

**GENETICS OF SOME POTENTIAL PARAMETERS IN *Zea mays* L.  
UNDER NORMAL AND MOISTURE DEFICIT CONDITIONS**



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M.Sc. (Hons.) Agri.  
86-ag-1252

IN  
**PLANT BREEDING & GENETICS**

A thesis submitted in partial fulfillment of the requirements for the degree of

**DOCTOR OF PHILOSOPHY**

IN  
**PLANT BREEDING AND GENETICS**

**DEPARTMENT OF PLANT BREEDING & GENETICS  
UNIVERSITY OF AGRICULTURE, FAISALABAD,  
PAKISTAN  
2012**

## **Acknowledgements**

I bow in gratitude and glory to “**ALMIGHTY ALLAH**” the most beneficial, the merciful and compassionate Whose bounteous blessing enabled me to complete this research work. My special praise to the Holy prophet **Hazrat Muhammad** (peace be upon him) Who is forever a torch of guidance and knowledge for humanity. I would like to express many sincere thanks to **Dr. Muhammad Saleem**, Professor, Department of Plant Breeding & Genetics, University of Agriculture, Faisalabad who provided me encouragement, enthusiasm, guidance and support during my Ph.D research work and write-up of this manuscript. His helping attitude and useful comments will remain in memories for the whole of my life. I would like to extend my sincere gratitude to the supervisory committee members **Dr. Muhammad Ahsan**, Assistant Professor, Department of Plant Breeding & Genetics, University of Agriculture, Faisalabad and **Dr. Asghar Ali**, Professor, Department of Agronomy for their valuable advice and invigorating encouragement during the course of present studies. I feel deep sense of gratitude to Prof. **Dr. Abdus Salam Khan**, Chairman, Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad for his precious guidance and encouragement during my studies. I am devoutly thankful to **Higher Education Commission, Pakistan** for providing financial assistance to make this whole story successful. Thanks are due to my sisters and brother who always prayed for my success in life. Finally, I wish to extend special thanks to my better half and kids for their patience, and inspiration to overcome the most desperate moments while completing this degree.

JAVED IQBAL

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## ABSTRACT

The germplasm for the conduct of present studies i.e. maize inbred lines were collected from various organizations working on maize crop and were sown in experimental area of the Department of Plant Breeding & Genetics, University of Agriculture, Faisalabad (Pakistan) evaluating identification and purity. Based upon morphological characters and distinct features fifty promising inbred lines were ear-marked and selfed to obtain seed for further breeding manipulations. The selected inbred lines were screened against moisture stress condition in the greenhouse, Department of Plant Breeding & Genetics, University of Agriculture, Faisalabad according to a Completely Randomized Design with three replications. On the basis of overall performance six inbred lines were selected and crossed in a complete diallel fashion. The parents, F<sub>1</sub> crosses and their reciprocals were sown for evaluation in a triplicate Randomized Complete Block Design under normal and moisture deficit conditions. Data for plant height, days to tasseling, days to silking, anthesis silking interval, days to maturity, grain yield per plant, 100-grain weight, ear leaf area, leaf temperature, relative water loss, cell membrane thermostability and photosynthetic rate were recorded from both the sets. Statistical analysis was conducted for gene action and combining ability estimates. The results revealed that material had significant variation for all the traits under study. Additive dominance model was fully or partially fit for all the traits under both conditions except anthesis-silking interval under normal conditions. Value of item "a" was significant for six traits under normal conditions and both a and b were significant for four traits. Under moisture stress conditions both additive and dominant gene action were significant for plant height, anthesis silking interval, grain yield per plant, ear leaf area, cell membrane thermostability and photosynthetic rate while additive gene action was significant for days to tasseling, days to silking, days to maturity, 100-grain weight, leaf temperature and relative water loss. Maternal effects for grain yield per plant, 100-grain weight and photosynthetic rate were significant under normal conditions while under moisture deficit conditions maternal effects were significant for days to tasseling, anthesis silking interval, grain yield per plant, 100-grain weight, ear leaf area and photosynthetic rate. Graphical presentation for gene action depicted that most of the traits including grain yield per plant displayed partial dominance under normal and moisture deficit conditions. Leaf temperature showed partial dominance under normal and complete dominance under moisture stress conditions. For grain yield per plant inbred line F-206 had the maximum dominant genes being nearest to the origin. Same was the case for 100-grain weight under normal conditions. Mean squares for general combining ability, specific combining ability and reciprocal effects were highly significant for all the traits under normal and moisture deficit conditions. Estimates of variance components due to general combining ability were greater than those of specific combining ability for all the traits under normal moisture deficit conditions. Reciprocal effects were found highly significant for all the traits under normal and moisture deficit conditions. Inbred line F-206 was best general combiner for most of the traits including grain yield per plant under both the conditions. The crosses F-192 × F-189 and F-110 × F-206 exhibited good SCA effects with outstanding mean performance for grain yield under moisture stress condition.

## ABBREVIATIONS

Sr. No.	Abbreviation	Stands for
1	ASI	Anthesis silking interval
2	CMT	Cell membrane thermo stability
3	S.E	Standard error
4	Ear leaf area	Area of leaf at the stem node where productive cob is attached
5	MS	Mean square
6	GCA	General combining ability
7	SCA	Specific combining ability
8	SS	Sum of squares
9	E	Environmental variance
10	D	Additive variance
11	H <sub>1</sub>	Dominance variance
12	H <sub>2</sub>	Proportion of positive and negative genes in the parents
13	F	Relative frequency of dominant and recessive alleles in the parents
14	h <sup>2</sup>	Dominance effect (over all loci in heterozygous phase)
15	$\sqrt{H_1/D}$	Mean degree of dominance

## CHAPTER I

### INTRODUCTION

Maize (*Zea mays* L.), the only cultivated member of the genus *Zea* and tribe Maydeae is an important and versatile cereal grain crop. It is sown over environments from 58<sup>0</sup> North latitude to 40<sup>0</sup> South latitude and in a range of altitude from sea level to 3800 meters. It is a profitable crop due to higher yield potential per unit area. Being a multipurpose crop, it is used as food, feed and fuel. It is a source of starch, oil, syrup, alcohol, gluten, glucose, flour, flakes, ethanol, custard powder and dextrose, etc. Maize is also used as raw material for paper and textile industries. It provides 15% of protein and 20% of calories (Bhatnagar *et al.*, 2004). Maize consumption has increased significantly with the expansion of livestock and poultry industry and the total demand of maize is estimated to be double by 2020 (Rosegrant *et al.*, 1999).

Globally, maize is sown on 160 M hectares. The total production is 829 million tonnes. The United States of America, Mexico, Brazil, China and India are leading corn producing countries. In Pakistan, maize crop is cultivated on 935.10 thousand hectares and total production is 3261.5 thousand tones with yield of 3488 kg per hectare. The major proportion of crop produce comes from Punjab and Khyber Pakhtoonkhah provinces. In Punjab, 504.9 thousand hectares are planted under maize with grain production of 2501.5 thousand tones and the average yield is 4954 kg per hectare (Anonymous, 2011). Although maize has a special position in agriculture of Pakistan but there is no prominent increase in area and production. Average yield is low as compared with world's average.

There are a number of factors responsible for low yield which warrants the attention of maize breeders. Boyer (1982) pointed out that plant productivity under stress conditions hardly reached its maximum potential, and about 75 percent of yield loss in corn was due to abiotic factors. Moisture deficiency is one of the major environmental perturbations. One-third of world's arable land is affected due to water deficiency (Kramer, 1980). Moisture stress is limiting factors for yield stability with far reaching impact on grain quality as well as grain yield and adversely affects the plant's ability to grow and complete a normal life cycle (Moussa and Aziz, 2008). Drought can occur at various stages of development, but has the most adverse effect on yield during and after

anthesis (Tuinstra *et al.*, 1997; Kebede *et al.*, 2001). Cakir (2004) reported that in maize, a drought event at tasselling leads to 20% decrease in kernel number on average in addition to reducing leaf area index.

Water deficiency reduces plant growth and reduces grain yield by affecting pollination and anthesis-silking interval. Low moisture can dry pollen grains, reduces the silk receptivity and pollen viability (Sinsawat *et al.*, 2004; Herrero and Jhonson, 1980). The main effect of drought is usually considered to be a reduction in growth (Mwanamwenge *et al.*, 1999). Xu *et al.* (2008) reported that more than of the decline in net photosynthetic rate is attributable to water stress. When the plant's photosynthetic efficiency is reduced, crop productivity and yield are affected adversely (Vitale *et al.*, 2007). Xu *et al.*, (2008) suggested leaf dehydration to be the factor resulting in photosynthesis decline, particularly in older leaves. Moisture deficiency enhances the effects of high temperature and causes many abnormalities including tassel blast, top firing, poor seed set and ultimately low yield. It also reduces leaf area development, leaf size and leaf dry matter accumulation resulting in lower canopy photosynthesis.

