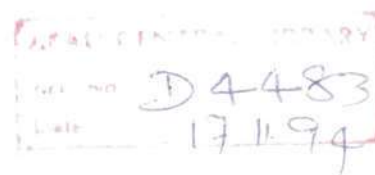


COMBINING ABILITY AND GENERATION MEAN ANALYSIS OF PLANT
HEIGHT, MATURITY AND OTHER YIELD CONTRIBUTING TRAITS
IN PEARL MILLET (Pennisetum glaucum (L.) R. Br.)



BY

REDDIGARI RAMA SUBBA REDDI

M Sc. (Ag)

THESIS SUBMITTED TO THE
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY
In the faculty of Agriculture

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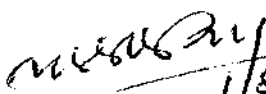
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AUGUST, 1994

CERTIFICATE

Mr.R.RAMA SUBBA REDDI has satisfactorily prosecuted the course of research and that the thesis entitled, COMBINING ABILITY AND GENERATION MEAN ANALYSIS OF PLANT HEIGHT, MATURITY AND OTHER YIELD CONTRIBUTING TRAITS IN PEARL MILLET (Pennisetum glaucum (L.) R.Br.) submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any other University.


1/8/94
(Dr.M.SHIVA SHANTH REDDY)
Major Advisor

CERTIFICATE

This is to certify that the thesis entitled, **COMBINING ABILITY AND GENERATION MEAN ANALYSIS OF PLANT HEIGHT, MATURITY AND OTHER YIELD CONTRIBUTING TRAITS IN PEARL MILLET (Pennisetum glaucum (L.) R.Br.)** submitted in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURE** of the Andhra Pradesh Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Mr.R.RAMA SUBBA REDDI** 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 him.

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LIST OF ABBREVIATIONS

B_1	: Back cross I generation ($F_1 \times P_1$)
B_2	: Back cross II generation ($F_1 \times P_2$)
$^{\circ}C$	: Degree centigrade
cm	: centimeter
CMS	: Cytoplasmic male sterile
D	: Dwarf (stature)
DF	: Days to 50 per cent flowering
E	: Early (flowering)
F_1	: First filial generation
F_2	: Second filial generation
Fig.	: Figure
g	: gram
GCA	: General combining ability
GW	: 500-grain weight
GM	: Grain yield per main panicle
ha	: hectare
kg	: kilogram
$kg\ ha^{-1}$	: kilogram per hectare
L	: Late (flowering)
P_1	: Parent I
P_2	: Parent II
PH	: Plant height
PN	: Panicle number
PL	: Panicle length

PG : Panicle girth
RH : Relative humidity
SCA : Specific combining ability
SE : Standard error
T : Tall (stature)
TN : Tiller number
% : per cent

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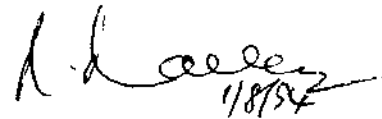
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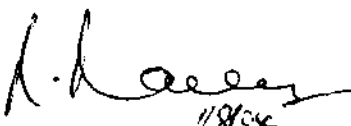
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(R. RAMA SUBBA REDDI)

DECLARATION

I, R.RAMA SUBBA REDDI hereby declare that the thesis entitled, COMBINING ABILITY AND GENERATION MEAN ANALYSIS OF PLANT HEIGHT, MATURITY AND OTHER YIELD CONTRIBUTING TRAITS IN PEARL MILLET (Pennisetum glaucum (L.) R.Br.) submitted to Andhra Pradesh Agricultural University for the Degree of DOCTOR OF PHILOSOPHY in Agriculture is a result of original research work done by me. It is further declared that the thesis or any part thereof has not been published earlier in any manner.

Date : 11/8/94


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ABSTRACT

The investigations were taken up to understand the genetic architecture of plant height, maturity, grain yield and other yield attributes in nine pearl millet inbreds comprising of one early dwarf (ICP 165), two late dwarf (ICP 57 and ICP 642) four early tall (ICP 828, ICP 64, ICP 811 and ICP 323) and two late tall (ICP 812 and ICP 126) lines. The studies, consisting of two experiments viz., diallel cross study involving 72 F_1 s and nine parents and combined study of six breeding generations (P_1 , P_2 , F_1 , F_2 , B_1 and B_2) pertaining to six selected crosses (ICP 165 x ICP 812, ICP 165 x ICP 126, ICP 57 x ICP 828, ICP 828 x ICP 812, ICP 828 x ICP 642 and ICP 811 x ICP 642), were conducted in kharif (1988 and 1989) and summer (1989 and 1990) seasons. Data on grain yield and yield attributes were analysed for heterosis, combining ability, gene action, character associations and path coefficient analysis by following mainly the methods of Griffing (1956), Hayman (1954a & b), Mather and Jinks (1971) and Dewey and Lu (1959).

SCA variance was greater in magnitude than GCA variance for flowering, plant height, tiller number, panicle length and grain yield. Seasonal differences influenced the expression of reciprocal effects for plant height, tiller number, panicle length and grain yield. Overdominance of earliness over late flowering and tallness over dwarf stature were indicated. All the productive hybrids were early maturing and tall, while dwarf hybrids were poor grain yielders. ICP 828, ICP 812, ICP 811 and ICP 126 were good general combiners for grain yield. GCA for grain yield was associated with GCA for other yield components. Rankings of parents based on per se performance differed from the rankings of GCA effects. Crosses with high SCA

generally involved at least one high general combining parent. SCA for grain yield was related to SCA for yield components.

$(H_1/D)^{1/2}$ ratio indicated overdominance for flowering, plant height, tiller number, panicle number and grain yield. The genetic analysis also revealed asymmetric distribution of genes with positive and negative effects and preponderance of dominant alleles in the parents for all the characters. Grain yield per plant was positively associated with all the characters except flowering which was negatively correlated. Grain yield per main panicle and panicle number contributed high direct effects to grain yield.

Generation mean studies revealed additive gene effects for most of the characters. Duplicate type of epistasis played major role in the inheritance of 500-grain weight, panicle number, panicle girth, tiller number, plant height and days to 50 per cent flowering while complementary epistasis was important for grain yield per main panicle. Both the types of epistasis were important in the inheritance of grain yield per plant.

The studies indicated the possibility of development of a synthetic involving six parents, ICP 828, ICP 812, ICP 811, ICP 323, ICP 642 and ICP 126, identified based on per se performance and GCA. Four best general combiners for grain yield (ICP 828, ICP 812, ICP 811 and ICP 126) can be used as restorers in crosses with suitable male sterile lines to develop F_1 hybrids. ICP 828, ICP 642 and ICP 165 lines can be converted into suitable male sterile sources for exploitation of heterosis available in the four best crosses identified viz., ICP 828 x ICP 126, ICP 642 x ICP 126, ICP 828 x ICP 642 and ICP 165 x ICP 812. Development of two elite populations, based on these heterotic crosses, was also suggested to serve as base populations for the future breeding programme.

...

INTRODUCTION

CHAPTER I

INTRODUCTION

Pearl millet [Pennisetum glaucum (L.) R.Br.] is one of the principal grain crops cultivated on an area of about 20 million hectares in the world, mainly in Africa, India and other Asian countries. In the United States of America, it is mainly grown for forage. Pearl millet occupies fourth position in India among cereal crops next to rice, wheat and sorghum. It is grown on an area of 10 million hectares with total production of 4.63 million tonnes and productivity of 463 kg ha⁻¹. The productivity of the crop has increased steadily from 303 kg ha⁻¹ in 1951-55 to 524 kg ha⁻¹ during 1981-85, mainly due to success in the hybrid and population breeding programmes. The increase is commendable as the crop is traditionally grown on semi arid tropics starved of ~~nutrition~~ and water. However, there has been slight decline in the productivity levels of the crop in the recent times, because of the increasing vulnerability of the hybrids to disease hazards due to narrow genetic base. Thus, diversification of parental lines is very much warranted. Systemic^{at} genetic studies are required to understand the variation in the available genetic stocks and formulate appropriate breeding strategies to improve the genetic potential of the crop.

Breeding for earliness has been recognised as an important objective, since the early maturing varieties fare better in the dry farming situations. Ever since the introduction of Tift 23A, a semi-dwarf male sterile line from the United States of America in 1962, inclusion of dwarf or semi-dwarf lines as female parents in hybrid

development has been a regular feature in pearl millet breeding. In spite of advances in breeding, the inheritance of these two important traits (maturity and height) has not received as much indepth and detailed investigation as is required in this crop. The role of height and maturity genes on yielding ability has not been as much appreciated in pearl millet as in other cereal crop like sorghum (Harinarayana, 1980). Some investigations have been undertaken in this crop to understand the genetic architecture of plant height (Burton and Fortson, 1966; Rachie et al., 1966; and Sreenivasulu and Sreeramulu, 1980) and maturity (Phul et al., 1970; Dass et al., 1984a; and Sagar et al., 1985). However, in all these studies, height and maturity traits were investigated separately using material pertaining to either of the two characters and rarely considered together. Information on interrelationships between plant height, maturity and grain yield is needed to understand the ideal genotype in terms of height and maturity for realising maximum yields in pearl millet.

With the above considerations in view, nine diverse pearl millet inbred lines representing different height and maturity groups were acquired from ICRISAT. The investigations were undertaken through diallel and generation mean analysis with the following objectives.

1. to evaluate the genotypes for their intrinsic value as parents in the crop improvement programme
2. to assess the extent of heterosis and combining ability in different crosses for height, maturity, grain yield and other yield contributing traits

3. to study the interrelationship of yield and yield contributing characters by path coefficient analysis
4. to understand the nature of gene action underlying the inheritance of height, maturity, yield and other yield attributes
5. to suggest an ideal plant type in terms of height and maturity and to formulate appropriate breeding strategy for achieving higher productivity levels in pearl millet.

...

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Pearl millet is one of the important crops where exploitation of heterosis has been successful in the past three decades. A number of techniques are being employed to identify superior parents based on their combining ability, to understand the nature of gene action determining yield and other yield attributes so as to develop suitable breeding strategies for achieving significant improvements. The present review concerns heterosis, combining ability, gene action and character association studies in pearl millet.

2.1 HETEROSIS

Heterosis or hybrid vigour in common use represents increase or decrease in the mean performance of F_1 hybrid over the parents. The term relative heterosis refers to the percent increase or decrease in the mean value of F_1 over the mid parental value while heterobeltiosis denotes the percent increase or decrease of F_1 over the superior parent (Rai, 1979).

Though hybrid vigour has been observed by many investigators it has been exploited earlier in only a few breeding programmes. In a mixture of hybrid and sibbed seedlings, Burton (1948) observed that the more vigorous hybrid seedlings crowded out most of the weaker inbred seedlings early in their cycle and such hybrid mixtures yielded almost as much as hundred percent more. At Coimbatore, Rao^{et al.} (1949 and 1951) took advantage of high natural crossing in pearl millet and developed three F_1 hybrids (X_1 , X_2 , and X_3) which outyielded the other

strains by 29 to 30 per cent. Chavan et al. (1955) obtained 10 to 15 per cent higher grain yields from a hybrid between the 'group' bred strains S 28-15-1 and A.F3-C-1-C-1. Durand (1961) observed heterosis in nine out of 10 pure line stocks in combination with the tester strain 161.

The exploitation of heterosis, however, became a viable commercial proposition only with the discovery of cytoplasmic genetic male sterility almost simultaneously in India and the United States of America in the late fifties (Burton, 1958; Menon, 1958 and 1959). The cytoplasmic male sterile lines Tift 23A and Tift 18A developed by G.W. Burton in the United States were supplied to Indian breeders in 1961 and were extensively crossed with the Indian inbreds (Burton, 1965). From 1964 to 1967, 148 trials were conducted with the CMS hybrids throughout the millet growing regions of India. Increase of 74 to 197 per cent was recorded by the best hybrid in each trial averaging 102 per cent higher grain yield than the best varietal check (Rachie et al., 1967). First CMS based commercial hybrid HB-1 was released in 1965 (Athwal, 1965) and release of many more hybrids followed in quick succession.

In a six parent diallel study, Ahluwalia (1962) reported lack of positive heterosis for grain yield in all but one hybrid in a six parent diallel study. He concluded that absence of co-adapted gene complexes and unfavourable genotype-environmental interactions could be potent barriers for yield improvement. Nineteen hybrids involving indigenous as well as exotic parents were studied by Ahluwalia and Patnaik (1963) for grain yield and other quantitative characters.

Five hybrids showed increased grain yields ranging from 33 to 70 per cent compared to the superior parent. Significant negative heterosis was observed for tiller number, panicle length, panicle girth and 500-grain weight in a majority of crosses.

Positive significant heterosis was reported by Lal and Singh (1968) for plant height, number of internodes, days to 50 per cent flowering and negative heterosis for tiller number, panicle number and 250-grain weight over mid parent as well as better parent. The studies of Mahadevappa (1968) revealed that heterosis for yield was closely associated with the geographical diversity of origin of the parental lines. Positive heterosis over mid parent for panicle length, panicle thickness, tiller number, panicle number, plant height, grain yield and grain size ~~was~~ reported by Tewari (1970), Singh and Singh (1972), Phul et al. (1973), Shinde and Dosale (1983), Shinde et al. (1983) and Setty (1986). However, negative heterosis was reported for tiller number (Singh et al., 1972), days to 50 per cent flowering (Phul et al., 1973) and number of productive tillers (Soundarapandian, 1973). Positive heterosis over better parent was reported for plant height, number of productive tillers, 1000-grain weight and grain yield by Subramanian and Rathinam (1980), Vaidya et al. (1983) and Rajasekaran (1985).

Positive heterosis for plant height, tiller number, panicle length, panicle weight and grain yield and negative heterosis for days to 50 per cent flowering were reported by Jayaraman (1989) while studying the sweetness of stem and grain yield. Heterosis was studied for 13 traits viz., days to 50 per cent flowering, plant height, leaf

length and width, nodes per main tiller, plant girth, length of first internode, tiller number, spike length and girth, grain density, seed size and grain yield by Kushwah and Singh (1992). They observed significant heterosis over mid parent for all the traits. The magnitude of heterosis was highest (397%) for grain yield and lowest (~5%) for days to 50 per cent flowering. Yield components manifested desirable heterotic effects.

In two sets of diallel crosses comprising eight restorer lines and eight non restorer lines, Setty and Appadurai (1992) estimated heterosis for a number of agronomic characters. The heterosis over mid parent was recorded upto 44.01 per cent for plant height, 20.92 per cent for panicle length, 43.46 per cent for tiller number, 7.55 per cent for days to 50 per cent flowering, 28.16 per cent for grain weight and 97.45 per cent for grain yield per plant. Nijhawan and Yadav (1993) identified four crosses viz, MS 842A x MS 3383B, MS 843A x HMS 3B, MS 843A x Pb 302B and MS 3383A x Pb401B depicting marked standard heterosis for grain yield in a seven parent diallel study.

2.2 COMBINING ABILITY AND GENE ACTION

The concept of combining ability was enunciated by Sprague and Tatum (1942). They used the term General combining ability to designate the average performance of a line in hybrid combinations. The term Specific combining ability was used to designate those cases in which certain combinations do relatively better or worse than would

be expected on the basis of the average performance of the lines involved.

A set of diallel crosses involving six pearl millet inbred lines was studied by Ahluwalia (1962) by graphical method. Tillering, plant height and yield per panicle were found to involve full dominance, overdominance and partial dominance respectively and all three characters gave evidence for epistatic effects. The Vr-Wr graphs suggested a complementary type of epistasis in case of tillering and duplicate type of interaction for yield per panicle.

Burton and Fortson (1966) studied the inheritance of plant height in pearl millet. Height measurements were made on over 39,000 parent, F_1 , F_2 and back cross plants of hybrids involving five dwarf (D_1 , D_2 , D_3 , D_4 and D_5) and four normal inbreds. F_1 hybrids between four of the dwarfs were as tall as normal dwarf inbreds, proving that these dwarfs carried different recessive genes for dwarfness. One dwarf x dwarf hybrid was little taller than its dwarf parent suggesting that both carried similar dwarf genes. Most dwarf x normal F_1 hybrids were significantly taller than their normal parents. Inheritance of dwarfness in D_1 and D_2 appeared to be conditioned largely by one or two recessive genes. Near normal F_2 distribution curves and minimum gene number estimates indicated that dwarfness in D_3 , D_4 and D_5 was controlled by more than two recessive genes.

A complete diallel study of 10 inbred lines and estimation of genetic components of variance (Mahadevappa and Ponnaiya, 1966) revealed mostly additive and a few partially dominant loci for days to

heading, complementary epistasis for plant height, additive and overdominance type of gene action for number of internodes, additivity for diameter of stem and some kind of nonallelic interaction for 1000-grain weight. In a line x tester analysis, Gupta and Singh (1967) observed high specific combining ability associated with GCA of either parents. High x high GCA combinations produced best specific combiners for yield.

In a set of 184 elite inbred lines crossed with two male sterile lines, Murthy et al. (1967) studied nature of gene action. Nonadditive gene action was present for tiller number and ear girth while substantial additive gene action was present for ear length. They also reported partial dominance for tiller number and ear girth and overdominance for ear length.

In a combining ability study involving four Indian, two African and one American inbred line, Nanda and Gupta (1967) identified three lines of Indian origin as good general combiners for grain yield. African and American lines were poor general combiners. They obtained higher SCA effects in the combinations in which at least one of the parent was a good general combiner. Some good general combiners showing poor SCA were attributed to the absence of genetic diversity between the two parents. In another combining ability study with seven dwarf₃ and one tall line of Indian origin, Gupta (1968) obtained high SCA effects in all GCA combinations viz. high x high, high x low and low x low. He suggested that the segregating generation of crosses among high x high general combiners could be utilised directly

for isolating superior segregants and indirectly in developing superior populations through various recurrent selection procedures with the ultimate objective of isolating promising inbreds for the production of single cross hybrids.

In a diallel analysis, Mahadevappa (1968) reported that tillering was controlled by dominant and complementary genes and plant height by complementary and overdominant genes. Studies of Gill et al. (1969) indicated that grain yield was a complex character. High SCA for grain yield was found to be related to GCA of the parental lines. Apart from GCA, genetic diversity between the parents also played an important role in the performance of a cross.

Phenotypic variability was analysed by Phul (1969) in three crosses of pearl millet with P_1 , P_2 , F_1 , F_2 , B_1 and B_2 generations sown on two dates of sowing. The behaviour of the F_1 indicated that the relationship of dominance was not consistent over the crosses. Additive variance was more important than the dominance variance in the days to 50 per cent flowering and plant height. For stem girth and ear length, the two components had varying magnitudes in different crosses. Heritability estimates varied from 31 to 89 per cent for flowering, 11 to 41 per cent for stem girth, 35 to 50 per cent for plant height and 27 to 84 per cent for ear length. The number of effective factors was generally low in majority of the cases.

The inheritance of grain size and grain ^yhardness were studied by Phul and Arhwal (1969) in a cross with seven generations viz. P_1 , P_2 , F_1 , F_2 , F_3 , B_1 and B_2 . Both these characters exhibited additive

as well as nonadditive variation. In case of grain size, inter allelic interaction of additive x dominance type accounted for bulk of the nonadditive variation while in case of grain ^YHardness dominance effects were relatively more important.

Gene effects for 15 grain and fodder contributing characters were calculated using P_1 , P_2 , F_1 , F_2 , B_1 and B_2 generations of a cross between two inbred lines (Singh and Lal, 1969). Additive gene effects were significant for all the characters. Epistatic gene effects were less important. Duplicate epistasis was exhibited by plant height, number of internodes, stem thickness, number of tillers, number of spike bearing branches, leaf width, days to 50 per cent flowering and 250-grain weight. Complementary epistasis was observed for number of branches, leaf length, peduncle length, peduncle thickness, spike length and spike thickness.

In a 5 x 5 diallel analysis, Badwal (1970) observed that SCA was important for grain yield while GCA was important for yield components like tiller number, ear length, ear girth, ear weight and 1000-grain weight. There were no reciprocal differences for the combining ability. The top ranking hybrids for grain yields involved parents of high x high GCA.

In a line x tester analysis involving 25 inbred lines and two male sterile lines, Gupta and Sidhu (1970) indicated that general and specific combining ability effects for yield related to that of the yield components of the male parents. The variance component due to SCA was high for majority of the characters except leaf number and

size. High yielding hybrid combinations involved high x high general combining parents. Phul et al. (1970) carried out a nine parent diallel analysis for earliness. The Vr-Wr regression indicated a predominantly additive type of gene action. Dominant genes were found to be more than recessive genes. Three effective factors appeared to be responsible for the variation in the character.

Studies of Bains (1971) revealed that GCA was more important than SCA for tiller number, days to 50 per cent flowering and ear thickness in pearl millet. In a 8x8 diallel cross study, Gupta and Singh (1971) studied gene action in relation to grain yield and its components viz., ear number, ear length and ear girth. Dominance of better parent was observed in all these characters. Vr-Wr graph indicated overdominance for grain yield and partial dominance for ear number, ear length and ear girth.

In a study of generation mean analysis involving six generations of two crosses, Singh et al. (1972) reported that additive, dominance and dominance x dominance gene effects played significant role in the inheritance of most of the characters. Maximum contribution of additive gene effect was observed for number of tillers, number of spikes, plant height, spike length and spike thickness. Dominance gene effects were found contributing maximum in the inheritance of the number of spikes, number of tillers, plant height, spike length and spike thickness. Complementary epistasis was observed for stem thickness, number of internodes, number of spike bearing tillers and spike thickness. Duplicate epistasis was observed for plant

height, days to 50 per cent flowering, tiller number, peduncle length, spike length and grain weight.

From a diallel analysis involving 22 dwarf derivatives in the F_1 and F_3 generations, Thakare and Murthy (1972a and 1972b) concluded that nonadditive gene action was predominant for developmental traits such as chlorophyll content, tillering, leaf size, leaf senescence, compactness of panicle and days to 50 per cent flowering. They further observed that the introduction of dwarfing genes in no way interfered with the GCA of parents for the developmental traits. Badwal et al. (1973) studied the combining ability of four male sterile lines and 10 inbred lines in a line x tester ~~analysis~~ and reported substantial nonadditive gene effects for grain yield, ear girth and days to 50 per cent flowering. They also indicated that the SCA of crosses in general was consistent with the GCA of the lines involved.

Inheritance of nine characters related to quality and productivity in pearl millet was studied by Chand et al. (1973) in three crosses with six parental generations. They found that significant contribution was made by dominance x dominance interaction for 1000-grain weight in cross IP 2093 x IP 1025 and additive x dominance in IP 1945 x IP 2093. They further observed duplicate epistasis in IP 1025 x IP 1945 and IP 2093 x IP 1025 and complementary epistasis in IP 1945 x IP 2093.

In a line x tester analysis involving three male steriles and 33 pollinators, Gupta and Singh (1973) observed that crosses with high

SCA had one or both of their parents with high GCA. High SCA for yield was related with high SCA for grain size, ear length, ear diameter and tiller number. Preponderance of additive variance for days to 50 per cent flowering, plant height, ear number, ear length, ear girth and grain yield was reported by Phul et al. (1973) in a combining ability analysis. It was observed that crosses between two good general combiners were not always good for SCA and average x average combinations proved to be important for most of the characters.

The studies of Tewari (1973) stressed the need to understand the inheritance of tiller number in pearl millet as this character considerably influenced the grain yield. Tiller number was the result of complete dominance to overdominance coupled with complementary epistasis. Preponderance of additive gene action for grain yield, ear length, ear girth, days to flowering and plant height and nonadditive gene action for number of tillers and number of grains per unit area was reported by Dass et al. (1974) in a line x tester analysis involving four male steriles and nine pollinators. Gill et al. (1974) reported that nonadditive gene effects were more important than additive effects for grain yield, number of ears, ear length, ear girth, plant height and earliness.

In a diallel analysis involving nine inbred lines, Nanda and Phul (1974) reported that the inheritance of grain yield and ear number was controlled mainly by genes showing dominance and epistasis while both additive and dominance components were important for ear length, ear girth and plant height. In a line x tester analysis involving five male steriles and nine inbreds, Pokhriyal et al. (1974)

observed that hybrids based on ms 628A were tall and late maturing. MS 628A was a good general combiner for yield. In another line x tester analysis, Tyagi et al. (1974) indicated that SCA was higher than GCA for plant height, tiller number, leaf number, stem thickness and fodder yield indicating the predominance of nonadditive gene action. In most of the cases, SCA of hybrids was directly related with GCA of parents. Per se performance of hybrids and their SCA effects were closely related and any one of these criteria may be used for assessing hybrid performance. The magnitude of heterosis was higher when parents having high x high or high x medium combining ability were involved.

In a diallel analysis study Ram and Singh (1975) indicated that days to heading appeared to be simple in inheritance and earliness was primarily due to dominant genes. In another diallel study with 10 inbred lines, Tyagi et al. (1975) reported high GCA : SCA ratio for days to ear emergence, ear number, ear length, ear diameter, 500-grain weight and grain yield revealing the preponderance of additive genetic variance for these characters. They suggested the use of biparental approach to accumulate more of additive genetic variance. In a 19 parent diallel study Varma and Ramanujam (1975) reported the presence of dominance components for plant height, green fodder and dry matter yield.

Chand and Ahmed (1976) conducted genetic studies in two crosses involving P_1 , P_2 , F_1 , F_2 , B_1 and B_2 generations. They observed that additive component was important for synchrony of tillers, leaf length, number of internodes and 1000-grain weight. Over-

dominance was observed for leaf width, smut incidence and grain density. The minimum number of genes estimated was less than unity for all the characters. Combining ability studies were carried out by Phul et al. (1976) using four male steriles and 19 restorers in a line x tester design. It was revealed that the per se performance of female parents was in agreement with GCA estimates for maturity and ear length. They further indicated that the best cross combination generally involved either both or one of the best combining parents. In a line x tester analysis of five A lines and 12 R lines, Pokhriyal et al. (1976) reported that additive gene action was more important for days to flowering and plant height while nonadditive gene action was preponderant for tiller number, ear length, ear girth and grain yield.

The nature and magnitude of genetic variation in respect of yield and its components ~~were~~ studied by Singh et al. (1979) in a 12 parent diallel involving F_1 and F_2 generations. They found that both additive and nonadditive components were significant for all the characters in both the generations. Further, they also observed overdominance for days to 50 per cent flowering, effective tillers, ear length, ear girth, test weight and grain yield and partial dominance for plant height.

In a line x tester analysis involving 11 inbreds and four male steriles, Govil et al. (1980) indicated that grain yield was controlled by nonadditive gene action while the component characters were controlled by additive as well as nonadditive effects. The

studies of Basavaraju et al. (1980) revealed predominance of non additive gene action for days to flowering, number of tillers, leaf number, plant height, ear girth, number of seeds and grain weight. The combining ability effects for Downy mildew had no adverse effect on combining ability effects of yield and yield contributing traits. The studies of Mukherji et al. (1980) with eight dwarf inbreds indicated predominance of nonadditive genetic variation in the inheritance of plant height, effective tillers per plant, ear length and grain yield per plant. The studies revealed that plant height, ear number and grain yield per plant were controlled by at least two pairs of genes. Presence of an excess of positive genes with dominance was indicated for plant height and ear girth while equal proportion of positive and negative genes with dominance was observed for the other traits.

In a diallel study, Sidhu et al. (1980) reported both additive and nonadditive gene action for tiller number, plant height and fodder yield. Both the general and specific combining ability effects were found to be important for plant height, number of ear bearing tillers, number of internodes per main shoot and grain yield per plant (Singh et al., 1980). Combining ability of nine inbred lines of different height groups was studied by Sreenivasulu and Sreeramulu (1980). Additive gene action was reported for plant height, days to 50 per cent flowering, internode length, stem girth, grain yield and panicle weight. Nonadditive gene action was observed to be more important in the inheritance of 1000-grain weight. In a 6 x 6 diallel cross study, Subramaniyan and Rathinam (1980) reported higher GCA

variance for grain yield, plant height, tiller number, peduncle length and 1000-grain weight.

High frequency of heterotic crosses was observed by Reddy and Arunachalam (1981) in combinations involving high x low general combining parental lines than in combinations involving high x high or low x low GCA. Both additive and nonadditive gene actions were found important for grain yield, ear length and ear girth (Govil et al., 1982). In a diallel study involving 15 parents, Kumar et al. (1982) found that both additive and nonadditive genetic variances were important in the expression of days to heading, days to maturity, plant height, tiller number and straw yield. However, the magnitude of nonadditive gene action was higher than that of additive gene action. Rao and Reddy (1982) also reported both additive and nonadditive types of gene action for plant height, days to flowering, ear length, ear girth, packing density and grain yield. The GCA and SCA effects revealed that none of the parents was useful for simultaneous improvement of all characters as they were found to be good for a single or a few characters only.

In a line x tester study, Singh et al. (1982) reported the presence of additive gene action for grain yield and yield related traits viz., plant height, ear number, ear length and ear girth. They found that African lines produced better GCA and SCA effects than the Indian lines. In a line x tester analysis, Tyagi et al. (1982) investigated the combining ability of 12 male steriles and 12 pollinators in six environments. Nonadditive gene action was predominant for grain yield, days to first ear emergence and 500-grain weight. In

general, hybrids having high SCA effects had at least one high combiner suggesting that either additive x additive or additive x dominance types of gene interactions were predominant in the material. The relative ranking of various crosses in different environments on the basis of SCA effects was different. The crosses showing high mean performance invariably did not show high SCA effects. Line x tester study by Bhamare *et al.* (1983) revealed greater SCA variances for ear head girth and 1000-grain weight.

Combining ability of 12 parents was studied by Chawla and Gupta (1983) in kharif and summer seasons. The relative proportions of GCA and SCA variances indicated the preponderance of nonadditive gene action for green fodder yield, leaf number, tiller number, plant height and duration. It was observed that good combiners for fodder yield were also good combiners for some of the yield components. GCA and SCA effects were variable in different seasons suggesting the need for genetic analysis in different seasons for a better understanding of gene expression before embarking on selection. They emphasized both combining ability and per se performance and involvement of one good combiner for selection of crosses. Greater magnitude of SCA variance was reported by Gopalan (1983) for plant height, tiller number, leaf number, stem thickness and fodder yield. The study also revealed that the best specific crosses had at least one good general combiner as a parent.

In another line x tester analysis, Dass *et al.* (1984a) reported predominance of nonadditive gene action for grain yield, ear

weight, effective tillers, plant height and days to 50 per cent flowering and additive gene action for 500-grain weight. In general there was no correspondence between mean performance and SCA effects of the crosses. Parents with high GCA produced superior hybrids. Dass et al. (1984b) studied the combining ability for days to heading in a 12 parent diallel study in F_1 and F_2 generations. Both additive and nonadditive gene effects contributed to the total genetic variation of the character. They also observed that the magnitude of SCA variances was substantially less in the F_2 generation.

The genetics of grain yield, plant height and ear head length was investigated by Dang et al. (1985) in a 10 x 10 diallel study. The genetic analysis revealed that though both additive and non-additive components of variance were important, the magnitude of nonadditive component was relatively higher. The proportion of dominant and recessive genes in parents indicated that for every one recessive gene influencing yield, plant height and ear head length, one to five dominant genes or gene groups were responsible for the expression. Investigations of Dass et al. (1985) on the genetics of ear head length, effective tillers, ^{ear} head weight and plant height in a 12 parent diallel study, revealed that both additive and nonadditive types of gene action were important for all the characters. At least one good general combiner was essential in getting good hybrid combination. It was also reported that there was no association between per se performance of a cross combination and its corresponding SCA effect.

Preponderance of nonadditive gene action for days to 50 per cent flowering, plant height, ear length, ear girth, 1000-grain weight and grain yield and additive gene action for tiller number was reported by Mehndiratta and Phul (1985) in a 18 parent diallel study over three environments. Significant reciprocal effects were observed for all the characters. In a 12 parent diallel study, Sagar et al. (1985) observed that both additive and nonadditive gene effects played a significant role in the genetic control of days to heading and maturity under different levels of moisture stress. Among the two, non-additive variance was predominant. In a line x tester analysis involving five male steriles and 20 land races, Vyas and Pokhriyal (1985) reported that the GCA variance was predominant for days to flowering, tillering, ear length, ear girth, 1000-grain weight and grain yield indicating the importance of additive effects. The high general combiners for grain yield also exhibited average to high GCA effects for most of the desirable yield components.

Manga and Saxena (1986) reported preponderance of both additive and nonadditive gene effects with complete dominance for synchrony of ear emergence in a diallel study involving 10 inbred lines. Positive and highly significant rank correlations between mean performance of parents and the GCA revealed that mean performance was a good indicator of the GCA of the parent. In a line x tester study involving two male steriles and seven restorers, Khairwal et al. (1987) reported that SCA was important for effective tillers and biological yield while GCA was predominant for days to 50 per cent flowering, plant height, grain yield and harvest index. In line x

tester study involving 10 male steriles and seven pollinators over two environments, Omprakash et al. (1987) reported that both additive and non-additive gene effects were important in the expression of plant height, days to heading, effective tillers, biological yield and harvest index. Harvest index and biological yield exhibited low predictability of performance based on GCA alone.

In a 6 x 6 diallel study, Mangat and Satija (1987) reported that both additive and dominance gene effects were important for grain yield, grain weight, head weight, days to flower initiation, days to 50 per cent flowering, tiller number and plant height. They also observed significant reciprocal effects for head weight and plant height. In a line x tester analysis involving grey and white seeded pearl millet inbreds, Navale et al. (1987) observed good correspondence between mean performance and GCA effects in grey as well as white seeded lines. The mean performance was associated with SCA effects in case of white seeded lines only.

Combining ability of yield and other traits was studied by Chinna and Phul (1988) under rainfed and irrigated environments. They observed that nonadditive variance was of major importance in the inheritance of days to 50 per cent flowering, plant height, tiller number, ear length, ear girth, 1000-grain weight and grain yield under both the environments. High GCA effects for grain yield were associated with high GCA for tiller number, ear length and ear girth. High SCA effects were observed when at least one of the parents was a good combiner. In a 11 parent diallel study, Dukare et al. (1988) studied the combining ability of maintainer lines and reported no

correspondence between mean performance of hybrids and SCA effects. The magnitude of additive and nonadditive variances was more or less same indicating the importance of both types of gene action. They concluded that recurrent selection would be more effective for getting desirable recombinations.

Combining ability of nine new pollen parents with two male sterile lines was studied by Harare and Harinarayana (1988) in a line x tester design. In this study, SCA variance was higher for 50 per cent flowering, effective tillers, ear length, plant height and grain yield while GCA variance was important for ear girth and number of nodes per plant. While studying the combining ability of five maintainer lines in a diallel cross study, Khairwal *et al.* (1988) observed that none of the maintainer lines was a good general combiner for all characters studied viz., days to 50 per cent flowering, plant height, ear length and grain yield. They suggested to utilise all the good combiners for different characters in multiple crosses to obtain optimum level of the traits and to extract transgressive segregants.

Heterosis and combining ability of 20 induced mutants of two R lines viz., K560 and M46 with three male steriles viz., 5050A, 5141A and 81A were studied by Rawat and Iyagi (1988). Highly heterotic crosses were in general good specific combiners but their parents did not always show high GCA. High GCA for grain yield was accompanied by high GCA for two or more yield components. Good specific combiners for grain yield did not necessarily show high SCA for other traits nor their parents good general combiners.

Sagar and Kapoor (1988) investigated the genetics of grain yield and drought index through diallel analysis under six levels of moisture stress. They observed that the SCA variance was more vulnerable to environmental changes. The component analysis indicated the preponderance of nonadditive gene effects. One to five dominant genes for each recessive gene for grain yield and two to three for drought index were estimated. Combining ability of 13 land races of Rajasthan was studied by Sharma et al. (1988) for grain yield and fodder yield in a line x tester analysis. They reported that additive and non-additive gene actions were equally important for plant height, days to 50 per cent flowering and leaf number while nonadditive gene action was more predominant for days to maturity, earlength and grain and fodder yield. Crosses with high SCA effects had either one or both parents with desirable GCA.

Investigations on the combining ability of sweetness of stem and grain yield in a 7 x 7 diallel analysis by Jayaraman (1989) revealed predominance of additive gene action for days to maturity, panicle length, brix at vegetative, flowering and maturity stages and straw yield and nonadditive gene action for tiller number, stem thickness, panicle weight and grain yield. A good correspondence between the per se performance of parents and GCA effects was also noticed.

While studying the combining ability of five male sterile lines and 21 pollinators in a line x tester design Sahane et al. (1989) observed that early female was essential to realise earliness in

hybrid combinations. The studies indicated that the mid late flowering 863A line possessed a gene for earliness which expressed only in hybrid combinations.

Inheritance of plant height was studied by Sagar (1990) in six crosses using P_1 , P_2 , F_1 , F_2 , B_1 and B_2 generations at panicle initiation and anthesis in four environments representing different levels of moisture stress during summer season. The analysis of F_2 and back crosses indicated prevalence of nonallelic interactions. Duplicate epistasis played a major role in the expression of the character.

In the combining ability studies involving two diallel sets of restorer and non restorer pearl millet lines, Setty and Appadurai (1992) observed predominance of additive gene action for grain size and grain yield. Additive and non additive gene actions were equally important for plant height, tiller number and days to 50 per cent flowering.

In a seven parent diallel study, Nijhawan and Yadav (1993) studied combining ability for grain yield, harvest index, dry matter accumulation and specific leaf weight at three stages of crop growth viz., panicle initiation, 50 per cent flowering and physiological maturity. The estimate of GCA variance was much smaller at all the three stages of crop growth than the corresponding estimates of SCA variance. They also observed that most of the crosses involving parents with high x low or low x low GCA effects outyielded the check hybrid.

Thirumeni and Vijendradas (1993) reported high heritability (broad sense) for *plant height* (86.94%) and tiller number (94.82%) in variability studies involving 15 genotypes of pearl millet. The genetic advance estimate was low for plant height (6.49%) and moderate for tiller number (22.44%). Ramamoorthy and Thulasidas (1994) studied the P_1 , P_2 , F_1 , F_2 , B_1 and B_2 generations of five pearl millet crosses for gene action of tiller number, panicle length and grain yield per plant. The study indicated preponderance of dominance gene action for the three characters. Duplicate type of epistasis was observed.

2.3 CHARACTER ASSOCIATIONS

Estimates of genotypic and phenotypic correlations among characters are useful in planning and evaluating breeding programmes. A knowledge of the correlations that exists between important characters may facilitate the interpretation of results and provide the basis for planning efficient programmes for the future. The progress in selection for an economic trait also depends upon the relationships of an economic trait not only with its components but also with other economic traits. The genetic correlations are governed by linkage and physiological relationships in the course of development. The expression of a complex trait such as grain yield depends upon the interplay of a number of component attributes. A better picture of the contribution of each component in building up the total genetic architecture of a complex trait may be obtained through the analysis of causal schemes.

Wright's (1921) path coefficient approach reveals the different ways in which the component attributes influence the complex

traits. Path coefficient analysis has been frequently used in genetic studies of crop plants since 1959 when Dewey and Lu applied the principle in soybean. A path coefficient is simply a standardised partial regression coefficient and as such measures the direct influence of one variable upon another and permits the separation of the correlation coefficient into components of direct and indirect effects. The use of the method requires a cause and effects situation among the variables and the experimenter must assign direction in the causal system based upon a priori grounds or experimental evidence (Dewey and Lu, 1959). Literature on character associations and path coefficient analysis in pearl millet is reviewed here.

Strong and positive association of grain yield with length and diameter of peduncle, grain density, yield of primary ear and tillering and negative correlation with plant height and no correlation with 1000-grain weight were reported by Mahadevappa and Ponnaiya (1967). Head weight, tiller number, earliness, grain size and grain density were the important components of grain yield in the studies of Gupta and Nanda (1971). They observed that head weight was an important selection criterion as its inclusion improved the efficiency of selection indices. Gupta and Sidhu (1972) reported that tiller number and grain size were the major yield components while grain density and plant height were important selection criteria for improving grain yield.

In variability and correlation studies of grain yield and its components viz., tiller number, ear length, ear girth and 1000-grain weight, Sanga and Singh (1973) observed that grain yield had no simple

correlation with any of its components at the phenotypic or genotypic level. The components themselves were highly associated. 1000-grain weight contributed maximum towards the variability in grain yield followed by ear girth and ear length.

Correlation and regression analysis of 204 pearl millet lines by Gupta and Dhillon (1974) revealed that tiller number was the most important attribute influencing grain yield followed by plant height, grain size and 50 per cent flowering. Grain yield, grain density, grain size, plant height and tiller number were positively inter-related but their relationship with 50 per cent flowering was negative. The importance of tiller number was also confirmed (Phul et al., 1974).

Path coefficient studies by Gupta et al. (1976) revealed tiller number as the most important yield component. It had not only a large direct effect, but also had an indirect effect via the earing span. The second important yield component was grain size. Plant height had an indirect effect via grain size and earing span. A shorter span of earing and earliness were positively associated with higher grain yield and there was considerable indirect influence of vegetative period via the earing span on grain yield.

Studies of Singh and Singh (1976) revealed positive direct contribution of tiller number, days to flowering and leaf number to grain yield while plant height had its indirect effect through days to flowering, tiller number and number of leaves. The direct and indirect influence of ear weight on grain yield was more pronounced in

the studies of Rao et al. (1980) pointing to the importance of the character as a selection criteria.

Correlations and path coefficients were investigated by Singh et al. (1980) in a diallel study. Plant height and number of internodes had positive and significant association with ear length, ear girth and 100-seed weight and negative association with productive tillers per plant. Ear length was positively associated with 100-seed weight. Productive tillers expressed maximum direct effect on grain yield.

An increase in grain yield and days to flowering with reduced plant height was reported by Govil et al. (1982). The presence of negative correlation of grain yield with plant height indicated the necessity of breakage of unfavourable gene combinations through biparental mating. Positive and significant correlation of grain yield with plant height, ear length, ear girth and test weight was reported by Mukherji et al. (1982). Effective tillers, plant height and 1000-grain weight exerted positive direct effect on grain yield. Plant height contributed indirectly to the total correlation of majority of the characters.

While studying the interrelationships among yield components, Reddy and Sharma (1982) observed that the yield per plot and yield per plant were highly correlated. Both these attributes were positively correlated with plant height, tiller number, ear number, ear length and test weight and negatively correlated with days to earing and days to maturity. Path coefficient analysis revealed that progress in

selection for high yielding inbreds could be made through selection for yield per plant, plant height, tillers per plant and yield per plot.

Correlation and path coefficient studies by Rajasekaran (1985) revealed that the number of productive tillers per plant, panicle length and 1000-grain weight had significant positive association with grain yield. Number of grains per unit length of panicle had negative association with grain yield. Number of productive tillers registered highest positive direct effect on grain yield followed by panicle length and 1000-grain weight.

Positive correlation of plant height, tiller number, number of internodes, ear number, number of seeds per ear head and 1000-grain weight with grain yield was reported by Kamala et al. (1986). Character association studies by Reddy et al. (1988) indicated that genotypic correlations were higher than phenotypic correlations for days to 50 per cent flowering, plant height, tiller number, grain yield and straw yield. Days to 50 per cent flowering had positive and significant correlation with plant height and grain yield and negative correlation with tiller number. Association of plant height was positive with grain and straw yield and negative with tiller number.

Association and path analysis studies by Jayaraman (1989) revealed that the association of grain yield was positive with tiller number and negative with days to 50 per cent flowering. Tiller number and panicle weight exhibited high direct effect on grain yield. Path analysis studies by Khairwal et al. (1990) indicated that plant height

had indirect effect on grain yield and biological yield while days to 50 per cent heading had negative effect on grain yield. They concluded that tall and early inbreds with high biological yield would be suitable for achieving higher grain yields in pearl millet.

The literature reviewed above indicated the possibility of genetic improvement in pearl millet by the information gained from the studies on heterosis, combining ability, generation mean analysis and character associations. Knowledge on gene action of maturity, height and other yield attributes can be profitably used to manipulate these traits for achieving higher yield potentialities in pearl millet through population improvement and heterosis breeding.

The review also indicated that the results reported by various workers with regard to combining ability, gene action and character association in pearl millet varied with the material used for investigation. The inferences drawn are valid for the concerned genetic material studied and hence can not be generalised. In the present investigation also, the conclusions are drawn with special reference to the set of nine pearl millet inbred lines and their F_1 s studied.

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MATERIALS AND METHODS

CHAPTER III MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 Diallel analysis

Nine pearl millet inbred lines representing different height and maturity groups acquired from Millet Breeding Unit of ICRISAT were utilised as parents for diallel analysis in the present investigation. The details of the parental lines are given below:

<u>Inbred</u>	<u>Maturity group</u>	<u>Height group</u>
ICP 165 (P ₁)	Early (E)	Dwarf (D)
ICP 57 (P ₂)	Late (L)	Dwarf (D)
ICP 828 (P ₃)	Early (E)	Tall (T)
ICP 64 (P ₄)	Early (E)	Tall (T)
ICP 812 (P ₅)	Late (L)	Tall (T)
ICP 811 (P ₆)	Early (E)	Tall (T)
ICP 323 (P ₇)	Early (E)	Tall (T)
ICP 642 (P ₈)	Late (L)	Dwarf (D)
ICP 126 (P ₉)	Late (L)	Tall (T)

Early : 50 per cent flowering between 55 to 60 days

Late : 50 per cent flowering above 60 days

Dwarf : Plant height of 100-120 cm

Tall : Plant height above 150 cm

The parents will be referred as P₁, P₂, P₃, P₄, P₅, P₆, P₇, P₈ and P₉ hereafter.

3.1.2 Generation mean analysis

From the diallel experiment, six cross combinations viz., $P_1 \times P_5$, $P_1 \times P_9$, $P_2 \times P_3$, $P_3 \times P_5$, $P_3 \times P_8$ and $P_6 \times P_8$ were selected and utilised for studying the gene action. Six breeding generations viz., P_1 , P_2 , F_1 , F_2 , B_1 and B_2 of each cross were studied.

<u>Cross combinations</u>	<u>Type of cross</u>
ICP 165 x ICP 812 ($P_1 \times P_5$)	Early Dwarf x Late Tall
ICP 165 x ICP 126 ($P_1 \times P_9$)	Early Dwarf x Late Tall
ICP 57 x ICP 828 ($P_2 \times P_3$)	Late Dwarf x Early Tall
ICP 828 x ICP 812 ($P_3 \times P_5$)	Early Tall x Late Tall
ICP 811 x ICP 642 ($P_6 \times P_8$)	Early Tall x Late Dwarf
ICP 828 x ICP 642 ($P_3 \times P_8$)	Early Tall x Late Dwarf

3.2 METHODS

3.2.1 Location

All the experiments were carried out at the Regional Agricultural Research Station, Palem of Andhra Pradesh Agricultural University.

3.2.2 Diallel crossing programme

The crosses were effected during summer season of 1988. The parents were grown separately for effecting crosses in a specific block. At the time of panicle emergence, the panicles were covered with butter paper bags to avoid cross pollination. Pollen collected from the male parent was dusted on the stigmas of panicles of female

parent at stigma emergence stage between 7.00 AM and 10.00 AM. Pollination by dusting of pollen was done for two consecutive days to ensure cross pollination of stigmas of all florets. The parents were maintained by selfing. The nine parents were crossed in all possible combinations including reciprocals which account for a total of 72 F_1 s.

3.2.3 Generation of material for generation mean analysis

During summer 1989, another crossing block was raised to generate the seed of F_2 , B_1 and B_2 generation. For this, parental lines of the six cross combinations were sown along with their respective F_1 s. The F_1 s were treated as females and the parents as males and crossed seed of B_1 ($F_1 \times P_1$) and B_2 ($F_1 \times P_2$) were generated by following the selfing and dusting procedure as in the diallel crossing programme. The selfed seed of F_1 plants was taken for raising of F_2 generation. The seeds from the selfed heads of P_1 and P_2 were collected. Fresh crosses were also effected to increase the seeds of all the six F_1 combinations.

3.2.4 Study of diallel crosses

A total of eighty one entries consisting of 36 direct crosses, 36 reciprocals and nine parents were evaluated in randomized block design replicated twice during kharif, 1988^(June-September) and summer, 1989^(January-April) seasons. The plot size for each entry was one row of five meters length. Inter and intra row spacings followed were 50 cm and 10 cm respectively. The field was uniformly fertilized at the rate of 80 kg N, 40 kg P_2O_5 and 40 kg K_2O per hectare. The kharif crop was raised

rained while the summer crop was given protective irrigation. Weather data pertaining to the crop seasons ~~were~~ furnished in Appendix A.

3.2.5 Combined study of different generations of crosses

Six cross combinations each comprising of six breeding generations were raised during kharif, 1989 and summer, 1990 seasons adopting a randomised block design with four replications. The crosses were randomized first within each replication and then within a cross, different generations were randomised. The row length, spacings and package of practices were similar to that of the diallel experiment. The gross plot size, however, varied for different generations. The number of rows grown and the number of plants selected from each generation for recording observations are given below:

Genera- tion	No.of rows/ replication	No.of plants studied in each repli- cation	Total No.of plants stu- died in each generation
P ₁	2	20	80
P ₂	2	20	80
F ₁	2	20	80
F ₂	8	100	400
B ₁	3	40	160
B ₂	3	40	160

3.2.6 Observations recorded

In diallel experiments, observations were recorded on ten competitive individual plants in each replication and the mean values

worked out. For the combined study of different generations, individual plant observations were taken on specific number of plants, as noted in table and mean values worked out. The particulars of characters studied in each experiment are as follows:

- (i) Days to 50 per cent flowering - number of days from date of sowing to ^{the} date when half of panicles in a plant had anther emergence
- (ii) Plant height - measured in centimetres at maturity from the base of the plant to the tip of the main panicle.
- (iii) Total number of tillers per plant - counted at boot leaf stage.
- (iv) Number of panicles harvested per plant
- (v) Panicle length - measured in centimetres from the base of the panicle to the tip.
- (vi) Panicle girth - measured in centimetres upto one decimal at the middle of the panicle where the girth was maximum.
- (vii) 500-grain weight - determined in grams upto two decimals by weighing five hundred random grains
- (viii) Grain yield per main panicle - weight in grams of grains obtained by threshing the main panicle.
- (ix) Grain yield per plant - weight in grams of grains obtained by threshing all panicles of a plant including the main panicle.

3.3 STATISTICAL ANALYSIS

3.3.1 Diallel experiment

3.3.1.1 Analysis of variance: The data were analysed separately for each character for all the treatments as per randomized block design (Rao, 1983).

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F ratio
Replications	$r-1$	R_s	M_r	M_r/M_e
Treatments	$t-1$	T_s	M_t	M_t/M_e
Error	$(r-1)(t-1)$	E_s	M_e	

Where r = number of replications

t = number of treatments

After the preliminary analysis of variance, when the treatment variance was significant, an effort was made to further partition, the ^atreatments variance into variance due to parents, crosses and parents vs. crosses. The crosses variance was further partitioned into variance due to direct crosses, reciprocal crosses and direct vs reciprocal crosses.

The variances due to direct and reciprocal crosses were in turn partitioned into different groups of crosses based on maturity and height of parents involved in the crosses. These partitioned variances were compared with the error to test their statistical significance (Rao et al., 1973). Partitioning of treatments variance into different components is given below :

Source	Degrees of freedom
Replications	1
Treatments	80
(i) Parents	8
(ii) Crosses	71
(iii) Parents vs crosses	1
<u>Crosses</u>	71
(i) Direct crosses	35
(ii) Reciprocal crosses	35
(iii) Direct vs reciprocals	1
<u>Direct crosses</u>	35
(i) Early dwarf x Early tall	3
(ii) Early tall x Early tall	5
(iii) Late dwarf x Late tall	2
(iv) Early dwarf x Late dwarf	1
(v) Early dwarf x Late tall	1
(vi) Early tall x Late dwarf	3
(vii) Early tall x Late tall	5
(viii) Late dwarf x Early tall	3
(ix) Late tall x Early tall	1
(x) Rest of the direct crosses	2
(xi) Groups of direct crosses	9
<u>Reciprocal crosses</u>	35
(i) Early tall x Early dwarf	3
(ii) Early tall x Early tall	5
(iii) Late tall x Late dwarf	2

Contd..

