct effect of oil content on grain yield was in negative direction at both Palem and Karimnagar, while at Rajendranagar, there was phenotypically negative and genotypically positive direct effects.

Protein content was significantly and negatively associated at genotypic level with ear girth, number of kernels per row and number of

kernels per ear at Rajendranagar, while at Karimnagar it was negatively and significantly correlated at genotypic level with number of kernel rows per ear.

5.5 PHENOTYPIC STABILITY FOR GRAIN YIELD AND ITS COMPONENTS

A desirable hybrid should possess stability in performance besides high yield. The high yielding ability and response to environmental changes are the two independent attributes of a genotype and are governed by separate gene system (Finlay and Wilkinson, 1963; Lin, 1992). A stable phenotypic expression of a character is the result of interaction between its genotype and the environment in which it develops. Therefore, the ability of some crop varieties to perform well under wide range of environmental conditions has long been appreciated. Although plant breeders are aware of important genetic differences in adaptability, they have not been able to exploit their full potentiality on account of difficulties in defining and measuring either adaptability itself or the complexity of environments. In recent times many models have been developed of which Eberhart and Russell (1966) has been widely adopted. They emphasized the need to study both linear (bi) and non-linear (S^2di) components of $G \times E$ interactions in the estimation of stability.

Linear regression is a measure of response of a particular genotype to the different environments. Stability is reflected by deviation from regression components where the mean performance of a genotype along with both these parameters represent a measure of adaptability of genotype.

In the present investigation, 45 hybrids along with 10 parents were evaluated for stability over three environments viz., Rajendranagar, Palem and Karimnagar following Eberhart and Russell (1966) model.

Grading of environment indicated that the Rajendranagar location was best for grain yield and most of the yield components. Pooled analysis of variance revealed the presence of genetic variability among the genotype for all the characters indicating differential response of genotype in different environments and exhibited their different nature of genetic system in controlling the stability performance.

Environment linear was also significant for all characters except protein and oil contents. Significant effect of environment was also reported by Cardoso *et al.* (1997), Gentinetta *et al.* (1988) and Gautam *et al.* (1998).

Pal and Prodhan (1994) reported significant G x E interaction for yield and yield components except ear diameter, number of kernel rows per ear and oil content. In the present study, G x E (linear) was

found to be significant for days to 50 per cent tasseling, days to 50 per cent silking, 50 per cent brown husk, ear height, plant height number of kernels per row. Thus prediction for most of the genotypes will be feasible for these traits across locations. However, the G x E (linear) interaction was non-significant for ear length, ear girth, number of kernel rows per ear, number of kernels per ear, 100 kernel weight, protein content, oil content and grain yield indicating that only non-linear component alone accounted for Genotype x Environment interaction.

Pooled deviation was significant for days to 50 per cent brown husk, number of kernels per ear, 100 kernel weight and grain yield indicating that the parents and hybrids differed considerably for their stability. Mahajan and Khehra (1992) for grain yield, ear length and 100 seed weight, Kumar *et al.* (1997) observed both linear and non-linear components of G x E interaction for maize oil.

Duration of a variety or a hybrid is an important attribute, which qualifies them to fit in crop rotation system in order to increase crop intensity. It also helps in escaping terminal drought. Days to 50 per cent tasseling, silking and brown husk, indicates the earliness of a genotype in maize. Most of the hybrids and parental lines exhibited stable performance for earliness. However, the parental lines P₃ and P₈

and cross combinations $P_2 \times P_5$, $P_3 \times P_8$ and $P_6 \times P_9$ were early and possessed desirable stability parameters.

In respect of plant height P_2 and P_4 possessed higher height and did not exhibit both linear and non-linear portion of Genotype $\times$ Environment interaction. The hybrids $P_1 \times P_{10}$, $P_1 \times P_5$ and $P_7 \times P_9$ possessed higher mean value and were stable as both b_i and S^2_{di} estimates were not significant.

Stability for ear height was observed in parental lines P_5 and P_6 and hybrids $P_5 \times P_7$, $P_4 \times P_9$, $P_4 \times P_{10}$ and $P_3 \times P_5$ with desirable means. The parental lines P_2 , P_4 and P_5 , among the hybrids, $P_4 \times P_7$, $P_6 \times P_{10}$, $P_9 \times P_{10}$ and $P_7 \times P_9$ possessed lengthy ears and both linear and non-linear portion of Genotype $\times$ Environment interactions were non-significant.