As the water resources are becoming scarce and agriculture sector is being suffered seriously. It is the dire need of the time to use the available moisture efficiently. The problem can be tackled by exploiting the agronomic approaches under stress conditions and developing crop varieties having tolerance (Edmeades *et al.*, 2004). Improvement of the existing genotypes and their utilization is rather more convenient as desired genetic makeup can be packed in a seed and be easily adapted (Campos *et al.*, 2004). Improvement of genotypes depends upon the presence of genetic variation. Selection of the traits associated with yield is more useful than selection for yield *per se*. To develop drought tolerance in maize genotypes, morphological and physiological characteristics which are less affected by genotype-environment interaction should be included in breeding programme (Martiniello, 1983; Matin *et al.*, 1989; Ritchie *et al.*, 1990; Castonguay and Markhart, 1992).

Genetic components and their contribution for the control of variation in a given trait are very important. Understanding of the genetic mechanism for moisture stress is the first prerequisite for tailoring tolerant genotypes. To this end present research project was planned and executed with the following objectives.

1. Evaluation of maize inbred lines for various morpho-physiological traits under moisture deficit conditions.

2. Identification of promising inbred lines to develop all possible combinations.
3. Estimation of variability from the parents and the crosses for various traits under normal irrigation and moisture deficit conditions.
4. To determine nature of gene action for various parameters and graphical presentation of parents along the regression line.

The study has generated information for moisture stress tolerance by studying gene effects for different morphological and physiological traits. Genetic basis of variation were determined to ascertain the nature and extent of genes contributing moisture stress tolerance. Hayman's graphical approach is a statistical procedure, which gives valuable information on the genetic components of variance and ratios of different genes in the inbred lines. The information so derived would be helpful to formulate program of further breeding plans for the evolution of promising maize genotypes tolerant to moisture stress.



## CHAPTER II

### REVIEW OF LITERATURE

#### 2.1 Moisture stress

Plants have to face many unfavourable conditions during growth and developmental stages in their natural environment. Environmental hurdles either in the form of biotic or abiotic stresses affect the yield and quality of the food. On global basis, agricultural production is adversely affected due to various stresses (Boyer, 1982; Bray, 2000). Moisture stress and soil infertility were the two major abiotic problems to agricultural production in the past (Beck *et al.* 1996) and will continue to have significant impact on agricultural production in future particularly in Asia and Africa (Rijsberman 2006).

Scarcity of irrigation water is a major bottleneck in crop production and a challenging task for the researchers. Moisture stress is a moderate loss of water which leads to the closure of stomata and limits the exchange of gases. Smirnoff (1993) demonstrated that in case of much loss of moisture, metabolism is disrupted and resultantly enzyme-catalysed reactions are stopped. For the fulfilment of the food requirements, it has to be produced optimally under available conditions of the soil, water and environment. To make food available on regular basis, there is dire need to tailor crop plants with durable resistance against moisture deficiency and other abiotic stresses. To this end development of tolerant crop varieties is the direct and feasible way to address the problem. Plants behave differently when they are to live and survive in a moisture stress condition. Some plants and crop varieties tend to avoid the period of stress and this will be taken as stress escape. According to Franks (2006) life span of *Brassica napus* is reduced in moisture deficit condition. However, this decrease in life span of a plant imposes adverse effect on the yield. In maize plant, due to decrease in maturity period in dry environment lesser biomass is produced and ultimately yield is reduced (Mungo and Njoroge, 1997). Dahlan *et al.* (1997) reported the reduced maturity period in maize plant as an example of stress escape in case of terminal stress. Under moisture deficit conditions the genotypes which show lesser change in their physiological activities termed as tolerant. Tolerance to low moisture stress is a base of yield stability under stress environments.

## 2.2 Moisture stress and plant growth

Water shortage is a serious threat and limiting factor to food production for human of the world specially that of sub-continent. Under the condition of moisture deficiency, plant water potential is decreased and affects the normal functions of the plant (Hsiao, 1973). Moisture deficiency affects the process of seedling germination. Germination and growth of the plant depends upon the moisture availability especially on the stored soil moisture which is rapidly decreasing owing to the prevalence of dry period. According to Bijagare *et al.* (1994) and Maiti *et al.* (1996) germination is decreased with increase in moisture stress. Maiti *et al.* (1996) reported low germination at high level of moisture deficiency. The studies revealed that germination of maize was influenced by moisture stress (Elemery *et al.*, 1995; Lemcoff, 1998). Nagy *et al.* (1995) demonstrated that response of maize seedlings under moisture stress was more than that of sorghum due to excessive decline in leaf water content. Matsuura *et al.* (1996) studied tolerance level against low moisture stress. Sorghum and pearl millet were observed as drought tolerant displaying lowest reduction in growth rate due to high leaf water status. Under moisture stress conditions, maize root length was reduced. Low moisture stress tolerance in sorghum and pearl millet was linked with water uptake ability and root length. The response of genotype to the moisture deficiency can clearly be observed under severe condition of moisture deficiency in soil (Grzesiak., 2001).

Growth of plants comprises many morphological and physiological aspects. Increase of cells through division and increase in size is not reversible and is considered as plant growth (Lyndon, 1990). Moisture deficiency affects the crop at every stage of development. However, intensity of the effect varies with the species, varieties and the stages of development (Doorenbos and Kassam, 1979). At early stage, maize plant is affected due to decrease in crop stand. Thus tolerance is necessary to face environmental factors after emergence. Moisture deficiency at early stage forces plant to respond physiologically. Solute flow in maize plant is reduced due to moisture deficiency and cell expansion is limited (Frensch and Hsiao, 1994).

The movement of water starts from soil to plant body and then to atmosphere. As any water drops on the soil it is absorbed through roots of the plant before it evaporates into the atmosphere (Lee *et al.*, 2005). As the water is transpired, the temperature of leaf surface is decreased. Growth stage of the plant determines the level of effect (Claasen and Shaw, 1970). Leaf wilting is a sign of moisture deficiency and it can be compensated by

providing additional water. According to NeSmith and Ritchie (1992) leaf area of affected plant is reduced and ultimately results into yield losses. Banziger *et al.* (2000) concluded that drought affects the development of root and stem. In case of prolonged moisture deficiency, stem growth and root expansion is reduced considerably. Cowan and Farquhar (1977) explained the functions of stomata that tend to minimize water losses. Seedling exposed to stress produces greater biomass (Latimer, 1990). Niklas (1991) reported that length of seedling was also affected due to the moisture deficiency. Low water potential decreases water conductance of the cell. Chazen and Newmann (1994) explained the response of corn to moisture deficit as hydraulic signals from the root and hardening of outer wall of the cell.

Transpiration is enhanced due to increase in stomatal conductance and partitioning of energy is affected (Kleidon, 2004). Due to non-availability of moisture the rate of photosynthesis is decreased and ultimately less photosynthates are available for assimilation. Exposed silks are desiccated due to low moisture stress and low relative humidity (Nielsen, 2005). Schussler and Westgate (1995) reported that silk growth and number of grains were associated with the flow of photosynthates. Bolanos and Edmeades (1996) concluded that anthesis silking interval (ASI) and grain abortion was the result of decrease in silk growth under stress condition. Zinselmeier *et al.* (1999) reported that ovule and seed development depends upon the flow of photosynthates which is disturbed due to the dehydration. Due to closed stomata leaf area is reduced and ultimately photosynthesis is reduced (Bruce *et al.*, 2002). According to Banziger *et al.* (2000) establishment of ears and kernels is affected due to moisture deficiency during flowering time. Boyle *et al.* (1991) reported that due to low water potential plant is unable to provide ingredients, which results in grain abortion. So dry matter in grain is associated with the amount of dry matter in plant (Yang *et al.*, 2001 a,b).

Reproduction, a key stage in the life cycle of the plant, is the outcome of successful completion of germination, growth, flowering, pollination and seed setting. All these processes are affected by the prevailing environment during the life span of plants. Kiesselbach (1999) divided the process of reproduction into three phases. At first stage both male and female flower parts are developed. Secondly, flowers are matured and finally pollination and fertilization occurs. According to Herrero and Johnson (1981) low moisture stress during anthesis, increases the anthesis silking material. Pollen viability is also decreased (Westgate and Boyer, 1985). Zygote is very much sensitive to moisture stress. Even after pollination and fertilization there are chances of failure of

reproductive process. If moisture deficiency occurs during microsporegenesis, pollen remains sterile. (Saini and Westgate, 2000). Nielsen (2005) reported that moisture deficiency for few days during silking and pollination causes forty to fifty percent loss in yield. Banziger *et al.* (2000) reported that female portion of the plants is more susceptible to water stress. According to Bolanos and Edmeades (1993) the parameters responsible for delay in emergence of female parts also affect the grain yield. In case of corn, moisture deficiency at any stage reduces the grain yield, but flowering stage is more critical. Grant *et al.* (1989) reported that moisture stress prevailing at emergence of male parts; the grain filling may lead up to complete barrenness.