Source	Degrees of freedom
(iv) Late dwarf x Early dwarf	1
(v) Late tall x Early dwarf	1
(vi) Late dwarf x Early tall	3
(vii) Late tall x Early tall	5
(viii) Early tall x Late dwarf	3
(xi) Early tall x Late tall	1
(x) Rest of the reciprocal crosses	2
(xi) Groups of reciprocal crosses	9
Error	80
Total	161

3.3.1.2 Estimation of heterosis

Heterosis expressed as per cent deviation of F_1 hybrid from its mid parent (MP), and better parent (BP) representing the relative heterosis (d_i) and heterobeltiosis (d_{ii}) respectively were calculated.

$$(i) \text{ Relative heterosis } (d_i) : \frac{\bar{F}_1 - \bar{MP}}{\bar{MP}} \times 100$$

$$(ii) \text{ Heterobeltiosis } (d_{ii}) : \frac{\bar{F}_1 - \bar{BP}}{\bar{BP}} \times 100$$

where,

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

$\bar{MP}$ = Mean values of two corresponding parents of the hybrid

$\bar{BP}$ = Mean of the better parent value

The significance of the values of heterosis was tested by t test as follows :

(i) To test the significance of relative heterosis (d_i) :

$$SE (d_i) = \sqrt{\frac{3}{2} \times \frac{Ems}{r}}$$

where,

Ems = Error mean square

r = Number of replications

$$t = \frac{\overline{F_1} - \overline{MP}}{SE (d_i)}$$

(ii) To test the significance of heterobeltiosis (d_{ii}) :

$$SE (d_{ii}) = \sqrt{2 \times \frac{Ems}{r}}$$

$$t = \frac{\overline{F_1} - \overline{BP}}{SE (d_{ii})}$$

3.3.1.3 Combining ability analysis

Since the parents were a set of chosen lines and both direct and reciprocal crosses were included in the investigation, the Method I and Model I of Griffing (1956) was used for the combining ability analysis. The fixed effects model (Model I) was followed in the present case since the conclusions were applicable only to the parents

and hybrids studied. The mathematical model for the combining ability analysis was assumed to be

$$x_{ij} = \mu + g_i + g_j + s_{ij} + r_{ij} + \frac{1}{bc} \sum_k \sum_l e_{ijkl}$$

$i, j = 1, \dots, P$ (Parents)

$k = 1, \dots, b$ (replications)

$l = 1, \dots, c$ (sample of plants)

where,

μ = Population mean
 g_i = General combining ability effect for the i^{th} parent
 s_{ij} = Specific combining ability effect for the cross between the i^{th} and j^{th} parents such that $s_{ij} = s_{ji}$

r_{ij} = Reciprocal effect involving the reciprocal crosses between the i^{th} and j^{th} parents such that $r_{ij} = r_{ji}$

e_{ijkl} = Environmental effect associated with the $ijkl^{\text{th}}$ observation.

The following restrictions were imposed on the combining ability elements.

$$\sum_i g_i = 0 \text{ and } \sum_i s_{ij} = 0 \text{ (for each } j \text{)}$$

Analysis of variance of Griffing's method I giving expectations of mean squares for the assumption of Model I are presented below :

Source	DF	Sum of squares	Mean sum of squares	Expectation of mean sum of squares
General combining ability	$p-1$	S_g	M_g	$\sigma^2 + 2p \left(\frac{1}{p-1} \right) \sum g_i^2$
Specific combining ability	$p(p-1)/2$	S_s	M_s	$\sigma^2 + \frac{2}{p(p-1)} \sum_i \sum_j s_{ij}^2$
Reciprocal effects	$p(p-1)/2$	S_r	M_r	$\sigma^2 + 2 \left(\frac{2}{p(p-1)} \right) \sum_i \sum_j r_{ij}^2$
Error	m	S_e	M_e'	σ^2

Where

$$S_g = \frac{1}{2p} \sum_i (X_{i.} + X_{.i})^2 - \frac{1}{p^2} X_{..}^2$$

$$S_s = \frac{1}{2} \sum_i \sum_j (x_{ij} + x_{ji})^2 - \frac{1}{2p} \sum_i (X_{.i} + X_{i.})^2 + \frac{1}{p^2} X_{..}^2$$

$$S_r = \frac{1}{2} \sum_i \sum_j (x_{ij} - x_{ji})^2$$

P = Number of parents

M_e' = $\frac{M_e}{b}$ where M_e is the error mean square for the randomised block design and b is the number of blocks

x_{ij} = Value of the cross between i^{th} and j^{th} parents (direct crosses) in the diallel table

x_{ji} = Value of the cross between j^{th} and i^{th} parents (reciprocal crosses) in the diallel table

$X_{i.}$ = Total of the array of the i^{th} parent in the diallel table

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

Combining ability effects

Combining ability effects were estimated as follows :

(i) General combining ability effect due to i^{th} parent,

$$\hat{g}_i = \frac{1}{2p} (X_{i.} + X_{.i}) - \frac{1}{2} \sum \frac{X_{..}}{p}$$

(ii) Specific combining ability effect due to ij^{th} cross,

$$\hat{s}_{ij} = \frac{1}{2} (x_{ij} + x_{ji}) - \frac{1}{2p} (x_{i.} + X_{.i} + x_{.j} + X_{.j}) + \frac{1}{2} \frac{X_{..}}{p}$$

(iii) Reciprocal effect,

$$\hat{r}_{ij} = \frac{1}{2} (x_{ij} - x_{ji})$$

Variances of combining ability effects

The variance effects were estimated as follows :

$$\text{Var} (\hat{g}_i) = \frac{(p-1)}{2p^2} \sigma^2$$

$$\text{Var } (\hat{s}_{ij}) = \frac{1}{2p^2} (p^2 - 2p + 2) \sigma^2 \quad (i \neq j)$$

$$\text{Var } (\hat{r}_{ij}) = \frac{1}{2} \sigma^2 \quad (i \neq j)$$

$$\text{Var } (\hat{g}_i - \hat{g}_j) = \frac{1}{p} \sigma^2 \quad (i \neq j)$$

$$\text{Var } (\hat{g}_i - \hat{g}_j) = \frac{1}{p} \sigma^2 \quad (i \neq j)$$

$$\text{Var } (\hat{s}_{ij} - \hat{s}_{ik}) = \frac{p-1}{p} \sigma^2 \quad (i \neq j, k; j = k)$$

(Used to test the difference between estimates of SCA effects having one common parent)

$$\text{Var } (\hat{s}_{ij} - \hat{s}_{kl}) = \frac{p-2}{p} \sigma^2$$

$$(i = j, k, l; j \neq k, l; k \neq l)$$

(used to test the difference between estimates of SCA effects having no common parent)

$$\text{Var } (\hat{r}_{ij} - \hat{r}_{kl}) = \sigma^2 \quad (i \neq j; k \neq l)$$

By taking square roots of the variances, the corresponding standard errors were computed.

GCA, SCA and reciprocal components of variance were estimated as per the following formulae :

$$\sigma_g^2 = \frac{1}{2p} \left[Mg - \frac{M_e^1 + p(p-1)M_s}{n^2 - n + 1} \right]$$

$$\sigma_s^2 = \frac{p^2}{2(p^2 - p + 1)} (M_s - M_e^1)$$

$$\sigma_r^2 = \frac{1}{2} (M_r - M_e^1)$$

3.3.1.4 Graphic and genetic analysis

The data of nine characters from the diallel experiments were also subjected to analysis as per the method suggested by Hayman (1954a and b). The following statistics computed in this analysis were used for graphic analysis.

V_r = Variance of the r^{th} array

W_r = Covariance between the parents and their offspring in the r^{th} array

W_r^1 = Covariance between the array means and offspring of the r^{th} array

V_{oLo} = Variance of the parents

V_{oLl} = Variance of the means of the arrays

V_{lLl} = Mean variance of the arrays

W_{oLo1} = Mean covariance between the parents and the arrays

$(\bar{m}_{Ll} - \bar{m}_{Lo})^2$ = Squared difference between the mean of the parents and mean of their n^2 progeny

E = Expected environmental component of variation

t^2 test = The validity of the assumptions for graphic and genetic analysis as postulated by Hayman (1954a) was tested by

$$t^2 = \frac{n-2}{4} \times \left[\frac{(\text{Var } V_r - \text{Var } W_r)^2}{(\text{Var } V_r \times \text{Var } W_r) - \text{Cov}^2(V_r, W_r)} \right]$$

which is an F with 4 and (n-2) degrees of freedom. Significant t^2 indicated failure of at least one of the assumptions postulated.

The hypothesis was also tested by the deviation of coefficient (b) from zero and unity.

The regression of covariance on variance and its SE were calculated as

$$b = \frac{\text{Cov}(W_r, V_r)}{\text{Var}(V_r)}$$

$$\text{Standard error (b)} = \frac{(\text{Var } W_r - b \text{ Cov } W_r, V_r)^{1/2}}{\text{Var } V_r (n-2)}$$

The significance of b from zero and unity were tested as follows :

$$\frac{b - 0}{\text{SE}(b)} \quad \text{and} \quad \frac{(1 - b)}{\text{SE}(b)}$$

These values were tested against table value of t for n-2 degrees of freedom.

Graphic analysis

The calculated values of W_r and V_r were plotted and regression graphs were drawn. The limiting parabola was constructed using the formula $W_r^2 = V_r \times V_{oLo}$ and the regression line on W_r , V_r graph was drawn using a regression equation $W_r = a + b V_r$. This was used to plot a linear regression line of unit slope. Then the actual W_r , V_r values were plotted.

Genetic analysis

Partitioning of the total variance was carried out by genetic analysis as proposed by Hayman (1954b) to estimate various genetic parameters as follows :

$$\begin{aligned}\hat{D} &= V_{oLo} - \hat{E} \\ \hat{F} &= 2 V_{oLo} - 4 W_{oLo1} - 2 (n-2) \hat{E} / n \\ \hat{H}_1 &= V_{oLo} - 4 W_{oLo1} + 4 V_{1L1} - (3n-2) \hat{E} / n \\ \hat{H}_2 &= 4 V_{1L1} - 4 V_{oL1} - 2 \hat{E} \\ \hat{h}^2 &= 4 (m_{L1} - m_{Lo})^2 - 4 (n-1) \hat{E} / n^2 \\ F_r &= 2 (V_{oLo} - W_{oLo1} + V_{1L1} - W_r - V_r) - 2 (n-2) \hat{E} / n\end{aligned}$$

where

$\hat{D}$ = Component of variation due to additive effects of genes
 $\hat{F}$ = The mean value of F_r over arrays, F being covariance of additive and non additive effects in the r th array.

$\hat{H}_1$ = Component of variation due to the dominance effect of the genes

$\hat{H}_2$ = Component of variation due to the dominance indicating asymmetry of positive and negative effects of genes

$\hat{H}_2$ = $H [1 - (u-v)^2]$ where

u = Proportion of positive alleles

v = Proportion of negative alleles

$$u + v = 1$$

$\hat{h}^2$ = Dominance effects (expressed as algebraic sum over all loci in heterozygous phase in all crosses)

Standard errors to test the significance of each of these genetic parameters were calculated by the following formulae (Hayman, 1954a).

$$SE(\hat{D}) = \{S^2 \times (n^2 + n^4)/n^5\}^{1/2}$$

$$SE(\hat{F}) = \{S^2 \times (4n^5 + 20n^4 - 16n^3 + 16n^2)/n^5\}^{1/2}$$

$$SE(\hat{H}_1) = \{S^2 \times (n^5 + 41n^4 - n^3 + 4n^2)/n^5\}^{1/2}$$

$$SE(\hat{H}_2) = \{S^2 \times (36n^4)/n^5\}^{1/2}$$

$$SE(\hat{h}^2) = \{S^2 \times (16n^4 + 16n^2 - 32n + 16)/n^5\}^{1/2}$$

$$SE(\hat{E}) = \{S^2 \times (n^4/n^5)\}^{1/2}$$

Where,

$$S^2 = 1/2 \text{ var } (W_r - V_r)$$

n = numbers of parents

From these genetic parameters, the following ratios were calculated.

$$(\hat{H}_1/\hat{D})^{1/2} = \text{Average degree of dominance over all loci.}$$

$$\frac{\hat{K}_D}{\hat{K}_R} = \frac{(4 \hat{D}H_1)^{1/2} + F}{(4 \hat{D}H_1)^{1/2} - F} = \text{The proportion of dominant and recessive genes in the parent.}$$

$$\frac{\hat{H}_2}{4 \hat{H}_1} = \text{Proportion of genes with positive and negative effects in the parents.}$$

$$\frac{\hat{h}^2}{\hat{H}^2} = \text{The number of groups of factors controlling the character and exhibiting dominance.}$$

$$h^2 \text{ (ns)} = \text{Heritability in narrow sense} = \frac{1/2 D + 1/2 H_1 - 1/2 H_2 - 1/2 F}{1/2 D + 1/2 H_1 - 1/4 H_2 - 1/2 F + E}$$

3.3.1.5 Genotypic and phenotypic correlations

The genotypic and phenotypic correlations between the characters under study for kharif and summer seasons were computed using diallel data as per the method of Johnson et al. (1955).

3.3.1.6 Path coefficient analysis

Path coefficient analysis as applied by Dewey and Lu (1959) and described by Rao (1983) was used to partition the correlation coefficients into direct and indirect effects.

3.3.2 Combined study of generations

The mean values were computed for each generation of P_1 , P_2 , F_1 , F_2 , B_1 and B_2 for each cross over four replications. The variances and corresponding standard errors of the means were computed from the deviations of the individual values from the pooled mean for each of the generation in each cross.

3.3.2.1 Study of the means

The adequacy of the data for a simple additive dominance model was tested utilising the A, B and C scaling tests of Mather and Jinks (1971).

$$\begin{aligned}\text{Scale A} &= 2 \bar{B}_1 - \bar{P}_1 - \bar{F}_1 = 0 \\ \text{Scale B} &= 2 \bar{B}_2 - \bar{P}_2 - \bar{F}_1 = 0 \\ \text{Scale C} &= 4 \bar{F}_2 - 2 \bar{F}_1 - \bar{P}_1 - \bar{P}_2 = 0\end{aligned}$$

Where P_1 , P_2 , F_1 , F_2 , B_1 and B_2 are mean of different generation means over all replications. The variance of the quantities A, B and C were calculated from the respective variances of the different generations as follows:

$$\begin{aligned}V_A &= 4 V \bar{B}_1 + V \bar{P}_1 + V \bar{F}_1 \\ V_B &= 4 V \bar{B}_2 + V \bar{P}_2 + V \bar{F}_1 \\ V_C &= 16 V \bar{F}_2 + 4 V \bar{F}_1 + V \bar{P}_1 + V \bar{P}_2\end{aligned}$$

Where, V_A , V_B and V_C are the variances of A, B and C, $V \bar{P}_1$, $V \bar{P}_2$, $V \bar{F}_1$, $V \bar{F}_2$, $V \bar{B}_1$ and $V \bar{B}_2$ are the variances of P_1 , P_2 , F_1 , F_2 , B_1 and B_2 generations respectively.

The standard errors of A, B and C were obtained as V_A , V_B and V_C respectively and were utilized for testing the significance of deviation of the scales from zero. The additive dominance model was considered inadequate when at least any one of three scales was found to deviate significantly from zero.

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3.3.2.2 Joint scaling test

The method proposed by Cavalli (1952) was adopted to estimate the goodness of fit (χ^2) of additive-dominance model. The three parameters m , d and h derived from the additive-dominance model were estimated by the weighted least square method (Mather and Jinks, 1971). From these estimated parameters, the expected generation means were calculated as follows:

$$P_1 = m + (d)$$

$$P_2 = m - (d)$$

$$F_1 = m + (h)$$

$$F_2 = m + 1/2 (h)$$

$$B_1 = m + 1/2 (d) + 1/2 (h)$$

$$B_2 = m - 1/2 (d) + 1/2 (h)$$

Where,

m = Population mean

(d) = additive component

(h) = dominance component

The adequacy of the simple additive dominance model was tested statistically by goodness of fit test between the estimated generation means and the observed generation means. For most of the crosses, the scaling tests and χ^2 test indicated inadequacy of simple additive-dominance model. Hence, a six parameter model (Mather and Jinks, 1971) was adopted assuming digenic interaction. Perfect fit

estimates of six parameters m , (d) , (h) , (i) , (j) and (l) were estimated as follows:

$$\begin{aligned} m &= 1/2 \bar{P}_1 + 1/2 \bar{P}_2 + 4 \bar{F}_2 - 2 \bar{B}_1 - 2 \bar{B}_2 \\ (d) &= 1/2 \bar{P}_1 - 1/2 \bar{P}_2 \\ (h) &= 6 \bar{B}_1 + 6 \bar{B}_2 - 8 \bar{F}_2 - \bar{F}_1 - 3/2 \bar{P}_1 - 3/2 \bar{P}_2 \\ (i) &= 2 \bar{B}_1 + 2 \bar{B}_2 - 4 \bar{F}_2 \\ (j) &= 2 \bar{B}_1 - \bar{P}_1 - 2 \bar{B}_2 + \bar{P}_2 \\ (l) &= \bar{P}_1 + \bar{P}_2 + 2 \bar{F}_1 + 4 \bar{F}_2 - 4 \bar{B}_1 - 4 \bar{B}_2 \end{aligned}$$

The standard errors of the above parameters were calculated and t test was applied to test the significance of deviation of the parameter from zero.

3.3.2.3 Estimation of minimum gene number, heritability (ns) and genetic advance

Minimum gene number (n)

Minimum number of genes controlling the expression of a single character was estimated by the following formulae of Sewell Wright as given by Burton (1951).

$$n = \frac{0.25 (0.75 - h + h^2) D^2}{V F_2 - V F_1}$$

Where,

$$h = \frac{\bar{F}_1 - \bar{P}_1}{\bar{P}_2 - \bar{P}_1}$$

$$D = \bar{P}_2 - \bar{P}_1$$

$\bar{P}_1$ = The mean of the smallest parent

$\bar{P}_2$ = The mean of the largest parent

$\bar{F}_1$ = The mean of the F_1 population

VF_1 = Variance of F_1 population

VF_2 = Variance of F_2 population

Heritability (ns):

Heritability (narrow sense) was estimated by the method of Allard (1960) as follows:

$$h^2 = \frac{2 VF_2 - (VB_1 + VB_2)}{VF_2} \times 100$$

Where,

VF_2 = Variance of F_2 population

VB_1 = Variance of B_1 generation

VB_2 = Variance of B_2 generation

Genetic advance (Gs)

Genetic advance was estimated as suggested by Allard (1960).

$$Gs = (K) \sigma_A h^2$$

Where,

K = Selection differential (2.06 was value of K at 5 per cent selection intensity)

σ_A = Phenotypic standard deviation obtained as $\sqrt{VF_2}$

h^2 = Heritability (ns)

Genetic advance was expressed as per cent of mean of the F_2 population.

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RESULTS

CHAPTER IV

RESULTS

Nine pearl millet inbreds representing different height and maturity groups and their 72 F_1 s (36 direct crosses and 36 reciprocals) were evaluated in kharif, 1988 and summer, 1989 seasons in the diallel study. Further, six crosses selected from the diallel experiment were studied in kharif, 1989 as well as ⁱⁿ summer, 1990 seasons along with six breeding generations (P_1 , P_2 , F_1 , F_2 , B_1 and B_2).

The results pertaining to the diallel and generation mean analysis studies in pearl millet are presented below.

4.1 DIALLEL ANALYSIS

Data recorded on grain yield per plant and the yield attributes viz., days to 50 per cent flowering, plant height, tiller number, panicle number, panicle length, panicle girth, 500-grain weight and grain yield per main panicle were analysed for mean performance and heterosis, combining ability, nature of gene action and character associations.

4.1.1 The Analysis of Variance

The results on analysis of variance for each of the nine characters studied are as follows :

4.1.1.1 Days to 50 per cent flowering: There were significant differences among the parents, crosses and parents vs crosses in both kharif and summer seasons (Table 1). The crosses in direct and reciprocal groups differed significantly in both seasons. The interaction

Table 1: Analysis of variance for grain yield and its attributes in kharif and summer seasons

Source of variation	D.F.	MEAN SUM OF SQUARES									
		Days to 50% flowering		Plant height		Tiller number		Panicle number		Panicle length	
		Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer
Replications	1	120.296**	0.500	2.607	10.500	0.060	0.012	0.119	0.355	56.632**	0.015
Treatments	80	22.753**	27.936**	2827.507**	1699.362**	0.832**	4.554**	0.592**	0.523**	28.314**	31.038**
Parents	8	75.698**	51.178**	3954.916**	2109.785**	2.375**	2.020**	1.010**	0.812**	69.775**	85.643**
Crosses	71	15.913**	9.847**	2060.673**	1229.149**	0.568**	4.895**	0.528**	0.495**	15.871**	18.557**
Parents x crosses	1	84.794**	1126.335**	48253.662**	29401.076**	0.123	0.580	1.763**	0.161	580.119**	480.390**
Direct crosses	35	11.967**	9.976**	2140.956**	1239.516**	0.552**	4.567**	0.568**	5.574**	15.598**	17.90**
ED x LD	1	0.480	3.802*	4.41	9.922	0.250	5.760**	0.122	0.810**	1.210**	0.16
ED x ET	3	2.684	1.026	390.204**	133.79**	0.775**	1.190*	0.275*	0.075	5.279**	9.743**
ED x LT	1	1.562	2.402	13.69	54.76**	0.002	1.000	0.81**	0.022	1.690*	0.122
LD x ET	3	1.794	11.527**	965.535**	436.690**	0.354*	10.017**	0.096	0.304*	4.110**	3.344**
LD x LT	2	22.985**	25.211**	1190.791**	32.421**	0.086	9.686**	0.281	0.506**	10.111**	2.531*
ET x ET	5	4.723*	5.134**	493.362**	444.586**	0.650**	7.641**	0.310*	0.219*	18.065**	13.41**
ET x LT	5	7.934**	5.025**	677.249**	261.521**	0.614**	0.565	0.119	0.398**	20.194**	15.853**
ET x LD	3	11.087**	0.388	1308.751**	578.354**	1.521**	2.115**	0.258	1.453**	11.453**	9.056**
LT x ET	1	0.722	0.022	14.44	7.29	0.302	1.322*	0.040	0.360	0.010	1.322
Rest	2	61.200**	34.081**	7388.611**	4138.221**	0.031	0.746	2.046**	0.501**	13.680**	7.431**
Direct cross groups	9	15.301**	14.969**	4877.289**	3110.308**	0.475**	5.932**	1.141**	0.683**	26.846**	43.595**
Reciprocal crosses	35	20.137**	9.999**	2039.254**	1253.870**	0.778**	5.255**	0.501**	0.491**	16.597**	19.732**
LD x ED	1	0.810	5.290**	0.01	1.322	1.322**	2.250**	0.040	0.090	1.690*	0.16
ET x ED	3	9.685**	0.973	1219.641**	168.067**	0.591**	1.565**	0.103	0.054	7.578**	17.927**
LT x ED	1	3.240	2.560*	9.61	94.09**	0.302	0.000	2.890**	1.102**	2.722**	0.16
ET x LD	3	2.090	13.161**	1204.114**	307.583**	0.521**	11.975**	0.156	0.177	3.340**	2.076*
LT x LD	2	24.851**	17.045**	1484.231**	25.631*	0.281	10.161**	0.111	0.351*	10.671**	3.161*
ET x ET	5	5.062*	7.083**	899.879**	484.196**	0.572**	9.434**	0.500**	0.454**	20.705**	14.393**
LT x ET	5	9.195**	8.009**	1008.037**	372.616**	0.563**	1.323**	0.750**	0.686**	21.649**	18.499**
LD x ET	3	18.008**	0.743	577.406**	525.743**	1.004**	2.857**	0.334*	0.117	14.391**	11.361**
ET x LT	1	10.562*	2.890*	127.690**	3.24	0.002	3.610**	0.122	0.122	0.490	5.062**
Rest	2	118.401**	28.246**	6551.206**	4202.251**	0.571**	1.220**	0.855**	0.681**	19.571**	7.181**
Reciprocal cross groups	9	27.004**	14.285**	4069.179**	3115.865**	1.319**	5.816**	0.752**	0.783**	25.646**	45.110**
Direct x Reciprocal crosses	1	6.206	0.013	0.464	1.101	0.886**	0.284	0.033	0.058	0.006	0.250
Error	80	1.653	0.616	53.346	5.612	0.107	0.309	0.095	0.092	0.297	0.695

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

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Table 1: Contd..

Source of variation	D.F.	MEAN SUM OF SQUARES					
		Panicke girth		500-grain weight		Grain yield/main panicle	
		Kharif	Summer	Kharif	Summer	Kharif	Summer
Replications	1	0.024	0.001	0.003	0.008	4.2180	0.406
Treatments	80	2.674**	3.311**	1.698**	1.471**	80.302**	126.008**
Parents	8	5.079**	3.097**	2.139**	2.130**	74.072**	81.186**
Crosses	71	2.316**	2.356**	1.500**	1.168**	52.562**	94.606**
Parents x crosses	1	8.780**	72.820**	12.196**	17.770**	2079.614**	2714.151**
Direct crosses	35	2.461**	2.178**	1.495**	1.080**	51.692**	92.898**
ED x LD	1	0.921*	0.64*	1.060**	0.116	2.25	48.302**
ED x ET	3	2.170**	1.299**	0.738**	0.848**	61.304**	57.177**
ED x LT	1	1.452**	0.184	0.001	0.001	18.922	1.96
LD x ET	3	1.375**	3.072**	0.513**	0.646**	9.648	155.150**
LD x LT	2	0.923**	2.510**	0.033	0.739**	9.286	75.461**
ET x ET	5	2.157**	1.744**	0.703**	1.132**	40.018**	100.485**
ET x LT	5	0.825**	1.167**	0.499**	0.361**	49.732**	74.942**
ET x LD	3	1.966**	0.427*	1.162**	0.628**	38.047**	51.844**
LT x ET	1	0.016	0.027	0.301*	0.990**	2.102	1.562
Rest	2	0.834**	0.411	1.553**	0.001	0.860	1.220
Direct cross groups	9	5.423**	4.511**	3.839**	2.376**	109.988**	175.284**
Reciprocal crosses	35	2.235**	2.599**	1.547**	1.285**	54.859	98.964**
LD x ED	1	0.0001	1.081**	2.397**	0.008	0.810	11.902*
ET x ED	3	1.872**	2.437**	0.808**	0.919**	70.655**	37.496**
LT x ED	1	0.050	0.008	0.010	0.161*	24.502	0.022
ET x LD	3	0.496*	2.994**	0.378**	0.819**	45.727**	107.851**
LT x LD	2	0.700**	1.538**	0.215*	0.418**	53.086**	56.94**
ET x ET	5	2.027**	1.706**	0.653**	1.433**	49.485**	75.589**
LT x ET	5	1.778**	2.465**	0.580**	0.456**	45.904**	114.651**
LD x ET	3	2.066**	0.730**	0.931**	0.742**	32.458*	75.016**
ET x LT	1	0.547	0.792*	0.838**	0.763**	1.44	45.562**
Rest	2	0.370	0.260	0.990**	0.035	0.646	20.220**
Reciprocal cross groups	9	4.795**	5.126**	3.986**	2.907**	95.820**	182.184**
Direct x Reciprocal crosses	1	0.102	0.072	0.024	0.113	2.667	1.867
Error	80	0.146	0.139	0.066	0.031	9.190	2.332

* Significant at 5% level ;

** Significant at 1% level

of direct and reciprocal crosses was not significant. The differences among various groups of direct and reciprocal crosses were significant in both seasons. Among the direct crosses, F_1 s in LDxLT, ETxET and ETxLT groups differed significantly in both seasons. Crosses of ETxLD group differed significantly in kharif while those in EDxLD and LDxET groups differed in summer season. Among the reciprocals, crosses in LTxLD, ETxET, LTxET and ETxLT groups differed significantly in both seasons. Reciprocal crosses pertaining to ETxED and LDxET groups differed significantly in kharif only while those of LDxED, LTxED and ETxLD groups differed in summer only.

4.1.1.2 Plant height: Mean squares of parents, crosses, parents vs crosses and groups of direct and reciprocal crosses were significant in both seasons (Table 1). The interaction of direct x reciprocal crosses was not significant. The differences were significant in EDxET, LDxET, LDxLT, ETxET, ETxLT and ETxLD groups in kharif and summer seasons and in summer only in EDxLT group among direct crosses. In the reciprocal crosses, the differences were significant in ETxED, ETxLD, LTxLD, ETxET, LTxET and LDxET groups (kharif and summer), ETxLT group (kharif) and LTxED group (summer).

4.1.1.3 Tiller number : The differences were significant among parents, crosses and groups of direct and reciprocal crosses in kharif and summer seasons (Table 1). The parents x crosses interaction was not significant. Interaction of direct and reciprocal crosses was significant in kharif. Significant differences were observed in EDxET, LDxET, ETxET and ETxLD groups in both kharif and summer, in ETxLT group in kharif and in EDxLD, LDxLT and LTxET groups in summer

among direct crosses. In the reciprocal crosses, the differences were significant in LDxED, ETxED, ETxLD, ETxET, LTxET and LDxET groups (kharif and summer), LTxLD and ETxLT groups (summer).

4.1.1.4 Panicle number: The differences among parents, crosses and various groups of direct and reciprocal crosses were significant (Table 1). Interaction of parents x crosses was significant in kharif season. Differences in ETxET group (Kharif and summer), EDxET and EDxLT groups (kharif), EDxLD, LDxET, LDxLT, ETxLT and ETxLD groups (summer) of direct crosses were significant. In reciprocals, the differences were significant in LTxED, ETxET and LTxET groups (kharif and summer), LDxET (kharif) and LTxLD group (summer).

4.1.1.5 Panicle length: There were significant differences among parents, crosses and groups of direct and reciprocal crosses in both the seasons (Table 1). Interaction of parents vs crosses was significant. Crosses in the direct cross groups of EDxET, LDxET, LDxLT, ETxET, ETxLT and ETxLD differed significantly in kharif and summer while EDxLD and EDxLT differed in kharif only. Among the reciprocals, crosses of ETxED, ETxLD, LTxLD, ETxET, LTxET and LDxET groups (kharif and summer), LDxED and LTxED groups (kharif) and ETxLT (summer) differed significantly.

4.1.1.6 Panicle girth: Differences among the parents, crosses and groups of direct and reciprocal crosses were significant in both the seasons (Table 1). Parents x crosses interaction was significant. Among the direct crosses, F_1 s in EDxLD, EDxET, LDxET, LDxLT, ETxET, ETxLT and ETxLD groups (kharif and summer) and EDxLT group (kharif)

differed significantly. Among the reciprocals, differences in the groups of ETxED, ETxLD, LTxLD, ETxET, LTxET and LDxET (kharif and summer) and LDxED and ETxLT (summer) were significant.

4.1.1.7 500-grain weight : Mean squares of parents, crosses, parents x crosses and groups of direct and reciprocal crosses were significant in both the seasons (Table 1). Significant differences were observed in the direct crosses belonging to EDxET, LDxET, ETxET, ETxLT, ETxLD and LTxET groups (kharif and summer), EDxLD group (kharif) and LDxLT group (summer). In reciprocals, the differences were significant in groups of ETxED, ETxLD, LTxLD, ETxET, LTxET, LDxET and ETxLT (kharif and summer), LDxED (kharif) and LTxED (summer).

4.1.1.8 Grain yield per main panicle : Parents, crosses, groups of direct and reciprocal crosses differed significantly in both seasons. Parents x crosses interaction was also significant (Table 1). Significant differences were observed in the direct crosses belonging to EDxET, ETxET, ETxLT and ETxLD groups (kharif and summer), EDxLD, LDxET and LDxLT groups (summer). In the reciprocals, the crosses belonging to ETxED, ETxLD, LTxLD, ETxET, LTxET and LDxET groups (kharif and summer), LDxED and ETxLT groups (summer) were significantly different.

4.1.1.9 Grain yield per plant : The differences were significant among parents, crosses and groups of direct and reciprocal crosses in both seasons (Table 1). Interaction of parents x crosses was also significant. Differences were significant among the direct crosses belonging to EDxET, LDxET, ETxET, ETxLT and ETxLD groups (kharif and summer), EDxLT and LDxLT groups (kharif) and LTxET group (summer). In

the reciprocals, the differences were significant among the crosses belonging to ETxED, ETxLD, ETxET, LTxET and LDxET groups in kharif and summer seasons while the crosses of LDxED, LTxED and LTxLD groups differed significantly in kharif season only.

4.1.2 Mean Performance and Heterosis

The performance of hybrids in relation to parents for each character is presented below.

4.1.2.1 Days to 50 per cent flowering: In general, the parents took more number of days to flower in summer season than in kharif (Table 2). In the early group (P_1 , P_3 , P_4 , P_6 and P_7) days to 50 per cent flowering in parents ranged from 53.10 (P_7) to 56.85 (P_4) in kharif and 56.15 (P_7) to 62.80 (P_1) in summer season. In the late group (P_2 , P_5 , P_8 and P_9), it ranged from 64.80 (P_5) to 67.35 (P_8) in kharif and 67.95 (P_8) to 72.25 (P_2) in summer. In kharif, the hybrids flowered between 50.60 ($P_9 \times P_5$) and 65.40 ($P_8 \times P_2$) days (Table 3). In summer, the days to 50 per cent flowering varied from 53.0 ($P_6 \times P_4$) to 62.8 ($P_2 \times P_9$). Twenty three hybrids took more number of days to complete 50 per cent flowering than their mid parent. in kharif. In summer all the 72 hybrids flowered in less number of days compared to the mid parental value.

The hybrids $P_9 \times P_5$ recorded highest negative heterosis of -23.18 per cent followed by $P_5 \times P_9$ (-20.37%) in kharif (Table 4). In summer season, $P_2 \times P_5$ (-20.68%) and $P_8 \times P_5$ (-20.30%) were the two hybrids with highest negative heterosis. In kharif, 13 hybrids viz., $P_2 \times P_5$, $P_2 \times P_9$, $P_3 \times P_5$, $P_3 \times P_8$, $P_5 \times P_6$, $P_5 \times P_8$, $P_5 \times P_9$, $P_8 \times P_9$, $P_5 \times P_2$, $P_9 \times P_2$,

Table 2: Mean expression of different characters in nine parents in kharif and summer seasons

Character	Season	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇	P ₈	P ₉	Mean	S.E.
Days to 50% flowering	Kharif	54.65	67.30	56.75	56.85	64.80	54.70	53.10	67.35	66.95	60.27	1.285
	Summer	62.80	72.25	61.40	62.60	68.20	60.30	56.15	67.95	68.45	64.45	0.784
Plant height (cm)	Kharif	103.60	94.40	168.65	158.90	157.70	195.95	204.75	105.70	207.10	155.19	7.303
	Summer	110.15	99.15	155.90	151.60	149.85	177.60	184.55	103.95	170.00	144.75	2.368
Tiller number	Kharif	4.20	5.30	4.00	7.00	4.45	6.00	4.90	4.45	6.60	5.21	0.327
	Summer	6.35	6.10	5.75	7.40	6.00	8.05	6.25	6.75	8.65	6.81	0.555
Panicke number	Kharif	2.25	2.15	1.55	2.90	3.75	3.60	3.25	2.85	2.80	2.78	0.308
	Summer	2.95	2.70	2.10	3.10	4.20	3.95	3.60	3.20	3.25	3.22	0.303
Panicke length (cm)	Kharif	17.05	30.70	10.30	18.50	15.70	21.80	24.00	24.40	18.40	20.09	0.544
	Summer	17.70	34.25	11.35	19.90	15.45	24.00	23.10	25.30	20.85	21.32	0.833
Panicke girth (cm)	Kharif	6.110	7.060	9.315	6.910	6.685	10.675	8.475	5.870	8.265	7.70	0.382
	Summer	6.020	6.575	8.825	6.085	5.795	8.595	7.170	5.140	6.750	6.77	0.372
500-grain weight (g)	Kharif	3.3385	2.7855	5.745	3.1820	3.3220	5.2820	4.5090	3.2250	3.7980	3.91	0.256
	Summer	2.850	2.8235	5.3395	2.8035	3.2235	5.255	4.5815	3.3940	3.4810	3.76	0.176
Grain yield/main panicle(g)	Kharif	13.15	22.75	13.50	14.50	9.80	29.30	21.75	19.65	15.45	17.76	3.031
	Summer	12.40	22.75	16.65	12.95	10.15	31.15	20.45	18.15	16.65	17.88	1.527
Grain yield per plant (g)	Kharif	24.85	43.85	18.85	35.05	30.05	83.75	55.80	45.05	35.05	41.36	3.520
	Summer	26.25	47.05	27.60	28.15	26.70	79.90	49.45	40.70	36.55	40.16	5.314

Table 3: Mean performance of hybrids for grain yield and its attributes in kharif and summer seasons

Days to 50% flowering				Plant height (cm)						Tiller number			
Cross	Kharif		Summer		Kharif		Summer		Kharif		Summer		
	Direct	Reci-	Direct	Reci-	Direct	Reci-	Direct	Reci-	Direct	Reci-	Direct	Reci-	
	cross	procal	cross	procal	cross	procal	cross	procal	cross	procal	cross	procal	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	
EDxLD													
P1xP2	57.45	56.95	56.05	55.65	132.60	138.75	125.30	129.55	5.30	5.65	6.20	6.45	
P1xP8	56.75	56.05	54.10	53.35	130.50	138.65	128.45	130.70	4.80	4.50	8.60	7.95	
EDxET													
P1xP3	58.10	59.65	54.65	55.65	203.35	215.45	178.05	176.80	5.95	5.25	6.85	6.30	
P1xP4	57.10	57.25	55.55	54.55	176.15	164.50	161.50	156.25	5.90	5.25	8.20	7.80	
P1xP6	55.55	54.75	55.75	56.15	201.55	208.75	179.35	174.35	6.10	5.55	8.65	8.40	
P1xP7	57.90	59.05	54.25	55.05	180.90	176.35	171.10	169.55	4.75	4.30	7.70	7.45	
EDxLT													
P1xP5	56.50	57.35	55.15	55.45	209.45	219.45	185.90	186.40	5.70	5.80	6.90	7.30	
P1xP9	57.75	55.55	56.70	57.05	213.15	216.35	193.30	196.10	5.75	6.35	7.90	7.30	
LDxET													
P2xP3	59.30	60.15	57.40	58.10	211.75	218.05	192.70	192.20	4.95	4.45	7.55	8.00	
P2xP4	58.15	58.65	54.90	54.65	170.75	167.65	161.85	165.55	5.70	5.45	9.85	10.85	
P2xP6	57.90	57.70	57.40	57.45	215.60	211.20	189.70	188.35	4.90	5.60	9.55	9.65	
P2xP7	57.00	58.50	60.75	60.90	216.20	219.35	191.50	189.90	5.60	5.15	5.00	5.20	
LDxLT													
P2xP5	56.35	57.60	55.70	56.05	210.50	220.60	196.85	194.90	5.65	5.25	10.15	10.80	
P2xP9	60.60	61.15	62.80	61.70	221.75	207.50	203.30	199.25	5.55	6.00	5.75	6.35	
P8xP9	63.05	64.65	59.15	60.15	257.25	259.85	204.25	202.00	5.95	5.60	7.85	7.95	

Contd.. Table 3

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
ETxET												
P3xP4	58.70	60.55	55.05	54.50	231.60	216.25	211.80	215.55	5.35	4.85	6.85	6.35
P3xP6	57.00	58.10	56.05	56.20	215.75	210.05	196.45	203.75	5.20	4.70	9.80	9.95
P3xP7	59.35	60.25	57.65	58.10	213.80	219.90	194.85	199.45	5.80	5.65	5.45	4.85
P4xP6	58.15	58.50	53.60	53.00	241.95	255.20	216.80	222.85	4.55	5.10	5.65	5.10
P4xP7	55.30	56.20	53.40	53.45	236.25	229.60	204.30	200.50	6.15	5.30	5.05	4.70
P6xP7	56.30	58.25	55.75	55.20	220.90	191.60	174.85	177.70	5.00	4.10	8.80	8.65
ETxLT												
P3xP5	55.50	57.25	54.30	54.50	201.00	196.30	185.25	182.90	4.75	4.50	6.55	7.00
P3xP9	58.95	59.45	58.70	59.50	231.30	227.05	217.30	221.30	5.60	5.10	6.00	5.65
P4xP5	59.30	60.85	55.15	55.80	226.60	218.80	205.25	199.35	5.30	5.20	6.70	7.05
P4xP9	61.05	59.10	54.80	54.55	249.10	245.25	214.55	216.10	5.35	5.75	5.55	5.20
P6xP9	56.65	54.85	54.95	54.05	251.75	261.90	205.20	209.50	4.80	4.70	5.35	5.85
P7xP9	57.70	59.65	55.55	55.35	236.85	229.40	210.70	208.40	6.25	5.80	6.05	5.35
ETxLO												
P3xP8	59.75	61.55	55.40	55.20	220.55	226.85	205.75	204.25	5.45	6.05	6.15	6.55
P4xP8	62.45	63.45	56.15	56.15	190.35	198.05	175.70	177.30	6.25	6.55	7.40	8.30
P6xP8	58.30	58.90	56.40	56.20	250.85	236.05	213.40	213.80	4.25	4.90	5.10	5.50
P7xP8	56.95	56.60	55.75	56.65	233.90	230.65	188.40	188.65	5.90	6.15	7.05	7.40
LTxET												
P5xP6	53.00	51.15	53.55	53.45	214.65	219.25	190.25	186.20	5.00	4.65	6.50	6.25
P5xP7	53.85	54.40	53.70	55.15	210.85	207.95	187.55	188.00	5.55	4.70	7.65	8.15
Rest												
P2xP8	63.30	65.40	62.05	60.95	115.35	120.50	111.05	111.40	4.70	4.55	5.85	6.65
P5xP8	56.00	54.35	54.90	54.25	220.80	222.90	194.60	198.15	4.95	4.20	5.05	5.25
P5xP9	52.45	50.60	54.90	54.65	220.45	216.00	184.00	180.45	4.85	5.25	4.65	5.35

Contd.. Table 3

Cross	Panicle number				Panicle length (cm)				Panicle girth (cm)			
	Kharif		Summer		Kharif		Summer		Kharif		Summer	
	Direct cross	Rect-procal cross	Direct cross	Rect-procal cross	Direct cross	Rect-procal cross	Direct cross	Rect-procal cross	Direct cross	Rect-procal cross	Direct cross	Rect-procal cross
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
EDxLD												
P1xP2	1.95	1.85	2.80	3.05	27.20	26.35	30.50	29.75	7.60	7.08	8.17	8.27
P1xP8	2.30	2.05	3.70	3.35	28.30	27.65	30.10	29.35	6.64	7.07	7.37	7.23
EDxET												
P1xP3	2.75	2.35	3.30	2.85	26.20	25.15	23.05	21.95	8.70	9.14	9.48	9.82
P1xP4	2.20	2.60	3.15	3.20	28.20	28.85	27.70	28.30	7.48	7.94	7.86	7.63
P1xP6	2.05	2.55	2.85	3.10	27.60	28.65	27.30	26.30	8.80	9.23	8.81	9.28
P1xP7	1.90	2.10	3.20	2.90	24.55	25.65	27.35	28.30	6.63	7.24	7.80	7.72
EDxLT												
P1xP5	3.15	3.45	3.55	4.05	26.75	26.05	26.00	25.10	7.41	7.88	8.35	8.18
P1xP9	2.25	1.75	3.40	3.00	25.45	24.40	25.65	24.70	8.61	8.10	7.92	8.09
LDxET												
P2xP3	1.80	2.05	2.10	2.25	29.25	28.80	32.15	32.60	9.43	9.09	10.87	10.77
P2xP4	1.60	2.00	2.85	2.35	28.70	29.10	31.80	32.40	7.89	8.21	8.26	8.66
P2xP6	1.45	1.55	2.50	2.85	27.00	27.80	29.25	30.35	9.61	9.36	10.75	11.13
P2xP7	1.95	2.20	2.00	2.20	30.45	30.90	31.15	31.65	8.37	8.72	9.47	9.08
LDxLT												
P2xP5	2.10	2.25	3.60	3.50	29.55	28.60	29.45	28.65	8.89	8.43	9.53	9.48
P2xP9	2.10	1.90	3.00	2.80	25.45	24.55	27.30	26.30	8.30	8.07	9.22	8.76
P8xP9	2.75	2.35	4.00	3.55	29.10	28.50	28.95	28.25	7.53	7.27	7.45	7.73

Contd... Table 3

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
ETxET												
P3xP4	2.65	3.05	3.05	2.55	27.25	27.80	26.10	26.55	9.53	8.91	10.01	9.54
P3xP6	1.80	1.90	2.90	3.05	21.80	20.85	21.85	21.00	11.49	11.05	11.04	10.80
P3xP7	2.20	2.00	2.65	2.35	21.30	22.10	23.20	23.95	9.39	9.17	10.69	10.51
P4xP6	2.35	2.60	3.05	3.45	25.40	26.25	25.30	26.20	9.18	8.93	9.33	9.25
P4xP7	2.85	3.00	3.65	3.55	28.65	28.45	29.25	28.65	8.40	8.06	8.45	8.31
P6xP7	2.00	2.20	3.15	3.05	26.70	27.10	26.30	26.85	9.16	9.70	9.93	10.21
ETxLT												
P3xP5	2.45	2.92	2.75	2.55	18.00	17.55	19.25	18.75	9.74	10.10	9.99	10.57
P3xP9	2.25	2.00	2.65	2.50	21.55	22.55	23.95	25.05	10.76	10.31	10.42	10.88
P4xP5	2.65	2.80	3.65	3.35	23.85	23.45	24.50	24.15	8.26	7.99	8.99	8.26
P4xP9	2.45	2.65	3.05	3.30	26.30	26.60	26.35	25.85	8.52	8.73	8.47	8.70
P6xP9	2.70	2.45	2.85	2.60	25.90	25.45	26.80	26.50	9.28	9.65	9.57	9.69
P7xP9	2.95	3.10	3.65	3.95	25.15	25.60	26.25	26.55	8.81	8.47	8.71	8.54
ETxLD												
P3xP8	2.50	2.30	2.80	3.15	24.30	23.75	25.50	24.90	8.77	8.54	8.58	8.67
P4xP8	2.60	2.50	3.85	3.70	27.40	27.65	29.25	29.65	6.98	6.75	8.25	7.57
P6xP8	2.90	2.70	3.55	3.25	29.10	28.50	30.35	29.65	8.20	7.96	8.02	7.96
P7xP8	3.30	3.25	3.55	3.45	29.60	30.05	29.30	29.70	6.67	6.36	7.48	7.27
LTxET												
P5xP6	3.15	2.85	4.15	3.85	23.25	22.80	22.50	21.90	8.78	9.13	9.11	9.42
P5xP7	2.95	3.20	3.55	3.50	23.15	23.50	23.65	24.15	8.91	8.39	8.94	8.53
Rest												
P2xP8	1.80	2.10	2.45	2.60	29.00	29.85	28.35	27.60	6.88	7.15	7.90	7.68
P5xP8	3.60	3.30	3.45	3.75	24.20	25.20	25.45	26.20	7.28	7.07	7.63	7.41
P5xP9	3.50	3.15	2.90	3.35	24.80	23.90	24.70	23.85	8.14	7.85	8.51	8.12

		500-grain weight (g)				Grain yield/main panicle (g)				Grain yield/plant (g)			
		Kharif		Summer		Kharif		Summer		Kharif		Summer	
		Direct	Reci- procal cross	Direct	Reci- procal cross	Direct	Reci- procal cross	Direct	Reci- procal cross	Direct	Reci- procal cross	Direct	Reci- procal cross
Cros													
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
EDxLD													
P1xP2	3.35	3.14	3.56	3.65	3.65	21.30	22.15	24.85	23.95	36.30	35.30	50.70	53.60
P1xP8	4.39	4.67	3.91	3.74	3.74	19.80	21.25	17.90	20.50	37.30	42.65	44.55	48.25
EDxET													
P1xP3	6.09	6.10	5.46	5.60	5.60	26.50	31.40	28.55	27.70	61.20	71.30	66.70	59.35
P1xP4	4.80	4.70	4.31	4.42	4.42	24.65	24.05	20.65	20.95	45.20	53.90	43.80	47.55
P1xP6	6.08	5.98	5.80	5.88	5.88	31.90	29.20	31.15	30.20	57.60	64.90	65.40	67.05
P1xP7	5.64	5.69	5.50	5.79	5.79	18.50	18.05	20.90	22.55	30.95	32.15	46.25	48.30
EDxLT													
P1xP5	4.64	4.76	4.42	4.31	4.31	28.00	29.35	27.15	27.45	70.45	80.85	65.10	70.30
P1xP9	4.61	4.65	4.43	4.71	4.71	23.65	24.40	28.55	27.60	45.20	38.65	67.20	59.95
LDxET													
P2xP3	4.73	4.61	5.14	5.29	5.29	34.50	35.15	45.05	45.85	54.75	64.10	78.25	82.05
P2xP4	3.89	3.85	3.80	3.77	3.77	30.20	28.30	26.00	30.35	42.60	49.30	54.00	57.20
P2xP6	5.08	4.92	4.59	4.75	4.75	33.25	26.05	42.95	42.45	42.95	34.35	86.70	88.55
P2xP7	4.72	4.78	4.79	4.83	4.83	35.15	35.45	42.40	45.80	62.35	70.40	73.45	81.75
LDxLT													
P2xP5	4.00	3.55	4.41	4.34	4.34	29.40	23.75	34.30	32.20	54.55	46.05	81.80	78.15
P2xP9	4.07	4.08	4.45	4.27	4.27	31.80	29.15	41.65	40.60	58.10	48.15	85.00	83.40
P8xP9	4.25	4.14	3.37	3.51	3.51	33.70	34.05	29.45	30.70	78.65	69.55	75.40	76.60

Contd.. Table 3

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
ETxET												
P3xP4	5.41	5.11	4.75	4.19	30.90	25.85	24.45	23.15	68.90	61.50	52.90	45.60
P3xP6	6.11	5.92	6.12	6.11	38.95	38.80	39.80	41.05	61.60	67.00	83.55	86.30
P3xP7	5.40	5.46	6.29	6.30	28.90	28.40	32.50	33.80	55.30	48.50	64.75	62.85
P4xP6	4.47	4.49	4.81	4.76	27.25	26.75	29.20	30.25	54.50	60.20	64.10	71.45
P4xP7	5.56	5.66	5.07	5.21	28.15	25.60	26.80	26.90	66.80	61.95	65.80	64.40
P6xP7	6.06	6.03	5.91	6.03	27.30	28.10	33.70	32.20	44.95	53.35	74.15	70.50
ETxLT												
P3xP5	5.41	5.59	4.81	4.91	30.85	28.25	34.30	34.50	63.75	58.50	70.60	67.60
P3xP9	5.59	5.75	5.37	5.44	34.45	37.40	43.60	44.00	71.40	66.50	85.00	84.00
P4xP5	4.20	4.23	4.25	4.25	26.45	28.90	31.15	25.40	59.10	64.70	73.55	67.80
P4xP9	5.28	5.31	4.37	4.25	31.00	31.35	25.95	25.90	64.90	70.95	56.55	60.20
P6xP9	5.37	5.46	5.02	5.07	40.35	39.55	38.35	37.30	92.20	84.10	77.90	74.05
P7xP9	5.29	5.28	5.02	5.01	28.05	29.70	32.10	27.60	69.35	74.15	72.45	70.80
ETxLD												
P3xP8	5.47	5.36	5.33	5.36	36.90	39.15	32.65	33.85	79.15	77.50	67.30	75.80
P4xP8	3.86	4.03	4.32	4.20	31.50	32.45	27.75	25.40	69.95	69.25	68.85	64.75
P6xP8	5.15	5.11	5.11	5.13	36.80	36.25	39.05	36.55	86.70	80.50	88.30	82.95
P7xP8	4.20	4.10	4.22	4.20	27.95	30.05	28.90	24.20	72.85	80.40	68.85	61.40
LTxCT												
P5xP6	5.03	5.16	5.53	5.52	23.90	25.15	29.45	24.25	60.90	57.60	78.05	72.65
P5xP7	4.49	4.25	4.53	4.65	25.35	23.95	28.20	31.00	62.40	60.20	67.40	73.40
Rest												
P2xP8	2.26	2.48	3.51	3.48	26.40	26.35	27.80	31.35	41.40	47.90	51.35	54.30
P5xP8	3.90	3.85	3.56	3.69	27.20	26.05	26.00	27.45	75.15	69.20	61.55	68.60
P5xP9	3.64	3.44	3.56	3.44	25.90	27.15	25.90	25.05	71.30	67.80	55.65	58.00

$P_6 \times P_5$, $P_8 \times P_5$ and $P_9 \times P_5$ flowered earlier than their early parents. In summer, majority of hybrids flowered earlier than their early parents. In kharif, 18 hybrids viz., $P_1 \times P_3$, $P_1 \times P_4$, $P_1 \times P_6$, $P_1 \times P_7$, $P_3 \times P_4$, $P_3 \times P_6$, $P_3 \times P_7$, $P_4 \times P_7$, $P_6 \times P_7$, $P_3 \times P_1$, $P_4 \times P_1$, $P_6 \times P_1$, $P_7 \times P_1$, $P_4 \times P_3$, $P_6 \times P_3$, $P_7 \times P_3$, $P_6 \times P_4$ and $P_7 \times P_6$ flowered later than their late parents. However, in summer none of the hybrids flowered later than their late flowering parents.

4.1.2.2 Plant height : In the category of dwarf parents (P_1 , P_2 and P_8) the height ranged from 94.4 cm in P_2 in kharif to 110.15 cm in P_1 in summer (Table 2). In the tall group (P_3 , P_4 , P_5 , P_6 , P_7 and P_9) it varied from 157.70 (P_5) to 207.10 cm (P_9) in kharif and 149.85 (P_5) to 184.55 cm (P_7) in summer. The range of height in the hybrids was 111.35 cm ($P_2 \times P_8$) in kharif to 222.85 cm ($P_6 \times P_4$) in summer (Table 3). Seventy one hybrids in kharif and 70 in summer ~~were~~ taller than the mid parental average. Only three hybrids in kharif ($P_1 \times P_7$, $P_7 \times P_1$ and $P_7 \times P_6$) and five hybrids in summer ($P_1 \times P_7$, $P_6 \times P_7$, $P_7 \times P_1$, $P_6 \times P_1$ and $P_7 \times P_6$) were shorter than their tall parents.