In respect of number of kernel rows per ear, the parents P_7 , P_8 and P_{10} and crosses $P_2 \times P_9$, $P_4 \times P_6$, $P_2 \times P_{10}$ and $P_8 \times P_{10}$ exhibited stable performance with higher mean values. For number of kernels per ear P_6 , P_7 and P_8 possessed higher mean and the hybrids $P_6 \times P_7$, $P_8 \times P_{10}$, $P_1 \times P_4$ and $P_1 \times P_7$ were found to be stable with unit regression and non-significant S^2_{di} estimates.

The predictable portion of $G \times E$ interaction was found to be non-significant for 100 kernel weight and thus the performance of parents and hybrids can be predicted across the environment.

The parents P_6 and P_7 had 32.94 and 32.17 g of 100 kernel weight and the hybrids $P_6 \times P_7$ and $P_2 \times P_{10}$ had 38.36 to 38.09 g of 100 kernel weight and exhibited stability for this character.

Kumar *et al.* (1997) reported G x E interaction and differential performance of the genotype under different environments for oil content. Considering three locations in the present study for oil content, P_3 and P_{10} and hybrids $P_6 \times P_8$, $P_3 \times P_8$ and $P_7 \times P_8$ exhibited stable performance.

The linear response of genotype for protein content was non-significant. P_3 , P_5 and P_{10} had higher protein content and among hybrids $P_2 \times P_5$, $P_5 \times P_6$, $P_3 \times P_6$ and $P_1 \times P_2$ had more than 11.60 per cent protein and were stable over the environments.

Among the parents, P_2 , P_6 , P_7 and P_8 registered high grain yield and non-significant bi and S²di estimates. The linear estimate of G x E interaction which gives the idea of responsive capacity of a particular genotype was found to be non-significant for two crosses but the non-linear component was non-significant for all the hybrids. Eberhart and Russell (1966) characterized an ideal genotype to be stable should possess unit regression, lowest deviation from the regression and higher mean to have practical value. Accordingly, the hybrids $P_6 \times P_7$, $P_2 \times P_{10}$, $P_1 \times P_4$ and $P_8 \times P_{10}$ were found to be stable across the locations with unit regression and non-significant deviation from regression.

The present study revealed the role of additive and non-additive gene action in most yield contributing characters. The preponderance of non-additive gene action was apparent. Hence, a breeder could exploit the non-additive gene action through heterosis breeding. To both additive and non-additive gene actions, recurrent selection procedures like population improvement programmes should be followed to obtain the elite inbreds for future breeding programmes and pyramiding of desirable genes.

Heterosis in the hybrids was achieved for ear length, ear girth, number of kernels per ear and 100 kernel weight. Hence, emphasis may be placed on these characters for achieving higher yield.

Since, stability analysis was based on three diversified locations, test the high yielding hybrids over more locations and different agro climatic situations to find out the real worth of the hybrids before their release for commercial cultivation.

SUMMARY

CHAPTER VI

SUMMARY

The present investigation entitled “Studies on genetic divergence, combining ability and stability for protein, oil and grain yield in maize (*Zea mays* L.) genotypes” was carried out at three locations viz., Rajendranagar, Palem and Karimnagar and the results obtained are summarized. The study was aimed to analyze genetic diversity, variability nature of gene action, estimates of heterosis, heterobeltiosis and standard heterosis, character association, path coefficient analysis, genotype x environment interaction and stability for grain yield, yield components, oil and protein content. For this purpose, 196 maize genotypes comprising 128 Quality Protein Maize (QPM) and 68 High Oil lines (HOL) were evaluated using Mahalanobis D^2 analysis to study the divergence present in the lines. Based on the clustering pattern, ten divergent inbred lines were selected during *kharif*, 2001 at College Farm, College of Agriculture, Rajendranagar, Hyderabad. These ten parents were crossed in diallel fashion (excluding reciprocals) during *rabi*, 2001-2002 at College Farm, College of Agriculture Rajendranagar, Hyderabad. The resulting 45 F_1 s along with ten parents and two checks were evaluated during *kharif*, 2002 at Rajendranagar, Palem and Karimnagar.

The analysis of variance revealed the existence of significant differences among the genotypes for all the traits studied. Combining

ability analysis revealed importance of both additive and non-additive gene actions in governing all characters, but non-additive gene action was found to be predominant.