### **2.3 Moisture deficiency and plant traits**

Banziger *et al.* (2000) stated that anthesis-silking interval, leaf rolling and leaf senescence are key points for improving yield of maize under drought environment. According to Shaw (1977) maize plant is mostly affected by stress during silking. Silk emergence is a measure of cob growth. Silking and tasseling both are affected by low moisture stress but silking is more sensitive. Anthesis-silking interval is a key parameter for cob development (Edmeades *et al.*, 1993; Vega *et al.*, 2001). Anthesis silking interval is increased under drought conditions (Duplessis and Dijkhuis 1967). Anthesis silking interval is correlated with barrenness and yield ( Bolanos and Edmeades, 1996). Grain yield depends on proper pollination, kernel set and early development of the kernels. Bad pollination at low water potential in maize was reported due to the widening of the anthesis-silking interval (Edmeades *et al.* 2000). A large ASI reduces the number of seeds per cob. The number of grains is correlated with grain yield under water deficit conditions at flowering. Number of kernels is important in determining grain yield than the weight of the kernels (Bolanos and Edmeades 1996). Pollination alone, however, cannot avoid reductions in kernel number. A continuous availability of assimilates to the developing ears is essential for early development of the kernels.

Physiological responses of plant under stress conditions are very important. Passioura (1993) proposed that physiological traits contributing towards yield are very important in variety improvement. According to Campos *et al.* (2004) selection based on responses i.e. increased yield potential, seed setting and silking is a tool to improve the genotypes. Duvick (1997) and Tallenaar *et al.* (1994; 2000) reported that in maize, stress tolerance is associated with improvement in yield. Leaf photosynthetic rate and leaf area depicts assimilation (Steduto, 1996). Cell expansion is influenced by water stress. Less

light is intercepted by plant if leaf area is less and there will be lesser source size for assimilates and there will be reduction in photosynthates.

Total biomass is positively correlated with the growth of plant. In maize crop biomass produced by plant is affected under moisture stress conditions. Aggarwal and Sinha (1983) reported that shoot weight is decreased under stress conditions. Low moisture stress limits the dry matter production in maize crop (Morizet *et al.*, 1983). According to Shiralipour and West (1984) dry matter of root and shoot in maize crop decreases under water deficit conditions. Length of fresh root and shoot is affected by moisture deficiency in maize crop (Thakur and Rai, 1984; Alam, 1985). Ramadan *et al.* (1985) found that root and vegetative growth in maize is decreased under moisture stress conditions. Plant naturally tends to increase its roots. Root density and depth are important traits which help plants to cope with drought (Hoogenboom *et al.*, 1987). Once a plant observes stress severely, its growth does not return to normal, however, leaf elongation is rapid after re watering (Jing and Hsiao, 1987). Photosynthetic rate is also affected under water deficit conditions. Low moisture stress during the life span of maize plant reduces the plant height, dry matter production and leaf growth (Gu *et al.*, 1989). According to Dai *et al.* (1990) low water stress limits the growth and development of maize plant. Stress at early stage increases root growth.

Genotypes tolerant to drought stress behave differently. Tolerant genotypes grow slowly under normal conditions but better under stress conditions than sensitive genotypes. Drought resistant genotypes observe higher transpiration rate and have higher relative water contents during period of stress than sensitive cultivars (Oregon *et al.*, 1993). Measurement of root dry weight is proper indicator for drought tolerance. Total dry matter production and root length is affected due to moisture deficiency (Petcu and Terbea, 1996). According to Dass *et al.* (2001) plant height is seriously affected when stress is imposed at early growth stage of maize plant. They concluded that anthesis silking interval increases during stress conditions and hybrids are more tolerant than inbred lines.

The hybrids and the inbred lines behave differently under moisture stress conditions. This difference is increased with the increase in intensity of drought (Betran *et al.*, 2003). Moisture deficits disturbs the source sink balance and this leads to purpling of leaf and tissues, reduction in yield and premature tissues senescence (Lee and Tollenaar, 2007). Moisture deficiency is most important abiotic stress which affects the production of corn (Ofori and Kyel-Baffour, 2008). Low moisture stress delays the silking and silking-

anthesis interval is increased. Resultantly grain filling period is reduced and physiological maturity is less affected (Fredrick *et al.*, 1989). Dai *et al.* (1990) concluded that effect of drought is different at different crop stages. Leaf area of drought tolerant varieties remains larger under moisture stress conditions.

Root is a key tool of a plant to cope with drought conditions. Plant is tolerant if it has longer roots. Under water deficit condition root to shoot ratio increases (Xu and Bland, 1993). Sacks *et al.* (1997) reported that meristem cells of primary root in case of maize got longer but rate of division was decreased. According to him maximum cell division rate was 8.2 cells per mm per hour under moisture stress. Under normal conditions rate of cell division was 13 cells per hour per mm. Aggarwal and Sinha (1983) reported that under water deficit conditions root weight increased and shoot weight decreased. Due to moisture stress conditions root and shoot weight of maize seedling decreased. (Shiralipour and West, 1984). Thakur and Rai (1984) also observed that moisture stress affects the fresh weight and length of root and shoot in maize crop at seedling stage and shoot is more affected than root.

Plant height, leaf growth and dry matter are reduced under moisture stress conditions (Gu *et al.*, 1989). Weerathworn *et al.* (1992) observed that dry root and shoot weight in maize seedling decreased under moisture stress. Plant height and size of leaf is reduced under water deficit conditions and intensity of reduction increases with increase in water stress (Yang and Hsiang, 1992). Resistant genotypes grow more slowly than sensitive ones under normal conditions. But under stress conditions resistant cultivars grow fastly and their root system is deeper (Oregon *et al.*, 1993). Plant height and grain yield of maize crop is affected under moisture stress conditions (Vicente *et al.*, 1999). Dass *et al.* (2001) concluded that plant height is reduced and anthesis silking interval is increased under water deficit conditions. Deep rooting system and shorter anthesis silking interval is associated with tolerance against drought (Trachse, 2009). Burke (2007) reported that leaf area, leaf size and leaf dry matter accumulation is decreased under drought conditions and ultimately lower canopy photosynthesis. Shoot growth is restricted and root growth continues. Due to low moisture stress leaf number is decreased. Under severe stress leaf growth can cease and leaf elongation decreased (Cakir, 2004; Prasad *et al.*, 2008).

Water deficit conditions have a prominent effect on yield. Larger reduction in yield is caused due to moisture stress at time of flowering. Pollen development is inhibited due to drought. Sterility is caused, spike development is reduced and

consequently seed number is decreased. Due to drought, grain filling period is reduced and thus seed number is decreased (Prasad *et al.*, 2008). Grain set is also associated with anthesis silking interval. Under drought conditions anthesis silking interval is increased. According to Bassetti and Westgate (1994) seed set is affected when anthesis silking interval exceeds eight days. Thus anthesis silking interval is a measure of growth rate of silk and grain setting percentage (Edmeads *et al.*, 2000). An important aspect of drought resistance in plants is root system. Root dry weight is a measure to select tolerant genotype. Maiti *et al.* (1996) concluded that shoot length, fresh root length and dry weight of shoot is affected under moisture stress conditions. Dry matter accumulation is significant parameter in relation to drought tolerance. Pectu and Terbea (1996) reported that dry matter was more in root under stress conditions than under normal conditions.

Campos *et al.* (2004) reported that deep root is very important for maize plant to be tolerant against drought. Root length is also associated with plant growth rate and leaf water content (Matsoura *et al.*, 1996). It has been noted that vegetative growth is sensitive to drought less as compared to reproductive stage and hybrids express better than landraces (Mabhaudhi, 2009). However, avoidance of plant is better in case of drought. Trachse (2009) concluded that maize plant with root morphology allowing the drought avoidance is more important than drought tolerance. Understanding of physiological traits in relation to water deficit conditions is very important for crop improvement. Many plant aspects are indicator of drought tolerance.

Characteristics of leaf play an important role in drought tolerance. Leaf area acts as source size and leaf photosynthetic rate represents the source intensity (Steduto, 1996). According to Lopez-Castanda and Richards (1994) leaf development and early vigour in cereal crops is related with improved water use efficiency. With faster water use efficiency plant saves the moisture loss from surface of soil. Expansion of the cell in some crops is sensitive aspect to moisture deficit conditions, Hsiao, 1973; Bradford and Hsiao, 1982; Passioura *et al.*, 1993). Less light is intercepted if leaf area is less. Borrel *et al.* (2000) reported that at maturity, green leaves were a sign of resistant genotype. If moisture availability is limiting during grain filling stage, leaf death occurs in sorghum (Stout and Simpson, 1978; Rosenow and Clark, 1981). Kamara *et al.* (2003) observed that under drought, leaf area index was associated with grain yield. Grain yield was reduced upto 25% with the removal of ear leaf. Yang and Hsiang (1992) observed that leaf length in maize genotypes was reduced under moisture deficit conditions.