Heterosis ranged from -4.36 to 75.00 per cent in kharif and -3.43 to 58.36 per cent in summer (Table 4). Heterobeltiosis varied between -13.87 and 42.60 per cent in kharif and -8.12 and 38.26 per cent in summer. $P_4 \times P_5$ (42.60%) and $P_8 \times P_5$ (41.34%) exhibited highest heterobeltiosis. None of the hybrids ~~was~~ shorter than ~~its~~ dwarf parents. Except three hybrids in kharif ($P_1 \times P_7$, $P_7 \times P_1$ and $P_7 \times P_6$) and five hybrids in summer ($P_1 \times P_7$, $P_6 \times P_7$, $P_6 \times P_1$, $P_7 \times P_1$ and $P_7 \times P_6$) all the hybrids were taller than their tall parents.

Table 4: Heterosis (d_i) and heterobeltiosis (d_{ii}) in 72 crosses for grain yield and its attributes in kharif and summer seasons

Cross	DAYS TO 50% FLOWERING										PLANT HEIGHT									
	Kharif					Summer					Kharif					Summer				
	Direct cross	Reciprocal cross	d_i	d_{ii}	d_i	Direct cross	Reciprocal cross	d_i	d_{ii}	d_i	Direct cross	Reciprocal cross	d_i	d_{ii}	d_i	Direct cross	Reciprocal cross	d_i	d_{ii}	d_i
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
EDxLD																				
P1xP2	-5.78**	-14.63**	-6.60**	-15.37**	-16.99**	-38.34**	-17.58**	-22.97**	33.93**	27.99**	40.15**	33.92**	19.73**	13.75**	23.79**	17.61**				
P1xP8	-6.76**	-15.73**	-8.11**	-16.77**	-17.24**	-20.38**	-18.39**	-21.48**	24.70**	23.46**	32.48**	31.17**	19.99**	16.61**	22.09**	18.65**				
EDxET																				
P1xP3	4.30*	2.37	7.09**	5.11*	-11.99**	-12.97**	-10.38**	-11.38**	49.38**	20.57**	57.94**	27.48**	33.84**	14.20**	32.90**	13.40**				
P1xP4	2.42	0.43	2.69	0.70	-11.40**	-11.54**	-12.99**	-13.13**	34.20**	10.83*	33.25**	3.52	23.40**	6.53**	19.38**	3.06*				
P1xP6	1.60	1.55	0.13	0.09	-9.42**	-11.22**	-8.77**	-10.58**	34.56**	2.85	39.37**	6.53	24.65**	0.98	21.18**	-1.82				
P1xP7	7.47**	5.94*	9.60**	8.05**	-8.78**	-13.61**	-7.44**	-12.34**	17.33**	-11.64**	14.38**	-13.87**	16.11**	-7.28**	15.06**	-8.12**				
LDxLT																				
P1xP5	-5.39**	-12.80**	0-3.97*	-11.49**	-15.80**	-19.13**	-15.34**	-18.69**	60.31**	32.81**	67.96**	39.15**	43.00**	24.05**	43.38**	36.55**				
P1xP9	-5.01**	-13.74**	-8.63**	-17.02**	-13.60**	-17.16**	-13.06**	-16.65**	37.20**	2.92	39.26**	4.46	37.99**	13.70**	39.99**	15.35**				
LDxET																				
P2xP3	-4.39*	-11.88**	-3.02	-10.62**	-14.10**	-20.55**	-13.05**	-19.58**	60.99**	25.55**	65.78**	29.29**	51.10**	23.60**	50.71**	23.28**				
P2xP4	-6.74**	-13.59**	-5.51**	-12.85**	-18.57**	-24.01**	-18.94**	-24.35**	34.82**	7.45	32.37**	5.50	29.09**	6.76**	32.04**	9.20**				
P2xP6	-5.08**	-13.96**	-5.40**	-14.26**	-13.39**	-20.55**	-13.31**	-20.48**	48.51**	10.02	45.47**	7.78*	37.09**	6.83**	36.11**	6.05**				
P2xP7	-5.31**	-15.30**	-2.82	-13.07**	-5.37**	-15.91**	-5.14**	-15.70**	44.54**	5.59	46.64**	7.13*	35.00**	3.76**	33.87**	2.89				
LDxLT																				
P2xP5	-14.68**	-16.27**	-12.79**	-14.41**	-20.68**	-22.90**	-20.18**	-22.42**	66.99**	33.48**	75.00**	39.88**	58.11**	31.36**	56.54**	30.06**				
P2xP9	-9.72**	-9.95**	-8.90**	-9.13**	-10.73**	-13.07**	-12.29**	-14.60**	47.09**	7.07*	37.64**	0.19	51.06**	19.58**	48.05**	17.20**				
P8xP9	-6.10**	-6.38**	-3.72*	-4.00*	-13.26**	-13.58**	-11.80**	-12.12**	64.45**	24.21**	66.11**	25.47**	49.11**	20.14**	47.47**	18.82**				

Contd.. Table 4

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
ETxLT																
P3xP4	3.34	3.25	6.60**	6.50**	-11.20**	-12.06**	-12.09**	-12.93**	41.41**	37.32**	32.04**	28.22**	37.75**	35.85**	40.19**	38.26**
P3xP6	2.28	0.43	4.26*	2.37	-7.88**	-8.71**	-7.64**	-8.46**	18.34**	10.10**	15.22**	7.11	17.81**	10.61**	22.18**	14.72**
P3xP7	8.05**	4.58*	9.69**	6.16**	-1.91	-6.10**	-1.14	-5.37**	14.51**	4.42	17.78**	7.39*	14.46**	5.58**	17.16**	8.07**
P4xP6	4.25*	2.28	4.88*	2.90	-12.77**	-14.37**	-13.75**	-15.33**	36.36**	23.47**	43.83**	30.23**	31.71**	22.07**	35.38**	25.47**
P4xP7	0.59	-2.72	2.22	-1.14	-10.06**	-14.69**	-5.92**	-14.61**	29.93**	15.38**	26.27**	12.13**	21.55**	10.70**	19.29**	8.64**
P6xP7	4.54*	3.01	9.55**	6.48**	-4.25**	-7.54**	-5.19**	-8.45**	10.25**	7.88*	-4.36	-6.42	-3.43**	-5.25**	-1.86	-3.71**
ETxLT																
P3xP5	-8.67**	-14.35**	-5.80**	-11.65**	-16.20**	-20.38**	-15.89**	-20.08**	23.18**	19.18**	20.30**	16.39**	21.17**	23.62**	19.64**	22.05**
P3xP9	-4.68*	-11.94**	-3.88*	-11.20**	-9.58**	-14.24**	-8.35**	-13.07**	23.11**	11.68**	20.85**	9.63**	33.35**	27.82**	35.80**	30.17**
P4xP5	-2.50	-8.45**	0.04	-6.09**	-15.67**	-19.13**	-14.67**	-18.18**	43.14**	42.60**	38.21**	37.69**	36.17**	35.38**	32.26**	31.49**
P4xP9	-1.37	-8.81**	-4.52*	-11.72**	-16.36**	-19.94**	-16.74**	-20.45**	36.12**	20.28**	34.01**	18.42**	33.42**	26.20**	34.39**	27.11**
P6xP9	-6.86**	-15.38**	-9.82**	-18.07**	-14.64**	-19.72**	-16.03**	-21.03**	24.92**	21.55**	29.95**	26.46**	18.06**	15.54**	20.54**	17.96**
P7xP9	-3.87*	-13.81**	-0.62	-10.90**	-10.83**	-18.84**	-11.15**	-19.13**	15.01**	14.36**	11.39**	10.76**	18.85**	14.16**	17.55**	12.92**
ETxLD																
P3xP8	-3.70*	-11.28**	-0.80	-8.61**	-14.34**	-18.46**	-14.65**	-18.76**	60.78**	30.77**	65.37**	34.50**	58.36**	31.97**	57.20**	31.01**
P4xP8	0.56	-7.27**	2.170	-5.79**	-13.97**	-17.36**	13.97	-17.36**	43.87**	19.79**	49.69**	24.63**	37.50**	15.89**	38.75**	16.95**
P6xP8	-4.46**	-13.43**	-3.48	-12.54**	-12.04**	-16.99**	-12.35**	-17.29**	66.31**	28.01**	56.50**	20.46**	26.15**	20.15**	51.87**	20.38**
P7xP8	-5.43**	-15.44**	-6.01**	-15.96**	-10.05**	-17.95**	-8.70**	-16.62**	50.60**	14.23**	48.59**	12.64**	30.60**	2.08**	30.77**	2.22
LTxCT																
P5xP6	-11.29**	-18.20**	-14.39**	-21.06**	-16.65**	-21.48**	-16.80**	-21.62**	21.39**	9.54*	23.99**	11.89**	16.20**	7.12**	13.72**	4.84**
P5xP7	-8.65**	-16.89**	-7.71**	-16.04**	-13.63**	-21.26	-11.29**	-19.13**	16.34**	2.97	14.74**	1.56	12.17**	1.62	12.44**	1.86
Rest																
P2xP4	-5.97**	-6.39**	-2.85	-2.89	-11.40**	-14.11**	-13.05**	-15.64**	15.29**	9.12	20.43**	14.00**	9.35**	6.83**	9.69**	7.16**
P5xP8	-15.24**	-16.85**	-17.74**	-19.30**	-19.35**	-19.50**	-20.30**	-20.45**	67.65**	40.01**	69.24**	41.34**	53.34**	29.86**	56.14**	32.23**
P5xP9	-20.37**	-21.65**	-23.18**	-24.42**	-19.64**	-19.79**	-20.01**	-20.16**	20.86**	6.44	18.42**	4.29	15.05**	8.23**	12.83**	6.14**

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

Contd.. Table 4

Cross	TILLER NUMBER										PANICLE NUMBER						
	Kharif					Summer					Kharif						
	Direct cross	Reciprocal cross	Direct cross	Reciprocal cross	Direct cross	Reciprocal cross	Direct cross	Reciprocal cross	Direct cross	Reciprocal cross	Direct cross	Reciprocal cross	Direct cross	Reciprocal cross	Direct cross	Reciprocal cross	Reciprocal cross
	d_1	d_{11}	d_1	d_{11}	d_1	d_{11}	d_1	d_{11}	d_1	d_{11}	d_1	d_{11}	d_1	d_{11}	d_1	d_{11}	d_{11}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(17)
EDxLD																	
P1xP2	11.57	0.00	18.94**	6.60	-0.40	-2.36	3.61	1.57	-11.36	-13.33	-15.90	-17.77	-0.88	-5.08	7.96	3.38	
P1xP8	10.98	7.86	4.04	1.12	31.29**	2.74	21.37**	17.77*	-9.80	-19.29	-19.60	-28.07*	20.32*	15.62	8.94	4.68	
EDxET																	
P1xP3	45.12**	41.66**	28.04**	25.00**	13.22	7.87	4.13	-0.78	44.73**	22.22	23.68	4.44	30.69**	11.86	12.87	-3.38	
P1xP4	5.35	-15.71**	-6.25	-25.00**	19.27**	10.81	13.45	5.40	-14.56	-24.13*	0.97	-10.34	4.13	1.61	5.78	3.22	
P1xP6	19.60**	1.66	8.82	-7.50	20.13**	7.45	16.66*	4.34	-29.91**	-43.05**	-12.82	-29.16**	-17.39*	-27.84**	-10.14	-21.51**	
P1xP7	4.39	-3.06	-5.49	-12.24	22.22*	21.25*	18.25**	17.32	-30.90**	-41.53**	-23.63*	-35.38**	-2.29	-11.11	-11.45	-19.44*	
EDxLT																	
P1xP5	31.79**	28.08**	34.10**	30.33**	11.74	8.66	18.21*	14.96	5.00	-16.00	15.00	-8.00	-0.69	-15.47*	13.28	-3.57	
P1xP9	6.48	-12.87*	17.59**	-3.78	5.83	-8.67	-2.66	-15.60*	-10.89	-19.64	-30.69**	-37.50**	9.67	4.61	-3.22	-7.69	
LDxET																	
P2xP2	6.45	-6.60	-4.30	-16.03*	27.42**	23.77*	35.02**	31.14**	-2.70	-16.27	10.81	-4.65	-12.50	-22.22*	-6.25	-16.66	
P2xP4	-7.31	-18.57**	-11.30*	-22.14**	55.42**	33.10**	71.20**	46.62**	-36.63**	-44.82**	-20.79	-31.03**	-1.72	-8.06	-18.96*	-24.19*	
P2xP6	-13.27**	-18.33**	-0.88	-6.66	34.98**	18.63**	36.39**	19.87**	-49.56**	-59.72**	-46.08**	-56.94**	-24.81**	-36.70**	-14.28	-27.84**	
P2xP7	9.80	5.66	0.98	-2.83	-19.02*	-20.00*	-15.78*	-16.00	-27.77**	-40.00**	-18.51	-32.30**	-36.50**	-44.44**	-30.15**	-38.88**	
LDxLT																	
P2xP5	15.89**	6.60	7.69	-0.94	67.76**	66.39**	78.51**	77.04**	-28.81**	-44.00**	-23.72*	-40.00**	4.34	-14.28*	1.44	-16.66*	
P2xP9	-6.72	-15.90**	0.84	-9.09	-22.03**	-33.52**	-13.89*	-26.58**	-15.15	-25.00*	-23.23*	-32.14**	0.84	-7.69	-5.88	-13.84	
P8xP9	7.69	-9.84*	1.35	-15.15**	1.94	-9.24	3.24	-8.09	-2.65	-3.50	-16.81	-17.54	24.03**	23.07	10.07	9.23	

Contd.. Table 4

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
L1xET																
P3xP4	-2.72	-23.57**	-11.81*	-30.71**	4.18	-7.43	-3.42	-14.18	19.10	-8.62	37.07**	5.17	17.30	-1.61	-1.92	-17.74
P3xP6	4.80	-13.33*	-6.00	-21.66**	42.02**	21.73**	44.20**	23.60**	-30.09**	-50.00**	-26.21*	-47.22**	-4.13	-26.58**	0.82	-22.78**
P3xP7	30.33**	18.36**	26.96**	15.30*	-9.16	-12.80	-19.16*	-22.40*	-8.33	-32.30**	-16.66	-38.46**	-0.07	-26.38**	-17.54	-34.72**
P4xP6	-30.00*	-35.00**	-21.53**	-27.14**	-26.86**	-29.81**	-30.09**	-32.91**	-27.69**	-34.72**	-20.00*	-27.77**	-13.47	-22.78**	-2.12	-12.65
P4xP7	3.36	-12.14*	-10.92*	-24.28**	-26.00**	-31.75**	-31.13**	-36.48**	-7.31	-12.30	-2.43	-7.69	8.95	1.38	5.97	-1.38
P6xP7	-8.25	-16.66**	-24.77**	-31.66**	23.07**	9.31	20.97**	7.45	-41.60**	-44.44**	-35.76**	-38.88**	-16.55*	-20.25**	-19.20**	-22.78**
L1xLT																
P3xP5	12.42	6.74	6.50	1.12	11.48	9.16	19.14*	16.66	-7.54	-34.66**	9.43	-22.66**	-12.69	-34.52**	-19.04*	-39.28**
P3xP9	5.66	-15.15**	-3.77	-22.72**	-16.66*	-30.63**	-21.52**	-34.68**	3.44	-19.64	-8.04	-28.57*	-0.93	-18.46*	-6.54	-23.07*
P4xP5	-7.42	-24.28**	-9.17	-25.71**	0.00	-9.45	5.22	-4.72	-20.30*	-29.33**	-15.78	-25.33**	0.00	-13.09	-8.21	-20.23**
P4xP9	-21.32**	-23.57**	-15.44**	-17.85**	-30.84**	-35.83**	-35.20**	-39.00**	-14.03	-15.51	-7.01	-8.62	-3.93	-6.15	3.93	1.53
P6xP9	-23.80**	-27.27**	-25.39**	-28.78**	-35.92**	-38.15**	-29.94**	-32.36**	-15.62	-25.00**	-23.43**	-31.94**	-20.83**	-27.84**	-27.77**	-34.17**
P7xP9	8.69	-5.30	0.86	-12.12*	-18.79*	-30.05**	-28.18**	-38.15**	-2.47	-9.23	2.47	-15.00	6.56	1.38	15.32*	9.72
L1xLD																
P3xP8	28.99**	22.47**	43.19**	35.95**	-1.60	-8.88	4.80	-2.96	13.63	-12.28	4.54	-19.29	5.66	-12.50	18.86	-1.56
P4xP8	9.17	-10.71*	14.41**	-6.42	4.59	0.00	17.31*	12.16	-9.56	-10.34	-13.04	-13.79	22.22**	20.31*	17.46*	15.62
P6xP8	-18.66**	-29.16**	-6.22	-18.33**	-31.08**	-36.64**	-25.67**	-31.67**	-10.07	-19.44*	-16.27	-25.00**	-0.69	-10.12	-9.09	-17.72*
P7xP8	26.20**	20.40**	31.55**	25.51**	8.46	4.44	13.84	9.62	8.19	1.53	6.55	0.00	4.41	-1.38	1.47	-4.16
L1xET																
P5xP6	-4.30	-16.66**	-11.00*	-22.50**	-7.47	-19.25**	-11.03	-22.36**	-14.28	-16.00	-22.44**	-24.00**	1.84	-1.19	-5.52	-8.33
P5xP7	18.71**	13.26*	0.53	-4.08	24.89**	22.40*	33.06**	30.40**	-15.71	-21.33*	-8.57	-14.66	-8.97	-15.47*	-10.25	-16.66*
Rest																
P2xP8	-3.58	-11.32	-6.66	-14.15*	-8.94	-13.33*	3.50	-1.48	-28.00*	-36.84**	-16.00	-26.31*	-16.94	-23.43*	-11.86	-18.75*
P5xP8	11.23	11.23	-5.61	-5.61	-20.78**	-25.18**	-17.64*	-22.22**	9.09	-4.00	0.00	-12.00	-6.75	-17.85*	1.35	-10.71
P5xP9	-17.21*	-26.51**	-4.97	-20.45**	-36.51**	-46.24**	-26.96**	-38.15**	6.87	-6.66	-3.81	-16.00	-22.14**	-30.95**	-10.06	-20.23**

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

Contd.. Table 4

PANICLE LENGTH														PANICLE GIRTH													
		Kharif				Summer				Kharif				Summer													
Cross		Direct cross	Reciprocal cross	Direct cross	Reciprocal cross	Direct cross	Reciprocal cross	Direct cross	Reciprocal cross	Direct cross	Reciprocal cross	Direct cross	Reciprocal cross	Direct cross	Reciprocal cross												
	d_i	d_{ij}	d_i	d_{ij}	d_i	d_{ij}	d_i	d_{ij}	d_i	d_{ij}	d_i	d_{ij}	d_i	d_{ij}	d_i												
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)											
EDxLO																											
P1xP2	13.92**	-11.40**	10.36**	-14.16**	17.42**	-10.94**	14.53**	-13.13**	15.48**	7.71	7.59	0.35	29.81**	24.33**	31.32**	25.77**											
P1xP8	36.55**	15.98**	33.41**	13.31**	40.00**	18.97**	36.51**	16.00**	10.93	8.75	18.11	15.79	32.16**	22.32**	29.56**	20.09**											
EDxET																											
P1xP3	91.59**	53.66**	83.91**	47.50**	58.69**	30.22**	51.11**	24.01**	12.86**	-6.54	18.57**	-1.82	27.78**	7.47*	32.30**	11.27**											
P1xP4	58.64**	52.43**	62.30**	55.94**	47.34**	39.19**	50.53**	42.21**	14.90**	8.24	21.96**	14.90**	29.94**	29.25**	26.14**	25.47**											
P1xP6	42.08**	26.60**	47.49**	31.42**	30.93**	13.75**	26.13**	9.58**	4.91	-17.51**	10.03*	-13.48	33.33**	2.92	40.44**	26.43**											
P1xP7	19.61**	2.29	24.96**	6.87**	34.06**	18.39**	38.72**	22.51**	-9.08*	-21.76**	-0.71	-14.57**	18.27**	8.78	17.05**	7.67											
EDxLT																											
P1xP5	63.35**	56.89**	59.08**	52.78**	56.86**	46.89**	51.43**	41.80**	15.82**	10.84	23.17**	17.87**	41.43**	38.78**	38.46**	35.88**											
P1xP9	32.37**	38.31**	26.91**	32.60**	41.24**	23.02**	28.14**	18.46**	19.86**	4.23	12.76**	-1.93	24.11**	17.40**	26.70**	19.85**											
LDxET																											
P2xP3	42.68**	-4.72**	40.48**	-6.18**	41.00**	-6.13*	42.98**	-4.81*	15.17**	1.23	11.02**	2.41	41.23**	23.22**	39.93**	22.09**											
P2xP4	16.66**	-6.51**	18.29**	-5.21**	17.45**	-7.15**	19.66**	-5.40	12.95**	11.75*	17.53**	16.28**	30.48**	25.62**	36.80**	31.71**											
P2xP6	2.85	-12.05**	5.90**	-9.44**	0.42	-14.59**	4.20	-11.38**	8.37*	-9.97**	5.55	-12.31**	41.72**	25.07**	46.53**	29.29**											
P2xP7	11.33**	-0.81	12.97**	0.65	8.63**	-9.05**	10.37**	-7.59**	7.75	-1.23	12.26**	2.89	37.86**	32.14**	32.19**	26.70**											
LDxLT																											
P2xP5	27.37**	-3.74*	23.27**	-6.84**	18.51**	-14.01**	15.29**	-16.35**	29.35**	25.92**	22.66**	19.40**	54.08**	44.94**	53.27**	44.18**											
P2xP9	3.66	-17.10**	0.00	-20.03**	-0.90	-20.29**	-4.53	-23.21**	8.38	0.48	5.38	-2.29	38.46**	36.66**	31.48**	29.77**											
P8xP9	35.98**	19.26**	33.17**	16.80**	25.46	14.42**	22.42	11.66**	6.61	-8.83	2.93	-11.97*	25.39**	10.44*	30.10**	14.59**											

Contd... Table 4

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
ETxET																
P3xP4	89.23**	47.29**	93.05**	50.27**	67.04**	31.15**	69.92**	33.41**	17.47**	2.30	9.83*	-4.34	34.27**	13.42**	28.03**	8.15*
P3xP6	35.82**	0.00	29.90**	-4.35	23.62**	-8.95*	18.81**	-12.50**	14.95**	7.63*	10.55**	3.51	26.80**	28.50**	24.05**	25.71**
P3xP7	24.19**	-11.25**	28.86**	-7.91**	34.68**	0.43	39.04**	3.67	5.62	0.85	3.14	-1.50	33.66**	21.13**	31.47**	19.15**
P4xP6	26.05**	16.51**	30.27**	20.41**	15.26**	5.41	19.36**	9.16**	4.40	-14.00**	1.56	-16.34**	27.11**	8.55*	26.08**	7.67*
P4xP7	34.82**	19.37**	33.88**	18.54**	36.04**	26.62	33.25**	24.02**	9.19*	-0.88	4.77	-4.89	27.57**	17.92**	25.38**	15.89**
P6xP7	16.59**	11.25**	18.34**	12.91**	6.69**	9.58**	8.92**	11.87**	-4.28	-14.14**	1.35	-9.08	26.03**	15.59**	29.52**	18.78**
ETxLT																
P3xP5	38.46**	14.64**	35.00**	11.78**	43.65**	24.59**	39.92**	21.35**	21.75**	4.56	26.25**	8.42*	36.73**	13.25**	44.66**	19.83**
P3xP9	50.17**	17.11**	57.14**	22.55**	48.75**	14.86**	55.59**	20.14**	22.41**	15.51**	17.29**	10.68*	33.80**	18.07**	39.77**	23.34**
P4xP5	39.47**	28.91**	37.13**	26.75**	38.61**	23.11**	36.63**	21.35**	21.58**	19.60**	17.61**	15.70**	51.34**	47.74	39.14	35.82**
P4xP9	42.54**	42.16**	44.17**	43.78**	29.32**	26.37**	26.87**	23.98**	12.35**	3.14	15.12**	5.68	31.98**	25.48**	35.64**	28.96**
P6xP9	28.55**	18.80**	26.61**	16.74**	19.50**	11.66**	18.17**	10.41**	-2.00	-13.06	1.90	-9.60	24.79**	11.40**	26.36**	12.79**
P7xP9	18.63**	4.79*	20.75**	6.66**	19.45**	13.63**	20.81**	14.93**	5.25	3.95	1.19	-0.05	25.21**	21.54**	22.77**	19.17**
ETxLD																
P3xP8	40.05**	-0.40	36.88**	-2.66	39.15**	0.79	35.87**	-1.58	15.50**	-5.85	12.47**	-8.31*	22.95**	-2.71	24.16**	-1.75
P4xP8	27.73**	17.29**	28.90**	13.31**	29.42**	15.61**	31.19**	17.19**	9.31	1.08	5.71	2.24	46.99**	35.57**	34.96**	24.48**
P6xP8	25.97**	19.26**	23.37**	16.80**	23.12**	19.96**	20.28**	17.19**	-0.87	-23.18**	-3.77	-25.43**	16.85**	-6.63	15.98**	-7.32
P7xP8	22.31**	21.31**	24.58**	23.15**	21.07**	15.81**	22.72**	17.39**	-6.93	-21.23**	-11.25*	-24.89**	21.60**	4.39	18.11**	1.39
LTxET																
P5xP6	24.00**	6.65**	21.60**	4.58	14.06**	-6.25	11.02**	-8.75*	1.15	-17.75**	5.18	-14.47**	26.61**	5.99	30.92**	9.59*
P5xP7	16.62**	-3.54	18.38**	-2.08	22.69**	2.38	25.29	4.54	17.54**	5.13	10.68*	-1.00	37.98**	24.75**	31.58**	18.96**
Rest																
P2xP8	5.26**	-5.53**	8.34**	-2.76	-4.78	-17.22**	-7.30**	-19.41**	6.41	-2.54	10.59*	1.27	34.86**	20.15**	31.19**	16.88**
P5xP8	20.69**	-0.81	25.68**	3.27	24.90**	0.59	28.58**	3.55	16.04**	8.97	12.70*	5.83	39.55**	31.66**	35.22**	27.86**
P5xP9	45.45**	34.78**	40.17**	29.89**	36.08**	18.46**	31.40**	14.38**	8.96*	-1.45	5.08	-4.96	35.75**	26.14**	29.53**	20.37**

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

Contd.. Table 4

500-GRAIN WEIGHT										GRAIN YIELD/MAIN PANICLE									
Kharif					Summer					Kharif					Summer				
Cross	Direct cross		Reciprocal cross		Direct cross		Reciprocal cross		Direct cross		Reciprocal cross		Direct cross		Reciprocal cross				
	d ₁	d ₁₁	d ₁	d ₁₁	d ₁	d ₁₁	d ₁	d ₁₁	d ₁	d ₁₁	d ₁	d ₁₁	d ₁	d ₁₁	d ₁	d ₁₁			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)			
E0xL0																			
P1xP2	9.63*	0.55	2.54	-5.94	72.92**	25.12**	28.82**	28.22**	18.66	-6.37	23.39**	-2.63	41.39**	9.23	36.27**	5.27			
P1xP8	33.67**	31.40**	42.86**	40.43**	25.16**	15.12**	19.97**	10.35*	20.73	0.76	29.57**	8.14	17.18*	-1.37**	34.20**	12.94			
E0xET																			
P1xP3	34.00**	5.93	34.29**	6.17	33.37**	2.28	36.90**	4.99	98.87**	96.29**	135.64**	132.59**	96.55**	71.47**	90.70**	66.36**			
P1xP4	47.01**	43.56**	44.16**	40.78*	52.77**	51.52**	56.45**	55.17**	76.85**	68.62**	73.96**	65.86**	62.91**	59.45**	65.28**	61.77**			
P1xP6	41.02**	15.07**	38.02**	13.28**	43.08**	10.34**	45.20**	11.97**	50.29**	8.87	37.57**	0.34	43.05**	0.00	38.69**	-3.04			
P1xP7	43.81**	25.14**	45.01**	26.19**	47.96**	20.00**	55.71**	26.29**	6.01	-14.94	3.43	-17.01	27.24**	2.20	37.29**	10.26			
L0xL1																			
P1xP5	34.35**	39.01**	42.94**	42.59**	45.71**	37.27**	41.92**	33.70**	144.00**	112.92**	155.77**	123.19**	140.79**	118.95**	143.45**	121.37**			
P1xP9	29.13**	21.32**	30.49**	22.60**	40.15**	27.44**	48.85**	35.36**	65.38**	53.07**	70.62**	57.92**	96.55**	71.47**	90.01**	65.76**			
L0xET																			
P2xP3	11.01*	-17.58**	8.12	-19.72**	25.25**	-3.60	28.72**	-0.93	90.34**	51.64**	93.93**	54.50**	128.68**	98.02**	132.74**	101.53**			
P2xP4	30.23**	22.12**	29.14**	21.10**	35.16**	34.69**	33.90**	33.43**	62.14**	32.74*	51.94**	24.39	45.65**	14.28*	70.02**	33.40**			
P2xP6	25.90**	-3.85	21.99**	-6.83	13.75**	-12.55**	17.50**	-9.67**	27.76**	13.48	0.09	11.09	59.36**	37.88**	57.51**	36.27**			
P2xP7	29.31**	4.60	31.07**	6.02	29.38**	4.56	30.42**	5.40	57.97**	54.50**	59.32**	55.82**	96.29**	86.37**	112.03**	101.31**			
L10xL1																			
P2xP5	33.05**	24.03**	18.08**	10.08	45.82**	36.77**	43.45**	34.55**	80.64**	29.23*	45.92**	4.39	108.51**	50.76**	95.74**	41.53**			
P2xP9	23.79**	7.29	24.00**	7.47	41.21**	27.87**	35.66**	22.85**	66.49**	39.78**	52.61**	28.13*	111.42**	83.07**	106.09**	78.46**			
P8xP9	21.04**	11.91	18.01**	9.11	-1.74	-0.48	2.29	3.60	92.02**	71.50**	94.01**	73.28**	69.25**	62.25**	76.43**	69.14**			

Contd.. Table 4

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
ETxET																
P3xP4	21.18**	-5.84	14.54**	-11.00*	16.73**	-10.98**	3.14	-21.35**	120.71**	113.10**	84.64**	78.27**	65.20**	46.84**	56.41**	39.03**
P3xP6	10.88**	6.41	7.37	3.04	15.56**	14.65**	15.34**	14.43**	82.00**	32.93**	81.30**	32.42**	66.52**	27.76**	71.75**	31.78**
P3xP7	5.36	-5.97	6.56	-4.89	26.88**	17.87**	27.06**	18.04**	63.97**	32.87*	61.13**	30.57*	75.20**	58.92**	82.21**	65.28**
P4xP6	5.80	-15.23**	6.15	-14.94**	19.46**	-8.40*	18.24**	-9.33**	24.42*	6.99	22.14	8.70	32.42**	-6.26	37.18**	-2.88
P4xP7	44.50**	23.24**	47.30**	25.62**	37.42**	10.76**	41.11**	13.72**	53.31**	-29.42*	16.89**	17.70	60.47**	31.05**	61.07**	31.54**
P6xP7	23.81**	14.75**	23.16**	14.15**	20.15**	12.45**	22.52**	14.67**	6.95	-6.82	10.08	-4.09	30.62**	8.18	24.80**	3.37
ETxLT																
P3xP5	20.79**	-5.70	24.55**	-2.75	12.16**	-9.94**	14.66**	-8.05*	164.80**	128.51**	142.48**	109.25**	155.97**	106.00**	157.46**	107.20**
P3xP9	17.31**	-2.56	20.59*	0.15	21.73**	0.55	23.43**	1.95	144.73**	122.97**	158.37**	142.07**	161.86**	161.86**	164.26**	164.26**
P4xP5	31.19**	30.38**	32.16**	31.34**	41.18**	31.98**	41.18**	31.98**	117.69**	82.41**	137.86**	99.31**	169.69**	140.54**	119.91**	96.13**
P4xP9	51.37**	39.09**	52.10**	39.77**	39.05**	25.52**	35.22**	22.06**	107.01**	100.64**	109.34**	102.91**	75.33**	55.85**	75.00**	55.55**
P6xP9	18.34**	1.72	20.33**	3.42	14.99**	-4.41	16.02**	-3.55	80.33**	37.71**	76.75**	34.98**	60.46**	23.11**	56.06**	19.74**
P7xP9	27.32**	17.28**	27.08**	17.06**	24.45**	9.50*	24.31**	9.38*	50.80**	28.96*	59.67**	36.55*	73.04**	56.96**	48.78**	34.96**
ETxLD																
P3xP8	21.98**	-4.76	19.53**	-6.68	22.15**	-0.10	22.71**	0.35	122.62**	87.78**	136.19**	99.23**	87.64**	79.88**	135.98**	86.50**
P4xP8	20.60**	19.79**	25.89**	25.05**	39.29**	27.18**	35.61**	23.82**	84.48**	60.30**	90.04**	65.13**	78.45**	52.89**	63.34**	39.94**
P6xP8	21.02**	-2.53	20.12**	-3.26	18.30**	-2.64	18.55**	-2.43	50.35**	25.59*	48.11**	23.72*	58.41**	25.36**	48.27**	17.33**
P7xP8	8.53	-6.91	6.08	-9.01	5.83	-7.87*	5.28	-8.35*	35.02**	28.50*	45.16**	38.16**	49.74**	41.32**	25.38**	18.82*
LTxET																
P5xP6	17.03**	-4.66	20.00**	-2.26	30.38**	5.18	30.29**	5.10	22.25	-18.43	28.64*	-14.16	42.61**	-5.45	17.43*	-22.15**
P5xP7	14.57*	-0.51	8.46	-5.81	16.14**	-1.06	19.15**	1.49	60.69**	-16.55	51.82**	10.11	84.31**	37.89**	102.61**	51.58**
Rest																
P2xP8	-24.76**	-29.89**	-17.49**	-23.11**	12.89**	3.40	11.99*	2.57	24.52	16.04	24.29	15.82	33.49**	20.00**	53.30**	37.80**
P5xP8	19.12**	17.36*	17.65**	15.93*	7.74	5.03	11.55*	8.75	84.71**	38.42*	76.91**	32.56*	83.74**	43.25**	93.99**	51.23**
P5xP9	3.77	-4.09	-2.05	-9.47	6.07	2.15	2.76	-1.03	105.14**	67.63**	115.04**	75.72**	93.28**	55.55**	86.94**	50.45**

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

Contd... Table 4

GRAIN YIELD/PLANT									
Cross	Kharif					Summer			
	Direct cross		Reciprocal cross		Direct cross		Reciprocal cross		
	d_i	d_{ii}	d_i	d_{ii}	d_i	d_{ii}	d_i	d_{ii}	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
EDxLD									
P1xP2	5.67	-17.21*	2.76	-19.49*	38.33**	7.75	46.24**	13.92	
P1xP8	6.72	-17.20*	22.03**	-5.32	33.08**	9.45	44.13**	18.55	
EDxET									
P1xP3	180.09**	146.27**	226.31**	186.92**	147.72**	141.66**	120.42**	115.03**	
P1xP4	50.91**	28.95**	79.96**	53.78**	61.02**	55.59**	74.81**	68.91**	
P1xP6	6.07	-31.22**	19.52**	22.50**	23.22	18.14**	26.33**	-16.08*	
P1xP7	-23.24**	-44.53**	-20.27**	-42.38**	22.19	-9.35	27.60*	-2.32	
EDxLT									
P1xP5	156.64**	134.44**	194.53**	169.05**	145.89**	143.82**	165.53**	163.29**	
P1xP9	50.91**	28.95**	29.04**	10.27	114.01**	83.85**	90.32**	64.02**	
LDxET									
P2xP3	74.64**	24.85**	104.46**	46.18**	109.64**	66.31**	119.82**	74.38**	
P2xP4	7.98	-2.85	24.96**	12.42	43.61**	14.77	52.12**	21.57	
P2xP6	-32.68**	-48.95**	-46.15**	-58.98**	36.58**	8.51	39.50**	10.82	
P2xP7	25.13**	11.73	41.29**	26.16**	52.22**	48.53**	69.43**	65.31**	
LDxLT									
P2xP5	47.63**	24.40**	24.62**	5.61	121.83**	73.85**	111.93**	66.09**	
P2xP9	47.27**	32.49**	22.05**	9.80	103.34**	80.65**	99.52**	77.25**	
P8xP9	96.37**	74.58**	73.65**	54.38**	95.21**	85.25**	98.31**	88.20**	

Contd... Table 4

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ETxET								
P3xP4	155.65**	-46.21**	128.20**	75.46**	89.77**	87.92**	63.58**	61.98**
P3xP6	20.07**	-26.44**	30.60**	-20.00**	55.44**	4.56	60.55**	8.01
P3xP7	48.15**	-0.89	29.93**	-13.08*	68.07**	30.94**	63.14**	27.09*
P4xP6	-8.24	-34.92**	1.34	-28.11**	18.64*	-19.77**	32.25**	-10.57
P4xP7	47.05**	19.71**	36.37**	11.02	69.58**	33.06**	65.97**	30.23**
P6xP7	-35.57**	-46.32**	-23.53**	-36.29**	14.65	-7.19	9.00	-11.76
ETxLT								
P3xP5	160.73**	112.14**	180.16**	127.95**	160.03**	155.79**	148.98**	144.92**
P3xP9	164.93**	103.70**	146.75**	89.72**	165.00**	132.55**	161.88**	129.82**
P4xP5	81.56**	68.61**	98.77**	84.59**	168.18**	161.27**	147.21**	140.85**
P4xP9	85.16**	85.16**	102.42**	102.42**	74.80**	54.71**	86.08**	64.70**
P6xP9	55.20**	10.08*	41.58**	0.41	33.79**	-2.50	27.17**	-7.32
P7xP9	52.66**	24.28**	63.23**	32.88**	68.48**	46.51**	64.65**	43.17**
ETxLD								
P3xP8	147.73**	75.69**	142.56**	72.03**	97.07**	65.35**	121.96**	86.24**
P4xP8	74.65**	55.27**	72.90**	53.71**	100.00**	69.16**	88.09**	59.09**
P6xP8	34.62**	3.52	25.00**	3.88	46.43**	10.51	37.56**	3.81
P7xP8	44.47**	30.55**	59.44**	44.08**	52.74**	39.23**	36.21**	24.16*
LTxET								
P5xP6	7.02	-27.28**	1.23	-31.22**	51.83**	2.31	36.30**	-9.07
P5xP7	45.36**	11.82	40.24**	7.88	77.01**	36.29**	92.77**	48.43**
Rest								
P2xP8	-6.86	8.10	7.76	6.32	17.03	9.13	23.76*	15.40
P5xP8	100.13**	66.81**	84.28**	53.60*	82.64**	51.22**	103.56**	68.55**
P5xP9	119.04**	103.42**	108.29**	93.43**	75.96**	52.25**	83.39**	58.68**

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

4.1.2.3 Tiller number: Number of tillers per plant in parents ranged from 4.00 (P_3) to 7.00 (P_4) in kharif and 6.00 (P_5) to 8.65 (P_9) in summer season (Table 2). In F_1 s, the mean tiller number varied from 4.10 in $P_7 \times P_6$ to 6.55 in $P_8 \times P_4$ in kharif (Table 3). In summer season, the tiller number of hybrids ranged from 4.65 ($P_5 \times P_9$) to 10.85 ($P_4 \times P_2$). *F₁* hybrids in kharif and 32 hybrids in summer recorded higher number of tillers than their mid parental average. Twenty one hybrids in kharif and 32 in summer recorded higher number of tillers than their better tillering parents.

The heterosis ranged from -30.00 to 45.12 per cent in kharif and -36.51 to 78.51 per cent in summer (Table 4). The heterobeltiosis varied from -35.00 to 41.66 per cent in kharif and -46.24 to 77.04 per cent in summer. Hybrid $P_1 \times P_3$ (45.12%) in kharif and $P_5 \times P_2$ (78.51%) in summer recorded maximum heterosis. The hybrids expressing highest heterobeltiosis for the tiller number were $P_1 \times P_3$ (41.66%) and $P_8 \times P_3$ (35.95%) in kharif and $P_5 \times P_2$ (77.04%) and $P_2 \times P_5$ (66.39%) in summer.

4.1.2.4 Panicle number: P_5 recorded highest number of panicles per plant both in kharif (3.75) and summer (4.20) among all the parents (Table 2). P_3 recorded lowest number in kharif (1.55) as well as in summer (2.10). In hybrids, the mean for panicle number ranged from 1.45 ($P_2 \times P_6$) to 3.60 ($P_5 \times P_8$) in kharif and 2.00 ($P_2 \times P_7$) to 4.05 ($P_5 \times P_1$) in summer (Table 3). Seventeen hybrids in kharif and 30 hybrids in summer exhibited high panicle number over their mid parental average. In kharif five hybrids viz. $P_1 \times P_3$, $P_7 \times P_8$, $P_3 \times P_1$, $P_4 \times P_3$ and $P_8 \times P_3$ recorded high panicle number than their better parents. In

summer, 15 hybrids recorded higher number of panicles over their better parents.

Heterosis ranged from -49.56 to 44.73 per cent in kharif and -36.50 to 30.69 per cent in summer (Table 4). Heterobeltiosis ranged from -59.72 to 22.22 per cent in kharif and -44.44 to 23.07 per cent in summer. The hybrid $P_1 \times P_3$ recorded highest heterosis in kharif (44.73%) as well as summer (30.69%). $P_1 \times P_3$ also recorded highest heterobeltiosis in kharif (22.22%). In summer, $P_8 \times P_9$ recorded highest heterobeltiosis of 23.07 per cent.

4.1.2.5 Panicle length: The parent P_3 had the shortest panicles in kharif (10.30 cm) as well as summer (11.35 cm) seasons, while P_2 recorded longest panicle length in both seasons (30.7 cm in kharif and 34.35 cm in summer) (Table 2). Panicle length in F_1 s varied from 17.55 cm ($P_5 \times P_3$) to 30.9 cm ($P_7 \times P_2$) in kharif (Table 3). In summer, the variation was slightly high ranging from 18.75 cm in $P_5 \times P_3$ to 32.6 cm in $P_3 \times P_2$ hybrid. In kharif, all the 72 hybrids recorded higher panicle length than the mid parental average. Only four hybrids ($P_2 \times P_9$, $P_9 \times P_2$, $P_2 \times P_8$ and $P_8 \times P_2$) exhibited shorter panicles than their parental averages in summer. A total of 49 hybrids in kharif and 51 hybrids in summer had longer panicles than their better parents.

Heterosis for the character ranged upto 93.05 per cent in kharif and 69.92 per cent in summer (Table 4). Heterobeltiosis ranged from -20.29 (kharif) to 46.89 per cent (summer). The hybrid $P_4 \times P_3$ recorded highest heterosis in kharif (93.05%) as well as in summer (69.92%). Highest heterobeltiosis of 55.94 and 42.21 per cent was recorded in kharif and summer seasons respectively by $P_4 \times P_1$ hybrid.

4.1.2.6 Panicle girth: Mean panicle girth of parents ranged from 5.87 cm (P_8) to 10.67 (P_6) in kharif and 5.14 cm (P_8) to 8.82 cm (P_3) in summer (Table 2). In hybrids, the range was 6.36 cm ($P_8 \times P_7$) to 11.49 cm ($P_3 \times P_6$) in kharif and 7.23 cm ($P_8 \times P_1$) to 11.13 cm ($P_6 \times P_2$) in summer (Table 3). All the 72 hybrids in summer and 64 hybrids in kharif expressed panicle girth exceeding the mid parental averages. Thirty seven hybrids in kharif and 68 hybrids in summer recorded higher panicle girth over their better parents.

The heterosis for the character ranged from -11.25 to 29.35 per cent in kharif and 15.98 to 54.08 per cent in summer (Table 4). The heterobeltiosis ranged from -25.43 to 25.92 per cent in kharif and -1.75 to 47.74 per cent in summer season. The hybrid $P_2 \times P_5$ recorded maximum heterosis in kharif (29.35%) as well as summer (54.08%). $P_2 \times P_5$ (25.92%) and $P_4 \times P_5$ (47.74%) hybrids recorded highest heterobeltiosis in kharif and summer seasons respectively.

4.1.2.7 500-grain weight: Mean values ranged from 2.79 g (P_2) to 5.75 g (P_3) in kharif season and 2.80 g (P_4) to 5.34 g (P_3) in summer season (Table 2). In hybrids the grain weight ranged from 2.26 g ($P_2 \times P_8$) to 6.11 g ($P_3 \times P_6$) in kharif and 3.44 g ($P_9 \times P_5$) to 6.30 g ($P_7 \times P_3$) in summer (Table 3). Only three hybrids in kharif and one hybrid in summer recorded grain weight values lower than their mid parental averages. Forty four hybrids in kharif and 52 in summer recorded higher grain weight than their better parents.

The heterosis ranged from -24.76 to 52.10 per cent (kharif) and -1.74 to 72.92 per cent in summer (Table 4). The hybrids $P_4 \times P_9$

(52.10%) and $P_1 \times P_2$ (72.92%) recorded highest heterosis for the character in kharif and summer seasons respectively. Highest heterobeltiosis was recorded by $P_1 \times P_4$ (43.56%) and its reciprocal $P_4 \times P_1$ (55.17%) in kharif and summer seasons respectively.

4.1.2.8 Grain yield per main panicle : Among the parents P_6 recorded highest grain yield per main panicle in both kharif (29.30 g) and summer (31.15 g) seasons while P_5 recorded lowest grain yield per main panicle in kharif (9.80 g) as well as summer (10.15 g) season (Table 2). In hybrids, the mean grain yields per main panicle ranged from 18.05 g in $P_7 \times P_1$ to 40.35 g in $P_6 \times P_9$ in kharif season (Table 3). In summer, the mean values of hybrids ranged from 17.90 ($P_1 \times P_8$) to 45.85 g ($P_3 \times P_2$). All the 72 hybrids have recorded higher grain yields per main panicle over the mid parental averages in kharif as well as summer seasons while 62 hybrids in kharif and 66 hybrids in summer recorded higher grain yields over their better parents.

The heterosis was recorded upto 164.80 per cent in kharif and 169.69 per cent in summer (Table 4). The heterobeltiosis ranged from -29.42 to 142.07 per cent in kharif and -22.15 to 164.26 per cent in summer. The hybrids $P_3 \times P_5$ (164.80%) and $P_4 \times P_5$ (169.69%) recorded highest heterosis for the character in kharif and summer seasons respectively. The hybrid $P_9 \times P_3$ recorded highest heterobeltiosis in kharif (142.07%) as well as summer (164.26%) seasons.

4.1.2.9 Grain yield per plant : The grain yields among the parents ranged from 18.85 g (P_3) to 83.75 g (P_6) in kharif and 26.25 g (P_1) to 79.9 g (P_6) in summer (Table 2). Among hybrids the grain yields

varied from 30.95 g ($P_1 \times P_7$) to 92.20 g ($P_6 \times P_9$) in kharif season (Table 3). In summer the grain yields ranged from 43.80 g ($P_1 \times P_4$) to 88.55 g ($P_6 \times P_2$). All the 72 hybrids in summer and 64 hybrids in kharif recorded mean grain yields higher than their mid parental averages. Fifty one hybrids in kharif and 62 hybrids in summer recorded higher grain yields over their better parents.

Heterosis for grain yields ranged from -46.15 to 226.31 per cent in kharif and 9.00 to 168.18 per cent in summer (Table 4). Heterobeltiosis ranged from -58.98 to 186.92 per cent in kharif and -19.77 to 163.29 per cent in summer. The hybrid $P_3 \times P_1$ recorded highest heterosis (226.31%) followed by $P_5 \times P_1$ (194.53%), $P_5 \times P_3$ (180.16%) and $P_1 \times P_3$ (180.09%) and $P_1 \times P_3$ (180.09%) in kharif while in summer, $P_4 \times P_5$ (168.18%), $P_3 \times P_9$ (165.00%) and $P_3 \times P_5$ (160.03%) expressed high heterosis. $P_3 \times P_1$ (186.92%) and $P_5 \times P_1$ (169.05%) hybrids in kharif and $P_5 \times P_1$ (163.29%) and $P_3 \times P_5$ (155.79%) hybrids in summer recorded high heterobeltiosis for grain yield per plant.

4.1.3 Combining Ability Analysis

The mean variances of combining ability are presented in table 5 for the nine characters under study. The variances for general and specific combining ability were highly significant for all the characters in kharif as well as in summer seasons. Mean squares due to reciprocal effects were significant for tiller number, grain yield per plant and panicle length in kharif season and for plant height and grain yield per main panicle in summer season. The ratios of σ_g^2 to σ_s^2 ranged from 0.0234 for tiller number in summer to

Table 5: Analysis of variance due to combining ability for grain yield and its attributes in kharif and summer seasons

Characters	Season	Mean variances due to				
		GCA	SCA	RCA	Error	$\sqrt{\sigma^2_g} / \sigma^2_s$
Days to 50% flowering	Kharif	48.2891**	13.6597**	0.8905	0.8266	0.2715
	Summer	36.7188**	22.6744**	0.2020	0.3082	0.0642
Plant height	Kharif	6636.0625**	1635.6806**	31.3111	26.6781	0.3125
	Summer	3986.6875**	963.2777**	5.6730**	2.8063	0.3165
Tiller number	Kharif	1.0294**	0.5704**	0.1259**	0.0538	0.0903
	Summer	3.2180**	4.2266**	0.1183	0.1548	0.0234
Panicle number	Kharif	1.7637**	0.2266**	0.0393	0.0479	0.8627
	Summer	1.5522**	0.1920**	0.0444	0.0460	0.9342
Panicle length	Kharif	70.0117**	15.6490**	0.2536*	0.1486	0.3525
	Summer	93.5625**	13.4312**	0.2647	0.3479	0.6146
Panicle girth	Kharif	11.1259**	0.4253**	0.0734	0.0731	3.0437
	Summer	10.5397**	1.2833**	0.0536	0.0699	0.7652
500-grain weight	Kharif	5.9923**	0.5422**	0.0118	0.0330	1.0731
	Summer	5.2421**	0.4596**	0.0107	0.0159	1.0807
Grain yield/main panicle	Kharif	131.0586**	57.2245**	2.8764	4.5951	0.1418
	Summer	300.9492**	70.3018**	2.8307**	1.1663	0.3354
Grain yield/plant	Kharif	753.7578**	367.7274**	22.2563**	6.1965	0.1082
	Summer	873.0781**	307.8289**	11.1351	14.1234	0.1941

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

3.0437 for panicle girth in kharif season. These ratios indicated the predominance of GCA component for 500 grain weight (kharif and summer) and panicle girth (kharif) and SCA component for all other characters under investigation. Combining ability effects of various characters are discussed below.

4.1.3.1 Days to 50 per cent flowering : All the three parents of late flowering group (P_2 , P_8 and P_9) and two parents in the early flowering group, (P_3 and P_4) exhibited positively significant GCA effects (Table 6). Three parents of early flowering group viz., P_1 , P_6 and P_7 had negatively significant GCA effects in kharif season. In summer season, three parents of late group viz., P_2 , P_8 and P_9 registered positively significant GCA effects while one late flowering parent P_5 and five early flowering parents (P_1 , P_3 , P_4 , P_6 and P_7) exhibited negatively significant GCA effects.

Out of the 36 direct crosses, 10 hybrids in kharif and 6 hybrids in summer indicated positively significant SCA effects while 10 hybrids in kharif and 19 hybrids in summer had negatively significant SCA effects (Table 7). Ten hybrids viz., $P_1 \times P_2$ (EDxLD), $P_1 \times P_8$ (EDxLD), $P_2 \times P_4$ (LDxET), $P_2 \times P_5$ (LDxLT), $P_4 \times P_7$ (ETxET), $P_6 \times P_9$ (ETxLT), $P_7 \times P_8$ (ETxLD), $P_5 \times P_6$ (LTxET), $P_5 \times P_8$ (LTxLD) and $P_5 \times P_9$ (LTxLT) were best specific combiners for earliness in both seasons. Reciprocal effects were significant for none of the hybrids (Table 8).