Parents, P_7 (BQPML-151) and P_1 (BQPML-142) for 100 kernel weight, P_5 (BHOL-111) and P_1 (BQPML-142) for protein content, P_6 (BQPML-148) and P_8 (BQPML-152) for oil content had higher *per se* performance and contributed more favourable genes at all three locations. In respect of grain yield, P_1 (BQPML-142), P_6 (BQPML-148), P_7 (BQPML-151) and P_8 (BQPML-152) were identified to be good general combiners. Considering all the locations and yield contributing characters, P_1 (BQPML-142), P_6 (BQPML-148) and P_8 (BQPML-152) can be given the status of good general combiners and genetically worthy.

In respect of protein content $P_3 \times P_6$ (BHOL-107 $\times$ BQPML-148) and $P_4 \times P_8$ (BQPML-145 $\times$ BQPML-152), for oil content $P_3 \times P_8$ (BHOL-107 $\times$ BQPML-152) and $P_6 \times P_8$ (BQPML-148 $\times$ BQPML-152) and for grain yield, $P_2 \times P_{10}$ (BHOL-104 $\times$ BQPML-157), $P_1 \times P_3$ (BQPML-142 $\times$ BHOL-107) and $P_1 \times P_4$ (BQPML-142 $\times$ BQPML-145) were the superior crosses. Most of the hybrids exhibited superiority over mean of parents and better parent for grain yield. On an average, the cross combinations, $P_1 \times P_3$ (BQPML-142 $\times$ BHOL-107), $P_1 \times P_4$ (BQPML-142 $\times$ BQPML-145), $P_1 \times P_5$ (BQPML-142 $\times$ BHOL-111), $P_1 \times P_{10}$ (BQPML-142 $\times$ BQPML-157) and $P_2 \times P_{10}$ (BHOL-104 $\times$ BQPML-

157) exhibited higher heterosis over three locations. For oil content $P_3 \times P_8$ (BHOL-107 $\times$ BQPML-152) and $P_6 \times P_8$ (BQPML-148 $\times$ BQPML-152) and for protein content, $P_2 \times P_7$ (BHOL-104 $\times$ BQPML-151), $P_5 \times P_6$ (BHOL-111 $\times$ BQPML-148) and $P_6 \times P_8$ (BQPML-148 $\times$ BQPML-152) were the superior crosses. High grain yield coupled with high protein and oil content was observed in the cross combination $P_6 \times P_8$ (BQPML-148 $\times$ BQPML-152).

Genotype $\times$ Environment interaction studied at three locations viz., Rajendranagar, Palem and Karimnagar was found significant for days to 50 per cent tasseling, days to 50 per cent silking, days to 50 per cent brown husk, ear height, plant height and number of kernels per row. The environment linear component was also significant for all characters except protein content and oil content. Pooled deviation was significant for days to 50 per cent brown husk, number of kernels per ear, 100 kernel weight and grain yield indicating that non-linear component of $G \times E$ interaction responsible for variation in these characters.

The parents, P_{10} (BQPML-157), P_3 (BHOL-107) and P_5 (BHOL-111) for protein content, P_{10} (BQPML-157) for oil content and P_2 (BHOL-104), P_6 (BQPML-148), P_7 (BQPML-151) and P_8 (BQPML-152) for grain yield possessed higher mean, unit regression and least deviation from regression. Among the hybrids, $P_6 \times P_7$ (BQPML-148 $\times$ BQPML-151), $P_2 \times P_{10}$ (BHOL-104 $\times$ BQPML-157), $P_1 \times P_4$ (BQPML-

142 x BQPML-145) and $P_8 \times P_{10}$ (BQPML-152 x BQPML-157) possessed higher mean and were stable for grain yield. Grain yield was positively significant and associated at genotypic and phenotypic level with number of kernels per ear, 100 kernel weight, number of kernels per row, ear girth, ear length, plant height and number of kernel rows per ear at genotypic and phenotypic levels at all locations.

Path coefficient analysis has shown direct relationship of number of kernels per ear, 100 kernel weight, number of kernels per row, number of kernel rows per ear, ear length with grain yield. The indirect effect of these characters on grain yield revealed influenced much by number of kernels per ear, 100 kernel weight, selection for these two characters will bring out desirable change or higher yield in desirable direction.