Leaf temperature is an important physiological parameter which is associated with drought tolerance. According to Blum *et al.* (1989) leaf temperature is easy to record in the field and has association with drought resistance. Plant water status in alfalfa has been associated with the leaf temperature (Idso *et al.*, 1981). It has been reported that varieties having deep root system in rice showed lower leaf temperature than those with a shallower root system (Hiryama *et al.*, 2006).

Water contents of leaf reduce with increase in moisture deficiency (Yang *et al.*, 2003). Ability of a plant to maintain high leaf water potential under drought is indication of drought tolerance (Jongdee *et al.*, 2002). According to Oregon *et al.* (1993) drought resistant cultivars had a higher transpiration rate during the onset of stress and had higher relative water content throughout the period of stress than drought susceptible cultivars. According to Valentovic *et al.* (2006) relative water content in maize decreases after drought stress but in tolerant cultivars this reduction is observed less than those of sensitive cultivars. Sadiq *et al.*, (1989) reported a progressive decline in water content with increase in stress duration in maize cultivars. An increase in water content was found after pre-treatment of drought in maize genotypes.

Photosynthesis is key factor of plants life and dry matter productivity depends upon photosynthetic capacity. According to Lawlor and Uprety (1993) economic yield of plants can be increased by increasing photosynthetic rate. Studies about photosynthesis revealed that C<sub>4</sub> plants are less sensitive to water stress (Ghannoun, 2009). C<sub>4</sub> plants are thriving in semi-arid and arid environment (Edwards and Still, 2008). Carvalho *et al.* (2010) reported that photosynthetic rate and stomatal conductance decreased with drought in maize cultivars. According to Carvalho (2010) the variation observed among the genotypes predicts that there is a valuable potential for crop improvement in relation to water stress tolerance. Maximum values of net photosynthetic rate of unstressed maize plant ranged between 15 and 30  $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ S}^{-1}$  (Carvalho *et al.*, 2010). He reported a relatively wide basis of physiological heterosis in corn that can be utilized for crop improvement.

Cell membrane stability is another physiological aspect of plants which determines its tolerance against stress. It is common to other stresses (Levitt, 1980). The intensity of damage indicates the tolerance against stress such as high temperature, drought and cold. (Dexter, 1956; Blum and Ebercon, 1981). Membrane stability or cell injury is an index for the measuring temperature and moisture stress tolerance (Reynolds *et al.*, 2005; Sullivan, 1972; Martineau *et al.*, 1979; Sadalla *et al.*, 1990; Fokar *et al.*, 1998). Moisture



stress deteriorates cell membrane and metabolic function is disturbed (Nir *et al.*, 1969; Buttrose and Swift, 1975). Cell membrane is injured due to drought stress and ionic secretion determines its magnitude (Ferrat and Lovatt, 1999). Relationship between leaves relative water content and leaves water potential is used to measure water deficiency in plant tissues and degree of resistance against water deficit conditions (Aminzadeh and Eshghi, 2006; Ferrot and Loratt, 1999; Khan and Stoddard, 2005). Neyestani and Azimzadeh (2003) in lentil and Vazan *et al.* (2005) in sugar beet observed association between membrane stability and yield under moisture stress and concluded that under stress plasma membrane stability was lower than under normal conditions. Saneoka *et al.* (2004) reported that water deficit leads to the damage of cellular membrane. Plants tolerate water stress by adapting osmotic adjustment (Begg and Turner, 1976; Turner and Begg, 1981; Feng *et al.*, 1994), which enables plants to explore a large volume of soil by roots. Increased soil water extraction increases grain yield (Morgan and Codon, 1986). Species, genotypes and degrees of stress determine the degree of osmotic adjustment (Turner and Jones, 1980; Tangpremsri *et al.*, 1995).

#### **2.4 Genetic analysis**

The use of biometrical techniques to derive information for genetic improvement of various crop plants is first pre-requisite for increasing productivity. With the help of various statistical techniques breeders have inferred information on the gene action involved in the expression of different parameters. Ana *et al.* (1997) concluded that additive type of genes was involved in controlling plant height. Bukhari (1986) reported that in maize, plant height was under the control of additive genes, while grain yield and grain weight were linked with overdominance. Regarding the plant height, it was reported that it was guarded by overdominance type of gene action (Siddiqui, 1988). Tabassum (1989) found that there was additive gene action present in controlling height of the plant.

Khotyleva and Lemesh (1994) reported that grain weight per ear in case of maize was the expression of additive genes. Malik *et al.*, (2004) found grain weight under gene effects with non-additive behaviour. Tabassum (2007) observed that thousand grain weight was inhibited by non-additive gene under normal and drought conditions. Wu (1987) reported that 1000-grain weight was controlled by additive and dominant genes. Bawzir (1983) observed that hundred seed weight in sorghum was under the influence of additive genes. Chapman and McNeal (1971) worked out that kernel weight was controlled by both type of gene behaviours. Regarding the days taken to tasseling, it has been observed that it was under additive gene control (Ramamurthy, 1980). Naved (1979)

concluded that days taken to tassling in maize were guarded by both type of genes. Saleen *et al.* (2002) observed that days taken to tasseling were controlled by over-dominant type of gene action while Saeed (1998) found this trait was controlled by additive of genes.

Silking is an important parameter for maize influenced with the genotype and environment. Dhillon *et al.* (1976) told that days in silking were under influence of over-dominant type of genes. Karim (1979) conducted 5 x5 diallel cross in maize and found that over-dominance was involved in expression of days in silking. According to Naved (1979) days to silking were under influence of dominant additive genes. Saeed (1998) reported that days to silking were controlled by additive genes. Yedeneov (1986) concluded that for days in physiological maturity, dominant effects were in the direction of early maturing parents. Breeding for high yield may be conducted by reducing period between tasselling and silking. Bolanos and Edemeads (1993) reported that reduced anthesis and silking interval is associated with high grain yield. Reduction in yield of 8.7% day<sup>-1</sup> has been reported due to increase in ASI from 0.4 to 10 days. According to Chapman *et al.* (1997) there is a high variability for anthesis silking interval. Betran *et al.* (2003) concluded that high yielding corn plant had lower tasseling and silking interval and more number of cobs. Zhang and Wang (1991) studied combining ability effects in ten hybrids from diallel cross based on Griffing's model 1 (1956). Significant general combining ability and specific combining ability effects were shown for all parameters except 100 grain. It was concluded that more attention should be paid in selecting parents with higher GCA.

Choukan (1999) studied parents and combinations for plant height and seed yield. SCA effects were found to be significant for these parameters. Paul and Debanth (1999) conducted analysis for combining ability in maize in 7 x 7 diallel. Both the SCA and GCA effects were important for weight per plant and plant height. Combining ability studies indicated that gene action in additive behaviour was significant. Revilla *et al.* (1999) studied 10 maize genotypes in diallel set. In case of plant height significant effects of GCA and SCA were recorded. Tallei and Kochaksarei (1999) conducted diallel cross analysis of 10 x 10 inbred lines and found that GCA for seed yield, stomata number and plant tallness were significant at 1% probability level. Dubey *et al.* (2001) told that mean squares for 100-grain weight were significant in crosses of fifteen maize inbred lines. Shreenivasa and Singh (2001) studied half diallel of drought tolerant inbred lines of maize under stress conditions and found significant differences for GCA and SCA effects. Parents Ib 1143 and Ib 1073 had positive GCA effects. Parents Ib 1155, Ib 1143 and Ib

1073 had positive GCA effects for plant tallness and seed yield. Ib 1073 x Ib 1143 and IB 1073 x Ib 1155 crosses had SCA effects for plant height and seed yield per plot. Altinbs and Tosun (1998) found that sorting the inbred lines on the basis of combining ability effects for seed index should be useful. Zia and Chaudhry (1980) reported that seed index was under control of dominant genes. Mahmood *et al.* (1990) reported that non-additive type of gene action in maize was responsible for grain weight. Yuan *et al.* (2003) evaluated parental lines and 25 cross combinations of corn. Seeds per row, thousand seed weight, rows per cob, seed yield and seed setting rate were studied. The variance of GCA for kernels per row was significantly higher than the SCA variance indicating additive gene effects.