4.1.3.2 Plant height : All the six parents, belonging to tall group viz., P_3 , P_4 , P_5 , P_6 , P_7 and P_9 registered positively significant GCA effects in both seasons (Table 6). Similarly the three parents belong-

Table 6: General combining ability effects of nine parents for grain yield and its attributes in kharif and summer seasons

Characters	Season	Parents								
		P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇	P ₈	P ₉
								SE(g _i)	SE(g _i -g _j)	
Days to 50% flowering	Kharif	-1.392**	1.815**	0.501*	0.576**	-1.775**	-1.867**	-1.367**	2.451**	1.057**
	Summer	-0.848**	2.834**	-0.123	-1.418**	-0.718**	-1.123**	-0.945**	0.929**	1.415**
Plant height	Kharif	-29.948**	-26.959**	6.896**	3.537**	4.376**	17.040**	9.543**	-11.539**	27.051**
	Summer	-23.802**	-19.429**	11.042**	6.500**	3.017**	11.461**	6.839**	-13.091**	17.461**
Tiller number	Kharif	0.006	-0.007	-0.199**	0.378**	-0.277**	-0.227**	0.042	-0.085	0.370**
	Summer	0.402**	0.591**	-0.225*	0.016	-0.117	0.541**	-0.467**	-0.183*	-0.556**
Panicle number	Kharif	-0.174**	-0.552**	-0.268**	0.081	0.558**	-0.027	0.153**	0.172**	0.056
	Summer	0.047	-0.454**	-0.491**	0.081	0.411**	0.089	0.050	0.225**	0.031
Panicle length	Kharif	0.169	3.105**	-3.291**	0.714**	-2.335**	-0.016	0.714**	1.828**	-0.888**
	Summer	-0.231	4.265**	-3.248**	0.601**	-2.878**	-0.253	0.637**	1.787**	-0.681**
Panicle girth	Kharif	-0.709**	-0.186**	1.232**	-0.276**	-0.163**	1.127**	-0.064	-1.204**	0.244**
	Summer	-0.666**	0.285**	1.349**	-0.349**	-0.188**	0.860**	-0.001	-1.195**	-0.094
500-grain weight	Kharif	0.092*	-0.846**	0.850**	-0.171**	-0.418**	0.704**	0.405**	-0.590**	-0.026
	Summer	-0.096**	-0.481**	0.790**	-0.365**	-0.350**	0.761**	0.530**	-0.528**	-0.259**
Grain yield/main panicle	Kharif	-4.595**	0.604	2.798**	-1.157*	-2.987**	3.620**	-1.157*	1.231*	1.642**
	Summer	-5.866**	5.086**	3.727**	-4.713**	-2.608**	4.955**	-0.030	-1.983**	1.433
Grain yield/plant	Kharif	-11.051**	-9.792**	1.451*	-1.040	2.226**	6.576**	0.284	6.426**	4.918**
	Summer	-11.484**	3.948**	1.365	-8.245**	0.017	12.676**	0.117	-1.282	2.887**

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

Table 7: Specific combining ability effects of crosses for grain yield and its attributes in kharif and summer seasons

Cross	Days to 50% flowering		Plant height		Filler number		Panicle number		Panicle length	
	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer
EDxLD										
P1xP2	-1.449*	-3.134**	-11.426**	-12.197**	0.188	-1.635**	0.132	0.193	-1.947**	-0.074
P1xP8	-2.885**	-3.354**	-27.946**	-16.386**	-0.558**	1.089**	-0.317*	0.113	0.530*	2.003**
EDxET										
P1xP3	1.539**	-0.876*	28.442**	7.329**	0.504**	-0.568*	0.499**	0.379**	3.349**	-0.185
P1xP4	-0.235	0.318	-7.274*	-6.678**	-0.097	0.614*	0.000	-0.092	2.194**	1.464**
P1xP6	0.184	0.923*	14.048**	6.335**	0.757**	0.614*	0.007	-0.300	2.524**	1.120**
P1xP7	3.009**	-0.554	-4.979	4.432**	-0.811**	0.672**	-0.472**	-0.195	-1.230**	1.253**
LDxLT										
P1xP5	1.867**	-0.131	36.012**	24.079**	0.732**	-0.152	0.421**	0.202	3.119**	2.495**
P1xP9	-1.240*	-0.690	13.637**	18.185**	0.385*	0.786**	-0.375**	-0.017	0.196	-0.076
LDxET										
P2xP3	-0.318	-1.959**	30.953**	17.982**	-0.381*	0.442	0.252	-0.017	3.763**	5.192**
P2xP4	-2.218**	-3.640**	-11.387**	-6.225**	-0.083	2.775**	-0.222	-0.164	-0.366	1.067**
P2xP6	-0.374	-1.284**	19.309**	14.138**	0.196	1.500**	-0.414**	-0.097	-1.136**	-0.376
P2xP7	-0.924	1.937**	31.181**	20.435**	0.052	-1.991**	-0.020	-0.642**	1.408**	0.331
LDxLT										
P2xP5	-1.290*	-3.240**	34.123**	29.432**	0.446**	3.033**	-0.325*	0.454**	2.858**	1.498**
P2xP9	-0.224	1.001**	10.523**	20.388**	0.124	-0.952**	0.002	0.185	-2.664**	-2.949**
P8xP9	2.114**	0.307	39.028**	15.899**	0.202	1.672**	-0.172	0.379**	2.413**	1.328**
ETxET										
P3xP4	0.320	-0.681	9.481**	13.277**	-0.367*	-0.157	0.543**	0.071	4.655**	2.806**
P3xP6	0.639	0.373	-15.046**	-5.259**	0.088	2.592**	-0.347*	0.238	-0.814**	-1.237**
P3xP7	2.439**	1.945**	-3.599	-3.586**	0.593**	-1.124**	-0.278*	-0.206	-1.169**	0.020

Contd.. Table 7

Cross	Days to 50% flowering			Plant height		Tiller number		Panicle number		Panicle length	
	Kharrif	Summer		Kharrif	Summer	Kharrif	Summer	Kharrif	Summer	Kharrif	Summer
P4xP6	1.389*	-1.156**		23.987**	19.007**	-0.614**	-1.999**	-0.072	-0.058	-0.319	-0.762*
P4xP7	-1.685**	-1.209**		15.834**	6.204**	0.016	-1.641**	0.196	0.321*	1.674*	1.545**
P6xP7	2.284**	0.545		-34.343**	-24.881**	-0.553**	1.683**	-0.520**	-0.186	0.755**	0.025
ETxLT											
P3xP5	-0.576	-1.756**		-16.632**	-12.839**	-0.186	0.150	-0.108	-0.408**	-2.044**	-1.037**
P3xP9	-0.585	0.809*		-8.782**	7.941**	-0.108	-0.360	-0.156	-0.103	0.783**	2.264**
P4xP5	3.048**	0.612		10.775**	9.927**	-0.139	0.008	-0.408**	-0.131	-0.175	0.437
P4xP9	0.214	-2.320**		12.575**	8.507**	-0.486**	-1.052**	-0.080	-0.075	1.177**	0.014
P6xP9	-1.665**	-2.790**		8.723**	-4.428**	-0.681**	-1.352**	0.052	-0.533**	1.333**	1.420**
P7xP9	0.759	-2.017**		-7.479*	2.393*	0.324*	-0.243	0.321*	0.571**	0.102	0.278
ETxLD											
P3xP8	-0.529	-2.504**		24.334**	24.193**	0.746**	-0.207	0.002	0.102	0.041	0.495
P4xP8	1.695**	-0.359		-1.807	0.235	0.818**	1.050**	-0.197	0.329*	-0.464	0.895*
P6xP8	-0.210	-0.504		33.939**	32.374**	-0.400**	-2.024**	0.160	-0.053	1.541**	2.300**
P7xP8	-2.535**	-0.781*		30.262**	11.921**	0.779**	0.908**	0.454**	0.077	1.835**	0.909*
LTxET											
P5xP6	-2.507**	-1.656**		-8.476*	-9.108**	0.041	-1.016**	-0.025	0.360**	-0.069	-0.832*
P5xP7	-0.957	-0.909**		-8.529**	-4.936**	0.071	1.517**	-0.131	-0.083	-0.500*	-0.024
Rest											
P2xP8	1.856**	0.737*		-47.585**	-39.108**	-0.570**	-1.124**	-0.164	-0.383**	-0.958**	-4.243**
P5xP8	-3.726**	-2.634**		25.003**	23.593**	-0.350*	-1.516**	0.224	-0.175	-0.239	0.750*
P5xP9	-5.982**	-2.920**		-17.212**	-21.108**	-0.331*	-1.293**	0.216	-0.456**	2.127**	1.670**
SE (sij)	0.575	0.351		3.271	1.061	0.146	0.249	0.138	0.135	0.244	0.373
SE (sij-sik)	0.857	0.523		4.869	1.579	0.218	0.370	0.206	0.202	0.363	0.556
SE (sij-sk1)	0.801	0.489		4.55	1.477	0.204	0.346	0.193	0.189	0.339	0.520

* Significant at 5% level ;

** Significant at 1% level

Contd... Table 7

Cross	Panicle girth		500-grain weight		Grain yield/main panicle		Grain yield/ plant	
	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer
EDxLD								
P1xP2	-0.124	-0.066	-0.682**	-0.421**	-2.226	-4.319**	-1.829	-4.940*
P1xP8	0.407*	0.495**	0.350**	-0.158*	-4.054**	-2.450**	-13.873**	-5.459*
EDxET								
P1xP3	0.035	0.297	0.465**	0.230**	2.804*	0.763	17.376**	8.518**
P1xP4	0.329	0.096	0.141	0.223**	2.059	1.880**	3.167*	0.779
P1xP6	0.235	0.181	0.548**	0.567**	3.582*	2.086**	7.251**	0.407
P1xP7	-0.657**	-0.241	0.483**	0.598**	-3.915**	-1.877**	-16.157**	-5.984*
EDxLT								
P1xP5	0.151	0.453**	0.342**	0.205*	8.315**	6.274**	26.001**	14.540**
P1xP9	0.459**	0.099	-0.118	0.321**	-0.965	3.008**	-10.415**	7.545**
LDxET								
P2xP3	-0.151	0.520**	-0.015	0.300**	3.479*	7.136**	9.292**	10.209**
P2xP4	0.147	-0.145	0.203	0.023	1.859	-1.697*	-1.690	-4.720
P2xP6	0.178	1.126	0.456**	-0.218**	-2.517	3.158**	-16.607**	6.373**
P2xP7	0.430*	0.326	0.504**	0.151	7.909**	9.544**	17.409**	8.907**
LDxLT								
P2xP5	0.644**	0.738**	0.351**	0.596**	1.015	1.272	-0.607	11.382**
P2xP9	-0.233	0.132	0.266*	0.496**	0.284	5.105**	-0.473	12.737**
P8xP9	0.000	0.216	0.129	-0.373**	3.057*	1.124	4.281**	9.768**
ETxET								
P3xP4	-0.101	0.108	-0.102	-0.557**	-1.209	-4.713**	6.315**	-8.470**
P3xP6	0.544**	0.045	-0.223	-0.044	4.512**	2.241**	-2.201	6.257*
P3xP7	-0.249	0.584**	-0.507**	0.368**	-0.934	0.047	-8.309**	-2.309

Contd... Table 7

Cross	Panicle girth		500-grain weight		Grain yield/main panicle		Grain yield/ plant	
	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer
P4xP6	-0.161	0.112	-0.732**	-0.215**	-3.406*	-0.016	-6.659**	-1.281
P4xP7	0.204	0.064	0.692**	0.368**	1.245	2.094**	6.656**	8.601**
P6xP7	0.005	0.543**	0.250*	0.066	-2.706*	-1.475	-16.184**	-5.095*
ETxLT								
P3xP5	0.484**	0.454**	0.385**	-0.189*	1.795	3.780**	3.973*	3.090
P3xP9	0.692**	0.728**	0.167	0.267**	3.540*	9.138**	4.106*	15.620**
P4xP5	0.203	0.496**	0.122	0.362**	3.876**	6.097**	2.240	14.276**
P4xP9	0.296	0.362*	0.809**	0.325**	2.745*	-0.294	5.573**	-0.892
P6xP9	-0.272	0.199	0.055	-0.064**	6.743**	1.936**	18.181**	-4.015
P7xP9	0.094	0.056	0.220	0.134	0.445	-1.052	8.073**	3.993
ETxLD								
P3xP8	0.260	-0.195	0.471**	0.475**	6.051**	2.005**	11.973**	6.840**
P4xP8	-0.015	0.788**	0.025	0.544**	3.957**	9.772**	5.740**	11.701**
P6xP8	-0.209	-0.339*	0.329**	0.279**	3.729**	5.327**	12.123**	9.604**
P7xP8	-0.577**	-0.095	-0.350**	-0.401**	0.982	-0.936	11.440**	1.662
LTxET								
P5xP6	-0.375*	-0.075	0.128	0.506**	-4.051**	4.997**	-8.026**	-1.970
P5xP7	0.511**	0.258	-0.305**	-0.197*	0.851	2.738**	0.315	5.637*
Rest								
P2xP8	0.040	0.033	-0.877**	-0.104	3.404*	-3.277**	-10.457**	-14.467**
P5xP8	0.181	0.235	0.199	-0.101	0.437	1.816**	5.048**	1.712
P5xP9	-0.446*	-0.065	-0.698**	-0.497**	-0.073	-2.850**	3.931*	-10.706**
SE(sij)	0.171	0.167	0.115	0.079	1.357	0.684	1.576	2.380
SE(sij-sik)	0.254	0.249	0.171	0.118	2.02	1.018	2.346	3.543
SE(sij-sk1)	0.238	0.233	0.160	0.111	1.890	0.952	2.195	3.314

* Significant at 5% level ;

** Significant at 1% level

Table 8: Reciprocal effects of crosses for grain yield and its attributes in kharif and summer seasons

Cross	Days to 50% flowering		Plant height		Tiller number		Panicle number		Panicle length	
	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer
EDxLD										
P1xP2	0.250	0.200	-3.074	-2.125	-0.175	-0.125	0.050	-0.125	0.425	0.375
P1xP8	0.350	0.375	-4.074	-1.125	0.150	0.325	0.125	0.175	0.324	0.374
EDxET										
P1xP3	-0.775	-0.500	-6.050	0.625	0.349*	0.275	0.200	0.225	0.525	0.549
P1xP4	-0.075	0.499	5.824	2.625*	0.324	0.199	-0.199	-0.024	-0.324	-0.299
P1xP6	0.399	-0.200	-3.600	2.500*	0.274	0.125	-0.250	-0.125	-0.525	0.500
P1xP7	-0.574	-0.399	2.274	0.775	0.224	0.125	-0.099	0.150	-0.550	-0.475
EDxLT										
P1xP5	-0.424	-0.149	-5.000	-0.250	-0.050	-0.200	-0.149	-0.250	0.350	0.449
P1xP9	1.100	-0.174	-1.600	-1.400	-0.300	0.299	0.250	0.200	0.525	0.474
LDxET										
P2xP3	-0.425	-0.349	-3.149	0.250	0.250	-0.224	-0.125	-0.075	0.225	-0.224
P2xP4	-0.250	0.125	1.550	-1.849	0.125	-0.500	-0.200	0.250	-0.199	0.300
P2xP6	0.100	-0.024	2.200	0.675	-0.350*	-0.049	-0.049	-0.175	-0.399	-0.549
P2xP7	-0.750	-0.075	-1.574	0.800	0.224	-0.099	-0.124	-0.100	-0.225	-0.249
LDxLT										
P2xP5	-0.625	-0.175	-5.050	0.975	0.200	-0.325	-0.075	0.049	0.474	0.400
P2xP9	-0.275	0.549	7.125	2.025	-0.224	-0.300	0.099	0.100	0.450	0.500
P8xP9	-0.800	-0.500	-1.299	1.125	0.174	-0.049	0.200	0.224	0.300	0.350
ETxET										
P3xP4	-0.925	0.274	7.675*	-1.875	0.250	0.250	-0.199	0.250	-0.274	-0.225
P3xP6	-0.549	-0.074	2.869	-3.649**	0.250	-0.075	-0.050	-0.074	0.474	0.424
P3xP7	-0.450	-0.224	-3.050	-2.300	0.075	0.300	0.100	0.150	-0.400	-0.375

Contd... Table 8

Cross	Days to 50% flowering			Plant height		Tiller number		Panicle number		Panicle length	
	Kharrif	Summer		Kharrif	Summer	Kharrif	Summer	Kharrif	Summer	Kharrif	Summer
P4xP6	-0.174	0.299		-6.625	-3.025*	-0.275	0.125	-0.125	-0.199	-0.424	-0.450
P4xP7	-0.450	0.024		3.324	1.899	0.475**	0.175	-0.075	0.050	0.099	0.299
P6xP7	-0.974	0.274		4.649	-1.425	0.450**	0.075	-0.100	0.050	-0.199	-0.275
ETxLT											
P3xP5	-0.875	-0.100		2.349	1.175	0.125	-0.224	-0.225	0.100	0.225	0.250
P3xP9	-0.249	-0.400		2.125	-2.000	0.250	0.175	0.125	0.075	-0.500	-0.549
P4xP5	-0.774	-0.324		3.900	2.949*	0.050	-0.175	-0.074	0.150	0.199	0.175
P4xP9	0.975	0.125		1.925	-0.775	-0.200	0.175	-0.100	-0.125	-0.150	0.250
P6xP9	0.900	0.450		-5.075	-2.149	0.050	-0.250	0.125	0.125	0.224	0.149
P7xP9	-0.975	0.100		3.725	1.150	0.224	0.349	-0.074	-0.149	-0.225	-0.149
ETxLD											
P3xP8	-0.899	0.100		-3.150	0.750	-0.300	-0.200	0.100	-0.175	0.274	0.300
P4xP8	-0.500	0.000		-3.849	-0.799	-0.150	-0.450	0.049	0.074	-0.125	-0.199
P6xP8	-0.299	0.100		7.400*	-0.199	-0.325	-0.200	0.100	0.150	0.299	0.349
P7xP8	0.174	-0.450		1.625	-0.125	-0.125	-0.175	0.024	0.050	-0.225	-0.200
LTxET											
P5xP6	0.924	0.050		-2.300	2.025	0.175	0.125	0.150	0.150	0.225	0.299
P5xP7	-0.275	-0.725		1.449	-0.224	0.425*	-0.249	-0.125	0.025	-0.174	-0.250
Rest											
P2xP8	1.049	0.549		-2.574	-0.174	0.074	-0.400	-0.150	-0.075	-0.424	0.375
P5xP8	0.825	0.325		-1.050	-1.774	0.375*	-0.099	0.150	-0.150	-0.500	-0.375
P5xP9	0.925	0.125		2.224	1.775	-0.200	-0.349	0.175	-0.224	0.449	0.425
SE (r1j)	0.642	0.392		3.652	1.184	0.164	0.278	0.154	0.151	0.272	0.417
SF(r1j-rk1)	0.909	0.555		5.165	1.675	0.231	0.393	0.218	0.214	0.385	0.589

* Significant at 5% level ;

** Significant at 1% level

Contd... Table 8

Cross	Panicle girth		500 grain weight		Grain yield/main panicle		Grain yield/ plant	
	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer
EDxLD								
P1xP2	0.260	-0.047	0.108	-0.044	-0.425	0.449	0.500	-1.449
P1xP8	-0.214	0.072	0.150	0.080	-0.725	-1.299	-2.675	-1.850
FDxET								
P1xP3	-0.220	-0.170	-0.006	-0.072	-2.450	0.424	-5.050**	3.674
P1xP4	-0.230	0.115	0.046	-0.052	0.200	-0.150	-4.350*	-1.875
P1xP6	-0.214	-0.234	0.047	-0.042	1.350	0.474	-3.650*	-0.825
P1xP7	-0.304	0.039	-0.023	-0.144	0.225	-0.824	-0.600	-1.025
FDxLT								
P1xP5	-0.235	0.087	-0.059	0.057	-0.675	-0.150	-5.200**	-2.599
P1xP9	0.255	-0.082	-0.024	-0.137	-0.375	0.475	3.275	3.624
LDxET								
P2xP3	0.170	0.050	0.061	-0.071	-0.325	-0.399	-4.674**	-1.900
P2xP4	-0.160	-0.199	0.016	0.017	0.950	-2.175**	-3.350	-1.600
P2xP6	0.125	-0.192	0.078	-0.075	3.600*	0.250	4.300*	-0.925
P2xP7	-0.174	0.195	-0.032	-0.019	-0.149	-1.700*	-4.024*	-4.150
LDxLT								
P2xP5	0.229	0.025	0.224	0.035	2.825	1.049	4.249*	1.825
P2xP9	0.114	0.232	-0.003	0.087	1.324	0.525	4.974**	0.799
P8xP9	0.130	-0.140	0.053	-0.069	-0.175	-0.624	4.549*	-0.600
ETxET								
P3xP4	0.310	0.232	0.148	0.276**	2.525	0.650	3.700*	3.674
P3xP6	0.219	0.119	0.096	0.005	0.074	-0.625	-2.700	-1.375
P3xP7	0.110	0.087	-0.030	-0.004	0.250	-0.650	3.400	0.949

Contd... Table 8

Cross	Panicle girth		500 grain weight		Grain yield/main panicle		Grain yield/ plant	
	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer
P4xP6	0.125	0.037	-0.007	0.024	0.250	-0.524	-2.850	-3.674
P4xP7	0.170	0.072	-0.053	-0.067	1.275	-0.050	2.425	0.700
P6xP7	-0.270	-0.137	0.015	-0.058	-0.400	0.750	-4.200*	1.825
ETxLT								
P3xP5	-0.180	-0.290	-0.084	-0.050	1.300	-0.099	-2.375	1.499
P3xP9	0.225	-0.232	-0.078	-0.037	-1.475	-0.200	2.449	0.500
P4xP5	0.134	0.362	-0.015	0.000	-1.224	2.875**	-2.799	2.875
P4xP9	-0.105	-0.117	-0.012	0.060	-0.175	2.500**	-3.024	-1.825
P6xP9	-0.184	-0.059	-0.045	-0.022	0.399	0.524	4.049*	1.924
P7xP9	0.170	0.085	0.004	0.002	-0.825	2.249**	-2.400	0.824
ETxLD								
P3xP8	0.115	-0.042	0.054	-0.012	-1.125	-0.599	0.824	-4.250
P4xP8	0.115	0.337	-0.084	0.057	-0.475	1.175	0.349	2.049
P6xP8	0.119	0.029	0.019	-0.005	0.274	1.250	3.099	2.675
P7xP8	0.155	0.107	0.047	0.011	-1.049	2.350**	-3.774*	3.724
LTxET								
P5xP6	-0.174	-0.155	-0.063	0.002	-0.625	2.600**	1.650	2.700
P5xP7	0.260	0.207	0.119	-0.058	0.699	-1.400	1.100	-3.000
Rest								
P2xP8	-0.135	0.107	-0.109	0.013	0.025	-2.025**	-3.250	-1.475
P5xP8	0.105	0.100	0.023	-0.062	0.575	-0.725	2.974	-3.525
P5xP9	0.145	0.194	0.102	0.055	-0.625	0.425	1.750	-1.174
SE(rlj)	0.191	0.186	0.128	0.089	1.515	0.763	1.760	2.657
SE(rlj-rkl)	0.270	0.264	0.181	0.126	2.143	1.079	2.480	3.758

* Significant at 5% level ;

** Significant at 1% level

ging to dwarf group viz., P_1 , P_2 and P_8 exhibited negatively significant GCA effects in kharif as well as summer seasons.

In kharif, 20 hybrids recorded positively significant SCA effects while 13 hybrids exhibited negatively significant SCA effects (Table 7). In summer, SCA effects were positively significant for 22 hybrids and negatively significant for 13 hybrids. Eleven hybrids viz., $P_1 \times P_2$ (EDxLD), $P_1 \times P_8$ (EDxLD), $P_1 \times P_4$ (EDxET), $P_2 \times P_4$ (LDxET), $P_3 \times P_6$ (ETxET), $P_6 \times P_7$ (ETxET), $P_3 \times P_5$ (ETxLT), $P_5 \times P_6$ (LTxET), $P_5 \times P_7$ (LTxET), $P_2 \times P_8$ (LDxLD) and $P_5 \times P_9$ (LTxLT) were best specific combiners for short stature in both seasons. Two hybrids in kharif viz., $P_3 \times P_4$ (ETxET) and $P_6 \times P_8$ (ETxLD) and five hybrids in summer viz., $P_1 \times P_4$ (EDxET), $P_1 \times P_6$ (EDxET), $P_4 \times P_5$ (ETxLT), $P_3 \times P_6$ (ETxET) and $P_4 \times P_6$ (ETxET) exhibited significant reciprocal effects (Table 8).

4.1.3.3 Tiller number : GCA effects of parents P_4 and P_9 were positively significant while those of P_3 , P_5 and P_6 were negative in kharif season (Table 6). In summer season, positively significant GCA effects were registered by three parents viz., P_1 , P_2 and P_6 and negatively significant effects by four parents viz., P_3 , P_7 , P_8 and P_9 . The parent P_3 had negatively significant GCA effect in both seasons while none of the parents exhibited positively significant GCA effects in both seasons.

Ten hybrids exhibited positively significant SCA effects while 12 hybrids recorded negatively significant SCA effects for this character in kharif (Table 7). In summer, an equal number of 14 hybrids showed positive and negatively significant SCA effects. $P_1 \times P_6$,

$P_1 \times P_9$, $P_2 \times P_5$, $P_4 \times P_8$ and $P_7 \times P_8$ were the best specific combiners for tiller number when both seasons were considered. Reciprocal effects were significant for four hybrids viz., $P_1 \times P_3$, $P_5 \times P_7$, $P_5 \times P_8$ and $P_2 \times P_6$ in kharif season (Table 8).

4.1.3.4 Panicle number: Parents, P_5 , P_7 and P_8 registered positively significant GCA effects while P_1 , P_2 and P_3 exhibited negatively significant GCA effects in kharif season (Table 6). The GCA effects of P_5 and P_8 were positively significant while those of P_2 and P_3 were negatively significant in summer season. P_5 and P_8 were the best general combiners for panicle number over both the seasons. Out of the 36 direct crosses, five hybrids recorded positively significant SCA effects and nine hybrids exhibited negatively significant effects in kharif (Table 7). In summer, seven hybrids registered positively significant SCA effects while six hybrids exhibited negatively significant SCA effects. $P_1 \times P_3$ and $P_7 \times P_9$ were the best specific combiners in both seasons. Reciprocal effects of none of the crosses were significant in either season (Table 8).

4.1.3.5 Panicle length : The parents P_2 , P_4 , P_7 and P_8 registered positively significant GCA effects in kharif as well as summer seasons (Table 6). Similarly, P_3 , P_5 and P_9 exhibited negatively significant GCA effects in both seasons. Because of their consistent and positive significant GCA effects in both seasons, P_2 , P_4 , P_7 and P_8 were the best general combiners for panicle length. In kharif season, 17 hybrids recorded positively significant SCA effects while 10 hybrids registered negatively significant SCA effects (Table 7). SCA effects were positively significant with 18 hybrids and negatively significant

with six hybrids in summer. Based on the SCA effects of both seasons, 12 hybrids viz., $P_1 \times P_8$, $P_1 \times P_4$, $P_1 \times P_6$, $P_1 \times P_5$, $P_2 \times P_3$, $P_2 \times P_5$, $P_8 \times P_9$, $P_3 \times P_4$, $P_4 \times P_7$, $P_3 \times P_9$, $P_6 \times P_8$ and $P_7 \times P_8$ were best specific combiners for panicle length. Reciprocal effects were not significant in any of the hybrids (Table 8).

4.1.3.6 Panicle girth : The GCA effects were positively significant for P_3 , P_6 and P_9 in kharif and P_2 , P_3 and P_6 in summer season (Table 6). These effects were negatively significant for P_1 , P_2 , P_4 , P_5 , P_7 and P_8 in kharif and P_1 , P_4 , P_5 and P_8 in summer. P_3 and P_6 were the best general combiners for panicle girth in both seasons.

Positively significant SCA effects were exhibited by eight hybrids in kharif and 11 hybrids in summer season (Table 7). Four hybrids in kharif and one hybrid in summer registered negatively significant SCA effects. Best specific combiners for panicle girth in both seasons were $P_1 \times P_8$, $P_2 \times P_5$, $P_3 \times P_5$ and $P_3 \times P_9$. Reciprocal effects of all the hybrids were non significant (Table 8).

4.1.3.7 500-grain weight: The parents P_1 , P_3 , P_6 and P_7 in kharif and P_3 , P_6 and P_7 in summer exhibited positively significant GCA effects (Table 6). GCA effects of P_2 , P_4 , P_5 and P_8 in kharif and P_1 , P_2 , P_4 , P_5 , P_8 and P_9 in summer were negatively significant. P_3 , P_6 and P_7 were the best general combiners for the character in both seasons.

Out of 36 direct crosses, 15 hybrids registered positively significant SCA effects while seven hybrids had negatively significant

SCA effects in kharif (Table 7). In summer, 18 and 10 hybrids registered positively and negatively significant SCA effects respectively. Considering the SCA effects in both seasons, $P_1 \times P_6$, $P_1 \times P_7$, $P_4 \times P_9$ and $P_3 \times P_8$ were the best specific combiners. Reciprocal effect was significant for $P_3 \times P_4$ hybrid in summer (Table 8).

4.1.3.8 Grain yield per main panicle : The parents P_3 (ET), P_6 (ET), P_8 (LD) and P_9 (LT) recorded positively significant GCA effects while P_1 (ED), P_4 (ET), P_5 (LT) and P_7 (ET) recorded negatively significant GCA effects in kharif season (Table 6). In summer season, positively significant GCA effects were recorded by P_2 (LD), P_3 (ET), P_6 (ET) and P_9 (LT) and negatively significant effects by P_1 (ED), P_4 (ET), P_5 (LT) and P_8 (LD). Considering both seasons, P_3 (ET), P_6 (ET) and P_9 (LT) were the best general combiners.

The SCA effects were positively significant for 14 hybrids in kharif and 20 hybrids in summer (Table 7). These effects were negatively significant for six hybrids in kharif and seven hybrids in summer. A total of 11 hybrids viz. $P_1 \times P_6$ (EDxET), $P_1 \times P_5$ (EDxLT), $P_2 \times P_3$ (LDxET), $P_2 \times P_7$ (LDxET), $P_3 \times P_6$ (ETxET), $P_3 \times P_9$ (ETxLT), $P_4 \times P_5$ (ETxLT), $P_6 \times P_9$ (ETxLT), $P_3 \times P_8$ (ETxLD), $P_4 \times P_8$ (ETxLD) and $P_6 \times P_8$ (ETxLD) were the best specific combiners in both seasons. Reciprocal effects of $P_2 \times P_6$ (LDxET) hybrid in kharif and $P_7 \times P_8$ (ETxLD), $P_5 \times P_6$ (LTxET), $P_2 \times P_8$ (LDxLD), $P_2 \times P_7$ (LDxET), $P_2 \times P_4$ (LDxET), $P_4 \times P_5$ (ETxLT), $P_4 \times P_9$ (ETxLT) and $P_7 \times P_9$ (ETxLT) hybrids in summer were significant (Table 8).

4.1.3.9 Grain yield per plant : GCA effects were positively significant for P_3 (ET), P_5 (ET), P_8 (LD) and P_9 (LT) and negatively significant for P_1 (ED) and P_2 (LD) in kharif (Table 6). In summer season, P_2 (LD), P_6 (ET) and P_9 (LT) recorded positively significant GCA effects and P_1 (ED) and P_4 (ET) recorded negatively significant GCA effects. P_6 (ET) and P_9 (LT) were the best general combiners for grain yield per plant when GCA effects of both the seasons were considered.

SCA effects were positively significant for 20 hybrids and negatively significant for nine hybrids in kharif season (Table 7). In summer season, 17 hybrids registered positively significant SCA effects while seven hybrids recorded negatively significant SCA effects. The hybrids $P_1 \times P_3$ (EDxET), $P_1 \times P_5$ (EDxLT), $P_2 \times P_3$ (LDxET), $P_2 \times P_7$ (LDxET), $P_8 \times P_9$ (LDxLT), $P_4 \times P_7$ (ETxET), $P_3 \times P_9$ (ETxLT), $P_3 \times P_8$ (ETxLD), $P_4 \times P_8$ (ETxLD) and $P_6 \times P_8$ (ETxLD) were the best specific combining hybrids over both seasons. Reciprocal effects were negatively significant for $P_1 \times P_3$ (EDxET), $P_1 \times P_4$ (EDxET), $P_1 \times P_6$ (EDxET), $P_1 \times P_5$ (EDxLT), $P_2 \times P_3$ (LDxET), $P_2 \times P_7$ (LDxET), $P_6 \times P_7$ (ETxET) and $P_7 \times P_8$ (ETxLD) hybrids in kharif (Table 8). They were positively significant in the same season for $P_2 \times P_6$ (LDxET), $P_2 \times P_5$ (LDxLT), $P_2 \times P_9$ (LDxLT), $P_8 \times P_9$ (LDxLT), $P_3 \times P_4$ (ETxET) and $P_6 \times P_9$ (ETxLT) hybrids.

4.1.4 Graphic Analysis

The test of t^2 was significant for days to 50 per cent flowering, grain yield per main panicle and grain yield per plant during summer season (Table 9). However, the test was not significant for

Table 9: Estimates of t^2 , b, SEb, (b-0)/SEb and (1-b)/SEb for grain yield and its attributes in kharif and summer seasons

Character	Season	t^2	b(Wr, Vr)	SEb	b-0/SEb	1-b/SEb
Days to 50% flowering	Kharif	0.161	0.610	0.248	2.465*	1.575
	Summer	6.370*	0.684*	0.093	7.335**	3.385*
Plant height	Kharif	0.903	0.899	0.079	11.446**	1.290
	Summer	0.920	0.881	0.088	10.004**	1.348
Tiller number	Kharif	0.008	0.609	0.312	1.952	1.250
	Summer	3.643	-0.305	0.179	-1.705	7.925**
Panicle number	Kharif	0.561	1.013	0.195	5.184**	-0.065
	Summer	0.401	0.640	0.214	2.998*	1.684
Panicle length	Kharif	1.382	0.681	0.156	4.368**	2.048
	Summer	0.093	0.988	0.116	8.487**	0.103
Panicle girth	Kharif	0.028	0.868	0.213	4.079**	0.619
	Summer	0.541	0.732	0.173	4.227**	1.550
500-grain weight	Kharif	1.753	0.840	0.090	9.324**	1.782
	Summer	1.397	0.823	0.104	7.887**	1.697
Grain yield/main panicle	Kharif	2.253	0.611	0.154	3.976**	2.531*
	Summer	48.779**	0.179	0.067	2.674*	12.243**
Grain yield/plant	Kharif	0.043	0.638	0.263	2.425*	1.377
	Summer	16.024**	0.438	0.093	4.689**	6.023**

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

all these characters during kharif season and also during both seasons for the other six characters viz., plant height, tiller number, panicle number, panicle length, panicle girth and 500 grain weight. The deviation of the regression slope of V_r , W_r from unity was significant for tiller number and grain yield per plant (summer) only. Thus both these tests have indicated that the assumptions of the diallel were largely fulfilled for the characters under study. The results of graphic analysis, for all the characters are furnished below :

4.1.4.1 Days to 50 per cent flowering

Kharif : The regression line in V_r - W_r graph originated above the point of origin (Fig. 1). The slope of the regression did not deviate significantly from unity. Parental arrays of P_4 , P_2 and P_8 were distributed above the regression slope. Parents P_1 , P_3 , P_6 and P_7 were close to each other beneath the regression line and close to the point of origin. Parents P_5 and P_9 were away from the point of origin and distributed below the regression slope.

Summer : The regression line in V_r - W_r graph originated below the point of origin (Fig. 2). The slope of the regression line significantly deviated from unity. Parental arrays of P_7 , P_8 and P_9 were distributed above the regression line. Parent P_4 was very closely placed beneath the regression slope above the V_r axis. Parent P_5 was away from point of origin and below the regression line. Parental arrays of P_1 , P_3 and P_6 were close to the point of origin and distributed below the V_r axis.

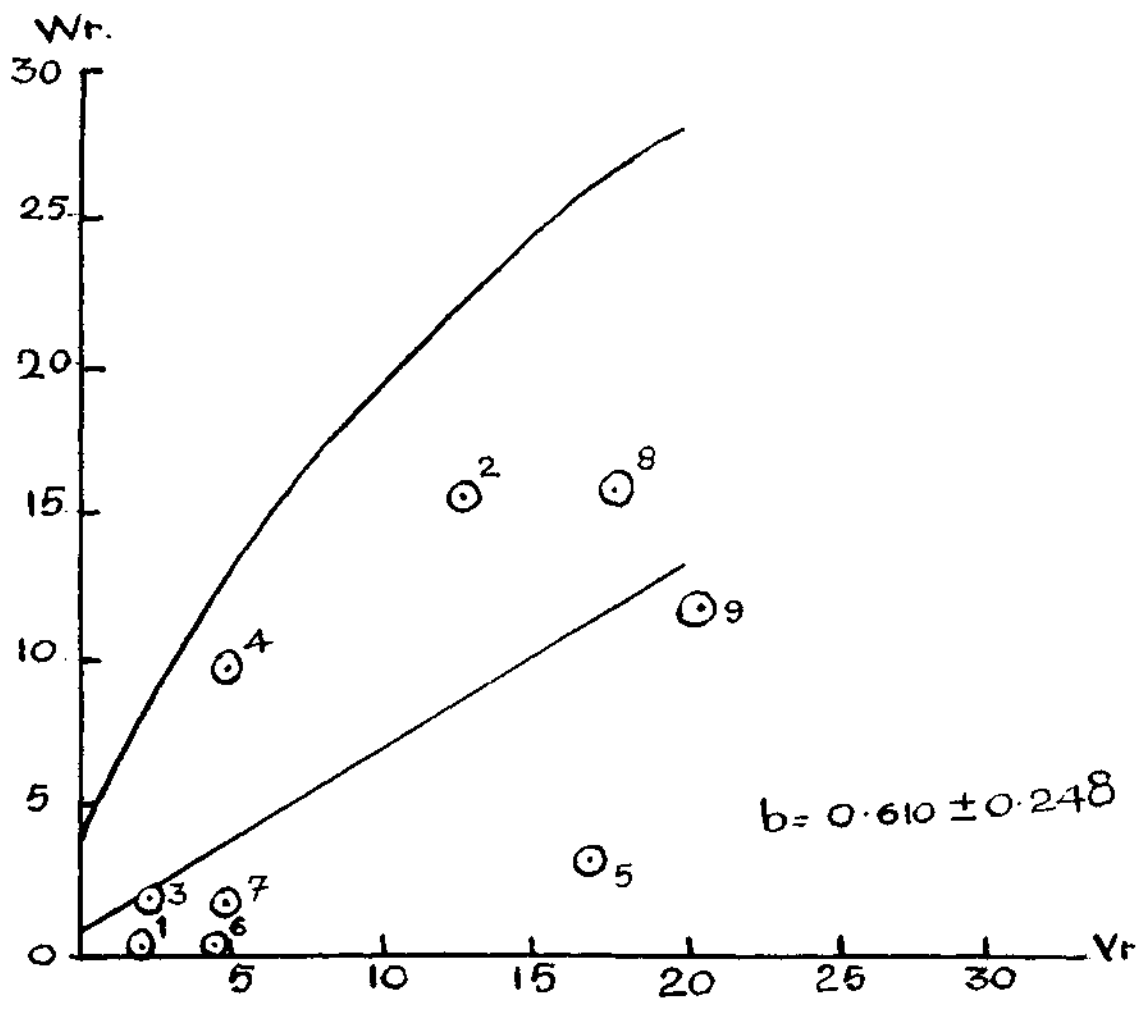
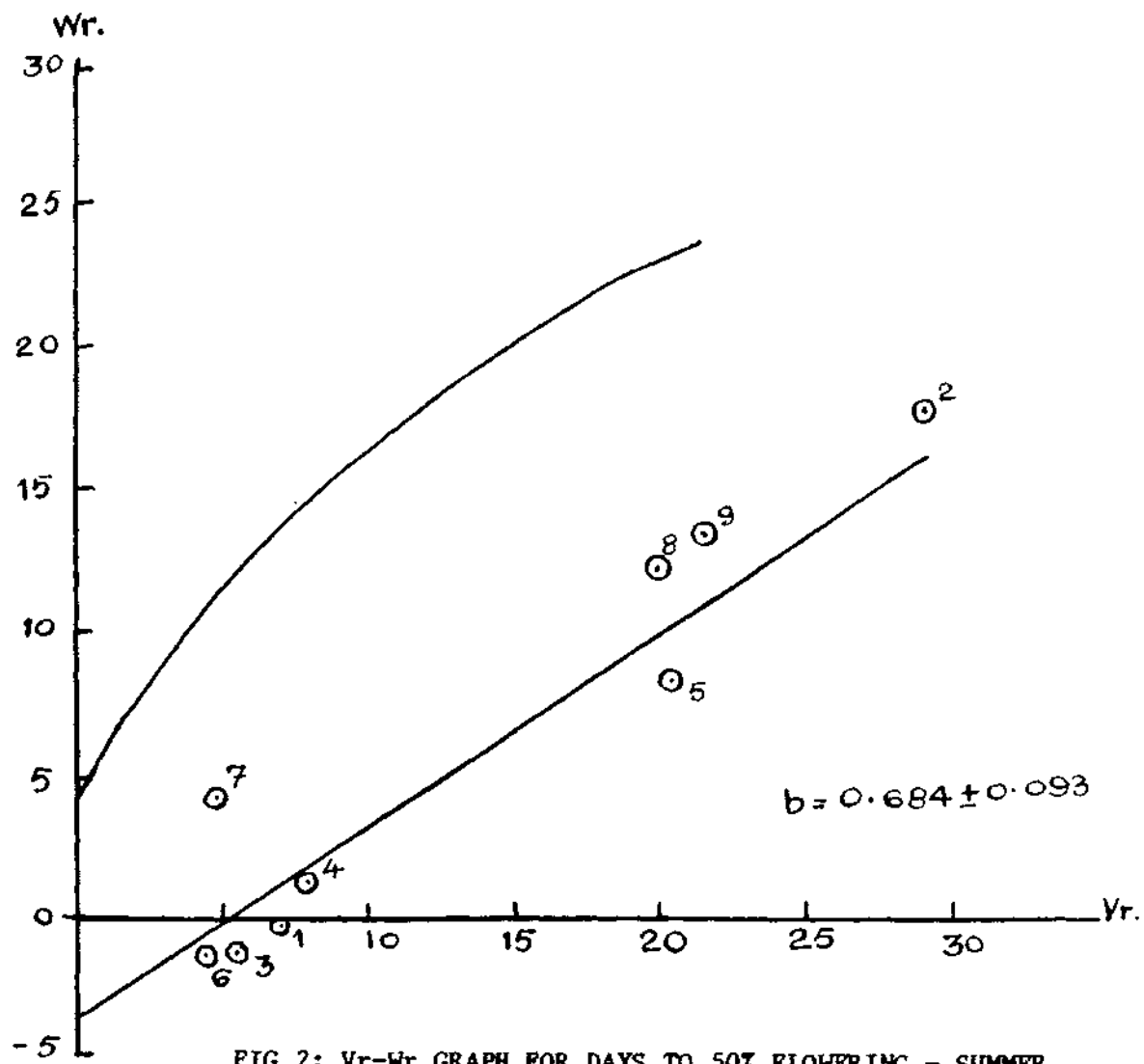


FIG 1: V_r - W_r GRAPH FOR DAYS TO 50% FLOWERING - KHARIF

FIG 2: V_r - W_r GRAPH FOR DAYS TO 50% FLOWERING - SUMMER

4.1.4.2 Plant height

Kharif : The regression line in the Vr-Wr graph cut the Wr axis below the point of origin (Fig. 3). The regression line did not deviate significantly from unity. P_8 and P_9 were far away from the point of origin. P_7 was just above the Vr axis and close to the point of origin. Parental arrays of P_3 , P_5 and P_6 were also near the point of origin but placed below the Vr axis. P_4 and P_1 were distributed midway along the regression slope.

Summer : The regression line in the Vr-Wr graph cut Wr axis below the point of origin as in kharif season (Fig.4). The regression line did not deviate significantly from unity. The arrays of parents P_7 , P_9 and P_3 were close to the point of origin and were above the Vr axis. P_5 and P_6 were also close to the point of origin but placed below the Vr axis. P_8 and P_2 were farthest from the point of origin while P_4 and P_1 were in the middle on the regression slope.

4.1.4.3 Tiller number

Kharif : The regression line in the Vr-Wr graph originated slightly below the point of origin (Fig.5). The regression line did not deviate significantly from unity. All the parental arrays were distributed above the Vr axis except P_6 . Among all the parents P_5 was closer to the point of origin while P_8 and P_1 were placed farthest from the point origin.

Summer : The regression line in the Vr-Wr graph started on the Wr axis above the point of origin and cut the Vr axis and passed below it

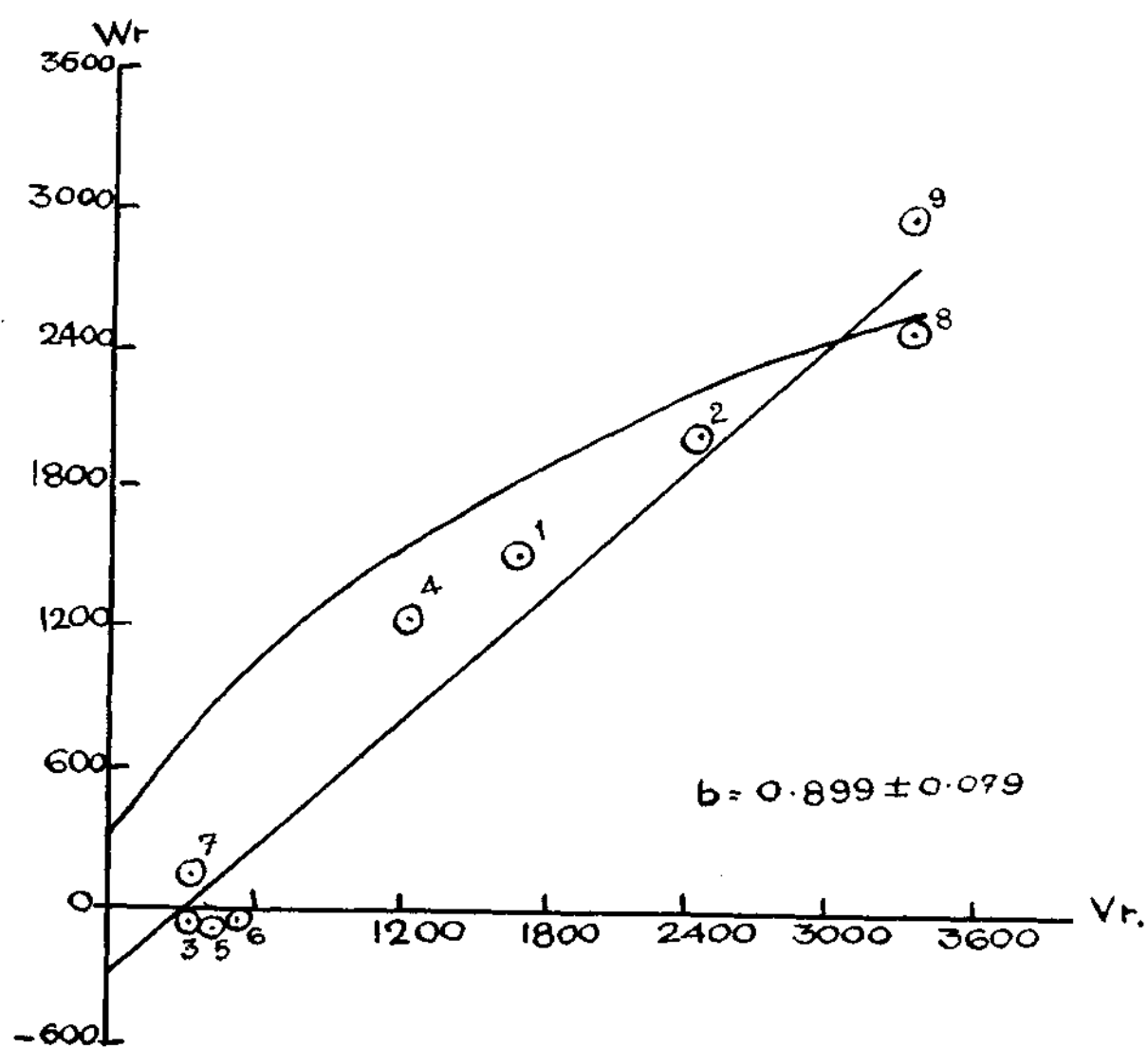


FIG 3: V_r - W_r GRAPH FOR PLANT HEIGHT - KHARIF

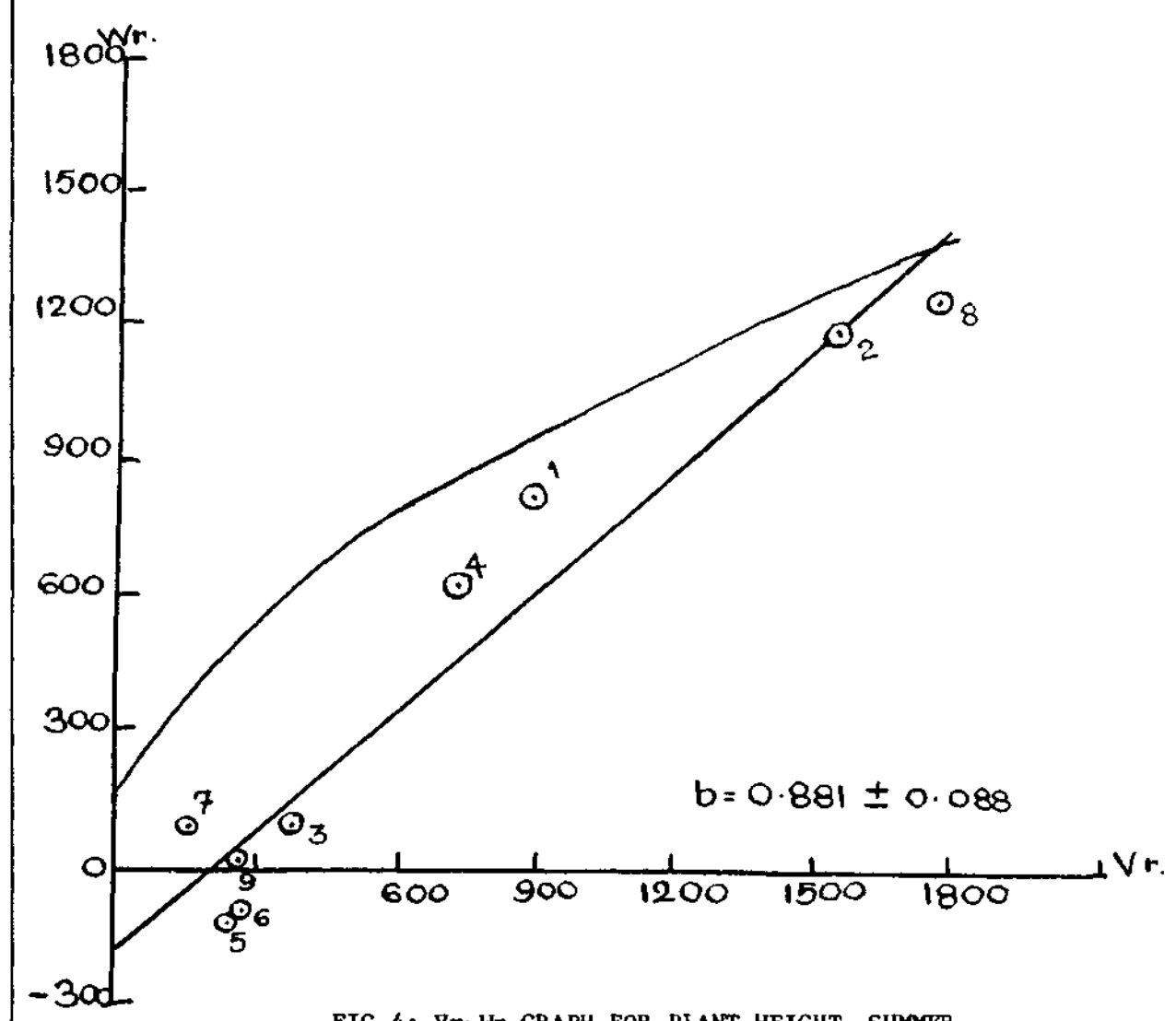


FIG 4: Vr-Wr GRAPH FOR PLANT HEIGHT - SUMMER

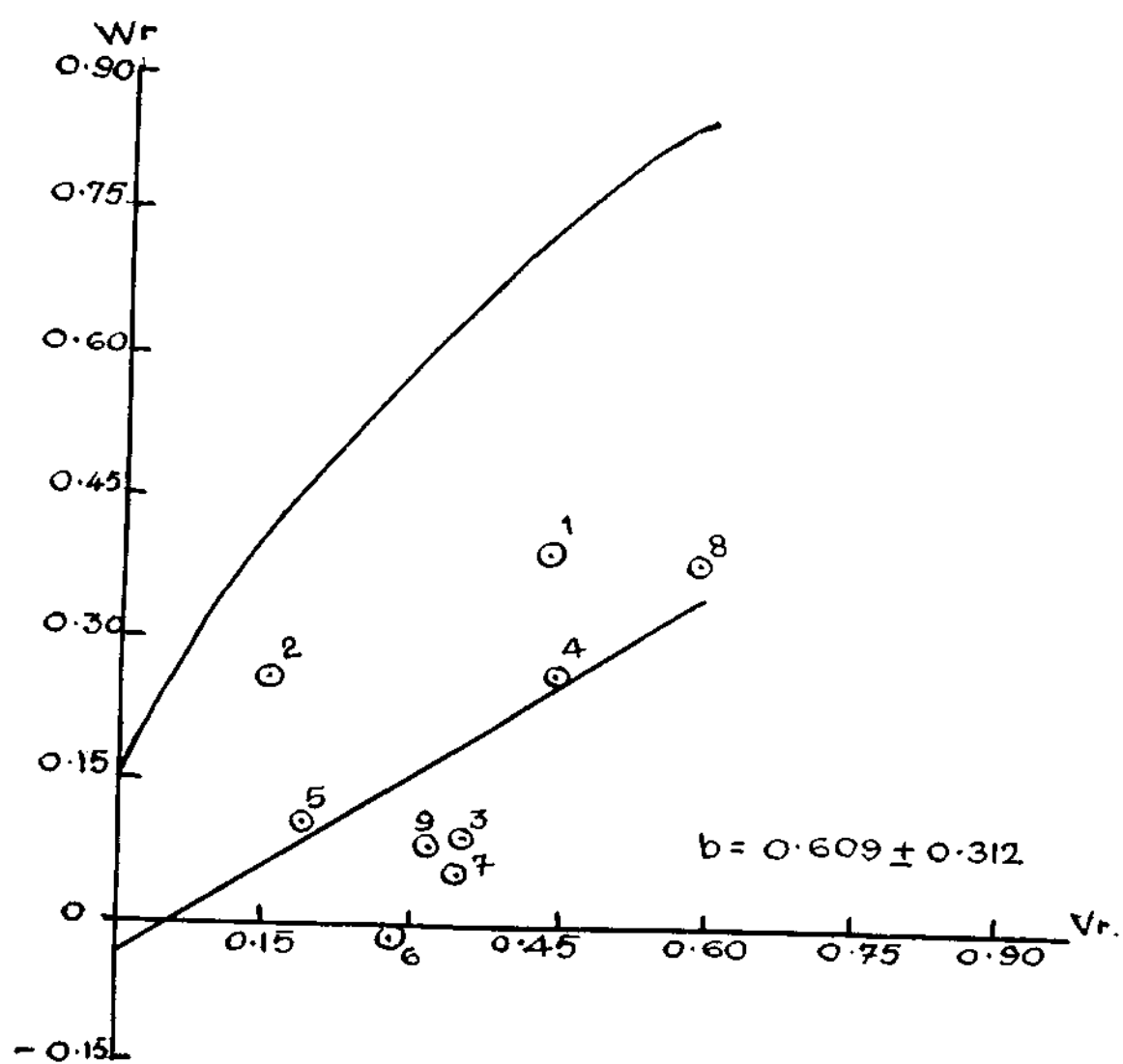


FIG 5: V_r - W_r GRAPH FOR TILLER NUMBER KHARIF

(Fig.6). The regression slope deviated significantly from unity. The parental arrays P_1 , P_8 , P_9 , P_3 , P_7 and P_2 were distributed above the Vr axis while those of P_4 , P_5 and P_6 were below the Vr axis. Among all the parents, P_1 was closest to the point of origin while P_2 , P_6 , P_4 and P_5 were farthest. P_9 , P_3 and P_7 were distributed midway on the regression slope.