The identified four superior crosses, $P_2 \times P_5$ (BHOL-104 x BHOL-111), $P_1 \times P_4$ (BQPML-142 x BQPML-145), $P_7 \times P_8$ (BQPML-151 x BQPML-152) and $P_6 \times P_8$ (BQPML-148 x BQPML-152) which performed well for high protein yield, high oil yield with high grain yield and good stability over all the three locations can be used as single cross hybrids.

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* Original not Seen

Note: The pattern of "Literature cited" is presented in accordance with the 'Guidelines' for thesis presentation of Acharya N. G. Ranga Agricultural University, Hyderabad.

APPENDICES

Appendix – I

Top ten superior hybrids for grain yield and their corresponding protein content and oil content over three locations

Crosses	Grain yield		Protein content		Oil content	
	Kg / plot	Kg / ha	Per cent	Kg / ha	Per cent	Kg / ha
P ₆ x P ₇	4.50	12000	9.51	1141	6.76	811
P ₂ x P ₁₀	4.34	11573	9.48	1097	6.57	760
P ₁ x P ₄	4.28	11413	10.79	1231	7.21	822
P ₈ x P ₉	4.26	11360	10.50	1192	7.52	854
P ₁ x P ₇	4.25	11333	10.15	1150	7.52	852
P ₁ x P ₅	4.21	11226	10.63	1193	7.42	832
P ₁ x P ₃	4.20	11200	10.99	1230	6.17	691
P ₂ x P ₉	4.12	10986	10.99	1207	6.41	704
P ₉ x P ₁₀	4.07	10853	9.82	1065	6.68	724
P ₅ x P ₇	4.05	10800	10.49	1132	6.59	711

Appendix – II

Top ten superior hybrids for protein content and their corresponding oil content and grain yield over three locations

Crosses	Protein content		Grain yield		Oil content	
	Per cent	Kg / ha	Kg / plot	Kg / ha	Per cent	Kg / ha
P ₂ x P ₅	11.82	1109	3.52	9386	7.39	693
P ₅ x P ₆	11.76	1176	3.75	10000	7.83	783
P ₃ x P ₆	11.75	946	3.02	8053	7.80	628
P ₁ x P ₂	11.60	1101	3.56	9493	6.16	584
P ₅ x P ₉	11.57	1033	3.35	8933	6.49	579
P ₆ x P ₈	11.49	1136	3.71	9893	8.77	867
P ₂ x P ₇	11.43	911	2.99	7973	6.60	526
P ₄ x P ₈	11.34	1158	3.83	10213	6.95	709
P ₁ x P ₆	11.28	1209	4.02	10720	6.71	719
P ₇ x P ₈	11.25	1206	4.02	10720	8.09	867

Appendix – III

Top ten superior hybrids for oil content and their corresponding protein content and grain yield over three locations

Crosses	Oil content		Grain yield		Protein content	
	Per cent	Kg / ha	Kg / plot	Kg / ha	Per cent	Kg / ha
P ₆ x P ₈	8.77	865	3.70	9866	11.49	1133
P ₃ x P ₈	8.67	885	3.83	10213	9.70	990
P ₃ x P ₁₀	8.37	729	3.27	8720	10.31	899
P ₇ x P ₈	8.09	867	4.02	10720	11.25	1206
P ₁ x P ₁₀	7.90	771	3.66	9760	10.23	998
P ₁ x P ₉	7.89	816	3.88	10346	9.76	1009
P ₆ x P ₁₀	7.88	781	3.72	9920	10.72	1063
P ₅ x P ₆	7.83	783	3.75	10000	11.76	1176
P ₂ x P ₆	7.82	775	3.72	9920	10.64	1055
P ₃ x P ₆	7.80	628	3.02	8053	11.75	946

Appendix – IV

Top four superior hybrids for grain yield protein content and oil content over three locations

Crosses	Grain yield		Protein content		Oil content	
	Kg / plot	Kg / ha	Per cent	Kg / ha	Per cent	Kg / ha
P ₂ x P ₅	4.21	11226	11.82	1326	7.43	834
P ₆ x P ₈	3.70	9866	11.49	1133	8.77	865
P ₇ x P ₈	4.02	10720	11.25	1206	8.09	867
P ₁ x P ₄	4.28	11413	10.79	1231	7.21	822

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