Prakash and Ganguli (2004) studied combining ability for plant tallness and other physiological and agronomic parameters in corn inbred lines and their combinations. For plant stature non-additive gene action was observed. Rezaei *et al.* (2005) studied 10 early maturing inbred lines of maize and genetic components for seed yield and yield parameters were worked out. Significant differences were observed among genotypes for all parameters. Reciprocal, SCA and GCA effects were observed important. Additive effects were found responsible for plant height. Barati *et al.* (2004) worked out GCA and SCA of five inbred lines of maize and their crosses and found that genes were important with additive impact for thousand seed weight. Nigussie and Zellke (2001) conducted combined analysis of variance which showed that effects for GCA and genotypes were important for all parameters observed. For plant height, SCA mean squares were important. The magnitude of GCA was more than that of SCA depicting the significance of additive genes for plant height. Rana and Venod (2001) studied 10 parents and 45 hybrids of maize for days to maturity and reported that for this trait additive gene behaviour was significant. Vicente *et al.* (2001) evaluated maize parental inbred lines and their 36 hybrids for plant height and other traits. Additive gene effects were concerned in the development of plant height. Gribincea (2002) studied plant height in F<sub>1</sub> generation of maize diallel cross (7 x 7). He concluded that both gene effects were statistically significant for genetic control of plant tallness. Ahmad (2002) reported that additive as well as non additive gene effects were imperative for plant tallness in maize. Akbar *et al.* (2008) studied six maize genotypes and their combinations in diallal set to work out combining ability effects. It was inferenced that non-additive type of gene was statistically significant for ear leaf area, plant height, number of grains per plant, seed index, seed yield and grain setting percentage. It was reported that cell membrane thermo

stability percentage, growing degree days to anthesis, growing degree days for silking, anthesis silking difference, plant height, hundred grain weight and kernel yield per plant were under manage of non-additive type of gene behaviour. Days taken to maturity were observed under the influence of additive genes. Hussain (2009) conducted combining ability analysis for six maize inbred lines and their F1. He concluded that plant height, leaf area, total biomass, grain yield, harvest index, leaf temperature and stomatal size were managed by additive of genes. Grains per row, grain weight, relative water contents, cell membrane thermostability percentage and stomatal frequency were under influence of dominant type of gene activity.

Tabassum *et al.* (2008) made combining ability analysis for eight maize inbred lines by using method I Model II (Griffing, 1956) and reported that all traits studied were under control of non additive type of genes. They identified promising inbred lines which were best general combiners for plant height, number of grains per ear and grain yield per plant. They also identified promising corn hybrids which were high yielding both under normal and water stress conditions.

Akbar (2008) assessed gene action following Hayman (1954), Jinks (1954) and Whitehouse *et al.* (1958) in a 6×6 diallel for twenty-two traits pertaining to seedling, physiological and agronomic nature under two temperature regimes. Grain yield per plant and most of the traits studied were conditioned by over dominant type of gene action along with maternal effect as well as reciprocal effect except maternal effect under both the temperature conditions. Growing degree days to 50% maturity under both the temperature conditions and transpiration rate under normal temperature condition was observed under partial dominant type of gene action Reciprocal effects influenced the effects of additive, dominant or both types of genes. Tabassum. (2004) worked out gene action of a complete diallel of eight maize inbred lines adopting the procedure proposed by Hayman (1954), Jinks (1954) and Whitehouse *et al.* (1958). Analysis revealed that all the characters showed additive and dominant genetics effects for plant height, leaf area, 1000-grain weight and grain yield.

## Chapter III

### MATERIALS AND METHODS

The germplasm for the conduction of present studies was collected from various research organizations working on maize crop viz., Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, National Agriculture Research Centre, Islamabad, Maize and Millet Research Institute, Sahiwal. Material collected was checked in field before using in further crossing program. For this purpose seventy four inbred lines of diverse origin were sown in the experimental area of the university during summer 2006-07 for assessing uniformity and purity. Based upon morphological characters and distinct features fifty promising inbred lines were ear-marked and selfed to obtain seed for further breeding manipulations. Left of the inbred lines were discarded due to off type plants.

#### **3.1 Screening**

The selected inbred lines were screened for moisture stress condition in the greenhouse. Seeds were sown in polythene bags and arranged in C.R.D. with three replications. Two sets of experiment were arranged, one for normal irrigation and other for moisture stress condition. For this purpose measured quantity of sand was used in polythene bags to grow the seed. 0.5 kg of sand was filled in each polythene bag and two seeds were sown per bag. One irrigation was given to both the experiments just after sowing. Fifty ml of water was given to each bag and estimated quantity of water was applied to both of the sets. After seven days irrigation was given only to seedling under normal set. After fourteen days irrigation was given to both the sets and seedlings were uprooted for recording data. The roots were washed in fresh water to remove sand and the adhered water was removed with blotting paper. Five seedlings were observed from each entry and data were recorded for following traits.

##### **3.1.1. Dry Root Weight**

For recording dry root weight the seedling roots were detached and thereafter placed in the oven under 70°C for 72 hours and weighed in grams with an electronic balance. The dry root weight so obtained was further used to calculate root to shoot weight.

### **3.1.2. Dry Shoot Weight**

Dry shoot weight was recorded by detaching the shoots from the roots. Shoots were put in oven under temperature of 70°C for seventy two hours. Then the shoots were weighed with electronic balance.

Six inbred lines viz.F-192, F-110, S-42, F-189, Y-330and F-206 were selected on the basis of root/shoot ratio as parents for making cross combinations in a complete diallel set. These inbred lines had been derived from local maize population.

During summer 2008 the selected inbred lines were sown in the field for making their all possible crosses including reciprocals. For this purpose seed of each genotype was sown in a row of five meter long. Two seeds were dibbled per hole. The plant spacing was kept 25 cm and row spacing 75 cm. Thinning was done at seedling stage and only one seedling per hole was maintained. Uniform agronomic and cultural practices were applied. To avoid contamination, the shoots of plants to be used a female was covered with glycine bags (8” x 4”) before silk emergence. The tassels of the male plants were covered with kraft paper bags (14” x 11”) before anthesis. When silks emerged, they were pollinated accordingly with the help of camel hair brush. Pollens were collected in Petri dishes and then were applied on to silks with the brush. Shoots were pollinated twice on consecutive days to ensure required seed setting. After pollination, the shoots were rebagged with their respective glycine bags. Tassels were also rebagged with Kraft paper bags of respective plants. After each pollination the instruments were sterilized thoroughly. Each female plant was tagged carefully for proper identification. Ten plants from each parent were selfed to produce seeds to be used for evaluation. At maturity the ears from all the 36 genotypes were harvested and dried at constant moisture contents (15%). After drying properly, the seeds from each plant were shelled for planting under normal and moisture deficit conditions during the next growing season.

### **3.2 Evaluation of material**

During spring 2009, the six parental lines and their all possible crosses including reciprocals were planted in the field under normal and moisture deficit conditions using a R.C.B.D. in triplicate. Seeds were dibbled and thinned. Only one plant per hill was maintained. When the seedlings established stand, plant to plant distance was maintained as 25 cm and rows were kept 75 cm apart. The rows length was kept five meters.

Each entry comprised five rows per replication. Non-experimental area was sown at the borders to minimize the border effect. Irrigations were applied following Kirda *et al.* (2005). To the normal set, usual irrigations were applied and to other set, 50% of the total irrigations were applied. All other agronomic treatments and plant protection measures were applied uniformly. At maturity ten random plants were selected from each entry from all replications and the data for the following parameters were recorded.

### **3.2.1 Plant height (cm)**

It was recorded in centimeters with the help of a measuring rod from the field level to the base of the tassel. Ten plants from each entry were measured and the average plant height was scored.

### **3.2.2 Days to tasseling (N)**

These were recorded by counting the days from germination to fifty percent tasseling from each treatment per replication.

### **3.2.3 Days to silking (N)**

Days for silking were recorded by counting days from germination to fifty percent silking from each entry per replication.

### **3.2.4 Anthesis silking interval (A.S.I)**

Anthesis, silking interval was recorded by subtracting days to 50% tasseling from days taken to 50% silking and the average was computed.

### **3.2.5 Days to maturity (N)**

Days for maturity were calculated by counting the days from germination to physiological maturity. Physiological maturity was ascertained by disconnection of silks from seed, drying of husk covers and development of black layer.

### **3.2.6 Grain yield per plant (g)**

Grain yield per plant was recorded by shelling the grains from all the ears of selected plants and then weighing it in grams with electronic balance.

### **3.2.7 100 grain weight (g)**

The weight of 100 grains was measured in grams with an electronic balance. The grains were taken from the bulk produce of each plot in each replication per treatment.

### **3.2.8 Ear leaf area (cm<sup>2</sup>)**

Ear leaf area was recorded from the randomly selected plants from each entry. Leaf area was measured using the formula given by McKee (1964).

Leaf area = Leaf width (cm) x Leaf length (cm) x 0.75

### **3.2.9 Leaf temperature (°C)**

For recording leaf temperature infra-red thermometer was used. Leaf temperature was recorded between 13:00 – 15:00 timing. Three fully exposed leaves per plant were observed and the average worked out.

### 3.2.10 Relative water loss

For recording relative water loss, three leaf samples were taken from each entry in each replication. Fully exposed leaves were sampled for this purpose. A sample of 1 x 8 cm<sup>2</sup> was cut from the area between edge and the midrib. Samples were placed in pre-weighed test tubes in a thermos pot and were immediately taken to laboratory. Test tubes were weighed and fresh weight (FW) was calculated. Afterwards leaf samples were dried in an incubator at 28°C and 50% R H for six hours and then were weighed. For recording dry weight (DW), samples were dried in an oven for 24 hours at 70°C. Then these samples were weighed.