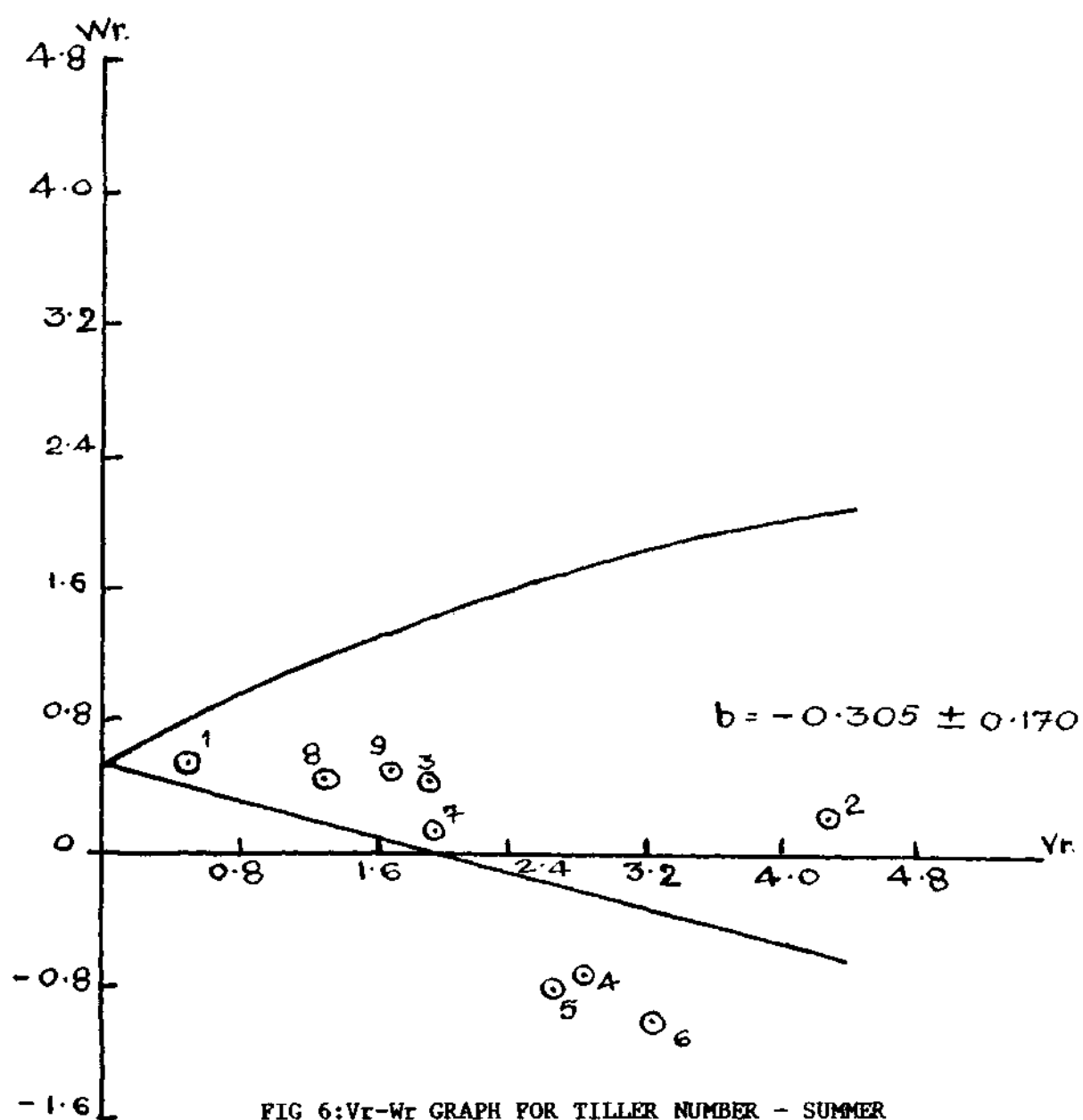
4.1.4.4 Panicle number

Khariif : The regression line in the Vr-Wr graph originated on the Vr axis below the point of origin (Fig.7). The slope of the regression line did not deviate significantly from unity. All the parental arrays were placed above the Vr axis except P_2 which was below the Vr axis and was very close to the point of origin. P_6 was farway from the point of origin while P_3 and P_5 were distributed midway along the regression slope.

Summer : The regression line in the Vr-Wr graph originated above the point of origin (Fig.8). The slope of the regression line did not deviate significantly from unity. Array points of all the parents were distributed above the Vr axis. Among all the parents, P_1 was closer to the point of origin while P_7 was placed far away from the point of origin. P_2 , P_8 and P_4 were positioned midway along the regression line.

4.1.4.5 Panicle length

Khariif : The regression line in the Vr-Wr graph originated on the Vr axis above the point of origin (Fig.9). The slope of the regression line did not deviate significantly from unity. All the parental

FIG 6: V_r - W_r GRAPH FOR TILLER NUMBER - SUMMER

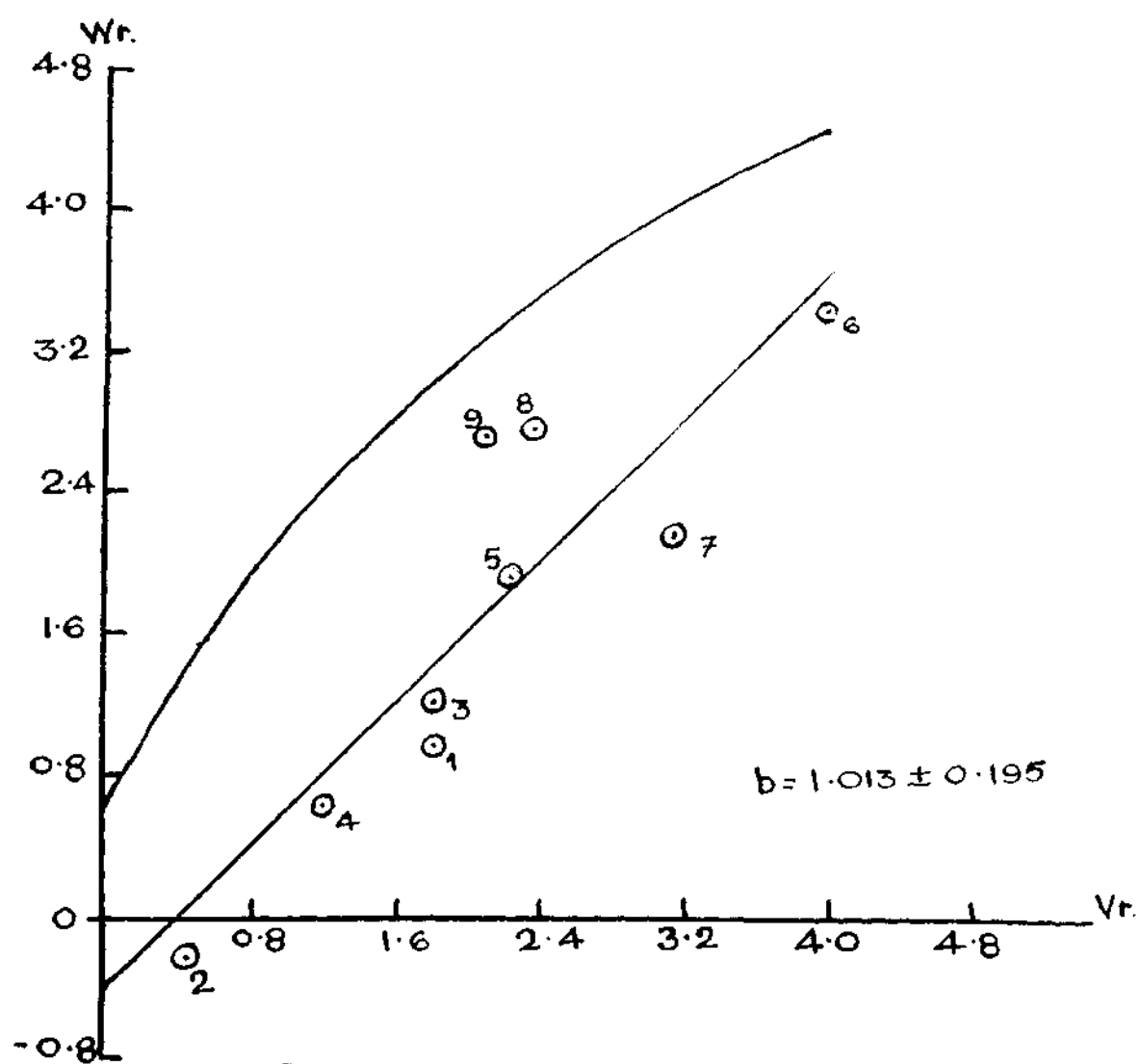


FIG 7: V_r - W_r GRAPH FOR PANICLE NUMBER - KHARIF

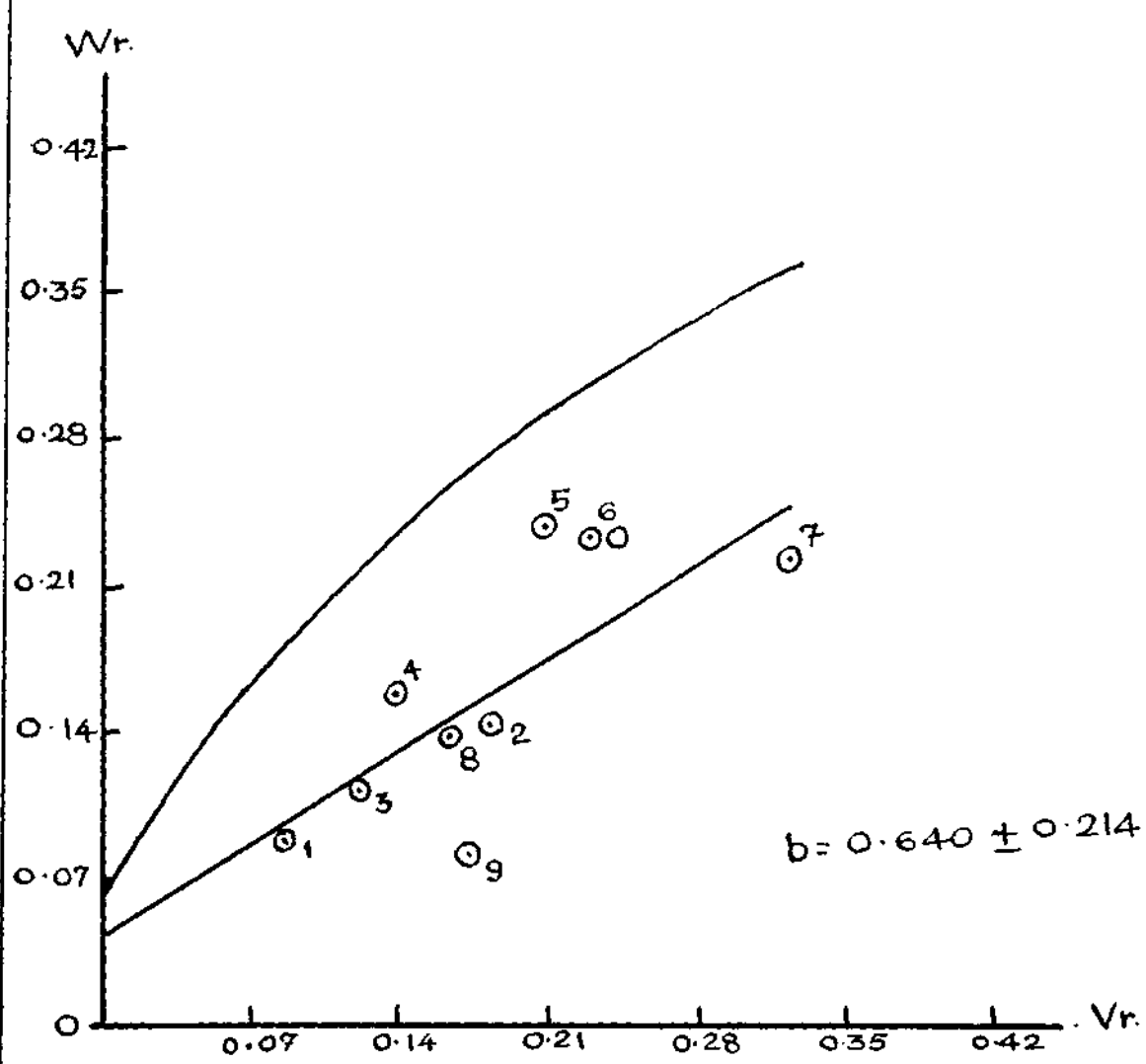


FIG 8: V_r - W_r GRAPH FOR PANICLE NUMBER - SUMMER

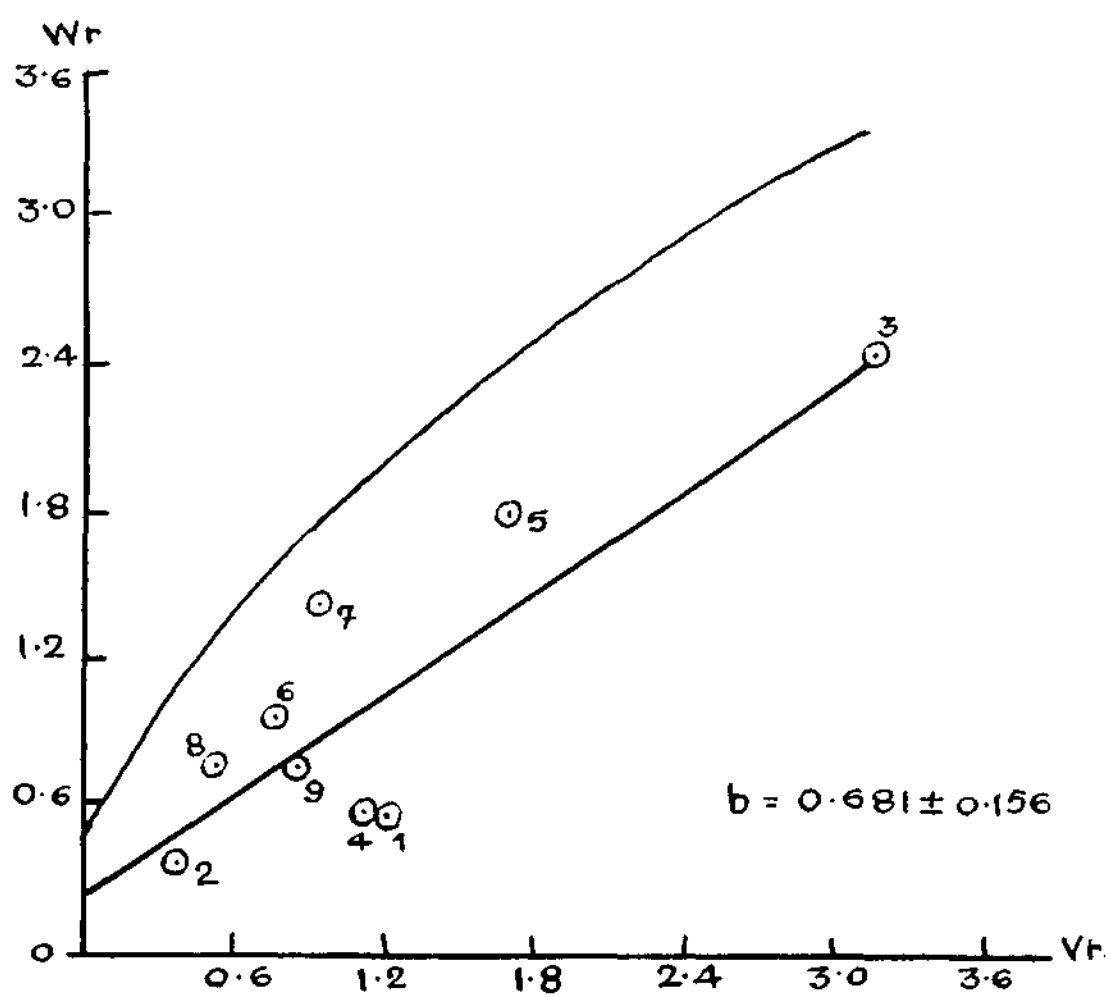


FIG 9: V_r - W_r GRAPH FOR PANICLE LENGTH - KHARIF

arrays were placed above the Vr axis. Parents P₈, P₆, P₇ and P₅ were distributed above the regression line and P₂, P₉, P₄ and P₁ were below the regression line. P₃ was far away from the point of origin. Parent P₂ was nearest to the point of origin among all the parents. Parents P₇ and P₅ were placed mid way along the regression line.

Summer : The regression line originated on the Wr axis above the point of origin as in kharif season (Fig.10). The slope of regression line deviated significantly from unity. In summer also all the parental arrays were distributed above Vr axis. Parent P₇, P₆, P₁ and P₅ were distributed above the regression line while the other parents were below the regression line. P₃ was far away from the point of origin while P₈, P₂ and P₉ were relatively nearer to the point of origin. P₁ and P₅ were distributed in the middle along the regression slope.

4.1.4.6 Panicle girth

Kharif : The regression line originated on the Wr axis above the point of origin (Fig.11). The slope of the regression did not deviate significantly from unity. All the parental arrays were distributed above the Vr axis. Parents P₈, P₄, P₂, P₁, P₆ and P₇ were placed closely just above the regression line while the parents P₃, P₉ and P₅ were just below the regression line. P₆, P₇, P₅ and P₁ were away from the point of origin. The other parents were positioned in the middle along the regression slope.

Summer : The regression line in the Vr-Wr graph passed through the point of origin (Fig.12). The slope of the regression line did not

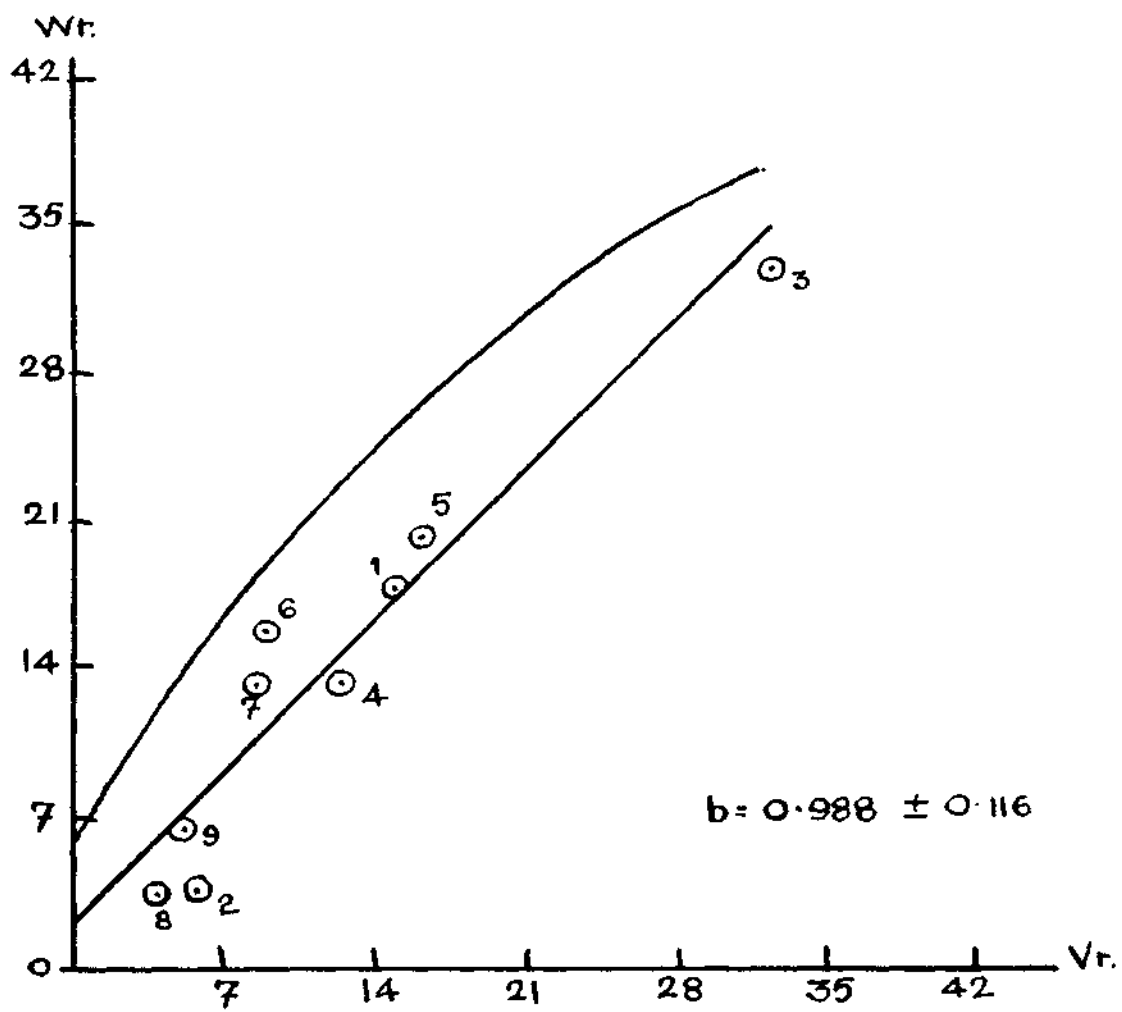


FIG 10: V_r - W_r GRAPH FOR PANICLE LENGTH - SUMMER

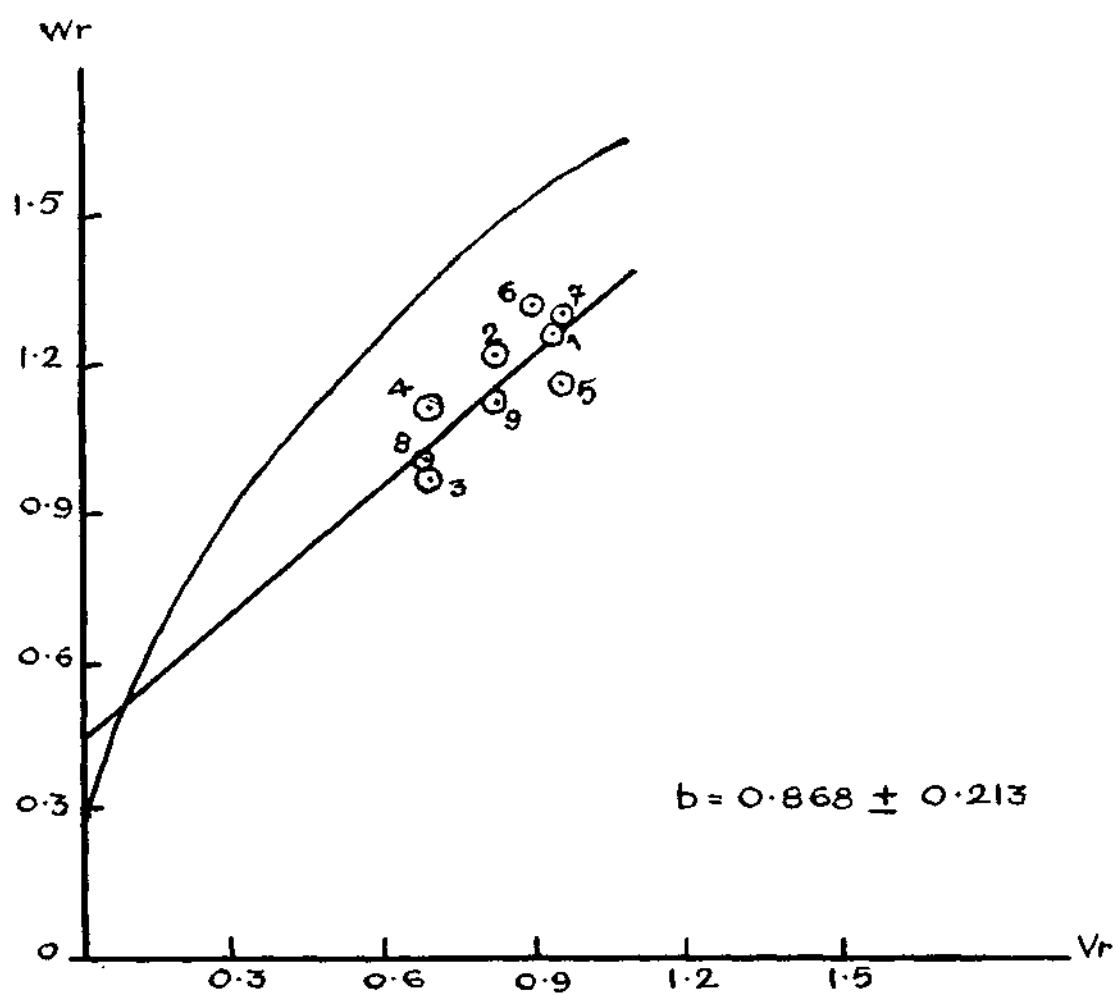


FIG 11: V_r - W_r GRAPH FOR PANICLE GIRTH-KHARIF

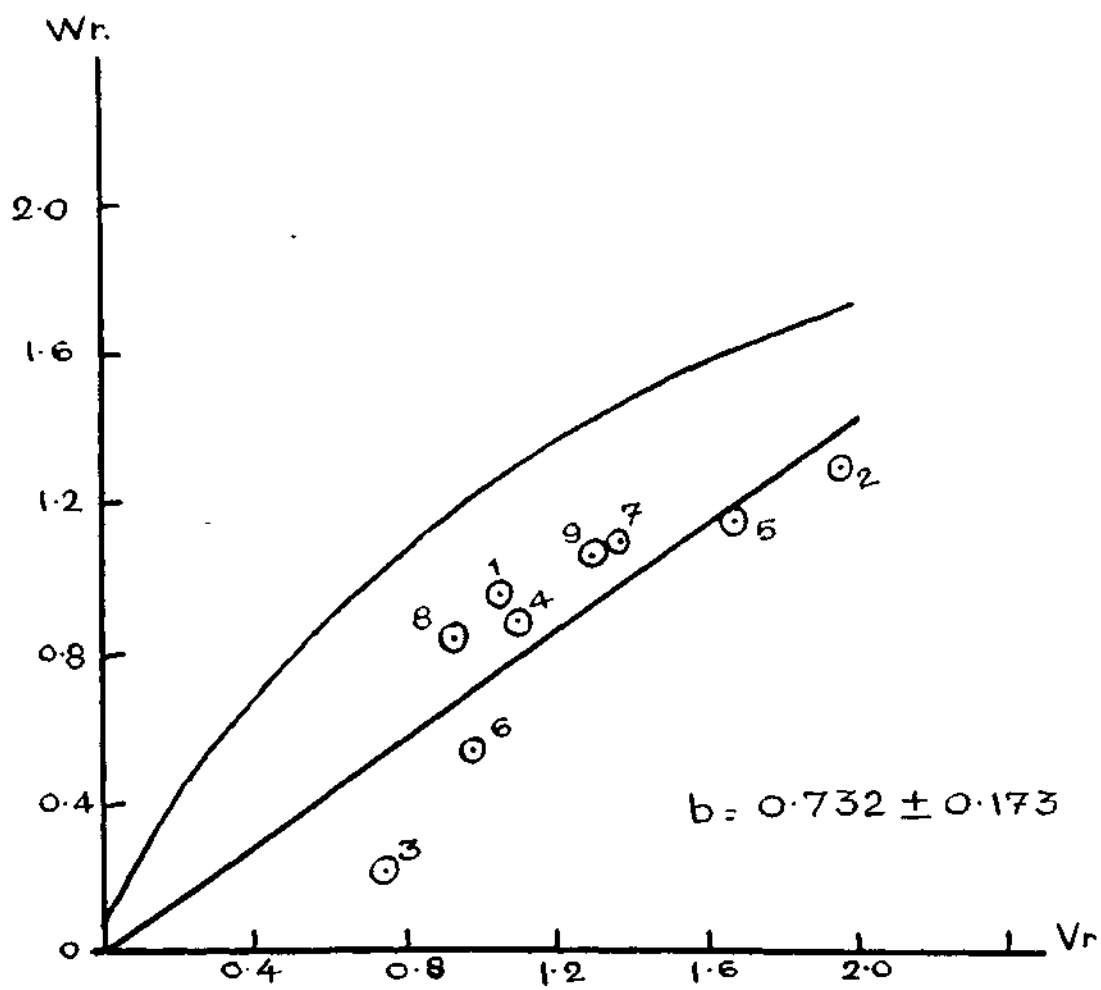


FIG 12: V_r - W_r GRAPH FOR PANICLE GIRTH - SUMMER

deviate significantly from unity. During the summer also all the parents were placed above the Vr axis. Parents P_8 , P_1 , P_4 , P_9 and P_7 were distributed just above the regression line while the other parents were below the regression line. Among all the parents, P_3 was closer to the point of origin and P_2 and P_5 were far[~]way from the point of origin. P_6 , P_8 , P_1 , P_4 , P_7 and P_9 were positioned midway along the regression slope.

4.1.4.7 500-Grain weight

Kharif : The regression line originated on the Wr axis just above the point of origin (Fig. 13). The slope of the regression line did not deviate significantly from unity. The parental lines were widely scattered along the regression line and were placed above the Vr axis. Parents P_7 , P_4 and P_1 were distributed below the regression line while all the remaining lines were placed just above the regression line. P_3 was comparatively closer to the point of origin and parent P_1 was farthest. P_5 , P_9 and P_4 were positioned midway along the regression line.

Summer: During summer also the regression line originated on the Wr axis just above the point of origin (Fig.14). The slope of the regression line did not deviate significantly from unity. The parents P_3 , P_4 , P_8 , P_2 and P_1 were distributed above the regression line over the Vr axis while parents P_6 , P_7 , P_5 and P_9 were below the regression line. Parent P_6 was relatively nearer to the point of origin, while P_1 was farthest. All other parents were distributed in the middle along the regression line.

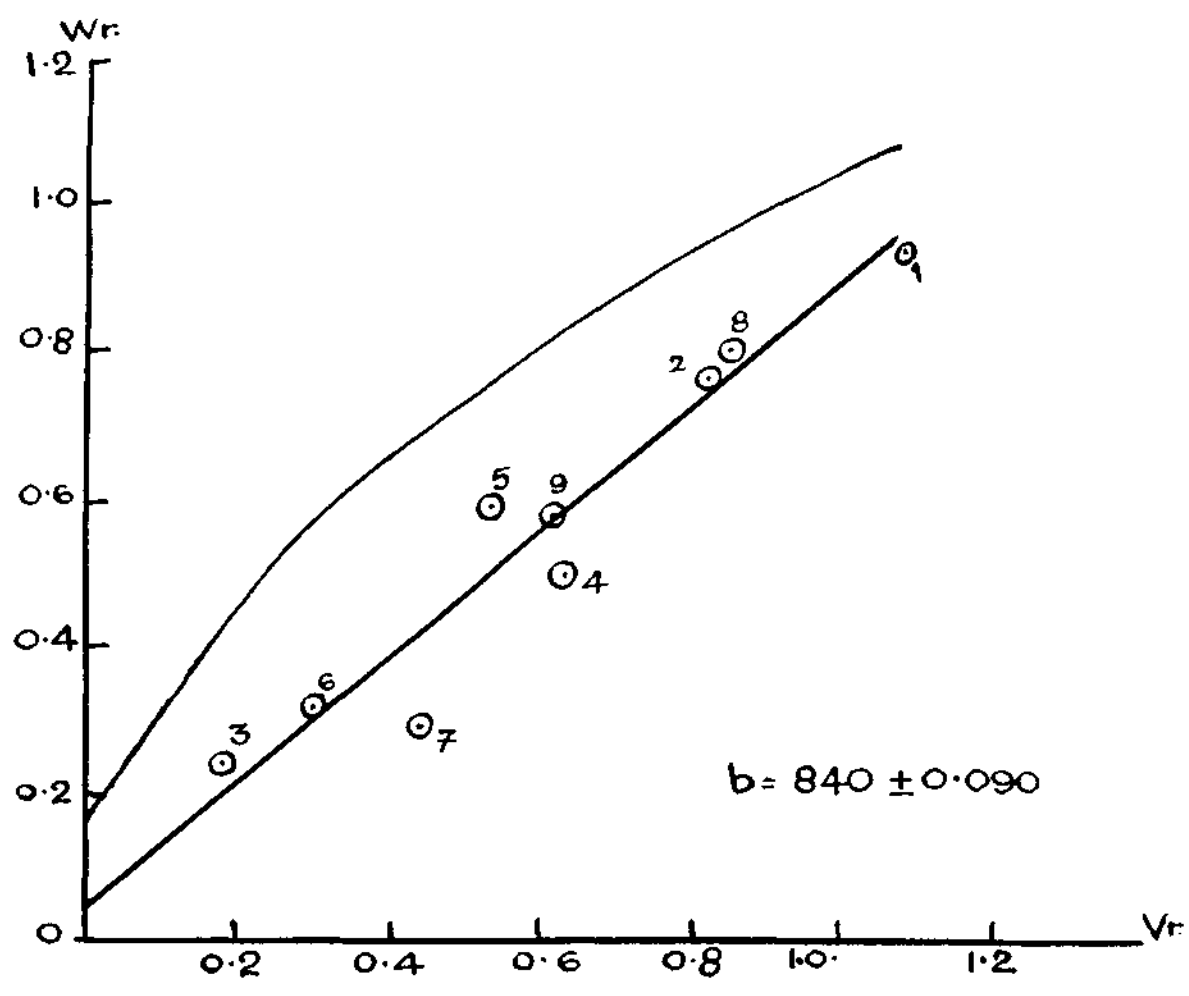


FIG 13: V_r - W_r GRAPH FOR 500-GRAIN WEIGHT - KHARIF

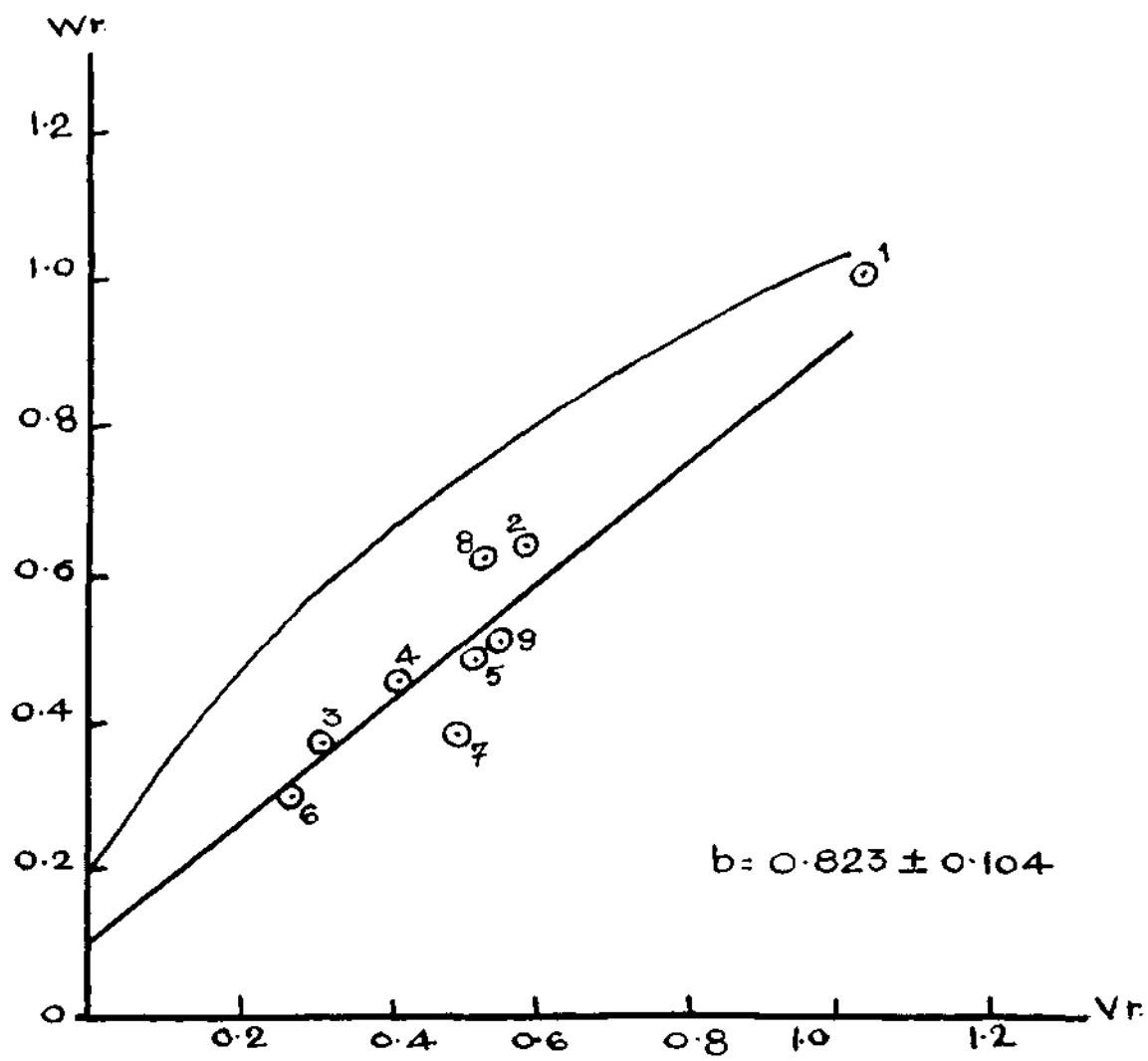


FIG 14: V_r - W_r GRAPH FOR 500-GRAIN WEIGHT - SUMMER

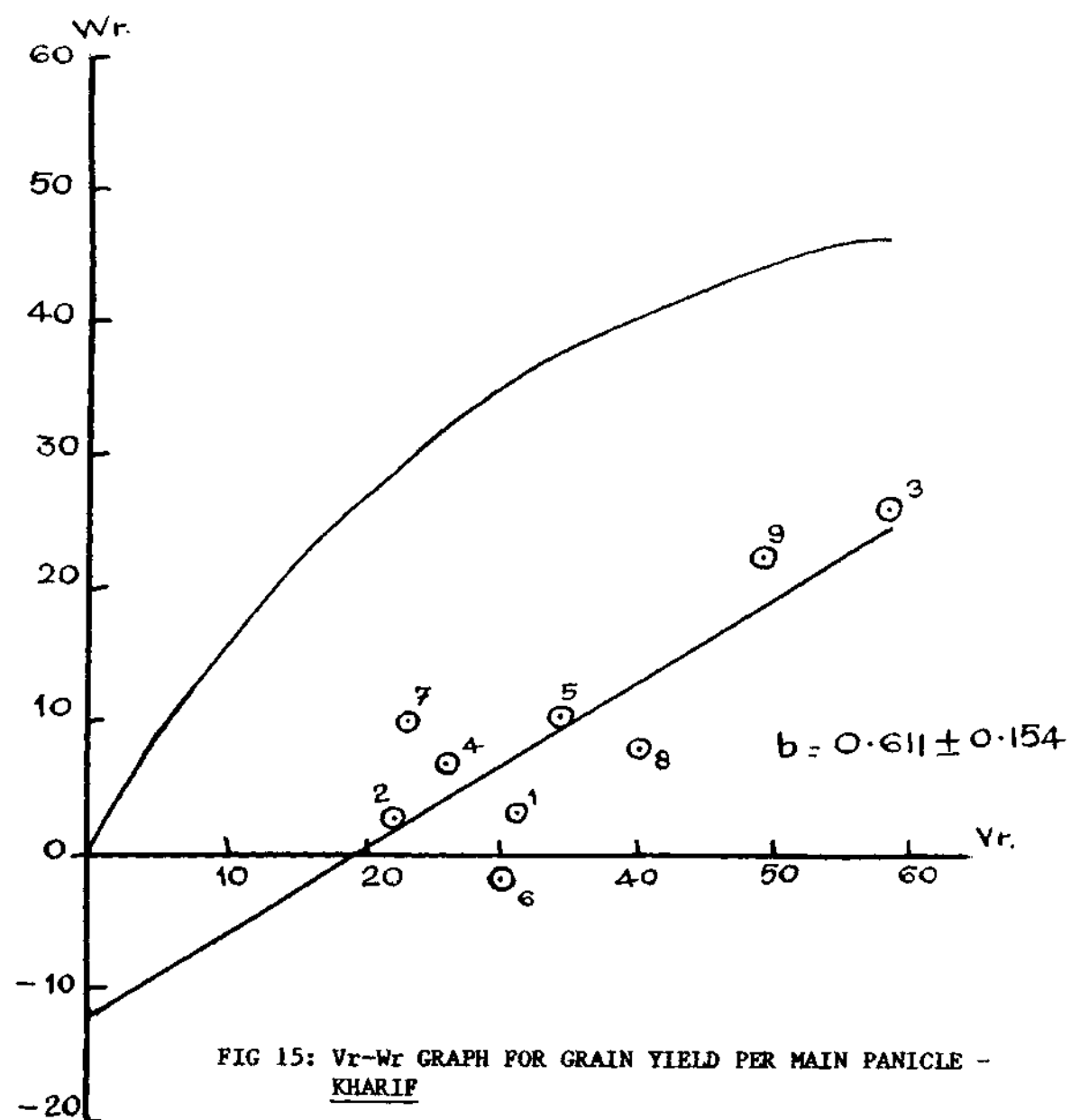
4.1.4.8 Grain yield per main panicle

Kharif : The regression line originated on the W_r axis below the point of origin (Fig.15). The slope of the regression line deviated significantly from unity. Parents P_2 , P_4 , P_5 , P_9 and P_3 were closely distributed all along the regression line. Parent P_7 was also above the regression line but scattered away from the line compared to others. Parents P_6 , P_1 and P_8 were distributed below the regression line. Among all the parents, P_6 was the only one placed below the V_r axis. P_3 and P_9 were far away from the point of origin while all the other parents were positioned mid way along the regression slope.

Summer : The regression line originated on the W_r axis above the point of origin unlike in kharif season (Fig. 16). The slope of the regression line deviated significantly from unity. All the parents were distributed along the regression line above the V_r axis. Parents P_4 , P_8 , P_9 and P_3 were above the regression line and the rest were below the regression line. Parents P_1 , P_5 and P_7 were just beneath the regression line. Parents P_4 and P_6 were comparatively nearer to the point of origin while P_3 , P_9 and P_2 were far away from the point of origin. P_8 , P_5 and P_7 were placed in the middle along the regression line.

4.1.4.9 Grain yield per plant

Kharif: The regression line originated on the W_r axis below the point of origin (Fig. 17). The slope of the regression line did not deviate significantly from unity. Parents P_2 , P_4 , P_8 , P_3 and P_9 were distributed above the regression line and P_5 , P_1 , P_7 and P_6 were below the regression line. Among them, the parents P_2 , P_5 and P_1 were below the



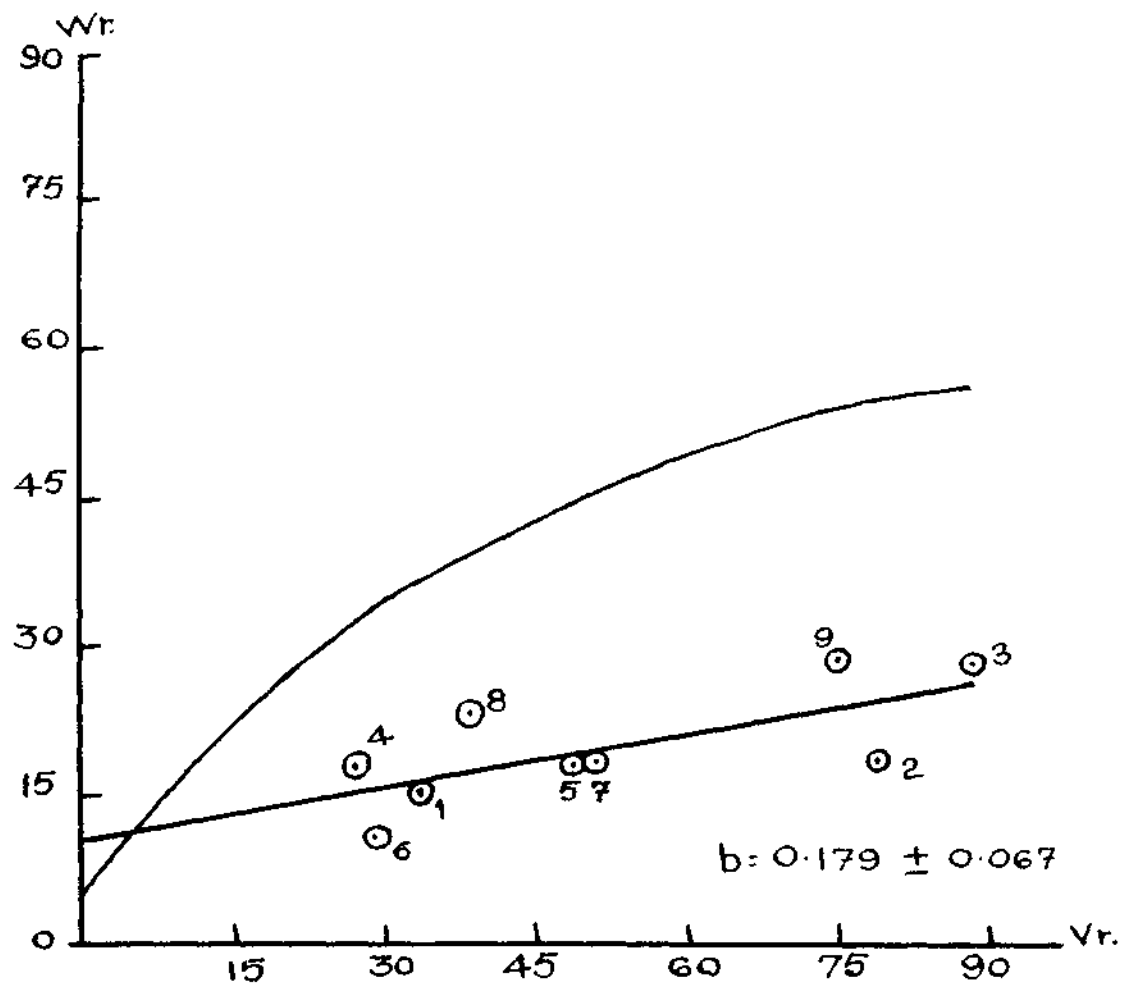
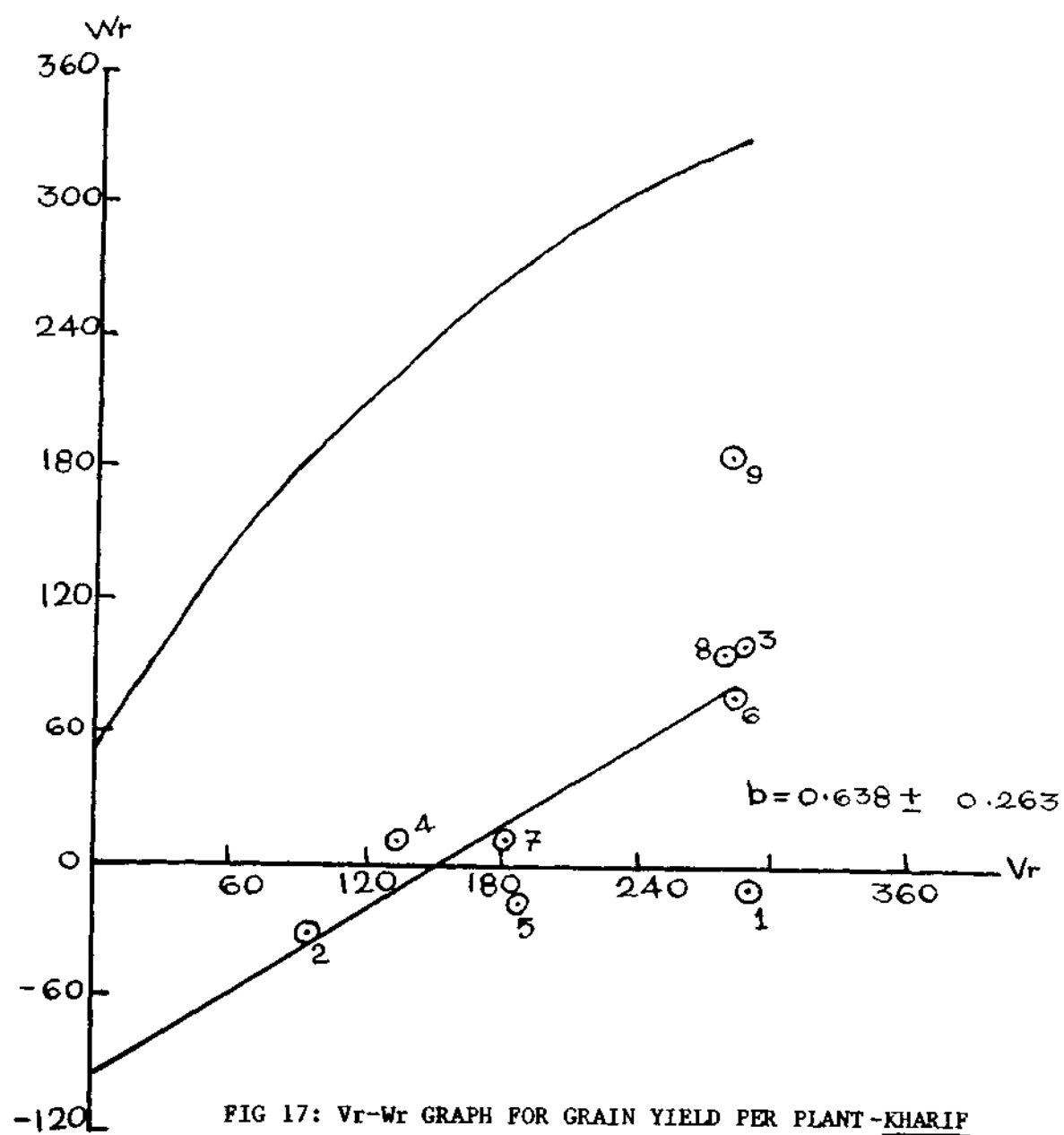


FIG. 16: V_r - W_r GRAPH FOR GRAIN YIELD PER MAIN PANICLE - SUMMER

FIG 17: V_r - W_r GRAPH FOR GRAIN YIELD PER PLANT -KHARIF

Vr axis. Parents P_6 , P_8 and P_3 were clustered closely towards the end of the regression line. Parent P_9 was scattered away from the regression line and point of origin. Parent P_2 was relatively closer to the point of origin while P_4 , P_5 and P_7 were distributed midway along the regression slope.

Summer : The regression line originated on the Wr axis just above the point of origin (Fig. 18). The slope of the regression line deviated significantly from unity. The parents were evenly distributed on both sides of the regression line all along the length. Parents P_6 , P_4 , P_8 , P_5 and P_3 were above the regression line while P_7 , P_1 , P_9 and P_2 were below the regression line. Parents P_6 and P_7 were relatively nearer to the point of origin while parent P_3 was farthest from the point of origin. Rest of the parents were positioned in the middle along the regression slope.

4.1.5 Genetic Analysis

The estimates of various genetic parameters and ratios are presented in Table 10 and 11.

4.1.5.1 Days to 50 per cent flowering : The estimates of D , F , H_1 and H_2 were significant in both the seasons while h^2 and E were not significant. The ratio of $(H_1/D)^{1/2}$ was more than unity in both the environments. The ratio of $H_2/4H_1$ was 0.135 and 0.201 in kharif and summer seasons respectively. KD/KR ratios of 3.728 in kharif and 2.197 in summer were recorded. The h^2/H_2 ratio ranged from -0.017 (kharif) to 0.059 (summer). The heritability estimate in narrow sense was high in summer (0.93) compared to kharif (0.769).

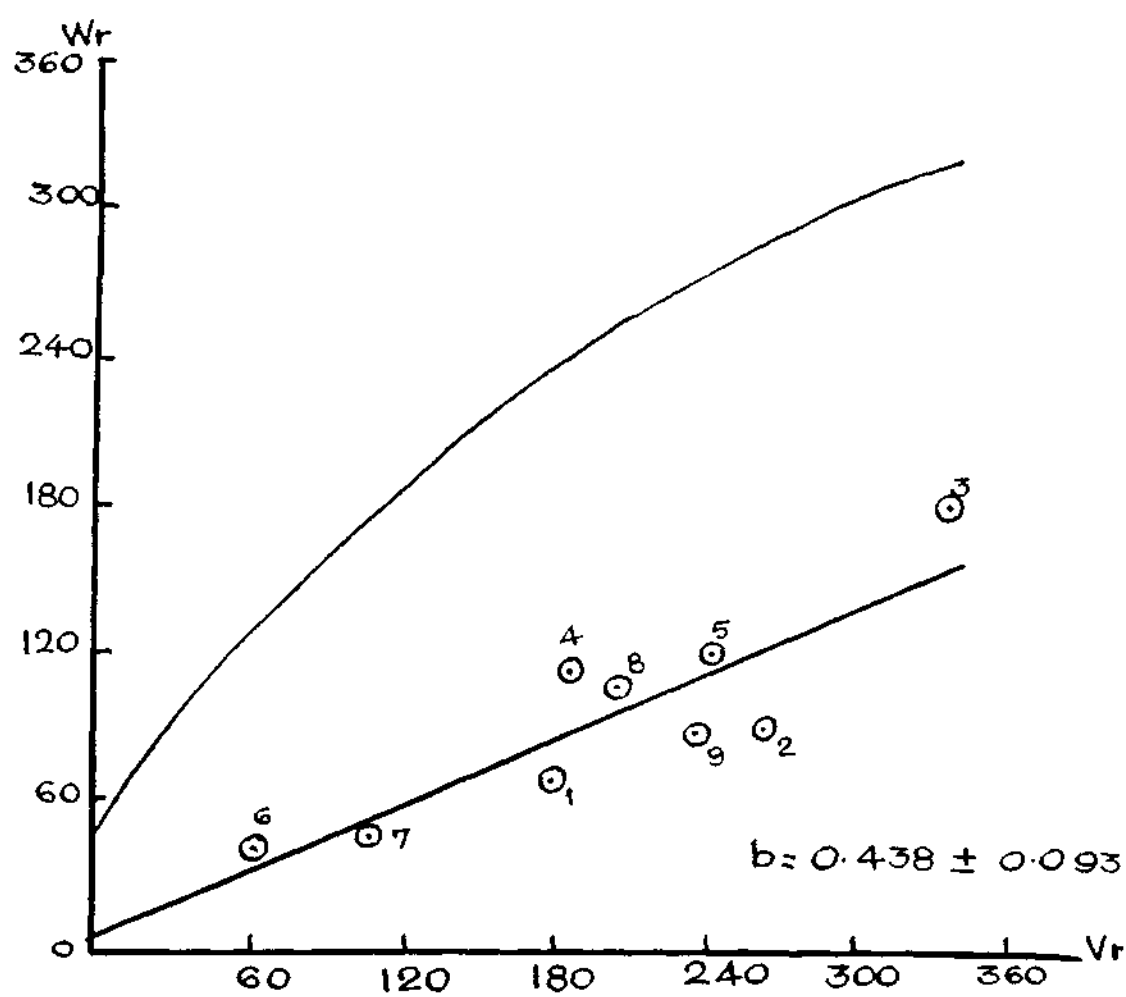


FIG 18: V_r - W_r GRAPH FOR GRAIN YIELD PER PLANT - SUMMER

Table 10: Estimates of genetic parameters for grain yield and its attributes in kharif and summer seasons

Character	Season	D	F	H ₁	H ₂	h ²	E
Days to 50% flowering	Kharif	36.290** +4.161	46.555** +9.708	44.853** +9.185	24.201* +7.896	-0.409 +5.289	1.558 +1.316
	Summer	25.283** +2.767	28.078** +6.455	55.620** +6.107	44.737** +5.250	2.625 +3.517	0.306 +0.875
Plant height	Kharif	1951.115** +189.037	692.055 +440.985	3428.434** +417.236	3218.687** +358.672	107.264 +240.278	26.349 +59.779
	Summer	1050.302** +117.749	368.550 +274.686	2061.805** +259.893	1876.516** +223.413	70.361 +149.667	4.593 +37.236
Tiller number	Kharif	1.134** +0.093	1.538** +0.216	1.651** +0.205	1.034** +0.176	-0.021 +0.118	0.054 +0.029
	Summer	0.857 +1.138	1.953 +2.655	9.924** +2.512	8.147** +2.160	-0.059 +1.447	0.153 +0.360
Panicle number	Kharif	0.437** +0.040	0.243** +0.092	0.524** +0.087	0.357** +0.075	-0.015 +0.050	0.048** +0.012
	Summer	0.359** +0.035	0.113 +0.081	0.377** +0.077	0.289** +0.066	-0.018 +0.044	0.047** +0.011
Panicle length	Kharif	34.391** +3.264	26.042* +7.613	37.404** +7.203	30.306** +6.192	1.219 +4.148	0.497 +1.022
	Summer	42.478** +2.044	28.953** +4.767	33.366** +4.511	26.177** +3.877	1.022 +2.598	0.344 +0.646
Panicle girth	Kharif	2.468** +0.051	0.333* +0.119	1.028** +0.113	0.706** +0.097	-0.007 +0.065	0.072** +0.016
	Summer	1.480** +0.152	-0.591 +0.355	2.685** +0.336	2.429** +0.288	0.150 +0.193	0.069 +0.048

Contd.. Table 10

Character	Season	D	F	H ₁	H ₂	h ²	E
500 grain weight	Kharif	1.037**	-0.135	1.173**	1.021**	0.017	0.033
		+0.060	+0.141	+0.133	+0.114	+0.077	+0.019
	Summer	1.050**	0.025	1.023**	0.887**	0.030	0.015
		+0.052	+0.122	+0.116	+0.099	+0.067	+0.017
Grain yield/ main panicle	Kharif	32.601**	29.303*	128.596**	104.458**	3.305	4.435*
		+5.175	+12.071	+11.421	+9.818	+6.577	+1.636
	Summer	39.439*	0.118	165.595**	138.295**	6.214	1.154
		+14.460	+33.733	+31.916	+27.437	+18.380	+4.573
Grain yield/ plant	Kharif	370.083**	551.845**	1070.438**	722.606**	11.913	6.426
		+44.408	+103.595	+98.016	+84.258	+56.445	+14.043
	Summer	285.923**	197.095	688.748**	586.771**	23.611	14.443
		+38.100	+88.881	+84.094	+72.290	+48.428	+12.048

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

Table 11: Estimates of genetic ratios for grain yield and its attributes in kharif and summer seasons

Character	Season	$(H_1/D)^{1/2}$	$H_2'/4H_1'$	KD/KR	h^2/H_a	Heritability (ns)
Days to 50% flowering	Kharif	1.112	0.135	3.728	-0.017	0.769
	Summer	1.483	0.201	2.197	0.059	0.930
Plant height	Kharif	1.326	0.235	1.309	0.033	0.965
	Summer	1.401	0.228	1.286	0.037	0.990
Tiller number	Kharif	1.208	0.156	3.560	-0.020	0.669
	Summer	3.402	0.205	2.007	-0.007	0.690
Panicle number	Kharif	1.071	0.170	1.661	-0.041	0.799
	Summer	1.025	0.191	1.362	-0.064	0.778
Panicle length	Kharif	1.043	0.203	2.140	0.040	0.940
	Summer	0.886	0.196	2.250	0.039	0.968
Panicle girth	Kharif	0.646	0.172	1.234	-0.010	0.944
	Summer	1.347	0.226	0.742	0.062	0.944
500 grain weight	Kharif	1.064	0.218	0.884	0.016	0.953
	Summer	0.987	0.217	1.024	0.034	0.973
Grain yield/main panicle	Kharif	1.986	0.203	1.585	0.032	0.756
	Summer	2.049	0.209	1.001	0.045	0.967
Grain yield/plant	Kharif	1.701	0.169	2.561	0.016	0.928
	Summer	1.552	0.213	1.571	0.040	0.869

4.1.5.2 Plant height : The estimates of D , H_1 and H_2 were significant in both the seasons while those of F , h^2 and E were not significant. The ratio of $(H_1/D)^{1/2}$ was more than one in both the seasons. The $H_2/4H_1$ ratios were consistent over seasons and ranged from 0.228 to 0.235. The KD/KR ratios ranged from 1.286 in summer to 1.309 in kharif season. The h^2/H_2 ratios were 0.033 and 0.037 in kharif and summer seasons respectively. High estimates of heritability in narrow sense ranging from 0.965 to 0.990 were recorded for this character.

4.1.5.3 Tiller number: The estimates of H_1 and H_2 were significant in kharif and summer seasons while h^2 and E estimates were not significant. The D and F estimates were significant in kharif only. The $(H_1/D)^{1/2}$ ratio varied between 1.208 (kharif) to 3.402 (summer). The proportion of $H_2/4H_1$ was 0.156 in kharif and 0.205 in summer. The KD/KR ratios ranged from 2.007 (summer) to 3.560 (kharif). The h^2/H_2 ratios of -0.020 and -0.007 were observed in kharif and summer seasons respectively. The estimate of narrow sense heritability was 0.669 in kharif and 0.690 in summer season.

4.1.5.4 Panicle number: The estimates of D , H_1 , H_2 and E were significant in both the seasons while F was significant in kharif season only. The estimate of h^2 was not significant. The ratio of $(H_1/D)^{1/2}$ was more than unity in both the seasons. The $H_2/4H_1$ ratio was 0.170 in kharif and 0.191 in summer season. KD/KR ratio was more than unity in both the seasons. The h^2/H_2 ratio ranged from -0.064 in summer to -0.041 in kharif season. Heritability (narrow sense) estimates were consistent registering values of 0.799 in kharif and 0.778 in summer.

4.1.5.5 Panicle length: In both the seasons, significant estimates of D , F , H_1 and H_2 were obtained while h^2 and E estimates were not significant. The ratio of $(H_1/D)^{1/2}$ was more than unity in kharif and less than unity in summer. The ratio of $H_2/4H_1$ ranged from 0.196 (summer) to 0.203 (kharif). The KD/KR ratio estimates of 2.140 and 2.250 were obtained in kharif and summer seasons respectively. The h^2/H_2 ratios were almost similar in both kharif (0.040) and summer (0.039) seasons. The narrow sense heritability estimate was 0.94 for kharif and 0.968 for summer season.

4.1.5.6 Panicle girth: The D , H_1 and H_2 estimates were significant in both kharif and summer seasons while the estimates of F and E were significant in kharif season only. The h^2 estimate was not significant. The $(H_1/D)^{1/2}$ ratio was less than unity in kharif and more than unity in summer. The $H_2/4H_1$ ratio was 0.172 in kharif and 0.226 in summer. The KD/KR ratio was more than one in kharif and less than one in summer season. The h^2/H_2 estimates recorded were -0.010 in kharif and 0.062 in summer season. The heritability (narrow sense) was 0.944 in both seasons.

4.1.5.7 500-grain weight: The estimates of D , H_1 and H_2 components were significant in both the seasons while those of F , h^2 and E were not significant. The $(H_1/D)^{1/2}$ ratio was around unity in both the seasons. The $H_2/4H_1$ ratio was less than 0.25 in both the seasons. The KD/KR ratio varied from 0.884 in kharif to 1.024 in summer season. The h^2/H_2 ratios of 0.016 and 0.034 were estimated for kharif and summer seasons respectively. The heritability (narrow sense) was 0.953 in kharif and 0.973 in summer.

4.1.5.8 Grain yield per main panicle : The D , H_1 and H_2 estimates were significant in both the seasons while the estimates of F and E were significant in kharif season only. The h^2 estimate was not significant in both the seasons. The $(H_1/D)^{1/2}$ ratio was more than 1 in both the seasons. The $H_2/4H_1$ ratio was less than 0.25 in both kharif and summer seasons. The KD/KR ratios of 1.585 and 1.001 were recorded in kharif and summer season respectively. The h^2/H_2 ratios ranged from 0.032 (kharif) to 0.045 (summer season). The heritability (narrow sense) was 0.756 in kharif and 0.967 in summer season.

4.1.5.9 Grain yield per plant : In both the seasons, the estimates of D , H_1 and H_2 were significant while F was significant in kharif season only. The h^2 and E estimates were not significant in both the seasons. The $(H_1/D)^{1/2}$ ratio was more than unity in kharif and summer seasons. The $H_2/4H_1$ ratio ranged between 0.169 (kharif) and 0.213 (summer). The KD/KR ratio was more than unity in both the seasons. The h^2/H_2 ratios obtained varied from 0.016 in kharif to 0.040 in summer. The heritability estimates (narrow sense) were 0.928 in kharif season and 0.869 in summer season.

4.1.6 Character Associations

Genotypic and phenotypic correlations between grain yield per plant and the yield component characters are presented in Table 12 and 13. The phenotypic and genotypic correlation coefficients agreed very closely. Hence the results pertaining only to genotypic correlations are discussed here for kharif and summer seasons, in order to avoid repetition.

Table 12: Genotypic correlations between different characters in kharif and summer seasons

Character	Season	Plant height	Tiller number	Panicle number	Panicle length	Panicle girth	500-grain weight	Grain yield/ main panicle	Grain yield/ plant
Days to 50% flowering	Kharif	-0.2306*	0.1218	-0.2434*	0.1080	-0.2599**	-0.3151**	0.0293	-0.1262
	Summer	-0.3592**	-0.1700	-0.2804**	-0.1285	-0.3728**	-0.3581**	-0.1574	-0.3432**
Plant height	Kharif		0.2305*	0.2701**	0.1001	0.4773**	0.5189**	0.6939**	0.6884**
	Summer		-0.2933**	-0.1575	-0.0976	0.5007**	0.5268**	0.4866**	0.5372**
Tiller number	Kharif			0.0479	0.1747	-0.0542	-0.0453	0.1788	0.1481
	Summer			0.1727	0.2186*	0.1808	0.0334	0.0462	0.1136
Panicle number	Kharif				-0.1346	-0.2290*	-0.1118	0.0268	0.5419**
	Summer				-0.0409	-0.4005**	-0.1871	-0.3596**	0.0520
Panicle length	Kharif					-0.2548**	-0.1393	0.4525**	0.2699**
	Summer					-0.0002	-0.1211	0.3589**	0.3378**
Panicle girth	Kharif						0.6984**	0.4987**	0.2800**
	Summer						0.7381**	0.7578**	0.6468**
500-grain weight	Kharif							0.4159**	0.3126**
	Summer							0.5291**	0.5102**
Grain yield/ main panicle	Kharif								0.7915**
	Summer								0.8915**

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

Table 13: Phenotypic correlations between different characters in kharif and summer seasons

Character	Season	Plant height	Tiller number	Panicle number	Panicle length	Panicle girth	500-grain weight	Grain yield/ main panicle	Grain yield/ plant
Days to 50% flowering	Kharif	-0.1985*	0.1095	-0.1529	0.1112	-0.2445*	-0.2717**	0.0079	-0.1026
	Summer	-0.2745	-0.1462	-0.2144*	-0.1214	-0.3430**	-0.3245**	-0.1511	-0.3033**
Plant height	Kharif		0.2069*	0.2370*	0.0983	0.4448**	0.4852**	0.5386**	0.6461**
	Summer		-0.2278	-0.1476	-0.0804	0.4316**	0.4667**	0.4505**	0.4748**
Tiller number	Kharif			0.0770	0.1428	-0.0630	-0.0319	0.1378	0.1600
	Summer			0.1607	0.2067*	0.1637	0.0375	0.0555	0.1257
Panicle number	Kharif				-0.1110	-0.2002*	-0.1047	-0.1922	0.4752**
	Summer				-0.0145	-0.3169**	-0.1455	-0.3276**	0.1387
Panicle length	Kharif					-0.2348*	-0.1270	0.3693**	0.2621**
	Summer					-0.0104	-0.1066	0.3431**	0.3313**
Panicle girth	Kharif						0.6472**	0.3882**	0.2412*
	Summer						0.6774**	0.7087**	0.5959**
500-grain weight	Kharif							0.3365**	0.2857**
	Summer							0.5051**	0.4810**
Grain yield/ main panicle	Kharif								0.6870**
	Summer								0.8622**

* Significant at 5% level ;

** Significant at 1% level

Kharif : Days to 50 per cent flowering had negative and significant association with plant height, panicle number, panicle girth and 500 grain weight. Its association with grain yield per plant was also negative but not significant. Its correlations with tiller number, panicle length and grain yield per main panicle were positive but not significant. The association of plant height was positive and significant with tiller number, panicle number, panicle girth, 500 grain weight, grain yield per main panicle and grain yield per plant. It was positive but non-significant with panicle length.

Tiller number exhibited positive and significant association with plant height and positive but non-significant association with 50 per cent flowering, panicle number, panicle length, grain yield per main panicle and grain yield per plant. Its association with panicle girth and 500-grain weight was negative but non-significant. Panicle number had significant and positive association with plant height and grain yield per plant and positive but non-significant association with tiller number and grain yield per main panicle. Its association was negative but non-significant with panicle length and 500 grain weight and significant with days to 50 per cent flowering.

Panicle length exhibited positive and significant association with grain yield per main panicle and grain yield per plant and positive but non-significant association with days to 50 per cent flowering, plant height and tiller number. Its association was negative and significant with panicle girth and non significant with panicle number and 500 grain weight. Panicle girth had positive and significant correlation with height, 500-grain weight, grain yield per main

panicle and grain yield per plant. Its association with tiller number was also positive but non-significant. The association of panicle girth was negative but non-significant with tiller number and significant with 50 per cent flowering, panicle number and panicle length, but non-significant with tiller number.

The association of 500-grain weight was positive and significant with plant height, panicle girth and grain yield per main panicle and grain yield per plant. Its association was negative and significant with 50 per cent flowering but non-significant with tiller number, panicle number and panicle length.

Grain yield per main panicle exhibited positive association with all the yield component characters. The association was significant with height, panicle length, panicle girth, 500-grain weight and grain yield per plant but non-significant with 50 per cent flowering, tiller number and panicle number. The association of grain yield per plant was positive and significant with plant height, panicle number, panicle length, panicle girth, 500 grain weight and grain yield per main panicle. Its association with tiller number was also positive but non-significant. It exhibited negative but non-significant association with 50 per cent flowering.

Summer : Days to 50 per cent flowering exhibited negative association with all the yield contributing characters under study. This association was significant with plant height, panicle number, panicle girth, 500-grain weight and grain yield per plant and non-significant with tiller number, panicle length and grain yield per main panicle.

Plant height had positive and significant association with panicle girth, 500-grain weight and grain yield per main panicle and grain yield per plant. Its association was negative and significant with days to 50 per cent flowering and tiller number and non-significant with panicle number and panicle length. The association of tiller number was positive and significant with panicle length and positive but non-significant with panicle number, panicle girth, 500-grain weight and grain yield per main panicle and grain yield per plant. It had negative and significant correlation with plant height and negative but non-significant association with days to 50 per cent flowering.

Panicle number exhibited positive but non-significant association with tiller number and grain yield per plant. Its association was negative and significant with days to 50 per cent flowering, panicle girth and grain yield per main panicle and non-significant with plant height, panicle length and 500-grain weight.

Panicle length exhibited positive and significant association with tiller number, grain yield per main panicle and grain yield per plant and negative but non-significant association with days to 50 per cent flowering, plant height, panicle number, panicle girth and 500-grain weight. Panicle girth had positive and significant association with plant height, 500 grain weight, grain yield per main panicle and grain yield per plant. Its association with tiller number was also positive but non-significant. It also exhibited negative and significant correlation with days to 50 per cent flowering and panicle

number. The association was negative with panicle length also but not significant.

The association of 500-grain weight was positive and significant with plant height, panicle girth and grain yield per main panicle and per plant. Its association with tiller number was also positive but non-significant. Its association was negative and significant with days to 50 per cent flowering and negative but non-significant with panicle number and panicle length.

Grain yield per main panicle exhibited positive and significant association with plant height, panicle length, panicle girth, 500-grain weight and grain yield per plant. Its association with tiller number was also positive but non-significant. It had negative and significant association with panicle number and negative but non-significant association with days to 50 per cent flowering.

Grain yield per plant was positively correlated with majority of the characters studied except days to 50 per cent flowering. The association was significant with plant height, panicle length, panicle girth, 500-grain weight and grain yield per main panicle. Its association with days to 50 per cent flowering was negative and significant.

4.1.7 Path Coefficient Analysis

The genotypic correlation coefficients of grain yield with other characters were further partitioned into direct and indirect effects and the same are presented in Table 14 and depicted in Fig.19 (kharif) and Fig.20 (summer).

Table 14: Direct and indirect (genotypic) effects of eight yield attributes on grain yield per plant in kharif and summer seasons

Character	Days to 50% flowering	Plant height	Tiller number	Panicle number	Panicle length	Panicle girth	500 grain weight	Grain yield/ main panicle	Correlation with grain yield/plant
Days to 50% flowering	Kharif Summer	0.0257 -0.0490	-0.0070 -0.0057	-0.1136 -0.1142	-0.0174 -0.0013	0.0518 0.0018	-0.0247 0.0007	0.0307 -0.1523	-0.1262 -0.3432**
Plant height	Kharif Summer	0.0180 0.0083	-0.0013 -0.0098	0.1261 -0.0641	-0.0161 -0.0010	-0.0951 -0.0024	0.0407 -0.0011	0.7277 0.4707	0.6884** 0.5372**
Tiller number	Kharif Summer	-0.0095 0.0039	-0.0057 0.0334	0.0224 0.0703	-0.0282 0.0022	0.0108 -0.0009	-0.0035 -0.0001	0.1875 0.0447	0.1481 0.1136
Panicle number	Kharif Summer	0.0190 0.0065	-0.0003 0.0058	0.4667 0.4072	0.0217 -0.0004	0.0456 0.0019	-0.0088 0.0004	0.0281 -0.3478	0.5419** 0.0520
Panicle length	Kharif Summer	-0.0084 0.0030	-0.0010 0.0073	-0.1611 -0.0167	-0.0628 0.0101	0.0508 0.0001	-0.0109 0.0002	0.4746 0.3472	0.2699** 0.3378**
Panicle girth	Kharif Summer	0.0203 0.0086	0.0003 0.0060	-0.1069 -0.1631	0.0411 -0.0001	-0.1992 -0.0047	0.0547 -0.0015	0.5230 0.7330	0.2800** 0.6468**
500-grain weight	Kharif Summer	0.0246 0.0083	0.0003 0.0011	-0.0522 -0.0762	0.0224 -0.0012	-0.1392 -0.0035	0.0783 -0.0020	0.4362 0.5118	0.3126** 0.5102**
Grain yield/ main panicle	Kharif Summer	-0.0023 0.0036	-0.0010 0.0015	0.0125 -0.1464	-0.0729 0.0036	-0.0994 -0.0036	0.0326 -0.0011	0.9998 0.9673	0.7919** 0.8915**

* Significant at 5% level Residual factor: Kharif : 0.2674

** Significant at 1% level Summer : 0.1791

Diagonal values indicate direct effects

Kharif: Grain yield per main panicle (0.9998), panicle number (0.4667) and 500-grain weight (0.0783) exerted positive direct effects on grain yield per plant and other characters showed negative direct effects. Plant height (0.7277), panicle girth (0.5230), panicle length (0.4746) and 500-grain weight (0.4362) influenced grain yield per plant indirectly through grain yield per main panicle.

Days to 50 per cent flowering influenced grain yield per plant indirectly through panicle girth (0.0518), grain yield per panicle (0.0307) and plant height (0.0257). Plant height exerted its influence on grain yield per plant mainly through grain yield per main panicle (0.7277), 500-grain weight, panicle number and days to 50 per cent flowering.

Tiller number contributed to grain yield through indirect effects of grain yield per main panicle (0.1875), panicle number (0.0224) and panicle girth (0.0108). Panicle number contributed to grain yield mainly through panicle girth (0.0456) and grain yield per main panicle (0.0281), panicle length (0.0217) and days to 50 per cent flowering (0.0190).

Panicle length influenced grain yield mostly through grain yield per main panicle (0.4746) and panicle girth (0.0508). Panicle girth had its influence on grain yield via grain yield per main panicle (0.5230), 500-grain weight (0.0547) and panicle length (0.0411).

500-grain weight exerted its influence on grain yield via grain yield per main panicle (0.4362), days to 50 per cent flowering

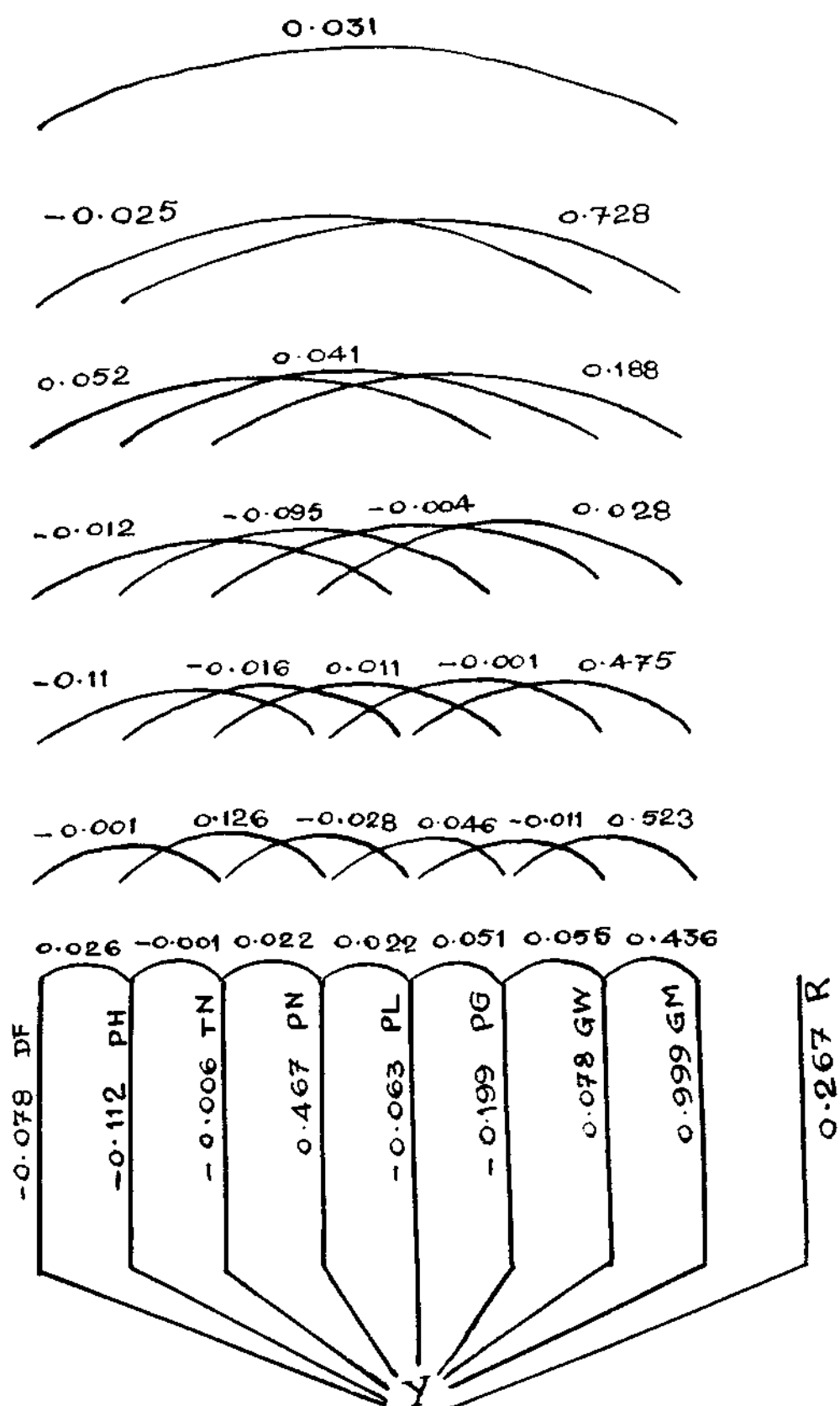


FIG 19: GENETYPIC PATH DIAGRAM-KHARIF

(0.0246) and panicle length. Grain yield per main panicle also contributed to grain yield per plant indirectly through 500-grain weight. Residual effect was 0.2674.

Summer: Grain yield per main panicle (0.9673), panicle number (0.4072), plant height (0.1365) and tiller number (0.0334) recorded positive direct effects on grain yield per plant. Panicle girth (0.7330), 500-grain weight (0.5118), plant height (0.4707) and panicle length (0.3472) exerted influence on grain yield per plant indirectly through grain yield per main panicle.

Days to 50 per cent flowering contributed positively to grain yield per plant through panicle girth and 500-grain weight. Plant height contributed to grain yield through grain yield per main panicle (0.4707) and days to 50 per cent flowering. Tiller number also exerted its influence on grain yield through panicle number (0.0703), grain yield per main panicle (0.0447), 50 per cent flowering and panicle length.

Panicle number exerted its influence on grain yield indirectly via 50 per cent flowering, tiller number, panicle girth and 500-grain weight. Panicle length contributed indirectly through grain yield per main panicle (0.3472), tiller number, days to 50 per cent flowering, 500-grain weight and panicle girth. Panicle girth exerted its influence on grain yield per plant mainly due to its indirect effect through grain yield per main panicle (0.7330), plant height, days to 50 per cent flowering and tiller number.

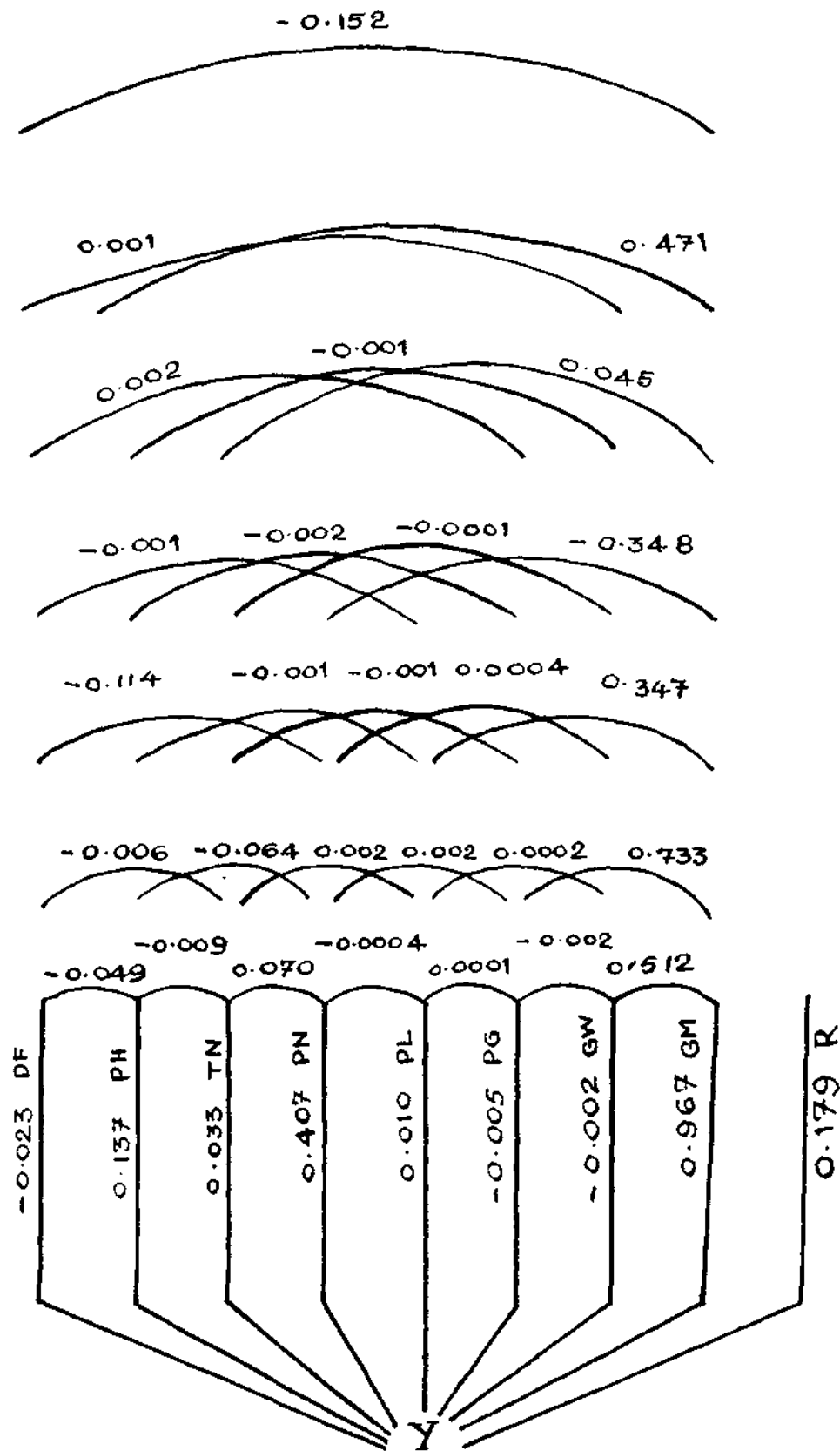


FIG 20: GENOTYPIC PATH DIAGRAM-SUMMER

The influence of 500-grain weight on grain yield per plant was mainly due to its indirect effect through grain yield per main panicle (0.5118), plant height, 50 per cent flowering and tiller number. Grain yield per main panicle also contributed to grain yield per plant due to its indirect effects through plant height, days to 50 per cent flowering, panicle length and tiller number. Residual effect was low (0.1791).

4.2 COMBINED STUDY OF GENERATIONS

The data on grain yield and its attributes obtained on combined study of six generations (P_1 , P_2 , F_1 , F_2 , B_1 and B_2) pertaining to six selected crosses viz., $P_1 \times P_5$, $P_1 \times P_9$, $P_2 \times P_3$, $P_3 \times P_5$, $P_3 \times P_8$ and $P_6 \times P_8$ were subjected to generation mean analysis to obtain information on additive, dominance and the other type of digenic interactions, minimum gene number, heritability and genetic advance.

4.2.1 Generation Mean Analysis

The results of scaling tests and generation mean analysis for the six cross combinations studied during kharif and summer seasons are presented below.

4.2.1.1 Days to 50 per cent flowering: The scaling and joint scaling tests indicated that the assumption of simple additive dominance model was satisfied only in cross $P_1 \times P_5$ (Table 15.1). In all the other crosses one or more scaling tests were significant in one or both seasons indicating the failure of simple additive dominance model. The partitioning of generation means into six genetic components viz., m ,

Table 15.1: Generation means and scaling tests for days to 50% flowering in kharif and summer seasons

Cross	Season	P ₁	P ₂	F ₁	F ₂	B ₁	B ₂	A	B	C	X ²
P ₁ x P ₅	Kharif	55.09 + 0.63	60.51 + 0.32	54.75 + 0.60	56.09 + 0.34	56.45 + 0.42	58.97 + 1.59	3.053** + 0.602	2.678 + 1.628	-0.760 + 1.014	4.20
	Summer	59.09 + 1.71	69.15 + 0.53	57.01 + 0.36	61.37 + 0.73	58.80 + 0.97	64.65 + 1.28	1.495 + 1.303	3.127* + 1.317	3.227 + 1.757	0.72
P ₁ x P ₉	Kharif	54.03 + 1.03	66.45 + 0.45	55.64 + 1.19	58.09 + 1.04	56.95 + 1.07	59.14 + 1.36	4.233** + 1.330	-3.798 + 1.501	0.590 + 2.536	0.14
	Summer	58.94 + 0.55	70.63 + 1.91	58.61 + 0.61	60.89 + 1.03	59.63 + 0.84	65.16 + 1.18	1.720 + 0.936	1.087 + 1.548	-3.238 + 2.383	3.12
P ₂ x P ₃	Kharif	64.54 + 0.43	57.17 + 0.34	57.88 + 1.17	60.12 + 1.16	60.14 + 1.28	58.67 + 1.73	-2.132 + 1.429	2.295 + 1.834	3.008 + 2.676	0.43
	Summer	69.76 + 1.10	59.31 + 1.15	59.71 + 0.84	63.31 + 2.42	64.97 + 3.24	63.89 + 3.13	0.455 + 3.317	8.765** + 3.209	4.740 + 4.996	3.68
P ₃ x P ₅	Kharif	56.45 + 0.87	60.91 + 0.48	53.16 + 1.58	55.10 + 1.62	55.67 + 1.35	55.74 + 1.89	1.727 + 1.628	-2.595 + 2.061	-3.268 + 3.729	0.29
	Summer	60.02 + 0.47	68.91 + 1.00	61.49 + 1.04	61.61 + 1.61	63.23 + 1.80	64.35 + 1.77	4.953* + 1.889	-1.695 + 1.913	-5.492** + 1.585	4.96
P ₃ x P ₈	Kharif	57.77 + 0.75	63.58 + 0.74	57.91 + 0.57	58.97 + 0.71	58.20 + 1.42	59.50 + 1.53	0.717 + 1.493	-2.493 + 1.596	-1.295 + 1.634	0.13
	Summer	59.89 + 1.21	63.56 + 1.42	58.20 + 0.78	62.13 + 3.41	61.11 + 2.43	62.29 + 3.14	4.133 + 2.536	2.818 + 3.246	8.680 + 6.931	0.21
P ₆ x P ₈	Kharif	53.92 + 0.85	63.19 + 1.47	57.53 + 1.88	59.24 + 1.45	57.38 + 1.34	59.96 + 1.27	3.215 + 1.687	-0.792 + 1.741	4.797 + 3.684	0.23
	Summer	59.90 + 1.25	63.94 + 0.37	56.45 + 0.93	62.17 + 2.67	61.99 + 2.45	61.22 + 1.58	7.630** + 2.573	2.052 + 1.660	11.962* + 5.471	1.31

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

(d), (h), (i), (j) and (l) indicated that m and (d) components were significant in all the six crosses in both seasons (Table 16.1). The (d) component was negative in crosses $P_1 \times P_5$, $P_1 \times P_9$, $P_3 \times P_5$, $P_3 \times P_8$ and $P_6 \times P_8$. The (h) component was significant in $P_1 \times P_5$ in kharif season. The (i) component was positive and significant in $P_1 \times P_5$ in kharif season and in $P_1 \times P_9$ and $P_3 \times P_5$ in summer season. The (j) component was also positive and significant in $P_1 \times P_9$ and $P_6 \times P_8$ crosses in kharif season and $P_3 \times P_5$ in summer season. It was significant but negative in $P_2 \times P_3$ in kharif. The (l) component was also negatively significant in $P_1 \times P_5$ in kharif and $P_1 \times P_9$ in summer.

4.2.1.2 Plant height: The scaling and joint scaling tests revealed that in none of the six crosses the assumption of simple additive dominance model was adequate and there is a possibility of digenic epistatic interaction (Table 15.2). The partitioning of generation means and estimation of genetic components revealed that m was significant for all the crosses in both the seasons (Table 16.2). The component (d) was negatively significant in both seasons in $P_1 \times P_5$, $P_1 \times P_9$ and $P_2 \times P_3$. It was positive and significant in both kharif and summer seasons in $P_3 \times P_8$ and $P_6 \times P_8$ and in summer only in $P_3 \times P_5$. The (h) component was negatively significant in $P_1 \times P_5$ and positively significant in $P_1 \times P_9$ and $P_3 \times P_5$ in summer season. The (i) component was negatively significant in both seasons in $P_1 \times P_5$ and in summer season only in $P_3 \times P_8$ and $P_6 \times P_8$. The (i) component was positively significant in $P_3 \times P_5$ in summer season. The (j) component was positive and significant in both seasons in $P_1 \times P_5$ and $P_2 \times P_3$ and in summer season only in $P_1 \times P_9$. This component was negative and significant in both seasons in $P_6 \times P_8$.

Table 16.1: Genetic effects for days to 50% flowering in kharif and summer seasons

Cross	Season	m	d	h	i	j	i
$P_1 \times P_5$	Kharif	51.310**	-2.713**	15.660**	6.490**	0.375	-12.220**
		+1.789	+0.176	+55.17	+1.780	+1.683	+3.432
	Summer	62.724**	-5.031**	0.306	-1.395	-1.632	-6.018
		+2.24	+0.448	+5.780	+2.165	+1.835	+3.649
$P_1 \times P_9$	Kharif	60.393**	-6.213**	-4.475	-0.155	8.030**	-0.280
		+2.728	+0.281	+6.747	+2.713	+1.822	+4.253
	Summer	58.736**	-5.844**	6.729	-6.045*	0.632	-8.852*
		+2.562	+0.498	+6.170	+2.514	+1.757	+3.737
$P_2 \times P_3$	Kharif	63.701**	3.681**	-8.509	-2.845	-4.428*	2.682
		+3.166	+0.137	+7.983	+3.163	+2.172	+5.038
	Summer	60.058**	5.225**	13.355	4.480	-8.310	-13.700
		+6.627	+0.397	+16.679	+6.615	+4.576	+10.297
$P_3 \times P_5$	Kharif	56.281**	-2.231**	-1.586	2.400	4.322	-1.533
		+3.999	+0.249	+9.586	-3.991	+2.376	+5.905
	Summer	55.719**	-4.444**	17.776	-6.762*	-6.648*	-12.007
		+4.099	+0.277	+9.987	+4.090	+2.565	+6.103
$P_3 \times P_8$	Kharif	61.155**	-2.900**	-5.498	-0.460	3.210	2.255
		+2.529	+0.262	+6.906	+2.515	+2.148	+4.465
	Summer	63.455**	-1.837**	-0.035	-1.730	1.315	-5.200
		+7.901	+0.465	+18.163	+7.887	+4.082	+10.539
$P_6 \times P_8$	Kharif	60.931**	-4.631**	-3.359	-2.375	4.008*	-0.048
		+3.467	+0.423	+66.841	+3.441	+2.028	+5.126
	Summer	64.199**	-2.019**	-0.346	-2.280	5.577	-7.403
		+6.086	+0.326	+13.837	+6.077	+2.990	+7.985

* Significant at 5% level ;

** Significant at 1% level

Table 15.2: Generation means and scaling tests for plant height in kharif and summer seasons

Cross	Season	P ₁	P ₂	F ₁	F ₂	B ₁	B ₂	A	B	C	χ ²
P ₁ x P ₅	Kharif	97.49 + 7.03	154.76 + 2.85	204.38 + 9.28	186.16 + 4.06	168.51 +14.89	149.74 +28.85	35.157 +15.986	-59.667 +30.241	83.650** +13.711	362.32**
	Summer	86.92 + 9.76	143.39 + 0.53	181.62 + 3.58	164.88 + 3.74	145.36 + 9.15	124.95 + 7.99	22.165* + 10.526	-75.107** + 8.193	65.948** +9.798	3166.90**
P ₁ x P ₉	Kharif	98.39 + 4.08	174.86 + 4.23	203.56 + 3.25	170.25 +11.86	164.99 +15.02	184.95 +10.03	28.040 +15.244	-7.725 +10.383	1.435 +24.178	14.72*
	Summer	81.15 + 7.37	171.40 + 4.06	194.10 + 2.66	170.56 + 7.43	161.10 + 3.21	182.43 + 5.79	46.945** + 5.066	-0.635 + 6.281	41.490** +15.729	14.67*
P ₂ x P ₃	Kharif	96.66 + 0.74	159.65 + 1.71	200.92 + 4.85	168.42 + 7.25	157.19 + 3.14	178.42 + 9.67	16.792** + 3.983	-3.730 +10.004	15.537 +15.514	1.07
	Summer	92.51 + 1.72	151.99 + 0.84	192.19 + 3.94	163.74 + 7.89	152.71 + 4.15	172.63 + 8.64	20.720** + 4.674	-1.080 + 8.876	26.075 +16.416	2.47
P ₃ x P ₅	Kharif	154.46 + 1.30	153.50 + 3.27	186.91 + 2.97	172.55 + 5.76	169.44 + 5.75	174.49 +13.12	-2.485 + 5.976	8.567 +13.302	8.422 +12.121	0.27
	Summer	154.41 + 1.92	143.01 + 0.80	177.64 + 3.03	161.26 + 6.93	169.27 + 4.41	171.95 + 8.79	6.495 + 4.757	23.245* + 8.929	-7.680 +14.316	46.03**
P ₃ x P ₈	Kharif	158.46 + 2.52	89.12 + 8.58	183.30 + 4.95	166.30 + 4.36	167.94 + 4.62	150.32 +16.08	-5.883 + 5.387	28.220 +16.824	51.008** +11.249	12.57*
	Summer	153.25 + 0.62	83.14 + 9.11	183.88 + 2.33	168.71 + 5.17	168.62 + 5.51	152.31 + 7.79	0.120 + 5.640	37.617** + 9.096	70.692** +11.601	20.19**
P ₆ x P ₈	Kharif	194.74 + 8.01	91.70 + 5.25	205.62 + 6.33	177.30 +12.58	183.24 + 6.53	160.47 +15.14	-33.882** + 8.287	23.615 +15.684	11.502 +26.570	15.36**
	Summer	179.22 + 4.47	90.80 + 2.54	205.92 + 1.74	181.19 + 4.17	181.01 + 1.61	162.46 + 6.87	-23.135** + 2.891	28.200** + 7.043	42.885** + 8.937	26.19**

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

Table 16-2 Genetic effects for plant height in kharif and summer seasons

Cross	Season	m	d	h	i	j	l
$P_1 \times P_5$	Kharif	234.285**	-28.638**	-162.580	-108.160**	94.825**	132.670
		+34.383	+1.898	+101.643	+34.331	+33.571	+67.948
	Summer	234.046**	-28.231**	-224.254**	-118.890**	697.272**	171.833**
		+14.479	+2.444	+40.121	+14.271	+13.096	+26.139
$P_1 \times P_9$	Kharif	117.345**	-37.838**	125.412	18.880	35.765	-39.195
		+29.852	1.470	+72.176	+29.816	+18.301	+43.440
	Summer	121.455**	-45.125**	123.775**	4.820	47.580**	-51.130*
		+16.408	+2.104	+36.330	+16.270	+7.847	+20.521
$P_2 \times P_3$	Kharif	130.631**	-31.494**	80.881	-2.475	20.523*	-10.587
		+17.718	+0.466	+42.181	+17.712	+10.207	+25.456
	Summer	126.525**	-29.737**	83.187	-4.275	19.460*	-17.525
		+18.477	+0.478	+42.783	+18.470	+9.637	+25.169
$P_3 \times P_5$	Kharif	156.321**	0.481	34.334	-2.340	-11.052	-3.742
		+18.403	+0.881	+48.853	+18.362	+14.431	+31.069
	Summer	111.293**	-5.700**	133.505**	-37.420*	-16.750	-67.160**
		+17.009	+0.518	+40.550	+17.001	+9.887	+24.277
$P_3 \times P_8$	Kharif	152.461**	34.671**	24.506	-28.670	-34.103	6.333
		+18.996	+2.235	+53.606	+18.864	+17.316	+35.212
	Summer	151.149**	35.056**	37.509	-32.955*	-37.498**	-4.782
		+14.254	+2.283	+35.987	+14.070	+10.575	+22.298
$P_6 \times P_8$	Kharif	164.989**	61.519**	8.599	-21.770	-57.498**	32.037
		+30.173	+2.394	+70.984	+30.076	+17.165	+42.223
	Summer	172.833*	44.213**	0.337	-37.820**	-51.335**	32.755
		+10.998	+1.286	+27.239	+10.922	+7.513	+16.686

* Significant at 5% level ;

** Significant at 1% level

and in summer season only in $P_3 \times P_8$. The (l) component was positively significant in $P_1 \times P_5$ and negatively significant in $P_1 \times P_9$ and $P_3 \times P_5$ in summer season.

4.2.1.3 Tiller number: None of the three scaling tests and joint scaling test was significant in any of the six crosses in either of the seasons for this character indicating that the simple additive-dominance model can be assumed for the gene action (Table 15.3). The m component was significant in both seasons in $P_1 \times P_9$, $P_2 \times P_3$ and $P_6 \times P_8$ and in summer season in $P_3 \times P_5$ (Table 16.3). The (d) component was negatively significant in $P_1 \times P_9$ and positively significant in $P_6 \times P_8$ in kharif season only. The (h) component was not significant in any of the crosses.

4.2.1.4 Panicle number: The scaling and joint scaling tests for the assumption of additive-dominance model were satisfied in $P_1 \times P_9$, $P_3 \times P_8$ and $P_6 \times P_8$ crosses (Table 15.4). In $P_1 \times P_5$, $P_2 \times P_3$ and $P_3 \times P_5$ crosses one of the three scaling tests were not satisfied in either kharif or summer seasons. The joint scaling test was not significant in any of the crosses (Table 16.4). The m component was significant in both seasons in $P_1 \times P_9$ and $P_6 \times P_8$ while it was significant in $P_1 \times P_5$ and $P_2 \times P_3$ in kharif and in $P_3 \times P_5$ and $P_3 \times P_8$ in summer season. In $P_3 \times P_5$, $P_3 \times P_8$ and $P_6 \times P_8$ the (d) component was significant and negative. The (h) and (i) components were positive and significant in $P_1 \times P_9$ in kharif season. The (j) component was negatively significant in $P_3 \times P_5$ in summer season. The (l) component was not significant in any of the crosses.