For calculating the relative water contents, formula suggested by Clarke (1987) was applied as under:

$$\text{Relative water loss \%} = \frac{(\text{FW} - \text{Weight after 6 hrs})}{(\text{FW} - \text{DW})} \times 100$$

Where FW = Fresh weight

DW = Dry weight

### 3.2.11 Cell membrane thermo stability (%)

Cell membrane thermostability (CMT) was estimated according to Ibrahim and James (2001). Upper and expanded leaves were removed and cut 0.75 centimeter diameter round with punch machine. These samples were washed with double ionized distilled water to remove surface adhered electrolytes. After washing well the leave samples were put in test tubes with 10 ml distilled water. Test tubes were put in water bath at 50°C for one hour. These were kept in controlled temperature room at 22°C for one night. The electrical conductivity of test tubes was measured next day with EC meter. The test tubes were then autoclaved at 120°C and 0.1 MPa for 15 minutes. The electrical conductivity of test tubes was again recorded and cell membrane thermo stability was calculated as under:



$$\text{Membrane thermo stability} = (1 - T_1/T_2) \times 100$$

Where

$T_1$  refers to electric conductivity reading after heat treatment

$T_2$  refers to electric conductivity reading after autoclave

### **3.2.12 Photosynthetic rate ( $\mu\text{mol}/\text{m}^2/\text{s}$ )**

Photosynthesis is a key phenomenon which depicts the status of growth and development of a plant. Photosynthetic rate was recorded with infra-red gas analyzer (IRGA) from the top third leaf of each plant.

## **3.3 STATISTICAL ANALYSIS**

The data for various morphological and physiological parameters were analyzed statistically as per method given by Steel *et al.* (1997). The parameters found significant were further analyzed.

### **3.3.1 Diallel Analysis**

The data were analyzed according to method proposed by Hayman (1954a), Jinks (1954) and Mather and Jinks (1982). Variation in diallel occurred due to differences among the genotypes. If maternal effects were not present, the differences among the genotypes yielded the additive variation. The most items in ANOVA were represented in simple terms. The “b” and “a” items tested significance of additive effect. If b was non-significant, a item was test of additive component. The mean dominance deviation of the cross from their mid parent value was tested by b<sup>2</sup>. The mean squares for c, d and block interactions were the estimates of variation due to environment, if the maternal effects were absent. Item c detects the maternal effects, if reciprocal crosses differ.

Gene action was worked out with the procedure proposed by Hayman (1954), Jinks (1954) and that of Whitehouse *et al.* (1958). Prior to the application of diallel cross analysis there were certain pre-requisites to follow:

1. Homozygous parents
2. Normal diploid segregations
3. No difference between reciprocal crosses
4. No linkage among genes affecting the characters
5. No multiple allelism
6. Lack of epistasis

Most of the assumptions were fulfilled and maternal effects were avoided by taking the averages of both the arrays. Crosses were arranged in arrays.  $W_r$  (covariance) of family means with non-recurrent parent and  $V_r$  (variance) of these means with an array was determined. From the variance and covariance the regression line was plotted. The position of this line was made according to the array spots. If the line starts from origin, it meant complete dominance. When it passed above the origin, it suggested the presence of partial dominance, and if touched the limiting parabola it suggested that no dominance and revealed additive nature of gene action. If it passed below the origin, it denoted the presence of over-dominance. The position of parental points indicated the dominance order; parents were located nearer to the origin which had more dominant genes. The parents with more recessive genes fell away from the origin, and those with similar frequencies of both genes occupied mid-points.

### **3.4 Limiting Parabola**

The limiting parabola was plotted as:

$$W_r^2 \text{ (covariance of genotypes)} = V_r \cdot V_p$$

using the individual variances ( $V_r$ ) and covariance ( $W_r$ ) values as their limiting points.

### **3.5 Test for the Validity of Assumptions of Diallel**

Assumption of Diallel cross analysis proposed by Hayman (1954b) were entertained while conducting the studies. To accomplish the assumption of no multiple allelism, absence of epistasis and independent gene allocation, two scaling tests were followed. From the mean diallel table, variances and co-variances were calculated. The regression on the variances of the co-variances was worked out. The regression coefficient was expected to be significantly different from zero but not from unity. Failure of this test meant that epistasis was present or genes were dependent in their activity. For the adequacy of the additive dominant model ANOVA of  $W_r + V_r$  and  $W_r - V_r$  was worked out as further test. If dominance was present  $W_r + v_r$  changed and  $W_r - V_r$  varied, epistasis was present. Failure of these tests invalidated the additive dominance model. If one test fulfilled the assumption, the model was partially adequate. For partially adequate models components of variance were worked out by scientists (Wilson *et al.*, 1978; Azhar and McNeilly, 1988).

### **3.6 Variation and Genetic Components**

Methods of estimating the genetic components of variation were suggested by Hayman (1954) and Mather and Jinks (1982). Singh and Choudhary (1985) gave the formulae for calculating the genetic components.

### 3.6.1 Variation due to Dominance Effect ( $H_1$ )

$$H_1 = V_p - 4W_r + 4V_r - 3n-2E/n$$

Where  $W_r$  = mean of covariances between parents and arrays

$V_r$  = mean of the variances

$N$  = number of parents

### 3.6.2 Additive Variation (D)

$$D = V_p - E$$

Where  $V_p$  = Variance of the parents

### 3.6.3 Variation due to dominance effect of genes correlated for gene distribution

$$H_2 = 4 V_r - 4 V_m - 2 E$$

Where  $V_m$  = Variance of the mean of arrays

### 3.6.4 Relative Frequency of Recessive and Dominant Genes

$$F = 2V_p - 4 W_r - 2 (n-2) E/n$$

The magnitude of sign of  $F$  depicted the relative frequency of recessive and dominant allele in the presence of unequal gene frequencies. Whenever the dominant alleles were more than recessive alleles  $F$  was positive.

### 3.6.5 Overall Dominance Effect of Hetrozygous Loci

$$h^2 = 4 (M_{Li} - M_{Lo})^2 - 4(n-1) E/n^2$$

Where  $(M_{Li} - M_{Lo})^2 = [1/n \times \{(G.T/n) - \sum \text{parental values}\}]^2$

G.T. = Grand total of all the observations

### 3.6.6 Environmental Variation (E)

$$E = \left[ \frac{\text{ErrorSS} + \text{Re } p\text{SS}}{\text{Errordf} + \text{Re } p\text{df}} \right] \div \text{No. of Re } p$$

Where, Error SS = error sum of square and

Rep. SS = replication sum of square in the analysis of variance

### 3.6.7 Average degree of dominance

$$\sqrt{H_1 / D}$$

$$3.6.8 \text{ Heritability (N.S)} = \frac{0.5D + 0.5H_1 + 0.5H_2 + 0.5F}{0.5D + 0.5H_1 + 0.25H_2 + 0.5F + E}$$

## 3.7 COMBINING ABILITY ANALYSIS

With the help of method I Model II (Griffing, 1956), combining ability were worked out. The genotypic variability in the material was splitted. S.S for these components were estimated as under:

$$\text{SS due to GCA} = (1/2n) \times \Sigma(Y_i + Y_j)^2 - (2/n^2) \times Y^2$$

$$\text{SS due to SCA} = (1/2) \times \Sigma \Sigma Y_{ij} x (Y_{ij} + Y_{ji}) - 1/2n \Sigma (Y_j + Y_i)^2 + (1/n^2) \times Y^2$$

$$\text{SS due to reciprocals} = (1/2) \Sigma \Sigma Y_{ij} + Y_{ji})^2$$

Where,

Y<sub>i</sub> & Y<sub>j</sub> = total of the ith and jth arrays in the mean table

Y<sub>..</sub> = grand total of the mean table

Y<sub>ij</sub> = mean value of the cross of ith parent with jth parent

Y<sub>ji</sub> = men values of the cross of jth parent with ith parent  
(reciprocal cross)

N = number of parents

### SS due to error

The error mean squares in the ANOVA were used after dividing with number of replications,

Thus, SS due to error = SS (error) in ANOVA/r

While, r = number of replications

With the values, analysis of variance for combining ability in method I model II was worked out given as follows

Source of variation	Degree of freedom	Sum of squares	Mean squares	F-value	Expected( mean squares)
GCA	(p-1)	Sg	Mg	Ng/Ms	$\sigma^2 e + 2(n-1)2/n \sigma^2 s + n \sigma^2 g$
SCA	P(p-1)/2	Ss	Ms	Ms/Me'	$\sigma^2 e + 2(n^2 - n + 1)/n^2 \sigma^2 s$
Reciprocal	P(p-1)/2	Sr	Mr	Mr/Me'	$\sigma^2 e + 2 \sigma^2 r$
Error	(r-1)(p2-1)	Se	Me'		$\sigma^2 e$

The estimation of variation was calculated as following:

$$\sigma^2_g = \frac{1}{2n} \left[ \frac{Mg - Me' + n(n-1)Ms}{n^2 - n - 1} \right]$$

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

$$\sigma^2_r = \frac{1}{2} (Mr - Me')$$

$$\sigma^2_e = Me'$$

Where  $\sigma^2_g$ , are the estimates of variance due to GCA,  $\sigma^2_s$  is due to SCA,  $\sigma^2_r$  is due to reciprocal effects and  $\sigma^2_e$  is due to environment.