Table 15.3: Generation means and scaling tests for tiller number in kharif and summer seasons

Gross	Season	P ₁	P ₂	F ₁	F ₂	B ₁	B ₂	A	B	C	χ^2
P ₁ x P ₅	Kharif	5.14 + 0.82 - 4.74 + 0.75	6.34 + 1.01 - 4.19 + 0.17	5.42 + 0.40 - 4.70 + 0.47	5.03 + 0.53 - 4.39 + 0.69	5.59 + 1.10 - 4.83 + 0.74	5.58 + 0.94 - 4.59 + 0.25	0.618 + 1.192 - 0.217 + 0.865	0.398 + 1.088 - 0.287 + 0.353	-1.215 + 1.329 - 0.765 + 1.530	9.07 1.55
	Summer										
P ₁ x P ₉	Kharif	4.70 + 0.45 - 4.49 + 1.05	5.99 + 0.72 - 5.40 + 1.11	5.18 + 0.89 - 5.36 + 0.42	4.78 + 0.61 - 5.53 + 0.52	4.93 + 0.56 - 5.14 + 0.46	5.01 + 0.65 - 5.51 + 0.56	-0.015 + 0.752 - 0.430 + 0.726	-1.133 + 0.863 - 0.252 + 0.817	-1.908 + 1.626 - 1.507 + 1.369	0.36 0.45
	Summer										
P ₂ x P ₃	Kharif	4.51 + 1.05 - 5.00 + 0.67	3.80 + 0.15 - 4.38 + 0.44	4.31 + 0.89 - 4.91 + 0.64	4.25 + 1.01 - 4.88 + 0.51	4.09 + 0.86 - 5.13 + 0.90	4.01 + 1.07 - 4.68 + 0.65	-0.645 + 1.102 - 0.342 + 1.010	-0.092 + 1.165 - 0.077 + 0.754	0.072 + 2.304 - 0.320 + 1.302	1.20 0.06
	Summer										
P ₃ x P ₅	Kharif	3.45 + 0.53 - 4.42 + 0.82	4.06 + 1.18 - 4.35 + 0.41	4.81 + 1.10 - 4.96 + 0.49	4.18 + 1.16 - 4.70 + 0.52	3.98 + 0.85 - 4.65 + 0.57	4.39 + 1.01 - 4.73 + 0.37	-0.308 + 1.048 - 0.092 + 0.125	-0.095 + 1.291 - 0.153 + 0.314	-0.428 + 2.703 - 0.110 + 0.088	0.08 0.20
	Summer										
P ₃ x P ₈	Kharif	3.34 + 0.63 - 4.34 + 0.30	3.85 + 0.70 - 4.31 + 0.61	3.94 + 0.45 - 4.52 + 0.43	3.78 + 0.77 - 4.52 + 0.53	3.96 + 0.66 - 4.80 + 0.39	3.80 + 0.78 - 5.12 + 0.64	0.635 + 0.766 - 0.733 + 0.471	-0.192 + 0.882 - 1.393 + 0.737	0.037 + 1.695 - 0.370 + 1.209	0.29 4.47
	Summer										
P ₆ x P ₈	Kharif	4.59 + 0.67 - 4.79 + 0.57	3.64 + 0.32 - 4.71 + 0.62	3.99 + 0.69 - 5.51 + 0.64	4.32 + 1.11 - 5.04 + 0.37	4.01 + 1.19 - 4.41 + 0.84	4.12 + 0.49 - 5.77 + 0.90	-0.545 + 1.284 - 1.485 + 0.943	0.610 + 0.621 - 1.305 + 1.002	1.080 + 2.375 - 0.365 + 1.106	1.95 0.21
	Summer										

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

Table 16.3: Genetic effects for tiller number in kharif and summer seasons

Cross	Season	m	d	h	i	j	l
$P_1 \times P_5$	Kharif	3.007	-0.100	5.663	2.230	0.220	-3.245
		+1.827	+0.327	+4.939	+1.797	+1.588	+3.178
	Summer	3.193	0.275	3.282	1.270	-0.070	-1.775
		+1.603	+0.192	+3.686	+1.591	+0.873	+2.178
$P_1 \times P_9$	Kharif	4.584**	-0.644**	0.204	0.760	1.118	0.388
		+1.500	+0.212	+3.616	+1.484	+0.955	+2.318
	Summer	5.769**	-0.456	-0.549	-0.825	-0.178	-0.142
		+1.321	+0.382	+3.223	+1.265	+1.053	+1.983
$P_2 \times P_3$	Kharif	4.966*	0.356	-2.201	-0.810	-0.553	1.548
		+2.452	+0.265	+5.839	+2.436	1.476	3.564
	Summer	4.588**	0.312	0.845	0.100	0.265	-0.520
		+1.513	+0.202	+3.947	+1.499	-1.178	+2.547
$P_3 \times P_5$	Kharif	3.731	-0.306	0.704	0.025	-0.213	0.377
		+2.687	+0.324	+6.198	+2.668	-1.470	+3.737
	Summer	4.437**	0.038	0.535	-0.050	-0.245	-0.010
		+1.255	+0.229	+2.982	+1.234	-0.815	+1.826
$P_3 \times P_8$	Kharif	3.189	-0.256	1.596	0.405	0.828	-0.848
		+1.870	+0.236	+4.419	+1.855	+1.125	+2.644
	Summer	2.570	0.012	5.835	1.755	-0.660	-3.880*
		+1.306	+0.170	+3.131	+1.295	-0.821	+1.910
$P_6 \times P_8$	Kharif	5.128*	0.475*	-2.090	-1.015	-1.155	0.950
		+2.569	+0.186	+5.914	+2.562	+1.341	+3.486
	Summer	4.565**	0.038	0.953	0.185	-2.790*	-0.005
		+1.449	+0.211	+4.035	+1.433	-1.300	+2.679

* Significant at 5% level ;

** Significant at 1% level

Table 15.4: Generation means and scaling tests for panicle number in Kharif and summer seasons

Cross	Season	P ₁	P ₂	F ₁	F ₂	B ₁	B ₂	A	B	C	χ^2
P ₁ x P ₅	Kharif	3.23 + 0.26 -	3.50 + 0.36 -	3.71 + 0.29 -	3.27 + 0.16 -	3.45 + 0.50 -	3.56 + 0.40 -	-0.032 + 0.54 -	-0.098 + 0.467 -	-1.080* + 0.512 -	0.91
	Summer	2.72 + 0.72 -	3.34 + 0.47 -	3.68 + 0.46 -	3.38 + 0.66 -	3.35 + 0.74 -	3.44 + 0.51 -	2.95 + 0.853 -	-0.132 + 0.605 -	0.108 + 1.481 -	0.02
P ₁ x P ₉	Kharif	3.04 + 0.37 -	2.54 + 0.39 -	3.18 + 0.31 -	2.81 + 0.10 -	3.16 + 0.10 -	2.83 + 0.13 -	0.107 + 0.259 -	-0.057 + 0.280 -	-0.675 + 0.481 -	0.69
	Summer	2.76 + 0.40 -	2.34 + 0.59 -	3.41 + 0.92 -	2.94 + 0.26 -	2.82 + 0.70 -	2.97 + 0.62 -	-0.535 + 0.859 -	0.185 + 0.826 -	-0.175 + 1.203 -	0.15
P ₂ x P ₃	Kharif	2.09 + 0.29 -	2.31 + 0.23 -	2.26 + 0.23 -	2.50 + 0.17 -	2.18 + 0.16 -	2.47 + 0.25 -	0.005 + 0.244 -	0.355 + 0.298 -	1.085* + 0.460 -	0.45
	Summer	2.01 + 0.42 -	2.03 + 0.49 -	2.25 + 0.40 -	2.05 + 0.47 -	2.17 + 0.36 -	2.11 + 0.83 -	0.078 + 0.463 -	-0.045 + 0.888 -	-0.327 + 1.084 -	0.22
P ₃ x P ₅	Kharif	2.29 + 0.45 -	2.80 + 0.57 -	3.19 + 0.53 -	2.95 + 0.44 -	2.84 + 0.23 -	3.33 + 0.48 -	0.205 + 0.415 -	0.668 + 0.621 -	0.338 + 1.122 -	0.79
	Summer	2.03 + 0.31 -	2.99 + 0.38 -	3.24 + 0.71 -	2.93 + 0.22 -	2.21 + 0.15 -	3.16 + 0.26 -	-0.848* + 0.412 -	0.095 + 0.476 -	0.212 + 0.940 -	2.76
P ₃ x P ₈	Kharif	2.24 + 0.44 -	2.76 + 0.59 -	2.81 + 0.44 -	2.67 + 0.40 -	2.82 + 0.36 -	2.88 + 0.61 -	0.595 + 0.477 -	0.195 + 0.710 -	0.045 + 1.018 -	1.27
	Summer	2.19 + 0.49 -	3.11 + 0.43 -	2.80 + 0.56 -	2.77 + 0.32 -	2.55 + 0.62 -	2.62 + 0.38 -	0.103 + 0.725 -	-0.678 + 0.519 -	0.170 + 0.956 -	1.61
P ₆ x P ₈	Kharif	2.52 + 0.36 -	2.45 + 0.29 -	2.67 + 0.46 -	2.86 + 0.43 -	2.52 + 0.60 -	2.77 + 0.49 -	-0.155 + 0.665 -	0.425 + 0.561 -	1.105 + 1.036 -	0.59
	Summer	2.13 + 0.52 -	3.44 + 0.99 -	2.95 + 0.17 -	2.95 + 0.47 -	2.63 + 0.55 -	3.16 + 0.60 -	0.180 + 0.614 -	-0.068 + 0.780 -	0.357 + 1.104 -	0.05

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

Table 16.4: Genetic effects for panicle number in kharif and summer seasons

Cross	Season	m	d	h	i	j	l
$P_1 \times P_5$	Kharif	2.412**	-0.137	2.120	0.950	0.065	-0.820
		+0.732	+0.112	+2.077	+0.724	+0.664	+1.382
	Summer	2.976	-0.306	0.916	-0.055	0.428	-0.218
		+1.610	+0.216	+3.828	+1.595	+0.994	+2.312
$P_1 \times P_9$	Kharif	2.062**	0.250	1.888*	0.725**	0.165	-0.775
		+0.296	+0.134	+0.773	+0.264	+0.314	+0.562
	Summer	2.725*	-0.212	0.163	-0.175	-0.720	0.525
		+1.085	+0.178	+3.073	+1.071	+1.000	+2.175
$P_2 \times P_3$	Kharif	2.925**	-0.113	-1.027	-0.725	-0.350	0.365
		+0.461	+0.092	+1.163	+0.452	+0.351	+0.746
	Summer	1.659	-0.006	0.984	0.360	0.123	-0.392
		+1.309	+0.161	+3.334	+1.299	+0.961	+2.100
$P_3 \times P_5$	Kharif	2.009	-0.256	2.586	0.535	-0.462	-1.408
		+1.050	+0.181	+2.466	+1.034	+0.647	+1.530
	Summer	3.471**	-0.481**	-1.951	-0.965	-0.942*	1.718
		+0.553	+0.122	+1.366	+0.540	+0.385	+1.056
$P_3 \times P_8$	Kharif	1.755	-0.263	2.592	0.745	0.400	-1.535
		+1.088	+0.185	+2.728	+1.073	+0.796	+1.725
	Summer	3.395**	-0.463**	-1.915	-0.745	0.780	1.320
		+0.990	+0.162	+2.608	+0.977	+0.799	+1.724
$P_6 \times P_8$	Kharif	3.323**	0.037	-1.213	-0.835	-0.550	0.565
		+1.167	+0.115	+2.923	+1.161	+0.806	+1.845
	Summer	3.026*	-0.656*	-0.209	-0.245	0.248	0.133
		+1.267	+0.280	+3.179	+1.236	+0.985	+1.960

* Significant at 5% level ;

** Significant at 1% level

4.2.1.5 Panicle length: In all the six crosses one or more scaling tests were significant in either or both seasons thereby indicating the presence of digenic epistatic interactions (Table 15.5). The joint scaling test was also significant for $P_1 \times P_5$ and $P_1 \times P_9$. The m component was significant in all the crosses (Table 16.5). The (d) component was positively significant in both seasons for $P_1 \times P_5$ and $P_2 \times P_3$. This component was negatively significant in both seasons for $P_3 \times P_8$ and in summer season for $P_1 \times P_9$ and kharif season for $P_3 \times P_5$. The (h) component was significant and negative in $P_2 \times P_3$ in summer season. The (i) component was negatively significant in both seasons for $P_1 \times P_5$ and summer season in $P_1 \times P_9$. The (j) component was positively significant in kharif season of $P_1 \times P_5$ and in summer season of $P_3 \times P_8$. The (l) component was positively significant in kharif season of $P_1 \times P_5$ cross only.

4.2.1.6 Panicle girth: Scaling and joint scaling tests were significant in cross $P_1 \times P_5$ only (Table 15.6). In all the other crosses one or more scaling tests were significant in either or both seasons indicating the need for the six parameter model. The m component was significant in all the crosses (Table 16.6). The (d) component was positively significant in both seasons in $P_3 \times P_5$, $P_3 \times P_8$ and $P_6 \times P_8$ and in summer season for $P_1 \times P_5$ and $P_1 \times P_9$ crosses. This component was negatively significant in both seasons for $P_2 \times P_3$ and kharif season for $P_1 \times P_5$ and $P_1 \times P_9$. The (j) component was positively significant in kharif season for $P_1 \times P_9$ and $P_2 \times P_3$ and negatively significant in summer season of $P_3 \times P_5$ and kharif for $P_6 \times P_8$. The (l) component was significant but negative in $P_3 \times P_8$ in summer season.

Table 15.5: Generation means and scaling tests for panicle length in kharif and summer seasons

Cross	Season	P ₁	P ₂	F ₁	F ₂	B ₁	B ₂	A	B	C	χ^2
P ₁ x P ₅	Kharif	18.77 + 0.54	16.23 + 0.85	26.39 + 0.74	23.74 + 2.17	23.40 + 1.54	17.77 + 3.28	1.633 + 1.603	-7.082* + 3.331	7.165 + 4.443	51.53**
	Summer	19.86 + 0.84	14.00 + 0.84	22.31 + 1.14	23.71 + 0.93	23.97 + 0.95	19.60 + 1.81	5.755** + 1.185	2.888 + 1.947	16.353** + 2.324	5.38
P ₁ x P ₉	Kharif	18.21 + 0.51	17.71 + 0.58	25.55 + 0.35	21.84 + 1.31	22.89 + 1.13	21.35 + 0.82	2.017 + 1.171	-0.557 + 0.833	0.315 + 2.676	32.29**
	Summer	19.28 + 0.46	21.41 + 1.16	25.17 + 1.11	24.91 + 1.11	22.57 + 0.90	24.00 + 0.88	0.690 + 1.082	1.407 + 1.194	8.583** + 2.661	4.13
P ₂ x P ₃	Kharif	28.80 + 0.89	11.09 + 1.02	26.59 + 0.41	21.74 + 1.28	25.10 + 1.56	17.78 + 1.74	-5.197** + 1.633	-2.110 + 1.827	-6.083* + 2.694	4.41
	Summer	26.72 + 3.49	16.00 + 1.61	24.63 + 1.20	23.29 + 1.04	24.90 + 0.62	20.09 + 1.62	-1.555 + 1.947	-0.445 + 1.910	1.205 + 3.129	2.38
P ₃ x P ₅	Kharif	12.01 + 0.36	14.72 + 0.53	17.92 + 0.82	17.37 + 0.99	14.82 + 1.60	18.10 + 1.62	-0.292 + 1.657	3.550* + 1.691	6.912** + 2.212	1.78
	Summer	14.29 + 1.64	14.44 + 1.14	17.61 + 1.18	19.12 + 1.98	16.72 + 0.95	19.32 + 2.60	1.545 + 1.386	6.590* + 2.726	12.550** + 4.293	3.34
P ₃ x P ₈	Kharif	11.29 + 0.53	23.42 + 1.62	22.63 + 0.96	19.85 + 0.96	16.42 + 0.79	22.91 + 1.21	-1.073 + 0.964	-0.220 + 1.537	-0.553 + 2.364	0.43
	Summer	12.41 + 0.95	20.50 + 2.36	25.47 + 1.42	23.13 + 1.11	21.11 + 1.49	22.83 + 0.88	-4.332* + 1.717	-0.320 + 1.631	8.668** + 3.017	2.33
P ₆ x P ₈	Kharif	22.95 + 0.40	22.76 + 1.27	25.64 + 1.35	24.09 + 0.86	24.66 + 1.79	23.30 + 1.02	0.728 + 1.924	-1.810 + 1.379	-0.647 + 2.384	0.15
	Summer	22.00 + 2.73	22.93 + 1.13	27.27 + 1.72	24.70 + 0.42	21.96 + 1.41	25.26 + 1.54	-5.355* + 2.147	0.315 + 1.851	-0.655 + 2.572	6.90

* Significant at 5% level ;

** Significant at 1% level

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Table 16.5: Genetic effects for panicle length in kharif and summer seasons

Cross	Season	m	d	h	i	j	l
$P_1 \times P_5$	Kharif	30.115**	1.275**	-21.792	-12.615*	8.715*	18.065*
		+5.657	+0.251	+13.933	+5.651	+3.659	+8.494
	Summer	24.641**	2.931**	-1.396	-7.710**	2.868	-0.933
		+2.778	+0.297	+7.252	+2.762	+2.133	+4.675
$P_1 \times P_9$	Kharif	16.817**	0.250	11.338	1.145	2.575	-2.605
		2.972	+0.192	+6.727	+2.966	1.445	3.859
	Summer	26.829**	-1.069**	-6.041	-6.485*	-0.716	4.388
		+2.565	+0.313	+5.922	+2.546	+1.408	+3.587
$P_2 \times P_3$	Kharif	21.169**	8.856**	-3.114	-1.225	-3.087	8.532
		+3.488	+0.339	+8.751	+3.471	+2.434	+5.391
	Summer	24.567**	5.362**	-5.147**	-3.205	-1.110	5.205
		+2.870	+0.962	+0.707	+2.705	+2.592	+4.638
$P_3 \times P_5$	Kharif	17.024**	-1.356**	0.504	-3.655	-3.842	0.397
		+3.022	+0.160	+7.916	+3.018	+2.295	+5.038
	Summer	18.777**	-0.075	2.555	-4.415	-5.045	-3.720
		+4.860	+0.498	+11.594	+4.635	+2.943	+6.983
$P_3 \times P_8$	Kharif	18.096**	-6.069**	2.496	-0.740	-0.853	2.033
		+2.446	+0.426	+5.966	+2.409	+1.681	+3.710
	Summer	21.111**	-4.044**	3.721	-4.655	4.652*	0.643
		+2.890	+0.635	+7.131	+2.820	+2.144	+4.531
$P_6 \times P_8$	Kharif	23.291**	0.094	0.829	-0.435	2.538	1.517
		+2.705	+0.334	+7.178	+2.685	+2.166	+4.714
	Summer	26.847**	-0.463	-8.998	-0.245	0.248	0.133
		+2.373	+0.339	6.917	+1.236	+0.98	+1.960

* Significant at 5% level ;

** Significant at 1% level

Table 15.6: Generation means and scaling tests for panicle girth in kharif and summer seasons

Cross	Season	P ₁	P ₂	F ₁	F ₂	B ₁	B ₂	A	B	C	X ²
P ₁ × P ₅	Kharif	7.06 + 0.10 -	7.30 + 0.13 -	8.43 + 0.09 -	7.89 + 0.14 -	7.91 + 0.19 -	7.67 + 0.25 -	0.322 + 0.202 -	-0.390 + 0.262 -	0.332 + 0.315 -	0.08
	Summer	7.29 + 0.38 -	6.15 + 0.70 -	7.71 + 0.56 -	7.55 + 0.74 -	7.30 + 0.32 -	7.11 + 0.43 -	-0.408 + 0.465 -	0.357 + 0.618 -	1.325 + 1.665 -	0.82
P ₁ × P ₉	Kharif	6.95 + 0.11 -	8.42 + 0.31 -	8.63 + 0.05 -	8.45 + 0.16 -	8.40 + 0.36 -	8.55 + 0.38 -	1.222** + 0.360 -	0.060 + 0.410 -	1.182** + 0.359 -	0.24
	Summer	6.33 + 0.45 -	6.25 + 0.33 -	7.63 + 0.29 -	7.70 + 0.32 -	7.54 + 0.26 -	7.16 + 0.26 -	1.132** + 0.373 -	0.438 + 0.339 -	2.965** + 0.768 -	0.56
P ₂ × P ₃	Kharif	7.88 + 0.06 -	9.65 + 0.33 -	9.92 + 0.23 -	9.22 + 0.35 -	9.39 + 0.35 -	9.60 + 0.20 -	0.985** + 0.373 -	-0.377 + 0.281 -	-0.492 + 0.772 -	0.61
	Summer	7.41 + 0.44 -	9.53 + 0.45 -	9.46 + 0.76 -	8.77 + 0.10 -	8.28 + 0.27 -	9.04 + 0.32 -	-0.302 + 0.514 -	-0.918 + 0.544 -	-0.765 + 0.932 -	0.46
P ₃ × P ₅	Kharif	10.22 + 0.13 -	7.11 + 0.11 -	10.34 + 0.17 -	9.83 + 0.17 -	10.64 + 0.35 -	8.98 + 0.17 -	0.727* + 0.367 -	0.510** + 0.194 -	1.317** + 0.390 -	0.12
	Summer	9.48 + 0.20 -	5.65 + 0.39 -	9.16 + 0.40 -	9.06 + 0.52 -	9.49 + 0.35 -	8.62 + 0.49 -	0.337 + 0.413 -	2.413** + 0.566 -	2.790* + 1.157 -	0.94
P ₃ × P ₈	Kharif	9.92 + 0.24 -	6.05 + 0.11 -	8.88 + 0.16 -	8.36 + 0.21 -	9.31 + 0.39 -	7.60 + 0.22 -	-0.185 + 0.414 -	0.270 + 0.243 -	-0.295 + 0.485 -	0.06
	Summer	9.25 + 0.67 -	5.84 + 0.32 -	8.08 + 0.20 -	8.28 + 0.22 -	9.14 + 0.28 -	7.50 + 0.35 -	0.948* + 0.448 -	1.070** + 0.400 -	1.858** + 0.613 -	0.56
P ₆ × P ₈	Kharif	9.83 + 0.20 -	6.17 + 0.05 -	8.29 + 0.05 -	8.51 + 0.69 -	8.73 + 0.22 -	7.97 + 0.64 -	-0.658** + 0.243 -	1.485* + 0.643 -	1.438 + 1.391 -	0.16
	Summer	8.68 + 0.36 -	5.89 + 0.26 -	8.19 + 0.32 -	8.31 + 0.27 -	8.64 + 0.24 -	7.60 + 0.49 -	0.415 + 0.337 -	1.115* + 0.528 -	2.305** + 0.678 -	0.18

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

Table 16.6: Genetic effects for panicle girth in kharif and summer seasons

Cross	Season	m	d	h	i	j	l
$P_1 \times P_5$	Kharif	7.584**	-0.121**	0.379	-0.400	0.713	0.468
		+0.428	+0.041	+1.113	-0.426	+0.325	+0.702
	Summer	8.100**	-0.570**	-1.813	-1.375	-0.765	1.425
		+1.594	+0.198	+3.444	+1.582	+0.663	+1.956
$P_1 \times P_9$	Kharif	7.589**	-0.736**	2.419	0.100	1.163*	-1.382
		+0.612	+0.082	+1.698	+0.607	+0.545	+1.099
	Summer	7.680**	0.040	0.127	-1.395	0.695	-0.175
		+0.750	+0.140	+1.745	+0.737	+0.462	+1.053
$P_2 \times P_3$	Kharif	7.664**	-0.886**	3.966*	1.110	1.363**	-1.708
		+0.821	0.084	+1.887	-0.816	+0.436	+1.112
	Summer	8.922**	-1.060**	-1.137	-0.455	0.615	1.675
		+0.487	+0.158	+1.439	+0.461	+0.520	+1.185
$P_3 \times P_5$	Kharif	8.744**	1.556**	2.756*	-0.080	0.217	-1.157
		+0.513	+0.044	+1.350	-0.511	0.398	+0.865
	Summer	7.605**	1.913**	4.270	-2.040	-2.075**	-2.710
		+1.212	+0.111	+2.792	+1.207	+0.642	+1.659
$P_3 \times P_8$	Kharif	7.605**	1.938**	1.742	0.380	-0.455	-0.465
		+0.623	+0.066	-1.606	+0.620	+0.466	+1.013
	Summer	7.386**	1.701**	2.871	0.160	-0.122	-2.177*
		+0.651	+0.187	+1.701	+0.624	+0.585	+1.084
$P_6 \times P_8$	Kharif	8.611**	1.831**	-0.104	-0.610	-2.143**	-0.217
		+1.544	+0.051	+3.442	+1.543	+0.686	+1.942
	Summer	8.060**	1.398**	0.882	-0.775	-0.700	-0.755
		+0.767	+0.112	+1.976	+0.759	+0.585	+1.266

* Significant at 5% level ;

** Significant at 1% level

4.2.1.7 500-grain weight: In all the crosses, one or more scaling tests were significant indicating the failure of simple additive-dominance model (Table 15.7). The partitioning of generation means into m, (d), (h), (i), (j) and (l) components indicated that m and (d) were significant in all the crosses (Table 16.7). The (d) component was negative in $P_1 \times P_5$, $P_1 \times P_9$ and $P_2 \times P_3$ crosses and positive in $P_3 \times P_5$, $P_3 \times P_8$ and $P_6 \times P_8$ crosses. The (h) component was positive and significant in both seasons for $P_1 \times P_9$ and $P_3 \times P_8$ and in summer season for $P_3 \times P_5$ and negatively significant in kharif season for $P_6 \times P_8$. The (i) component was positively significant in both seasons for $P_1 \times P_9$ and $P_3 \times P_8$ and in summer season for $P_3 \times P_5$. It was also significant but negative in kharif season for $P_1 \times P_5$. The (j) component was positively significant in $P_1 \times P_5$ and $P_1 \times P_9$ in both seasons and only in summer season for $P_2 \times P_3$ and $P_3 \times P_5$ crosses. It was significant and negative in $P_3 \times P_8$ and $P_6 \times P_8$ in both kharif and summer seasons. The (l) component was negatively significant in both seasons for $P_1 \times P_9$ and $P_3 \times P_8$ and summer season for $P_3 \times P_5$. This component was positively significant in summer for $P_2 \times P_3$ and kharif for $P_6 \times P_8$.

4.2.1.8 Grain yield per main panicle: In all the crosses, one or more scaling tests or joint scaling test were significant in either or both seasons (Table 15.8). The m component was significant in both seasons in $P_1 \times P_5$, $P_1 \times P_9$, $P_2 \times P_3$ and $P_6 \times P_8$ (Table 16.8). In $P_3 \times P_5$, the m component was significant in summer season only. The (d) component was positive and significant in $P_2 \times P_3$, $P_3 \times P_5$ and $P_6 \times P_8$ in both seasons and in $P_1 \times P_5$ in summer season. It was negatively significant in kharif and summer for $P_1 \times P_9$ and in kharif only for $P_3 \times P_8$. The (h) component was

Table 15.7: Generation means and scaling tests for 500-grain weight in kharif and summer seasons

Cross	Season	P ₁	P ₂	F ₁	F ₂	B ₁	B ₂	A	B	C	X ²
P ₁ x P ₅	Kharif	2.51 + 0.07	3.49 + 0.06	5.44 + 0.56	4.67 + 0.70	4.71 + 0.72	3.49 + 0.53	1.474 + 0.769	-1.945** + 0.600	1.779* + 0.713	5.16
	Summer	2.44 + 0.07	3.51 + 0.13	5.18 + 0.31	4.25 + 0.58	4.20 + 0.48	3.79 + 0.51	0.785 + 0.507	-1.110* + 0.537	0.685 + 1.213	1.11
P ₁ x P ₉	Kharif	2.52 + 0.02	4.29 + 0.19	4.94 + 1.06	4.18 + 0.26	5.40 + 0.26	4.59 + 0.53	3.344** + 0.588	-0.051 + 0.756	0.036 + 1.296	19.20**
	Summer	2.46 + 0.07	3.94 + 0.31	4.75 + 0.21	3.98 + 0.05	4.57 + 0.52	4.16 + 0.48	1.942** + 0.528	-0.365 + 0.514	0.003 + 0.298	5.43
P ₂ x P ₃	Kharif	3.21 + 0.16	6.33 + 0.17	4.44 + 0.33	4.19 + 0.25	3.68 + 0.25	4.63 + 0.89	-0.288 + 0.312	-1.507 + 0.906	-1.653* + 0.631	1.76
	Summer	3.18 + 0.09	6.18 + 0.07	4.58 + 0.15	3.97 + 0.11	3.62 + 0.15	4.53 + 0.19	-0.523** + 0.172	-1.705** + 0.207	-2.657** + 0.282	1.59
P ₃ x P ₅	Kharif	6.29 + 0.17	3.40 + 0.22	6.02 + 0.44	5.10 + 0.51	6.25 + 0.39	4.43 + 0.43	0.176 + 0.451	-0.553 + 0.495	-1.328 + 1.145	0.61
	Summer	5.84 + 0.33	3.17 + 0.16	5.88 + 0.12	4.75 + 0.04	6.23 + 0.42	4.20 + 0.10	0.745 + 0.453	-0.652** + 0.145	-1.768** + 0.245	4.05
P ₃ x P ₈	Kharif	6.34 + 0.17	3.35 + 0.03	4.80 + 0.16	4.27 + 0.23	5.30 + 0.22	4.38 + 0.50	-0.538 + 0.246	0.612 + 0.516	-2.215** + 0.502	7.16
	Summer	6.22 + 0.09	3.28 + 0.04	4.63 + 0.07	4.23 + 0.09	5.11 + 0.25	4.32 + 0.04	-0.635* + 0.261	0.733** + 0.056	-1.862** + 0.198	4.57
P ₆ x P ₈	Kharif	5.42 + 0.21	3.30 + 0.03	4.65 + 0.31	4.27 + 0.37	3.95 + 0.30	3.88 + 0.33	-2.173** + 0.357	-0.183 + 0.364	-0.947 + 0.821	17.16**
	Summer	4.88 + 0.27	3.63 + 0.30	3.77 + 0.18	4.01 + 0.08	3.81 + 0.38	4.17 + 0.26	-1.042* + 0.414	0.940** + 0.314	-0.033 + 0.328	0.06

* Significant at 5% level ;

** Significant at 1% level

Table 16.7: Genetic effects for 500-grain weight in kharif and summer seasons

Cross	Season	m	d	h	i	j	l
$P_1 \times P_5$	Kharif	5.254**	-0.489**	-2.534	-2.250*	3.419**	2.721
		+0.954	+0.024	+2.772	+0.954	+0.892	+1.898
	Summer	3.983**	-0.538**	-0.137	-1.010	1.895*	1.335
		+1.356	+0.036	+3.138	+1.356	+0.705	+1.848
$P_1 \times P_9$	Kharif	0.144	-0.886**	11.350**	3.258**	3.394**	-6.551**
		+0.795	+0.049	+2.138	+0.794	+0.600	+1.674
	Summer	1.626*	-0.741**	6.274**	1.575*	2.307**	-3.152*
		+0.717	+0.079	+2.140	+0.712	+0.722	+1.437
$P_2 \times P_3$	Kharif	4.914**	-1.559**	-2.408	-0.142	1.219	1.937
		+1.050	+0.058	+2.951	+1.049	+0.929	+1.942
	Summer	4.251**	-1.501**	-1.466	0.430	1.182**	1.798**
		+0.325	+0.027	+0.850	+0.324	+0.247	+0.552
$P_3 \times P_5$	Kharif	3.897**	1.448**	2.699	0.951	0.729	-0.574
		+1.179	+0.070	+2.702	+1.177	+0.594	+1.612
	Summer	2.646**	1.331**	5.189**	1.860**	1.397**	-1.953*
		+0.447	+0.093	+1.331	+0.438	+0.466	+0.892
$P_3 \times P_6$	Kharif	2.554**	1.498**	4.610*	2.289**	-1.150*	-2.362*
		+0.714	+0.043	+1.879	+0.712	+0.551	+1.195
	Summer	2.786**	1.469**	3.906**	1.960**	-1.366**	-2.057**
		+0.311	+0.026	+0.850	+0.310	+0.262	+0.549
$P_6 \times P_8$	Kharif	5.772**	1.061**	-4.889*	-1.410	-1.989**	3.766**
		+0.865	+0.054	+2.008	+0.863	+0.461	+1.205
	Summer	4.329**	0.626**	-0.729	-0.070	-1.983**	0.172
		+0.502	+0.101	+1.462	+0.492	+0.504	+0.977

* Significant (P

** Significant (P

Table 15.8: Generation means and scaling tests for grain yield /main panicle in kharif and summer seasons

Cross	Season	P ₁	P ₂	F ₁	F ₂	B ₁	B ₂	A	B	C	X ²
P ₁ x P ₅	Kharif	11.34 + 0.87	11.76 + 0.80	33.23 + 1.97	22.13 + 1.06	23.07 + 3.32	18.11 + 3.33	1.583 + 3.490	-8.768* + 3.496	-1.050 + 3.113	14.72**
	Summer	11.06 + 0.94	8.92 + 0.28	23.77 + 1.84	17.04 + 1.75	18.24 + 2.56	15.81 + 2.01	1.648 + 2.756	-1.075 + 2.210	0.623 + 4.085	0.07
P ₁ x P ₉	Kharif	10.75 + 0.96	17.91 + 1.44	28.24 + 1.69	21.61 + 2.34	22.40 + 2.43	18.82 + 1.31	5.808* + 2.620	-8.510** + 1.713	1.303 + 5.122	5.43
	Summer	10.52 + 0.83	16.29 + 0.54	24.14 + 1.11	15.29 + 0.78	15.42 + 1.01	15.92 + 2.72	-3.827** + 1.228	-8.580** + 2.794	-13.948** + 2.054	12.66*
P ₂ x P ₃	Kharif	21.97 + 1.72	16.29 + 1.42	46.36 + 1.82	33.91 + 1.86	34.60 + 2.45	33.28 + 3.96	0.863 + 2.756	3.905 + 4.127	4.652 + 4.386	0.61
	Summer	20.59 + 0.82	15.38 + 0.17	47.11 + 4.26	27.38 + 1.11	30.57 + 1.72	26.29 + 2.90	-6.565* + 2.768	-9.917** + 3.601	-20.667** + 5.271	8.80
P ₃ x P ₅	Kharif	16.96 + 0.43	10.61 + 1.17	35.34 + 3.54	28.71 + 3.99	31.62 + 2.53	25.59 + 1.99	10.940** + 3.096	5.225 + 2.726	16.600 + 8.924	6.51
	Summer	16.28 + 0.51	10.29 + 0.34	33.59 + 1.51	22.34 + 2.40	23.82 + 0.98	20.22 + 1.37	-2.217 + 1.266	-3.425* + 1.569	-4.367 + 5.094	2.37
P ₃ x P ₈	Kharif	16.84 + 0.67	18.95 + 0.93	35.97 + 1.91	25.72 + 1.78	27.81 + 4.93	26.50 + 4.24	2.803 + 5.036	-1.920 + 4.373	-4.837 + 4.194	4.48
	Summer	16.29 + 0.14	16.68 + 1.21	35.69 + 2.55	22.65 + 2.26	28.64 + 2.16	19.59 + 2.24	5.315* + 2.512	-13.178** + 2.647	-13.738* + 5.374	8.99
P ₆ x P ₈	Kharif	31.01 + 0.99	18.92 + 1.06	40.80 + 2.53	33.84 + 1.71	34.17 + 3.09	30.78 + 2.91	-3.472 + 3.374	1.845 + 3.213	3.833 + 4.494	3.75
	Summer	27.89 + 2.46	17.39 + 0.06	32.20 + 2.07	24.06 + 0.47	22.78 + 4.58	20.34 + 3.82	-14.533** + 4.851	-8.897* + 3.958	-13.435** + 2.789	927.18**

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

Table 16.8: Genetic effects for grain yield/main panicle in kharif and summer seasons

Cross	Season	m	d	h	i	j	l
$P_1 \times P_5$	Kharif	17.685*	-0.213	2.220	-6.135	10.350*	13.320
		+5.166	+0.296	+14.789	+5.158	+4.739	+9.587
	Summer	10.044*	-1.069**	14.254	-0.050	2.723	-0.523
		+4.780	+0.246	+12.055	+4.774	+3.286	+7.620
$P_1 \times P_9$	Kharif	18.336*	-3.581**	3.194	-4.005	14.318**	6.707
		+5.454	+0.433	+12.599	+5.436	+2.894	-7.485
	Summer	11.866*	-2.881**	1.404	-1.540	4.753	10.868
		+3.306	+0.248	+9.305	+3.297	+2.949	+6.140
$P_2 \times P_3$	Kharif	19.016*	2.844**	32.229*	0.115	-3.042	-4.883
		+5.991	+0.558	+15.955	+5.965	+4.793	+10.262
	Summer	13.796*	-2.606**	21.019	4.185	3.353	12.297
		+4.045	+0.210	+11.275	+4.039	+3.400	+8.294
$P_3 \times P_5$	Kharif	14.222	3.175**	36.845	-0.435	5.715	-15.730
		+8.606	+0.311	+18.754	+8.600	+3.279	+10.862
	Summer	14.556*	-2.994**	12.114	-1.275	1.208	6.918
		+5.056	+0.154	+10.877	+5.084	+1.711	+6.059
$P_3 \times P_8$	Kharif	12.174	-1.056**	30.404	5.720	4.722	-6.603
		+7.424	+0.287	+20.819	+7.418	+6.531	+13.638
	Summer	10.606	-0.194	23.094	5.875	18.493**	1.988
		+5.494	+0.304	+13.089	+5.486	+3.173	+8.127
$P_6 \times P_8$	Kharif	30.429**	6.044**	3.284	-5.460	-5.317	7.087
		+5.459	+0.364	+14.540	+5.447	+4.303	+9.516
	Summer	32.632**	5.250**	-33.858	-9.995	-5.635	33.425**
		+6.067	+0.616	+18.108	+6.036	+6.087	+12.201

* Significant at 5% level ;

** Significant at 1% level

positive and significant for $P_2 \times P_3$ in kharif only. The (i) component was not significant in any of the six crosses. The (j) component was positively significant in $P_1 \times P_5$ and $P_1 \times P_9$ in kharif and in $P_3 \times P_8$ in summer. The (l) component was significant in $P_6 \times P_8$ only in summer season.

4.2.1.9 Grain yield per plant: The scaling and joint scaling tests indicated the inadequacy of a simple additive dominance model in all the crosses (Table 15.9). The m component was significant in $P_6 \times P_8$ during both seasons (Table 16.9). The component was significant during kharif season in $P_2 \times P_3$ and during summer season in $P_1 \times P_9$ and $P_3 \times P_5$ crosses. The (d) component was negative and significant in both seasons in $P_1 \times P_9$ and $P_3 \times P_8$ and in kharif season in $P_1 \times P_5$. It was positively significant in $P_2 \times P_3$ (both seasons) and $P_3 \times P_5$ and $P_6 \times P_8$ (kharif). The (h) component was positively significant in kharif in $P_1 \times P_9$, $P_3 \times P_5$ and $P_3 \times P_8$ crosses. In none of the crosses, (i) component was significant. The (j) component was positively significant in $P_1 \times P_9$ (kharif and summer) and negatively significant in $P_3 \times P_6$ (summer). The (l) component was positive and significant during summer season in crosses $P_3 \times P_5$. However this component was negative and significant in the same cross during kharif.

4.2.2 Minimum Gene Number, Heritability (ns) and Genetic Advance

The estimates of minimum gene number, heritability (narrow sense) and genetic advance obtained for different characters in the six selected crosses are presented below (Table 17).

Table 15.9: Generation means and scaling tests for grain yield/plant in kharif and summer seasons

Cross	Season	P ₁	P ₂	F ₁	F ₂	B ₁	B ₂	A	B	C	X ²
P ₁ x P ₅	Kharif	26.29 + 2.04	26.19 + 1.86	86.94 + 8.19	57.18 + 0.52	63.12 +10.62	50.09 +11.96	13.005 +11.432	-15.945 +12.673	-0.630 + 9.323	12.62*
	Summer	22.86 + 5.20	23.29 + 3.01	65.89 + 8.01	43.75 + 8.98	43.78 + 6.83	40.40 + 6.49	-1.185 + 8.333	-8.370 + 7.772	-2.945 + 20.288	9.06
P ₁ x P ₉	Kharif	24.89 + 3.61	36.15 + 6.82	67.24 + 8.12	47.48 + 5.36	58.35 + 6.51	44.00 + 3.79	24.580** + 7.883	-15.382* + 6.516	-5.583 + 14.571	83.89**
	Summer	24.38 + 4.31	32.06 + 6.46	60.10 + 9.98	35.58 + 3.18	34.49 + 7.42	36.21 + 8.14	-15.495 + 9.201	-19.747* +10.080	-34.337* +13.414	64.03**
P ₂ x P ₃	Kharif	37.65 + 5.10	30.46 + 2.69	83.42 + 6.39	71.28 + 7.35	65.22 + 7.54	70.11 + 9.27	9.370 + 8.575	26.333** + 9.895	50.167* +16.589	15.85**
	Summer	35.40 + 4.61	26.93 + 5.39	82.26 +13.17	47.76 + 9.39	55.08 + 5.95	46.61 +15.44	-7.507 + 9.171	-15.967 +16.998	-35.830 +24.121	20.70**
P ₃ x P ₅	Kharif	31.31 + 5.12	23.43 + 4.92	82.76 +16.33	68.46 + 6.52	73.36 + 3.30	67.97 +10.06	32.660** + 9.168	29.748* +13.185	53.607* +22.712	51.01**
	Summer	29.05 + 4.42	24.21 + 1.60	78.99 +13.56	50.86 + 5.45	43.90 + 3.45	49.11 + 3.55	-20.232* + 7.923	-4.975 + 7.693	-7.817 +18.827	67.44*
P ₃ x P ₈	Kharif	30.49 + 4.97	39.44 + 6.83	76.66 +11.21	58.36 + 5.78	64.93 + 8.64	63.27 +10.04	22.715* +10.590	10.430 +11.996	10.180 +17.561	130.68**
	Summer	30.19 + 5.54	39.46 + 4.43	70.78 +12.96	49.83 + 7.58	59.44 +13.35	41.35 + 7.47	17.932 +15.097	-27.532** +10.135	-11.880 +21.258	6.98
P ₆ x P ₈	Kharif	59.79 + 7.15	36.49 + 3.61	84.03 + 8.85	75.76 + 9.38	69.40 +18.02	68.85 +13.77	-5.008 +18.893	17.173 +14.573	38.715 +21.574	23.49**
	Summer	49.41 + 6.27	41.19 + 8.01	66.35 + 2.12	55.68 + 7.73	49.56 +16.35	50.40 +15.11	-16.632 +16.678	-6.737 +15.671	-0.590 +16.453	127.42**

* Significant at 5% level ;

** Significant at 1% level

Table 16.9: Genetic effects for Grain yield/plant in kharif and summer seasons

Cross	Season	m	d	h	i	j	l
P ₁ x P ₅	Kharif	30.047	-1.450*	51.640	-2.310	28.950	5.250
		+16.044	+0.690	+48.249	+16.029	+16.054	+33.068
	Summer	29.685	-0.213	20.038	-6.610	7.185	16.165
		+20.333	+1.503	+46.096	+20.277	+9.899	+27.397
P ₁ x P ₉	Kharif	15.739	-5.631**	75.476*	14.780	39.962**	-23.978
		+13.250	+1.928	+31.956	+13.109	+8.465	+20.566
	Summer	29.124*	-3.843*	-5.171	-0.905	4.252	36.147
		+12.862	+1.941	+36.238	+12.721	+11.682	+25.312
P ₂ x P ₃	Kharif	48.251*	3.594*	56.141	-14.465	-16.963	-21.238
		+18.990	+1.442	+46.653	+18.93	+12.289	+28.910
	Summer	18.808	4.238*	52.335	12.355	8.460	11.120
		+25.084	+1.773	+62.804	+25.020	+16.919	+40.414
P ₃ x P ₅	Kharif	18.569	3.944*	13.396**	8.800	2.912	-71.208**
		+16.888	+1.178	+42.230	+16.795	+11.164	+29.955
	Summer	44.021**	2.419	-7.631	-17.390	-15.257**	42.597*
		+12.034	+1.382	+27.467	+11.975	+5.476	20.157
P ₃ x P ₈	Kharif	11.998	-4.475*	120.775*	22.965	12.285	-56.110
		+17.704	+2.113	+46.739	+17.578	+13.902	+31.283
	Summer	32.545	-4.838*	30.910	2.280	45.465**	7.320
		+21.607	+1.773	+55.640	+21.533	+15.707	+36.696
P ₆ x P ₈	Kharif	74.668**	11.650**	-4.988	-26.530	-22.200	14.345
		+29.492	+2.002	+78.035	+29.424	+23.026	+50.025
	Summer	68.08**	4.113	-47.882	-22.780	-9.895	46.150
		+27.228	+2.542	+74.009	+27.109	+22.836	+47.458

* Significant at 5% level ;

** Significant at 1% level

4.2.2.1 Days to 50 per cent flowering: Estimates of minimum number of genes ranged from 1.01 in cross $P_2 \times P_3$ to 6.53 in cross $P_1 \times P_9$ in kharif season. In summer season, the minimum gene number ranged from 0.53 ($P_6 \times P_8$) to 3.36 ($P_1 \times P_5$). Heritability (ns) was high in $P_2 \times P_3$ (99%), $P_1 \times P_5$ (94%) and $P_6 \times P_8$ (94%) in kharif and in $P_3 \times P_8$ (93%) and $P_6 \times P_8$ (92%) in summer season. Genetic advance was recorded upto 11.2 per cent ($P_2 \times P_3$) in kharif and 15 per cent in summer.

4.2.2.2 Plant height: Estimates of minimum gene number were high for cross $P_3 \times P_8$ (2.59) in kharif and for $P_1 \times P_5$ (3.04) in summer. Lowest estimates of minimum gene number was obtained for $P_3 \times P_5$ (0.69) in both kharif and summer seasons. Heritability (ns) ranged from 39 ($P_6 \times P_8$) to 63 per cent ($P_1 \times P_9$) in kharif season. In summer season, the heritability (ns) estimates ranged from 19 ($P_3 \times P_5$) to 86 per cent ($P_1 \times P_5$). High estimates of genetic advance were recorded in $P_1 \times P_9$ (26.6%) and $P_2 \times P_3$ (23.3%) in kharif and $P_1 \times P_5$ (26.7%) and $P_2 \times P_3$ (25.3%) in summer.

4.2.2.3 Tiller number: Estimates of minimum number of genes for tiller number ranged from 0.01 ($P_1 \times P_5$) to 0.30 ($P_1 \times P_9$) in kharif and 0.03 ($P_1 \times P_5$ and $P_3 \times P_8$) to 0.22 ($P_1 \times P_9$) in summer. Heritability (ns) estimates varied from 17 ($P_1 \times P_9$) to 31 per cent ($P_2 \times P_3$) in kharif and 15 ($P_3 \times P_5$) to 38 per cent ($P_1 \times P_5$) in summer. Genetic advance was recorded upto 34 per cent ($P_2 \times P_3$) in kharif and 35.7 per cent ($P_1 \times P_5$) in summer.

4.2.2.4 Panicle number: Minimum gene number estimated for panicle number was highest (4.58) in cross $P_3 \times P_8$ in kharif season. However lowest values were obtained in $P_2 \times P_3$ and $P_6 \times P_8$ in the same season. In

Table 17: Minimum gene number, heritability (ns) and genetic advance in six selected crosses for grain yield and its attributes in kharif and summer seasons

Cross	Minimum gene number		Heritability (ns) (%)		Genetic advance (%)	
	Kharif	Summer	Kharif	Summer	Kharif	Summer
Days to 50% flowering						
P1xP5	1.58	3.36	94	89	10.5	11.0
P1xP9	6.53	3.17	52	57	4.8	7.2
P2xP3	1.01	1.40	99	70	11.2	9.3
P3xP5	1.76	1.11	28	72	2.9	9.1
P3xP8	1.71	0.55	74	93	6.6	11.2
P6xP8	1.23	0.53	94	92	10.7	15.0
Plant height						
P1xP5	2.11	3.04	55	86	19.7	26.7
P1xP9	1.61	2.94	63	56	26.6	19.2
P2xP3	1.20	1.34	47	55	23.3	25.3
P3xP5	0.69	0.69	54	19	14.1	4.6
P3xP8	2.59	3.00	44	51	13.7	15.4
P6xP8	2.05	2.05	39	44	15.9	16.5
Tiller number						
P1xP5	0.01	0.03	22	38	20.7	35.7
P1xP9	0.30	0.22	17	25	17.8	18.1
P2xP3	0.06	0.04	31	23	34.0	17.4
P3xP5	0.10	0.10	23	15	27.7	10.9
P3xP8	0.04	0.03	27	31	28.0	19.0
P6xP8	0.04	0.07	20	16	24.1	13.9
Panicle number						
P1xP5	0.03	0.07	36	41	40.4	47.3
P1xP9	4.13	0.23	28	32	27.4	40.5
P2xP3	0.01	0.03	30	37	28.4	49.3
P3xP5	0.03	0.41	28	29	33.9	34.1
P3xP8	4.58	0.36	40	44	40.1	43.3
P6xP8	0.01	1.10	50	43	55.6	41.4

Contd.. Table 17

Cross	Minimum gene number		Heritability (ns) (%)		Genetic advance (%)	
	Kharif	Summer	Kharif	Summer	Kharif	Summer
Panicle length						
P1xP5	1.36	2.65	72	66	27.9	17.1
P1xP9	0.94	1.59	62	64	24.7	15.0
P2xP3	1.81	1.94	52	61	26.8	22.0
P3xP5	0.48	0.43	84	65	39.2	26.1
P3xP8	1.94	4.92	67	86	28.4	24.0
P6xP8	0.22	0.48	48	75	13.3	25.2
Panicle girth						
P1xP5	0.50	0.88	54	47	13.6	11.6
P1xP9	0.64	0.94	59	82	13.4	19.1
P2xP3	2.11	4.89	31	29	8.7	6.1
P3xP5	2.36	4.47	73	83	20.8	16.5
P3xP8	1.18	0.01	84	59	26.7	12.8
P6xP8	1.21	3.40	57	29	16.8	5.4
500 grain weight						
P1xP5	1.24	0.48	47	33	25.9	29.5
P1xP9	1.10	0.27	29	27	19.4	25.4
P2xP3	1.22	0.37	38	34	20.5	30.7
P3xP5	1.26	0.49	24	31	11.0	24.3
P3xP8	0.98	0.38	40	34	21.3	28.2
P6xP8	0.59	0.11	39	44	19.0	34.2
Grain yield/main panicle						
P1xP5	1.91	1.96	52	67	39.3	50.6
P1xP9	0.77	1.10	67	42	60.1	37.0
P2xP3	2.26	4.39	70	66	45.7	51.8
P3xP5	1.12	1.81	33	62	21.8	49.5
P3xP8	1.17	2.57	29	28	22.3	18.5
P6xP8	1.65	0.33	67	64	33.2	51.5
Grain yield/plant						
P1xP5	1.33	1.80	36	51	40.1	51.2
P1xP9	2.76	2.48	14	32	16.5	41.9
P2xP3	1.34	1.91	26	40	28.2	57.3
P3xP5	2.09	4.55	28	31	27.7	33.4
P3xP8	1.59	1.00	30	38	32.9	48.8
P6xP8	1.05	0.86	50	54	46.6	59.8

summer the estimates ranged from 0.03 ($P_2 \times P_3$) to 1.1 ($P_6 \times P_8$). Heritability (ns) estimates for panicle number varied from 28 ($P_1 \times P_9$) to 50 per cent ($P_3 \times P_5$) in kharif and 29 ($P_3 \times P_5$) to 44 per cent ($P_3 \times P_8$) in summer. Genetic advance was highest in $P_6 \times P_8$ (55.6%) and lowest in $P_1 \times P_9$ (27.4%) in kharif season. In summer season highest estimates of genetic advance was obtained in $P_2 \times P_3$ (49.31%) followed by $P_1 \times P_5$ (47.3%) and $P_3 \times P_8$ (43.3%).

4.2.2.5 Panicle length: Cross $P_3 \times P_8$ recorded high estimates of minimum gene number both in kharif (1.94) and summer (4.92) seasons. Lowest estimate of minimum gene number was registered in $P_6 \times P_8$ (0.22) in kharif season. Cross $P_3 \times P_5$ (84%) and $P_1 \times P_5$ (72%) in kharif and $P_3 \times P_8$ (86%) and $P_6 \times P_8$ (75%) in summer recorded high heritability (ns) estimates. Cross $P_3 \times P_5$ recorded high estimates of genetic advance in kharif (39.2%) as well as summer (26.1%) seasons.

4.2.2.6 Panicle girth: Minimum number of genes estimated for panicle girth ranged from 0.5 ($P_1 \times P_5$) to 2.36 ($P_3 \times P_5$) in kharif and 0.01 ($P_3 \times P_8$) to 4.47 ($P_3 \times P_5$) in summer. The cross $P_3 \times P_8$ (84%) in kharif and $P_3 \times P_5$ (83%) in summer recorded highest heritability (ns) estimates. Lowest heritability estimates were obtained by $P_2 \times P_3$ in kharif as well as summer seasons. Genetic advance ranged from 8.7 ($P_2 \times P_3$) to 26.7 per cent ($P_3 \times P_8$) in kharif and 5.4 ($P_6 \times P_8$) to 19.1 per cent ($P_1 \times P_9$) in summer.

4.2.2.7 500-grain weight: The estimates of minimum gene number ranged from 0.59 ($P_6 \times P_8$) to 1.26 ($P_6 \times P_8$) in kharif and 0.11 ($P_6 \times P_8$) to 0.49 ($P_3 \times P_5$) in summer season. Heritability (ns) estimates varied from 24

($P_3 \times P_5$) to 47 per cent ($P_1 \times P_5$) in kharif and 27 per cent ($P_1 \times P_9$) to 44% ($P_6 \times P_8$) in summer season. Cross $P_1 \times P_5$ recorded genetic advance of 25.9 per cent followed by $P_3 \times P_8$ (21.3%) and $P_2 \times P_3$ (20.5%) in kharif season. In summer season, $P_6 \times P_8$ (34.2%) and $P_2 \times P_3$ (30.7%) recorded high estimates of genetic advance.

4.2.2.8 Grain yield per main panicle: The estimate of minimum number of genes was highest in cross $P_2 \times P_3$ in kharif (2.26) as well as summer (4.39) season. The estimate was lowest in $P_1 \times P_9$ (0.77) and $P_6 \times P_8$ (0.33) in kharif and summer seasons respectively. High estimates of heritability (ns) were recorded $P_2 \times P_3$ (70%) in kharif and $P_1 \times P_5$ (67%) in summer. Other crosses with high heritability (ns) estimates were $P_1 \times P_9$ (67%) and $P_6 \times P_8$ (67%) in kharif and $P_2 \times P_3$ (66%) and $P_6 \times P_8$ (64%) in summer. Genetic advance was recorded upto 60.1 per cent ($P_1 \times P_9$) in kharif and 51.8 per cent in ($P_2 \times P_3$) in summer.

4.2.2.9

Grain yield per plant: Estimates of minimum gene number varied from 1.34 ($P_2 \times P_3$) to 2.76 ($P_1 \times P_9$) in kharif and 1.00 ($P_3 \times P_8$) to 4.55 ($P_3 \times P_5$) in summer season. Heritability (narrow sense) estimate was highest in $P_6 \times P_8$ (50%) followed by $P_1 \times P_5$ (36%) in kharif. In summer season also these two crosses recorded high estimates (54 and 51%). High estimates of genetic advance were recorded in summer season (33.4 to 59%) compared to kharif season (16.5 to 46.6%). Cross $P_6 \times P_8$ recorded highest estimates of genetic advance in kharif (46.6%) as well as summer (59.8%) seasons.

DISCUSSION

CHAPTER V

DISCUSSION

In India, pearl millet is mainly cultivated as a grain crop in kharif under rainfed conditions, while a small acreage is irrigated in summer season. The first pearl millet hybrid of India, HBI had the yield potential of 2,500 to 3,000 kg ha⁻¹. The present day hybrids also have a similar potential although small yearly improvements are reflected in the mean yields as compared with check varieties. Yield barriers need to be broken for quantum jumps, so that pearl millet can become competitive with other kharif crops. Because of their late maturity, majority of the released hybrids have not become popular in the drought prone areas of Rajasthan (Gill, 1990). Breeding of early maturing, bold grained and high tillering hybrids has been emphasised in pearl millet so that the varieties suit to dryfarming situations. The hybrids should not be very tall as they are prone to lodging under better management conditions. Information about the genetic architecture of the parents and the mode of gene action governing maturity, plant height and other yield contributing traits would be helpful in formulating appropriate breeding strategies. The present investigation was, hence, oriented towards eliciting strategic information on the above aspects and to formulate a breeding strategy to be adopted in pearl millet.

The studies were undertaken with a 9x9 full diallel and generation means of (P₁, P₂, F₁, F₂, B₁ and B₂) of six selected crosses. The nine parents chosen for the study included one early dwarf (ICP 165), two late dwarf (ICP 57 and ICP 642), four early tall

(ICP 828, ICP 64, ICP 811 and ICP 323) and two late tall (ICP 812 and ICP 126) inbred lines acquired from ICRISAT. The inbred lines also represented diversity for yield contributing characters like panicle number, panicle length, panicle girth and seed size. The investigation consisted of two experiments viz., diallel evaluation and combined study of various generations of selected crosses. The experiments were conducted in two different crop growing seasons viz.. kharif and summer, from 1988 to 1990 at Regional Agricultural Research Station, Palem, A.P. Agricultural University.

The investigations revealed significant differences among parents and crosses for grain yield, maturity, height and other yield attributes *in* both the environments (kharif and summer seasons). The interaction of parents vs crosses was also significant for all the characters except tiller number, indicating that nonadditive gene effects were large for these characters. Significant differences were observed among various groups in direct as well as reciprocal crosses for all characters revealing the diversity of parents in different groups.

The flowering behaviour of parents was quite different from that of the hybrids in response to the environments. This was brought out remarkably by the fact that while the parents in general took more number of days to complete 50 per cent flowering in summer season (56 to 72 days) than in kharif (53 to 67 days), the hybrids were slightly earlier to flower in summer (53 to 63 days) than in kharif (51 to 65 days). The late flowering of parental inbreds in summer might be due

to slow initial crop growth because of low temperatures prevalent in January and February months (the summer crop was sown in first fortnight of January). The early flowering behaviour of hybrids in summer can be attributed to their inherent homeostatic nature to adapt to the adverse environmental conditions.

In pearl millet, days to 50 per cent flowering is the best indicator of maturity duration of a genotype. Several workers have considered observations on days to 50 per cent flowering to investigate maturity behaviour (Thakare and Murthy, 1972a; Phul et al., 1973; Tyagi et al., 1975; Phul et al., 1976; Tyagi et al., 1982; Dass et al., 1984a; Mehndiratta and Phul, 1985 and Vyas and Pokhriyal, 1985). Sagar et al. (1985) observed similar combining ability effects and gene effects for days to 50 per cent flowering and days to maturity over a number of environments. They suggested that the information gained on days to 50 per cent flowering can be used reliably, while breeding for early maturity in pearl millet.

The data on flowering behaviour of parents and the F_1 s over seasons ~~are~~ furnished in Appendix B. All the crosses in the early x early group were early in flowering (55 to 59 days). In the early x late and late x early groups also the F_1 s flowered in below 60 days (53 to 60 days). In majority of these crosses, the hybrids were earlier than the earliest of the parents indicating overdominance of earliness over the late flowering. In the late x late group, comprising six crosses, three F_1 s viz. ICP 57 x ICP 126 (62 days), ICP 642 x ICP 126 (62 days) and ICP 57 x ICP 642 (63 days) were late flowering while the other three hybrids, ICP 57 x ICP 812 (56 days), ICP 812 x

ICP 642 (55 days) and ICP 812 x ICP 126 (53 days) were early in flowering. It is interesting to note that, all these three early crosses in the late x late group involved ICP 812 as one of the parents indicating that this late flowering inbred had genes controlling earliness which were expressed only in the hybrid combination (Sahane et al., 1989).

For plant height, the parents and hybrids were almost stable, over the seasons, compared to days to 50 per cent flowering. Crosses in the dwarf x dwarf group viz., ICP 165 x ICP 57, ICP 165 x ICP 642 and ICP 57 x ICP 642 produced dwarf F_1 s (115 to 132 cm) (Appendix C). These F_1 s were considerably shorter than the other tall inbreds and their increased height over their parents could have been largely an expression of heterosis as pointed out by Burton and Fortson (1966).

In the tall x tall group, all the F_1 s were tall with their heights ranging from 191 to 234 cm. The hybrids in the dwarf x tall or tall x dwarf groups were also tall in stature. In all the three groups, in majority of the crosses, the F_1 s were taller than the tallest of the parents, revealing overdominance of tallness over the dwarf stature in the material. Sreenivasulu and Sreeramulu (1980) also made similar observations.

Critical examination of mean performance for grain yield per plant, days to 50 per cent flowering and plant height pertaining to top hybrids in each of the ten groups of crosses (based on height and maturity), revealed that majority of the best performing hybrids (65

to 85 g/plant) completed 50 per cent flowering in 53 to 60 days and recorded height ranging *from* 190 to 230 cm.

Cross	Group	Mean performance over seasons		
		Grain yield (g/plant)	Days to 50% flowering	Plant height (cm)
ICP 165 x ICP 828	EDxET	64.64	57.01	193.41
ICP 165 x ICP 812	EDxLT	71.67	56.11	200.30
ICP 57 x ICP 828	LDxET	69.79	58.74	203.68
ICP 642 x ICP 126	LDxLT	75.35	61.75	230.84
ICP 828 x ICP 811	ETxET	74.61	56.84	206.50
ICP 828 x ICP 126	ETxLT	76.73	59.15	224.24
ICP 811 x ICP 126	ETxLT	82.06	55.13	232.09
ICP 812 x ICP 811	LTxET	67.30	52.79	202.59
ICP 828 x ICP 642	ETxLD	74.94	57.98	214.35
ICP 811 x ICP 642	ETxLD	84.61	57.45	228.53
ICP 165 x ICP 57	EDxLD	43.98	56.53	131.55
ICP 165 x ICP 642	EDxLD	43.19	55.06	132.08
ICP 57 x ICP 642	LDxLD	48.74	62.93	114.58

All the three dwarf hybrids (ICP 165 x ICP 57, ICP 165 x ICP 642 and ICP 57 x ICP 642) were low grain yielders (43 to 49 g per plant). They flowered in 55 to 63 days with heights ranging *from* 115 to 132 cm. Based on the data, it may be concluded that, greater emphasis needs to be bestowed to earliness and tall stature, for achieving break through in pearl millet improvement.

The development of a plant breeding strategy hinges mainly on the support provided by genetic information on the inheritance and behaviour of major quantitative characters associated with yield or any economic trait of concern to the breeder. To derive such genetic information, it is necessary to conceive of a genetic model in relation to the material that is proposed to be utilised. This process will, in turn, involve the designing of a suitable mating system to fit into the chosen genetic model. Diallel crossing is one such mating system with universal application in plant breeding. In the present investigation, the material generated through the diallel mating system, involving nine pearl millet inbred lines, chosen for their diversity for height, maturity and other yield attributes, was evaluated in the two normal crop growing seasons of Andhra Pradesh viz., kharif and summer. The data were subjected to combining ability analysis of Griffing's (1956) Method I and Model I and graphical and genetical analysis of Hayman (1954a and b) to obtain a generalised view of the genetic architecture in the material for various characters.

The combining ability analysis revealed significant differences for general and specific combining ability variances for all the characters studied viz., grain yield per plant and per main panicle, days to 50 per cent flowering, plant height, tiller number, panicle number, panicle length, panicle girth and 500-grain weight in kharif, as well as summer seasons, indicating the importance of both additive as well as nonadditive gene action. A comparative study of σ_g^2 to σ_s^2 estimates revealed preponderance of σ_s^2 for days to 50

per cent flowering, plant height, tiller number, panicle length, grain yield per main panicle and grain yield per plant in both the seasons. This indicated the importance of nonadditive gene action in the inheritance of these characters. Estimates of σ_g^2 was predominant for 500-grain weight, indicating the role of additive gene action in its inheritance. The estimate of σ_g^2 to σ_s^2 ratio for panicle number (0.8627 in kharif and 0.9342 in summer) indicated that both additive and nonadditive types of gene action were important for this character. Panicle girth was observed to be governed by non additive gene action in summer (0.7652) and predominantly additive gene action in kharif (3.0437). The differential expression of panicle girth brings out the influence of seasonal effects on the expression of genetic variance as indicated by Gupta (1980). According to Rojas and Sprague (1952), specific combining ability effects become of relatively greater importance when the lines under test had been subjected to previous testing and selection. This holds good for the parental material used in the present investigation, since these inbreds acquired from ICRISAT are used frequently in the ICRISAT as well as national breeding programmes.

Reciprocal differences were absent for days to 50 per cent flowering, panicle number, panicle girth and 500-grain weight in both kharif and summer seasons. Maternal effects were however, evident for plant height and grain yield per main panicle in summer and for tiller number, panicle length and grain yield per plant in kharif season, indicating the importance of evaluation of the material in more number of seasons. Gupta (1968) emphasised that reciprocal differences must

be studied to have a detailed knowledge of the breeding value of the parents and the type of gene effects involved in the inheritance of quantitative characters.

A knowledge of general and specific combining ability effects is helpful in planning a successful breeding programme. General combining ability is the average performance of parent as judged from its performance in an array of crosses, while specific combining ability designates the specific performance of a cross combination against the expectations from the combining ability of the parents involved.

Based on the general combining ability effects computed, the nine parents were classified as high, average and low general combiners depending on the statistical significance and magnitude of the values of the GCA effects. ICP 828, ICP 812, ICP 811 and ICP 126 were high combiners, while ICP 323 and ICP 642 were the average combiners and ICP 165, ICP 57 and ICP 64 were poor combiners for grain yield per plant. It was observed that high combiners for yield were also good combiners for some of the yield attributes. For instance, ICP 828 was also a superior combiner for panicle girth, 500-grain weight and grain yield per main panicle, besides being an average combiner for earliness. ICP 812 was a good combiner for earliness, height and panicle number. ICP 811 was also a good combiner for earliness, panicle girth, 500-grain weight and grain yield per main panicle, besides being an average combiner for tiller number. ICP 126 was a better combiner for grain yield per main panicle and plant height and an average combiner for tiller number, panicle number and panicle girth.

The association of GCA of grain yield with GCA of other yield contributing traits was also reported by Chawla and Gupta (1983).

Best parents identified on the basis of combining ability and mean performance for various characters are listed in appendix D. It was revealed that best combining parents were also the better performers in case of panicle length, panicle girth and 500-grain weight. However, the pattern was different for earliness and tiller number. It indicates that differences exist in mean performance and combining ability and no single criterion will give desirable results. The nine parents were ranked for their mean performance and combining ability for grain yield.

Parent	Ranks based on	
	Mean Performance	GCA effect
ICP 165	8	9
ICP 57	3	7
ICP 828	9	4
ICP 64	6	8
ICP 812	7	5
ICP 811	1	1
ICP 323	2	6
ICP 642	4	3
ICP 126	5	2

Perusal of the above ranks revealed that the rankings based on per se performance and GCA effects were quite different, with the

exception of ICP 811. ICP 811, ICP 642, ICP 126, ICP 323, ICP 812 and ICP 828 were identified ^{as promising parents} considering both per se performance and GCA effects together.

In the present investigation, specific combining ability of crosses for grain yield was also related to the SCA of yield attributes. ICP 811 x ICP 642, ICP 828 x ICP 126 and ICP 828 x ICP 642 were some of the superior specific combiners for grain yield per plant. ICP 811 x ICP 642 was also a better specific combiner for grain yield per main panicle, plant height, panicle length and 500-grain weight. ICP 828 x ICP 126 was a good specific combiner for grain yield per main panicle and panicle length. In the same way, ICP 828 x ICP 642 was also a superior specific combiner for grain yield per main panicle, plant height and 500-grain weight. Other good specific combiners for grain yield like ICP 64 x ICP 323, ICP 165 x ICP 828, ICP 165 x ICP 812 and ICP 57 x ICP 828 also exhibited high and positive SCA effects for two or more yield attributes. Similar observations were made by Badwal (1970), Gupta and Singh (1973), Vyas and Pokhriyal (1985) and Patel and Kukadia (1988). It was also revealed, that the crosses with high SCA for grain yield involved at least one high general combining parent (Badwal, 1970; Vyas and Pokhriyal, 1985; and Nijhawan and Yadav, 1993).

Best crosses were identified for different characters based on per se performance over seasons, heterotic response and specific combining ability effects (Appendix E). A close look at the information has revealed that ranking on the basis of heterotic response and SCA effects did not reflect the rankings based on per se performance.

Heterobeltiosis, being $\overline{F_1} - \overline{BP}$, can more or less depend on the performance of the better parent concerned. Similarly SCA effects are nearly a measure of deviation of F_1 performance. Obviously there is every possibility of getting a cross with high per se performance but with low heterobeltiosis, if the performance of the better parent is high. On the contrary, there can also be a cross with poor per se performance but high heterotic response, if the parental performance is poor. It means that the best cross combination on the basis of heterosis and SCA effects alone need not reflect high per se performance. The per se performance is the realised value, while heterotic response and SCA effects are estimates. Hence, the former should be given due importance while making selection among cross combinations. Considering all the three criteria together, four hybrids viz., ICP 828 x ICP 126, ICP 642 x ICP 126, ICP 828 x ICP 642 and ICP 165 x ICP 812 were identified to be superior for grain yield. These crosses recorded mean grain yields per plant (72 to 77 g) and exhibited high and positive SCA effects in both seasons. Heterobeltiosis among them varied between 75 and 150 per cent.

The implications of graphic and genetic analysis have been discussed by Jinks (1954) and Hayman (1954a and b) and Mather and Jinks (1971 and 1977). The essential information to be gained from the graphic analysis are the average degree of dominance based on the distance of the regression line, the relative proportion of dominant and recessive genes in the parents from the distribution of their respective array points along the regression line and a measure of genetic diversity among the parents from the distance between array

points. The genetic analysis provides the estimates of the mean degree of dominance, the proportion of genes with positive and negative effects in the parents and the proportion of dominant and recessive genes in the parents.

The interpretations of graphic and genetic analysis are meaningful only when a simple additive dominance model of gene action is adequate to account for the behaviour of diallel (Mather and Jinks, 1977). The t^2 values and regression coefficient of W_r on V_r values were used for testing the validity of assumptions in the present investigation. The nonsignificant t^2 values and nonsignificant deviation of 'b' from unity for plant height, panicle number, panicle length, panicle girth and 500-grain weight indicated the adequacy of the simple additive-dominance model and fulfilment of the assumptions for these traits. However, the significant t^2 values and significant deviation of b from unity in one or both seasons for days to 50 per cent flowering, tiller number, grain yield per main panicle and per plant indicated the failure and non fulfilment of certain assumptions for these characters. The results of the present study have to be considered in terms of the above limitations. The position of array points in V_r - W_r graph was highly sensitive to environmental alterations for all the characters. Such changes in position of array points were found not uncommon, when tests were conducted at different environments (Jana, 1975; Kumar *et al.*, 1980; Narayana, 1981 and Jayaraman, 1989), indicating the environmental influences on dominance effects. Although a reversal in the position of array points may be interpreted as different loci being active in different environments,

a more likely explanation would be the reversal of dominance effects at loci that control the character in different environments (Jana, 1975 and Jaya Yaman, 1989).

Overdominance of genes for grain yield per plant was revealed by the interception of regression line below the point of origin in kharif season. The excess of H_1 component to D component and the ratio of $(H_1/D)^{1/2}$ more than unity in both the seasons established the role of overdominance in the inheritance of this character. Asymmetrical distribution of positive and negative alleles was indicated by the ratio of $H_2/4H_1$ being less than theoretical value (0.25) in both the seasons. Preponderance of dominant alleles in the parents was evident from the KD/KR ratio which exceeded unity. The position of ICP 165, ICP 57 and ICP 812 below Vr line in kharif and above Vr line in summer indicated the differential reaction of these genotypes to the environmental fluctuations.

The higher H_1 estimates than D and more than unity values of $(H_1/D)^{1/2}$ in both seasons indicated overdominance for days to 50 per cent flowering. Interception of the regression below the point of origin during summer season also established overdominance. Thus, the results of the graphical and genetical analysis confirmed the earlier observation of overdominance of earliness over late maturity in early x late or late x early crosses. Parents, ICP 828, ICP 812, ICP 165 and ICP 811 were nearer to the point of origin and expressed most of the dominant genes. ICP 642 and ICP 126 had more recessive genes because of their position away from the origin. The value of $H_2/4H_1$ was less

than 0.25 indicating the asymmetrical distribution of positive and negative alleles. KD/KR ratio was more than unity indicating preponderance of dominant alleles than recessives in the parents.

For plant height also, overdominance was indicated by the dominance ratio $(H_1/D)^{1/2}$ being more than unity in both kharif as well as summer seasons, which was confirmed by the interception of regression line below the point of origin. Overdominance of tallness over dwarf stature was also indicated earlier in the behaviour of parents and F_1 s in the dwarf x tall or tall x dwarf crosses. In both the seasons, ICP 828, ICP 812, ICP 811, ICP 323 and ICP 126 were close to the point of origin, indicating that they possessed most of the dominant alleles, while ICP 57 and ICP 642 had more of recessive alleles. The position of ICP 165 and ICP 64, on the Vr-Wr graph, indicated equal number of dominant and recessive alleles in them. Asymmetrical distribution of positive and negative effects of dominance in parents was established by $H_2/4H_1$ ratio which was less than 0.25 in both the seasons. Since KD/KR ratio was more than unity in all the seasons, the preponderance of dominant alleles than the recessive alleles in the parents was indicated.

Higher H_1 estimates than D, and more than unity value of $(H_1/D)^{1/2}$ in both the seasons, indicated overdominance for tiller number. In kharif, the regression line intercepted the Y axis below the point of origin which again indicated overdominance. Inversion in the position of regression line and its deviation from unity in summer indicated the influence of the environment on the expression of the character. Asymmetrical distribution of positive and negative effects

of dominance in the parents was revealed by $H_2/4H_1$ ratio which was less than 0.25 in both the seasons. Preponderance of dominant alleles was inferred from the KD/KR ratio which was more than unity. The position of the parents on the graph in kharif was entirely different from that in summer, which once again revealed the effect of environmental fluctuations on the trait.

In respect of panicle number, the genetic ratio of $(H_1/D)^{1/2}$ revealed overdominance. The interception of the regression line on the Wr axis below the point of origin in kharif, also confirmed the prevalence of overdominance. Asymmetry in distribution of genes with positive and negative effects was indicated by the $H_2/4H_1$ ratio which was less than 0.25. Differential position of parental array points in kharif and summer seasons also brought out the influence of the environment on panicle number. More than unity of KD/KR estimates, obtained in both seasons, revealed the preponderance of dominant alleles.

The regression line intercepted Wr axis above the point of origin during both seasons indicating partial dominance for panicle length. The estimates of $(H_1/D)^{1/2}$ revealed partial dominance in summer and overdominance in kharif. The $H_2/4H_1$ estimates were less than 0.25 indicating the asymmetrical distribution of genes with positive and negative effects of the trait. KD/KR estimates of more than unity were obtained in both the seasons revealing the preponderance of dominant alleles. As seen by the distribution of array points on the graph, parent ICP 57 had more number of dominant alleles, while

ICP 828 indicated more recessive alleles, and ICP 812 had equal number of dominant and recessive alleles for panicle length.

Interception of the regression line on the W_r axis indicated partial dominance in kharif, and complete dominance in summer season for panicle girth. However, the $(H_1/D)^{1/2}$ estimates revealed partial dominance in kharif and overdominance in summer for the trait. The ratio of $H_2/4H_1$ revealed asymmetrical distribution of positive and negative effects of dominance in the parents. The KD/KR ratio was more than unity in kharif, indicating the preponderance of dominant alleles in the parents. However, this ratio indicated recessive alleles in summer season. Differential expression of the character in different environments was also indicated by the position of parents in the graph in kharif and summer seasons.

For 500-grain weight, the interception of the regression line on the W_r axis has indicated partial dominance in both seasons. $H_2/4H_1$ ratio indicated asymmetrical distribution of positive and negative effects for dominance in the parents. The KD/KR ratio indicated preponderance of recessive alleles in the parents in kharif and equal distribution of recessive and dominance alleles in summer. Parent ICP 165 had more number of recessive alleles while ICP 828 and ICP 811 had more number of dominant alleles.

The yield is a complex character and is collectively influenced by various component characters that are highly subjected to environmental variations. In selection for yield, greater emphasis should be placed on the attributes that indicate less variability due

to environment. Adverse association of characters can not only limit productivity but also impede rapid genetic advance (Gupta, 1980). Hence, study of correlations between yield and its components and their relative contribution to the yield is of great value in planning and evaluating breeding programmes. Genotypic and phenotypic correlations were worked out among grain yield per plant and other yield attributes, utilising the diallel evaluation data. The magnitude of both genotypic and phenotypic correlations was almost similar in each season which indicated that the environmental influence was less.

Grain yield per plant and grain yield per main panicle were ~~strongly~~ correlated in kharif as well as summer seasons. Grain yield was also positively correlated with plant height, panicle number, panicle length, panicle girth and 500-grain weight. Grain yield was negatively, associated with days to 50 per cent flowering. Flowering had negative association with height, panicle girth, 500-grain weight and grain yield per plant. Plant height was positively correlated with panicle girth, 500-grain weight, grain yield per plant and grain yield per main panicle.

While studying association of more number of independent variables with a particular dependent variable, it necessitates the study of interdependence of each component by partitioning them into direct and indirect effects exerted through other characters. Under such circumstances the total correlations are not sufficient to explain the true association for an effective manipulation of the character. The path coefficient analysis furnishes a method for partitioning the correlation coefficients into direct and indirect

effects based on the importance of the causal factors involved (Dewey and Lu, 1959).

The path coefficient analysis revealed that grain yield per main panicle was the most important character because of its highest positive direct effect on grain yield in both the seasons. The indirect effects of most characters via this attribute were also positive in kharif and summer seasons. Panicle number also registered high positive direct effect across the seasons. 500-grain weight exhibited positive direct effect in kharif, while plant height and tiller number had positive direct effect in summer season. Days to 50 per cent flowering and panicle girth exhibited negative influence on grain yield in both seasons. Panicle length exerted positive direct effect in summer only. From this study, it is evident that selection for the improvement of grain yield can be efficient if it is based on grain yield per main panicle and panicle number as these two characters satisfied both the requirements of association analysis as well as path analysis.

In the present study, days to 50 per cent flowering and grain yield were negatively correlated which presupposes that if selection is made for higher grain yield, the population would tend to become early. This was remarkably brought out by the earlier finding in this study when all the high grain yielding hybrids were invariably early maturing.

Estimating components of genetic variation is essential for understanding fundamental genetic phenomena predicting gain under

selection in heterozygous populations and identifying parents which might yield superior F_1 hybrids. Sprague (1963) listed three major factors that must be considered and which may limit progress in the analysis of genetic variation viz., the number of genes involved, the type of gene action and the genotype-environment interaction. Cockerham (1959) noted that epistatic gene action is not uncommon in the inheritance of qualitative traits and that there is no sound biological reason why this type of gene action should be less common in the inheritance of quantitative traits. As the number of genetic factors conditioning a trait increases, it seems reasonable to suppose that the number of interactions among factors will also increase.

Means and variance for the parental, F_1 , F_2 and single back cross generations (B_1 and B_2) of the six crosses selected from the diallel programme and evaluated in kharif and summer seasons were used to analyse the genetic variation. The crosses selected for the study were ICP 165xICP 812 (early dwarf x late tall), ICP 165xICP 126 (early dwarf x late tall), ICP 57 x ICP 828 (late dwarf x early tall), ICP 828 x ICP 812 (early tall x late tall), ICP 828xICP 642 (early tall x late dwarf) and ICP 811xICP 642 (early tall x late dwarf) which had contrasting parents for height and maturity.

Additive gene action was important in the inheritance of earliness, plant height, panicle length, panicle girth, 500-grain weight, grain yield per main panicle and grain yield per plant. ICP 57xICP 828 and ICP 811xICP 642 crosses were associated with significant and positive values of additive gene effects for some of the yield attributes viz., panicle number, panicle length, 500-grain

weight and grain yield per main panicle besides desirable and negative (d) values for flowering. This indicates that improvement of yield can be effective if the selection of the yield components is made in the segregating generations.

Dominance gene effects (h) were found contributing maximum in the inheritance of 500-grain weight among all the characters studied. This gene effect also contributed to some extent in the inheritance of height (ICP 165xICP 812, ICP 165xICP 126, ICP 828 x icP 812), grain yield per plant (ICP165xICP 126, ICP 828xICP 812 and ICP 828xICP 642), grain yield per main panicle (ICP 57xICP 828), panicle girth (ICP 57xICP 828 and ICP 828xICP 812), panicle length (ICP 57xICP 828) and days to 50 per cent flowering (ICP 165xICP 812).

Additive x additive (i) type of non-allelic interaction played significant role in the inheritance of 500-grain weight (ICP 165xICP 126, ICP 828xICP 812 and ICP 828xICP 642), 50 per cent flowering (ICP 165xICP 812, ICP 165xICP 126 and ICP 828xICP 812), height (ICP 165xICP 812, ICP 828xICP 812, ICP 828xICP 642 and ICP 811xICP 642), panicle number (ICP 165xICP 126) and panicle length (ICP 165xICP 812 and ICP 165xICP 126).

Additive x dominance (j) type of interaction played prominent role in the inheritance of 500-grain weight. Other characters influenced by this type of interaction were grain yield per main panicle (ICP 165xICP 812, ICP 165xICP 126 and ICP 828xICP 642), grain yield per plant (ICP 165xICP 126, ICP 828xICP 812 and ICP 828xICP 642), days to 50 per cent flowering (ICP 165xICP 126, ICP 57xICP 828,

ICP 828xICP 812 and ICP 811xICP 642) and panicle girth (ICP 165xICP 126). 500-grain weight exhibited dominance x dominance (1) type of interaction also.

\\ Duplicate type of epistasis played major role in the inheritance of 500-grain weight, panicle number, panicle girth, tiller number, plant height, 50 per cent flowering and grain yield per plant while complementary type of epistasis was important in the inheritance of grain yield per main panicle. Both types of epistasis were equally important in the inheritance of grain yield per plant.

Minimum number of genes, estimated as per the method of Burton (1951) and averaged over crosses, was about unity for tiller number, panicle number and 500 grain weight and 1-2 for other characters, viz., days to 50 per cent flowering, plant height, panicle length, panicle girth, grain yield per main panicle and grain yield per plant. Burton (1951), Lal and Singh (1970) and Chand and Ahmed (1976) also obtained such low estimates of minimum gene number for yield and yield attributes in pearl millet. While outlining the formula for the estimation of minimum gene number controlling the expression of a character based on the mean of parents, F_1 and F_2 populations, Burton (1951) stated that the formula will furnish an unbiased estimate of the minimum gene number subject to certain assumptions like non existence of linkage between pertinent genes, supply of all plus factors by one parent and all minus factors by the other parent, equal importance of all genes, same degree of dominance for all the plus factors, and absence of interaction between pertinent nonallelic genes. When these assumptions do not apply, the formula

gives an estimate that may be much smaller than the true number. As revealed by the graphical and genetical analyses, the parents involved in the crosses were asymmetric in the distribution of positive and negative effects of alleles. Nonallelic interaction was also detected in the inheritance of many of the characters. Hence, non-fulfilment of some of the above assumptions could be the reason for the low estimates of minimum gene number.

High estimates of heritability (ns) were obtained for days to 50 per cent flowering (76.5%) and panicle length (67.2%). The estimates were moderate for panicle girth (57.5%), grain yield per main panicle (56%), plant height (51.3%), panicle number (36.8%), grain yield per plant (36%) and 500-grain weight (35.1%). Selection for flowering, panicle length, panicle girth and grain yield per main panicle would be feasible in view of moderate to high heritability.

The estimates of expected genetic advance were fairly high for grain yield per plant and grain yield per main panicle, moderate for panicle length, tiller number and 500 grain weight and low for days to 50-per cent flowering and plant height. The high values of genetic advance for grain yield per panicle and per plant and panicle number indicates that selection can be effective for these characters.

Conclusions and Future line of work

The genetic analysis of height, maturity and grain yield using diverse parental material, indicated that the ideal genotype should be tall (200 cm) and early (complete 50 per cent flowering

between 55 and 60 days) for realising higher yield potential in pearl millet hybrids. To produce such hybrids, the crosses should be planned between parents of early x early or early x late in combination with dwarf x tall genotypes. However, further studies are needed with more number of diverse parents for these characters to draw generalised conclusions. Based on the genetic information gained through combining ability, heterosis, character association and generation mean analysis for height, maturity, yield and other yield contributing traits the following breeding programme is suggested.

As nonadditive gene action was predominant besides considerable additive gene action in the material, development of populations such as synthetics for commercial cultivation or creation of elite populations for selection cycles for the extraction of superior recombinants for use in regular hybrid and population breeding programmes will be most suitable to exploit the potential available. Heterosis can be exploited in selected crosses.

Based on the rankings of per se performance and GCA effects, six parents viz., ICP 828 (early tall), ICP 812 (late tall), ICP 811 (early tall), ICP 323 (early tall), ICP 642 (late dwarf) and ICP 126 (late tall) are selected for involvement in the synthetic development programme. Keeping the uniformity of height for the synthetic population in view, only one dwarf line is suggested for inclusion as dwarf x tall or tall x tall crosses produce tall F_1 s only. The six selected inbreds will be crossed in all possible combinations to obtain 30 F_1 s. Equal quantities of all the 30 F_1 combinations are bulked and allowed for random mating for 2 to 3 generations in isolation under disease

pressure and the final population is tested in yield trials, before release for general cultivation (Rao et al., 1985).

Four productive hybrids viz., ICP 828 x ICP 126, ICP 642 x ICP 126, ICP 828 x ICP 642 and ICP 165 x ICP 812 were identified based on per se performance, heterobeltiosis and high SCA effects. The five parents involved in these crosses could be intermated to develop a base population with new recombinants. Another base population could also be developed by compositing and allowing a few generations of random mating among the four superior hybrids themselves. The base populations thus developed could then be improved by an appropriate method of recurrent selection such as S_2 and S_1 progeny selection system, full sib selection system and combined half sib and S_1 selection system (Goulas and Lonngvist, 1976). Elite populations thus developed may serve as source material for use in developing superior hybrid combinations/synthetics/experimental varieties or may be recombined for second cycle of selection to develop still superior populations with greater hybrid vigour originating from concentration of plus factors and due to interaction effects (dominance and epistasis).

For successful cultivation of hybrids, it is essential to have choice of hybrids with diverse parentage. The development of these hybrids provide alternate source of resistance on account of genetic diversity of male parent. The best general combiners for grain yield viz., ICP 828, ICP 812, ICP 811 and ICP 126 identified in the present investigation can be crossed with the available male sterile lines of A_1 , A_2 and A_3 sources to determine the type of their

restorability. The hybrids built on suitable male sterile source may be tested for their productivity performance.

Higher levels of heterobeltiosis, ranging from 75 to 150 per cent, were recorded in the four earlier mentioned hybrids viz., ICP 828 x ICP 126, ICP 642 x ICP 126, ICP 828 x ICP 642 and ICP 165 x ICP 812. High grain yield potential of these hybrids coupled with high heterosis and SCA effects make them ideal for exploitation of hybrid vigour. For this, ICP 828, ICP 642 and ICP 165 can be converted into suitable male sterile source before the crosses are made with the respective restorer lines to produce F_1 hybrids.

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SUMMARY

CHAPTER VI

SUMMARY

The present investigation was formulated to understand the inheritance of plant height, maturity, yield and other yield attributes, to identify superior parents and cross combinations and suggest appropriate breeding strategies for realising higher grain yield in pearl millet.

Nine inbreds of pearl millet representing diverse height and maturity groups viz., ICP 165 (Early dwarf), ICP 57 (late dwarf), ICP 828 (early tall), ICP 64 (early tall), ICP 812 (late tall), ICP 811 (early tall), ICP 323 (early tall), ICP 642 (late dwarf) and ICP 126 (late tall) were acquired from ICRISAT and crossed in all possible combinations including reciprocals. Further, six breeding generations (P_1 , P_2 , F_1 , F_2 , B_1 and B_2) pertaining to six selected cross combinations viz., ICP 165xICP 812, ICP 165xICP 126, ICP 57xICP 828, ICP 828xICP 812, ICP 828xICP 642 and ICP 811xICP 642 were also generated. The nine parents and 72 hybrids were evaluated in two normal pearl millet growing seasons of Andhra Pradesh viz., kharif (1988) and summer (1989). Combined study of six different generations of the selected crosses was also carried out in kharif (1989) and summer (1990) seasons. Both the experiments were conducted at Regional Agricultural Research Station, Palem of A.P. Agricultural University. Observations were recorded on yield and yield attributes viz., days to 50 per cent flowering, plant height, tiller number, panicle number, panicle length, panicle girth, 500-grain weight, grain yield per main panicle and grain yield per plant. Combining ability analysis was done

following Griffing's (1956) method I and Model I and graphical and genetical analysis by Hayman (1954a and b). Path coefficient analysis was carried out as per the method of Dewey and Lu (1959). Generation mean analysis was done following the method of Mather and Jinks (1971).

The results revealed that the interaction of parents vs. crosses was significant for yield and yield attributes except tiller number in both seasons indicating predominance of nonadditive gene effects for the characters. Early x early or early x late crosses produced early hybrids. In majority of the crosses the hybrids were earlier than the best parents indicating overdominance of earliness over late flowering. Interestingly, some latexlate crosses (ICP 57xICP 812, ICP 812xICP 642 and ICP 812xICP 126) involving ICP 812 produced early hybrids. Dwarf x tall or tall x tall crosses produced tall hybrids indicating overdominance of tallness over dwarf stature.

The ratio of σ_g^2 to σ_s^2 revealed predominance of non-additive gene action for days to 50 per cent flowering, plant height, tiller number, panicle length and grain yield, while both additive and nonadditive gene actions were important for panicle number. Reciprocal differences were noticed for plant height and grain yield per main panicle in summer season and for tiller number, panicle length and grain yield per plant in kharif season, indicating the influence of GxE interactions on the expression of maternal effects.

ICP 828, ICP 812, ICP 811 and ICP 126 were good general combiners for grain yield. They were also good combiners for some of

the yield attributes like grain yield per main panicle, panicle length, panicle girth and grain size. Rankings of the parents based on per se performance differed with their GCA rankings indicating the necessity for consideration of both factors while selecting parents.

Specific combining ability of crosses for grain yield was related to the SCA of yield components. Top specific combiners for grain yield viz., ICP 811 x ICP 642, ICP 828 x ICP 126 and ICP 828 x ICP 642 were also good specific combiners for some of the yield attributes. Crosses showing high sca in majority of the cases involved at least one high general combining parent.

All the best performing hybrids in the study flowered in 55-60 days and grown to a height of 200 cm while all the dwarf hybrids whether early or late were low grain yielders. Four superior crosses viz., ICP 828 x ICP 126, ICP 642 x ICP 126, ICP 828 x ICP 642 and ICP 165 x ICP 812 were identified based on high mean yield, heterobeltiosis and significant SCA effects.

The ratio of $(H_1/D)^{1/2}$ indicated overdominance for days to 50 per cent flowering, plant height, tiller number, panicle number, panicle length, panicle girth and grain yield, and partial to complete dominance for 500-grain weight. The $H_2/4H_1$ ratio indicated asymmetric distribution of genes with positive and negative effects in the parents for all the characters. KD/KR ratio revealed the preponderance of dominant alleles in the parents for all the characters.

Grain yield per plant was highly correlated with grain yield per main panicle and also positively and significantly correlated with

plant height, panicle number, panicle length, panicle girth and 500-grain weight. However, grain yield was negatively associated with days to 50 per cent flowering. Days to 50 per cent flowering exhibited negative association with plant height, panicle girth, 500-grain weight and grain yield per plant. Plant height was positively correlated with panicle girth, 500-grain weight and grain yield.

Path coefficient analysis revealed that grain yield per main panicle was the most important trait because of its highest positive direct effect on grain yield. The indirect effect of majority of yield components via this character was also positive in both the seasons. Panicle number also registered substantial positive direct effect on grain yield across the seasons. Days to 50 per cent flowering exerted negative influence on grain yield in both the seasons.

Generation mean analysis revealed that additive gene effects were important in the inheritance of maturity, plant height, panicle length, panicle girth, 500-grain weight, grain yield per main panicle and grain yield per plant. Dominance gene effects were found to have contributed maximum in the inheritance of 500-grain weight. Duplicate type of epistasis played major role in the inheritance of 500-grain weight, panicle number, panicle girth, tiller number, plant height and days to 50 per cent flowering while complementary epistasis was important for grain yield per main panicle. Both the types of epistasis were equally important in the inheritance of grain yield per plant.

Genetic advance estimates were fairly high for grain yield per plant, grain yield per main panicle and panicle number, moderate for panicle length, tiller number and 500-grain weight and low for days to 50 per cent flowering and plant height.

The results conclusively indicated the possibility of development of a synthetic involving six parents (ICP 828, ICP 812, ICP 811, ICP 323, ICP 642 and ICP 126), identified based on per se performance and general combining ability for grain yield. Further, two elite populations, one by intermating parents and the other by intermating hybrids pertaining to four best single crosses (ICP 828 x ICP 126, ICP 642 x ICP 126, ICP 828 x ICP 642 and ICP 165 x ICP 812) identified based on per se performance, heterobeltiosis and high SCA effects, could be developed to serve as base populations for further use in the pearl millet breeding programme.

Best combiners identified for grain yield (ICP 828, ICP 812, ICP 811 and ICP 126) during the study can be used as restorers with the suitable male sterile lines for the development of F_1 hybrids. Conversion of ICP 828, ICP 642 and ICP 165 into suitable male sterile sources can also be taken up before crossing with the respective restorers (ICP 126, ICP 642 and ICP 812) to exploit heterosis available in the crosses, ICP 828 x ICP 126, ICP 642 x ICP 126, ICP 828 x ICP 642 and ICP 165 x ICP 812, for realising higher productivity potentials in pearl millet.

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* Original not seen

Notes: The following information is for the use of the
person who is to be responsible for the application of the
information.

APPENDICES

Appendix A: Weather data for the crop period from 1-1-1988 to 27-5-1990, Regional Agricultural Research Station, Palen

Meteorological week	Rainfall (mm)			Mean maximum temperature (°C)			Mean minimum temperature (°C)			Mean RH (%) at 7.22 hrs.			Mean RH (%) at 14.22 hrs.		
	1988	1989	1990	1988	1989	1990	1988	1989	1990	1988	1989	1990	1988	1989	1990
Jan. 1-7	-	-	-	27.0	28.7	28.2	13.6	14.4	16.2	89.6	88.6	91.7	46.4	38.4	52.4
Jan. 8-14	-	-	-	28.1	28.6	29.1	13.9	13.9	15.3	89.3	87.3	86.7	47.4	40.7	37.4
Jan. 15-21	-	-	-	29.3	29.3	31.5	14.9	14.1	13.8	89.1	87.1	71.1	40.7	36.6	26.1
Jan. 22-28	-	-	-	30.6	30.3	31.5	13.9	14.9	13.7	90.6	86.7	74.6	31.7	42.3	29.6
Jan. 29-4 Feb.	-	-	-	31.9	30.9	32.5	16.1	14.2	14.5	84.0	79.3	74.9	33.0	26.6	29.6
Feb. 5-11	-	-	-	31.6	33.3	32.2	14.4	14.0	15.5	74.4	70.7	77.6	30.7	28.6	33.3
Feb. 12-18	3.0	-	-	32.4	33.4	32.7	19.1	16.0	18.0	87.9	75.4	81.1	41.4	30.6	34.3
Feb. 19-25	-	-	-	32.9	32.0	32.7	21.2	16.5	17.6	83.7	76.7	71.9	40.1	36.4	30.9
Feb. 26-4 Mar.	-	-	-	34.7	34.4	33.2	21.4	17.3	19.3	78.9	72.0	72.6	37.5	30.7	31.1
Mar. 5-11	-	17.8	-	34.1	34.3	33.9	20.7	16.9	21.2	76.7	74.3	76.1	37.0	38.1	31.9
Mar. 12-18	-	1.8	-	36.5	32.4	33.7	20.6	19.3	20.4	73.1	77.6	77.5	44.1	33.3	33.2
Mar. 19-25	-	1.5	-	36.9	35.7	33.8	23.1	20.0	21.5	76.3	63.1	63.1	53.3	34.7	28.4
Mar. 26-1 Apr.	-	15.8	0.2	36.7	31.5	33.1	22.1	19.8	21.9	75.1	78.0	69.3	58.7	43.7	37.2
Apr. 2-8	-	11.2	2.1	37.9	36.9	35.0	22.1	20.0	23.4	72.3	61.9	74.5	70.6	30.9	39.4
Apr. 9-15	1.6	-	-	37.9	38.5	38.4	22.6	22.0	25.7	79.0	63.4	60.0	66.6	31.4	34.8
Apr. 16-22	16.4	-	6.8	36.7	38.2	38.9	22.7	23.8	24.4	79.0	63.4	66.1	77.8	35.4	40.2
Apr. 23-29	1.2	2.5	-	35.2	38.7	40.3	23.1	25.5	24.3	79.1	65.1	58.0	70.7	33.1	34.5
Apr. 30-6 May	3.6	1.1	6.1	37.9	39.1	35.3	24.4	24.1	25.2	82.1	60.7	65.0	65.0	54.0	38.9
May 7-13	-	-	74.2	41.6	40.5	30.0	28.6	26.5	23.1	61.7	61.4	79.0	21.7	26.2	29.0
May 14-20	-	-	41.0	41.5	41.2	32.5	28.4	27.7	23.5	48.4	61.1	73.0	29.0	31.4	39.4
May 21-27	19.2	-	4.6	38.0	38.7	34.1	24.4	25.6	23.9	69.1	77.6	40.6	40.6	35.0	37.2
May 28-3 June	1.4	8.8	-	40.9	37.2	-	26.6	25.4	-	63.6	67.1	-	35.7	39.6	-
June 4-10	99.7	33.0	-	36.6	34.9	-	23.7	23.6	-	77.0	80.1	-	46.3	58.8	-
June 11-17	1.5	15.4	-	35.3	32.9	-	24.6	24.4	-	70.9	80.1	-	42.4	51.9	-
June 18-24	25.2	0.1	-	32.4	34.3	-	23.0	25.0	-	81.0	75.1	-	40.7	42.3	-
June 25-1 July	-	13.8	-	33.0	31.4	-	23.9	23.6	-	74.3	79.7	-	51.8	55.1	-
July 2-8	63.8	18.9	-	31.7	31.3	-	23.3	24.3	-	77.0	83.3	-	62.9	60.4	-
July 9-15	46.2	81.5	-	30.0	31.0	-	22.2	23.2	-	92.6	89.3	-	69.6	67.9	-
July 16-22	57.7	115.5	-	27.2	28.7	-	22.3	23.2	-	90.9	89.3	-	82.3	76.0	-
July 23-29	133.0	61.7	-	28.0	28.3	-	21.5	23.4	-	89.7	84.1	-	76.0	69.7	-
July 30-5 Aug.	20.5	-	-	27.2	31.0	-	22.2	23.6	-	90.3	78.7	-	75.4	56.2	-
Aug. 6-12	3.6	9.4	-	28.6	31.8	-	22.6	23.7	-	87.4	82.6	-	69.4	58.7	-
Aug. 13-19	74.6	23.6	-	29.8	30.1	-	21.4	23.1	-	90.3	89.1	-	72.7	68.7	-
Aug. 20-26	35.8	44.6	-	29.1	28.6	-	22.5	23.1	-	89.1	88.0	-	69.1	71.0	-
Aug. 27-2 Sept.	51.5	18.1	-	29.4	30.2	-	22.6	23.1	-	90.3	83.7	-	76.4	62.1	-
Sept. 3-9	43.8	-	-	29.1	30.9	-	21.7	23.3	-	90.3	81.1	-	73.0	60.0	-
Sept. 10-16	58.9	27.6	-	31.2	29.4	-	22.6	23.3	-	89.9	87.4	-	65.3	69.1	-
Sept. 17-23	26.6	62.0	-	29.1	31.3	-	22.9	23.4	-	88.0	91.0	-	75.0	69.6	-
Sept. 24-30	63.0	22.0	-	28.4	28.7	-	22.1	22.6	-	91.4	94.5	-	72.0	75.6	-

Appendix B: Flowering behaviour of parents and hybrids

Hybrid	Group	Days to 50% flowering (Mean over seasons)		
		F ₁	P ₁	P ₂
ICP 165xICP 828	ExE	57.01	58.72	59.08
ICP 165xICP 64	ExE	56.11	58.72	59.73
ICP 165xICP 811	ExE	55.55	58.72	57.50
ICP 165xICP 323	ExE	56.56	58.72	54.63
ICP 828xICP 64	ExE	57.20	59.08	59.73
ICP 828xICP 811	ExE	56.84	59.08	57.50
ICP 828xICP 323	ExE	58.84	59.08	54.63
ICP 64 xICP 811	ExE	55.81	59.73	57.50
ICP 64 xICP 323	ExE	54.59	59.73	54.63
ICP 811xICP 323	ExE	56.38	57.50	54.63
	Mean	56.49	58.91	56.96
ICP 165xICP 57	ExL	56.53	58.72	69.78
ICP 165xICP 642	ExL	55.06	58.72	67.65
ICP 165xICP 812	ExL	56.11	58.72	66.50
ICP 165xICP 126	ExL	56.76	58.72	67.70
ICP 828xICP 812	ExL	55.39	59.08	66.50
ICP 828xICP 642	ExL	57.98	59.08	68.65
ICP 828xICP 126	ExL	59.15	59.08	67.70
ICP 64 xICP 812	ExL	57.78	59.73	66.50
ICP 64 xICP 642	ExL	59.55	59.73	68.65
ICP 64 xICP 126	ExL	57.38	59.73	67.70
ICP 811xICP 642	ExL	57.45	57.50	68.65
ICP 811xICP 126	ExL	55.13	57.50	67.70
ICP 323xICP 642	ExL	56.49	54.63	68.65
ICP 323xICP 126	ExL	57.06	54.63	67.70
	Mean	56.99	58.26	67.86
ICP 57 xICP 828	LxE	58.74	69.78	59.08
ICP 57 xICP 64	LxE	56.59	69.78	59.73
ICP 57 xICP 811	LxE	57.61	69.78	57.50
ICP 57 xICP 323	LxE	59.29	69.78	54.63
ICP 812xICP 811	LxE	52.79	66.50	57.50
ICP 812xICP 323	LxE	54.28	66.50	54.63
	Mean	56.55	68.69	57.18
ICP 57 xICP 812	LxL	56.43	69.78	66.50
ICP 57 xICP 642	LxL	62.93	69.78	68.65
ICP 57 xICP 126	LxL	61.56	69.78	67.70
ICP 812xICP 642	LxL	54.88	66.50	68.65
ICP 812xICP 126	LxL	53.15	66.50	67.70
ICP 642xICP 126	LxL	61.75	67.75	67.70
	Mean	58.45	68.34	67.81

Appendix C: Mean performance of parents and hybrids for plant height

Cross	Group	Plant height (cm) (Mean over seasons)		
		F ₁	P ₁	P ₂
ICP 165xICP 57	DxD	131.55	106.88	96.72
ICP 165xICP 642	DxD	132.08	106.88	104.83
ICP 57 xICP 642	DxD	114.58	96.78	104.83
	Mean	126.07	103.51	102.12
ICP 165xICP 828	DxT	193.41	106.88	162.28
ICP 165xICP 64	DxT	164.60	106.88	155.25
ICP 165xICP 812	DxT	200.30	106.88	153.78
ICP 165xICP 811	DxT	191.00	106.88	186.78
ICP 165xICP 323	DxT	174.48	106.88	194.65
ICP 165xICP 126	DxT	204.73	106.88	188.70
ICP 57 xICP 828	DxT	203.68	96.78	162.28
ICP 57 xICP 64	DxT	166.45	96.78	155.25
ICP 57 xICP 812	DxT	205.71	96.78	153.78
ICP 57 xICP 811	DxT	202.22	96.78	186.78
ICP 57 xICP 323	DxT	204.24	96.78	194.65
ICP 57 xICP 126	DxT	207.95	96.78	188.70
ICP 642xICP 126	DxT	230.84	104.83	188.70
	Mean	196.12	102.04	174.74
ICP 828xICP 642	TxD	214.35	162.28	104.83
ICP 64 xICP 642	TxD	185.35	155.25	104.83
ICP 812xICP 642	TxD	209.11	153.78	104.83
ICP 811xICP 642	TxD	228.53	186.78	104.83
ICP 323xICP 642	TxD	210.40	194.65	104.83
	Mean	209.55	170.55	104.83
ICP 828xICP 64	TxT	218.80	162.28	155.25
ICP 828xICP 812	TxT	191.36	162.28	153.78
ICP 828xICP 811	TxT	206.50	162.28	186.78
ICP 828xICP 323	TxT	207.00	162.28	194.65
ICP 828xICP 126	TxT	224.24	162.28	188.70
ICP 64 xICP 812	TxT	212.50	155.25	153.78
ICP 64 xICP 811	TxT	234.20	155.25	186.78
ICP 64 xICP 323	TxT	217.66	155.25	194.65
ICP 64 xICP 126	TxT	231.25	155.25	188.70
ICP 812xICP 811	TxT	202.59	153.78	186.78
ICP 812xICP 323	TxT	198.59	153.78	194.65
ICP 812xICP 126	TxT	200.23	153.78	188.70
ICP 811xICP 323	TxT	191.76	186.78	194.65
ICP 811xICP 126	TxT	232.09	186.78	188.70
ICP 323xICP 126	TxT	221.34	194.65	188.70
	Mean	212.67	164.13	183.02

Appendix D: Best parents on the basis of combining ability
and mean performance for yield and yield
attributes

Character	Best parent based on	
	GCA	Mean performance
Grain yield/plant	ICP 811 ICP 126 ICP 828	ICP 811 ICP 323 ICP 57
Grain yield/main panicle	ICP 811 ICP 828 ICP 126	ICP 811 ICP 57 ICP 323
Days to 50% flowering (earliness)	ICP 811 ICP 812 ICP 323 ICP 165	ICP 323 ICP 811 ICP 165 ICP 828
Plant height	ICP 126 ICP 811 ICP 828 ICP 64	ICP 323 ICP 126 ICP 811 ICP 828
Tiller number	ICP 165 ICP 64	ICP 64 ICP 811
Panicle number	ICP 812 ICP 642	ICP 812 ICP 811
Panicle length	ICP 57 ICP 642 ICP 323	ICP 57 ICP 642 ICP 323
Panicle girth	ICP 828 ICP 811	ICP 811 ICP 828
500 grain weight	ICP 828 ICP 811 ICP 323	ICP 828 ICP 811 ICP 323

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Appendix E: Best crosses based on Per se performance, heterobeltiosis and SCA effects in different characters

Character	Best crosses based on		
	<u>Per se</u> performance	Heterobeltiosis	SCA
Grain yield/plant	ICP 811xICP 642	ICP 165xICP 812	ICP 165xICP 812
	ICP 811xICP 126	ICP 165xICP 828	ICP 57 xICP 323
	ICP 828xICP 126	ICP 828xICP 812	ICP 165xICP 828
	ICP 642xICP 126	ICP 828xICP 126	ICP 811xICP 642
	ICP 828xICP 642	ICP 64 xICP 812	ICP 828xICP 126
Grain yield/main panicle	ICP 57 xICP 828	ICP 828xICP 126	ICP 57 xICP 323
	ICP 828xICP 126	ICP 165xICP 812	ICP 165xICP 812
	ICP 57 xICP 323	ICP 828xICP 812	ICP 828xICP 126
	ICP 828xICP 811	ICP 64 xICP 812	ICP 57 xICP 828
	ICP 811xICP 126	ICP 828xICP 642	ICP 64 xICP 812
Earliness	ICP 812xICP 811	ICP 165xICP 57	ICP 812xICP 126
	ICP 812xICP 126	ICP 812xICP 126	ICP 812xICP 642
	ICP 812xICP 323	ICP 812xICP 811	ICP 165xICP 642
	ICP 64 xICP 323	ICP 812xICP 642	ICP 57 xICP 64
	ICP 165xICP 642	ICP 57 xICP 812	ICP 828xICP 323
Plant height	ICP 64 xICP 811	ICP 64 xICP 812	ICP 811xICP 642
	ICP 811xICP 126	ICP 812xICP 642	ICP 57 xICP 812
	ICP 64 xICP 126	ICP 828xICP 642	ICP 165xICP 812
	ICP 642xICP 126	ICP 57 xICP 812	ICP 642xICP 126
	ICP 811xICP 642	ICP 323xICP 642	ICP 57 xICP 323
Tiller number	ICP 828xICP 811	ICP 57 xICP 812	ICP 57 xICP 812
	ICP 165xICP 811	ICP 65 xICP 812	ICP 828xICP 811
	ICP 642xICP 126	ICP 828xICP 812	ICP 64 xICP 642
Panicle number	ICP 165xICP 812	ICP 165xICP 828	ICP 165xICP 828
	ICP 812xICP 642	ICP 642xICP 126	ICP 323xICP 126
	ICP 812xICP 811	ICP 64 xICP 642	ICP 165xICP 812
Panicle length	ICP 57 xICP 323	ICP 165xICP 812	ICP 57 xICP 828
	ICP 57 xICP 828	ICP 165xICP 64	ICP 828xICP 64
	ICP 57 xICP 64	ICP 828xICP 64	ICP 165xICP 812
Panicle girth	ICP 828xICP 811	ICP 57 xICP 812	ICP 828xICP 126
	ICP 828xICP 126	ICP 64 xICP 812	ICP 57 xICP 812
	ICP 828xICP 812	ICP 165xICP 812	ICP 828xICP 812
500 grain weight	ICP 828xICP 811	ICP 165xICP 64	ICP 64 xICP 126
	ICP 828xICP 323	ICP 165xICP 812	ICP 165xICP 811
	ICP 811xICP 323	ICP 64 xICP 812	ICP 165xICP 323