SCA effects were estimated using the equation

$$g_i = \frac{1}{2n} (Yi. + Y.i) - \frac{1}{n^2} Y..$$

SCA effects were estimated using the equation:

$$S_{ij} = \frac{1}{Y} (Yij + Yji) - \frac{1}{2n} (Yi. + Y.i + Yj. + Y.j) + \frac{1}{n^2} Y..$$

Reciprocal effects were calculated by using the formula

$$r_{ij} = \frac{1}{2} (Yij - Yji)$$

Variance was worked out as following:

$$Var(g_i) = \frac{(n-1)}{2n^2} \sigma^2_e$$

$$Var(s_{ij}) = \frac{(n-1)^2}{2n^2} \sigma^2_e$$

$$Var(r_{ij}) = \frac{1}{2} \sigma^2_e$$

SE(standard errors) were worked out as given:

$$S.E.(g_i) = \sqrt{Var(g_i)}$$

$$S.E.(s_{ij}) = \sqrt{Var(s_{ij})}$$

$$S.E.(r_{ij}) = \sqrt{Var(r_{ij})}$$

## CHAPTER IV

### RESULTS AND DISCUSSION

#### **4.1 Analysis of variance**

Analysis of variance for 6 x 6 maize diallel cross under both the regimes (Table-4.1&4.2) depicted that all the traits viz., plant height, days taken to tasseling, days taken to silking, anthesis silking interval, days to maturity, grain yield per plant 100-grain weight, ear leaf area, leaf temperature, relative water loss, cell membrane, thermostability and photosynthetic rate were highly significant. Further analysis for genetic component was conducted for all the parameters.

#### **4.2 Scaling Test**

Significant data were put to scaling test to determine its validity for assumption of diallel analysis (Hayman, 1954a) and additive dominance model. Table 4.3A& 4.3B represents the data under both the normal and moisture deficit conditions. Regression analysis and ANOVA of arrays were worked out. According to the Table 4.3, the present data showed that plant height, days to anthesis, days to silking, days to maturity, ear leaf area, leaf temperature relative water loss is partially adequate under normal conditions. While grain yield per plant, 1000-grain weight, cell membrane, thermo-stability and photosynthetic rate were fully adequate. Under moisture deficit conditions plant height, days to tasseling, days to silking, anthesis silking interval, days to maturity, 100-grain weight, leaf temperature, relative water loss and photosynthetic rate were partially adequate. Grain yield per plant and cell membrane thermo-stability is fully adequate. Inadequate traits were not further subjected to genetic analysis (Hayman, 1954). Adequacy tests depicted that there was different behaviour of traits under different moisture conditions as reported by Jana (1975) and Tabassum (2004).

#### **4.3 DIALLEL ANALYSIS**

##### **1 Plant height (cm)**

This trait was partially adequate for additive dominance model under both the conditions. It was depicted that both items “a” and “b” were significant which indicated the importance of both additive and dominant genetic effects, respectively (Table 4.5). Item  $b_3$  was significant which depicted the importance of specific gene effects. Values of  $b_1$  and  $b_2$  were non-significant indicating no directional dominance and asymmetrical

**Table 4.1 Mean squares for various parameters in *Zea mays* L. of 6 x 6 diallel cross under normal condition**

Characters	Mean Squares		
	Replication d.f. 2	Genotype d.f. 35	Error d.f. 70
Plant height	339.7	954.30**	323.9
Days to tasseling	1.22	34.45**	30.99
Days to silking	1.52	30.15**	19.14
Anthesis silking interval	0.06	0.66**	0.007
Days to maturity	137.4	11.95**	110.6
Grain yield per plant	0.62	664.79**	28.91
100-grain weight	1.59	25.11**	0.86
Ear leaf area	340.2	1730.00**	273.4
Leaf Temperature	1.21	10.19**	3.32
Relative water loss	10.36	107.26**	32.63
Cell membrane stability	3.27	81.84**	14.85
Leaf photosynthetic rate	12.62	21.93**	0.77

**Table 4.2 Mean squares for various parameters in *Zea mays* L. of 6 x 6 diallel cross under moisture deficit condition**

Characters	Mean Squares		
	Replication d.f. 2	Genotype d.f. 35	Error d.f. 70
Plant height	100.5	848.8**	173.00
Days to tasseling	23.57	34.48**	11.38
Days to silking	5.46	30.44**	25.35
Anthesis silking interval	0.01	2.62**	0.07
Days to maturity	439.16	96.61**	84.23
Grain yield per plant	4.47	456.62**	30.87
100-grain weight	2.63	13.47**	2.28
Ear leaf area	34.70	1032.2**	101.00
Leaf Temperature	25.55	11.48**	7.36
Relative water loss	8.43	95.55**	13.01
Cell membrane stability	0.10	80.08**	13.16
Leaf photosynthetic rate	2.63	14.09**	0.86



**Table: 4.3 Tests for adequacy of additive-dominance model for various parameters in *Zea mays* L. under normal condition**

Traits	Regression analysis		Analysis of variances of arrays		Remarks
	b <sub>0</sub>	b <sub>1</sub>	W <sub>r</sub> + V <sub>r</sub>	W <sub>r</sub> - V <sub>r</sub>	
<b>Plant Height</b>	4.36*	1.13 <sup>NS</sup>	1.64 <sup>NS</sup>	1.63 <sup>NS</sup>	Partially adequate
<b>Days to Tasseling</b>	4.69*	0.69 <sup>NS</sup>	0.66 <sup>NS</sup>	1.48 <sup>NS</sup>	Partially adequate
<b>Days to Silking</b>	5.39*	0.92 <sup>NS</sup>	0.56 <sup>NS</sup>	0.68 <sup>NS</sup>	Partially adequate
<b>Anthesis-Silking Interval</b>	0.98 <sup>ns</sup>	0.71 <sup>NS</sup>	15.22**	12.79 <sup>NS</sup>	Model is inadequate
<b>Days to Maturity</b>	6.96*	1.44 <sup>NS</sup>	0.055 <sup>NS</sup>	1.26 <sup>NS</sup>	Partially adequate
<b>Grain yield per plant</b>	5.96*	0.66 <sup>NS</sup>	11.66**	4.53*	Model is Fully adequate
<b>100 Grain Weight</b>	9.55*	0.017 <sup>NS</sup>	26.49**	1.34 <sup>NS</sup>	Model is fully adequate
<b>Ear leaf Area</b>	19.80*	-0.29 <sup>NS</sup>	1.44 <sup>NS</sup>	1.18 <sup>NS</sup>	Partially adequate
<b>Leaf temperature</b>	7.89*	0.86 <sup>NS</sup>	2.15 <sup>NS</sup>	0.50 <sup>NS</sup>	Partially adequate
<b>Relative water loss</b>	7.38*	1.94 <sup>NS</sup>	1.12 <sup>NS</sup>	0.28 <sup>NS</sup>	Partially adequate
<b>Cell membrane thermo stability</b>	11.59*	0.45 <sup>NS</sup>	6.60*	0.59 <sup>NS</sup>	Model is fully adequate
<b>Photosynthetic Rate</b>	10.78*	-0.11 <sup>NS</sup>	6.77**	0.28 <sup>NS</sup>	Model is fully adequate

**Table-: 4.4 Tests for adequacy of additive-dominance model for various parameters of *Zea mays* L. under moisture deficit conditions.**

Parameters	Regression analysis		ANOVA of arrays		Remarks
	b <sub>0</sub>	b <sub>1</sub>	Wr + Vr	Wr - Vr	
<b>Plant Height</b>	4.03*	-0.23 <sup>NS</sup>	2.24 <sup>NS</sup>	1.09 <sup>NS</sup>	Partially adequate
<b>Days Taken to Tesseling</b>	4.43*	1.57 <sup>NS</sup>	1.68 <sup>NS</sup>	0.74 <sup>NS</sup>	Partially adequate
<b>Days Taken to Silking</b>	s6.19*	1.07 <sup>NS</sup>	0.62 <sup>ns</sup>	1.45 <sup>NS</sup>	Partially adequate
<b>Anthesis-Silking Interval</b>	27.73*	-1.69 <sup>NS</sup>	3.16 <sup>ns</sup>	0.005 <sup>NS</sup>	Partially adequate
<b>Days Taken to Maturity</b>	11.08*	1.59 <sup>NS</sup>	0.12 <sup>ns</sup>	0.75 <sup>NS</sup>	Partially adequate
<b>Grain yield per plant</b>	4.28*	0.49 <sup>NS</sup>	13.98**	4.43*	Fully adequate
<b>100 Grain Weight</b>	6.20*	-0.28 <sup>NS</sup>	1.29 <sup>NS</sup>	1.39 <sup>NS</sup>	Model is partially adequate
<b>Cob Leaf Area</b>	15.24*	0.16 <sup>NS</sup>	12.39**	2.12 <sup>NS</sup>	Fully adequate
<b>Leaf Temperature</b>	6.75*	1.75 <sup>NS</sup>	0.93 <sup>NS</sup>	1.24 <sup>NS</sup>	Partially adequate
<b>Relative water loss</b>	7.81*	0.86 <sup>NS</sup>	0.98 <sup>NS</sup>	0.39 <sup>NS</sup>	Partially adequate
<b>Cell Membrane Thermo stability</b>	8.13*	-0.26 <sup>NS</sup>	18.63**	0.69 <sup>NS</sup>	Fully adequate
<b>Photosynthetic Rate</b>	7.54*	1.05 <sup>NS</sup>	2.21 <sup>NS</sup>	0.19 <sup>NS</sup>	Partially adequate

**Table: 4.5-A ANOVA table of 6 x 6 diallel in *Zea mays* L. for plant height under normal condition**

Source	d.f.	M.S.	F. Value	Retesting Against _____	
				c	d
A	5	4752.63	15.4276**	-	-
b <sub>1</sub>	1	0.40	0.0089 <sup>NS</sup>		
b <sub>2</sub>	5	149.15	1.0806 <sup>NS</sup>		
b <sub>3</sub>	9	890.35	2.3850* <sup>NS</sup>		
b	15	583.95	2.1391* <sup>NS</sup>		
c	5	19.27	0.0425 <sup>NS</sup>		
d	10	78.22	0.2278 <sup>NS</sup>		
Total	35	954.31	2.9464		
a x blocks	10	308.06			
b <sub>1</sub> x blocks	2	45.02			
b <sub>2</sub> x blocks	10	138.02			
b <sub>3</sub> x blocks	18	373.31			
b x blocks	30	273.00			
c x blocks	10	453.47			
d x blocks	20	343.37			
Total x blocks	70	323.89			

**Table: 4.5-B ANOVA table of 6 x 6 diallel in *Zea mays* L for plant height under moisture deficit condition**

Source	d.f.	M.S.	F. Value	Retesting Against	
				c	d
a	5	4055.56	49.3394**		
b <sub>1</sub>	1	56.24	0.1193 <sup>NS</sup>		
b <sub>2</sub>	5	100.86	0.5371 <sup>NS</sup>		
b <sub>3</sub>	9	716.90	4.8009**		
b	15	467.51	2.5461**		
b <sub>1</sub>	5	241.45	0.7029 <sup>NS</sup>		
d	10	121.17	1.0324 <sup>NS</sup>		
Total	35	848.84	4.9054		
a x blocks	10	82.20			
b <sub>1</sub> x blocks	2	471.43			
b <sub>2</sub> x blocks	10	187.78			
b <sub>3</sub> x blocks	18	149.33			
b x blocks	30	183.62			
c x blocks	10	343.48			
d x blocks	20	117.37			
Total x blocks	70	173.04			

**Table-:4.6 Components of variation for plant height.****A-Under normal condition**

<b>Components</b>	<b>Estimates</b>
E	117.93* ± 18.48
D	591.43* ± 48.90
H <sub>1</sub>	107.94 ± 124.14
H <sub>2</sub>	153.43 ± 110.90
F	57.19 ± 119.47
h <sup>2</sup>	-65.45 ± 74.64
√H <sub>1</sub> /D	0.43
Heritability (n.s)	0.61

**B-Under moisture deficit condition**

<b>Components</b>	<b>Estimates</b>
E	62.19*± 14.15
D	584.48* ±37.45
H <sub>1</sub>	168.24 ± 95.07
H <sub>2</sub>	187.29* ± 84.93
F	135.55 ± 91.49
h <sup>2</sup>	-24.14 ± 57.16
√H <sub>1</sub> /D	0.54
Heritability (n.s)	0.66

Fig. 4.1 A. Graphical representation of plant height under normal condition

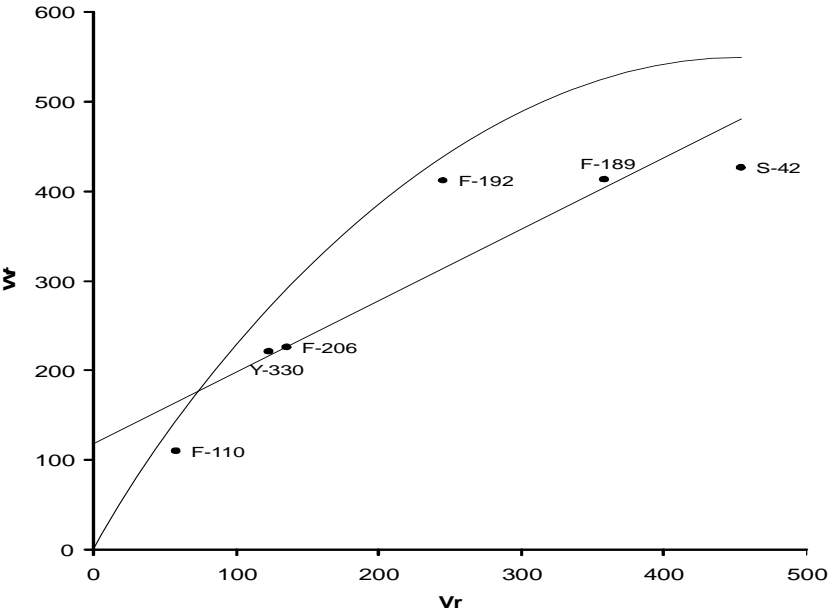
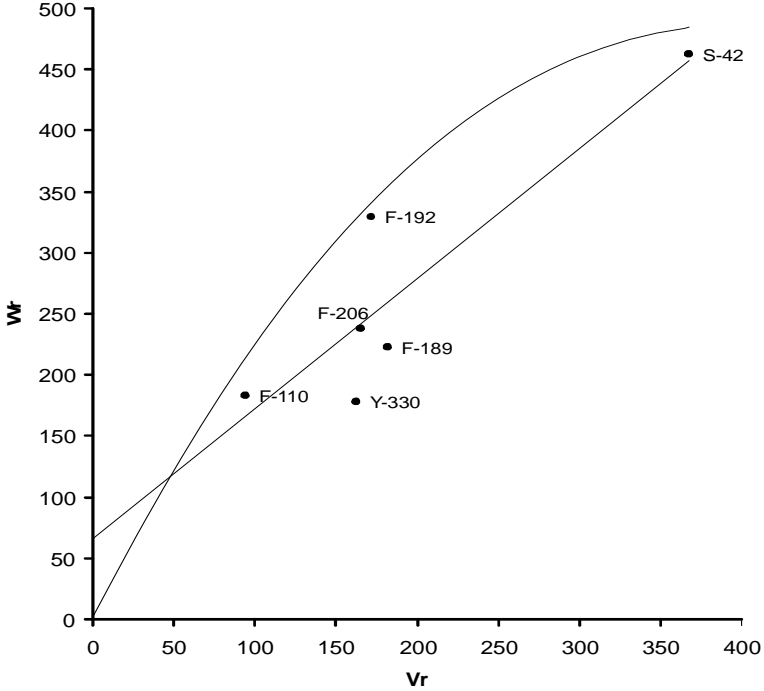


Fig. 4.1 B. Graphical representation of plant height under moisture deficit condition



gene distribution. Non-significant values of c and d indicated the absence of maternal and reciprocal effects.

Under moisture deficit condition (Table 4.5 B) for items “a” and “b” were significant depicting the importance of additive and dominant genetic effects, respectively. Non-significance of  $b_1$  depicted the absence of directional dominance for this trait. Item  $b_2$  was also non-significant which revealed the symmetrical gene distribution. Specific gene effects were reflected by the significant values of  $b_3$ . Non-significant values of c and d depicted the absence of maternal and reciprocal effects, respectively.

Genetic components of variation were worked out according to Hayman (1954b) and are given in Table 4.6 b. Significant values of D under both conditions depicted the importance of additive genetic effects. Environmental variation was also significant under both the conditions. In case of moisture deficit condition  $H_2$  was significant while  $H_1$  was non-significant. Unequal values of  $H_1$  and  $H_2$  indicated the different distribution of dominant genes.

Heritability in narrow sense under both conditions was more than 50% and displayed that most of genetic variation transmitted from the parents was of the additive nature under both the environments. Degree of dominance indicated the involvement of additive gene action for inheritance of this trait.

Graphical presentation of the data (Fig. 4.1a and 4.1b) depicted the partial dominance type of gene action for plant height under normal and moisture deficit conditions. This additive type of gene action for plant height was also reported by Bukhari (1986), Tabassum (1989), Mahajan and Khera (1991) Perez *et al.* (1996) and Hussain (2009). Sharma and Bhalla (1990) reported dominance type of gene action while Siddiqui (1988), Shakil (1992), Shabbir and Saleem (2002) and Akbar (2008) reported over dominance type of gene action for plant height.

The intercept of the regression line was positive under both conditions (Fig. 4.1 and 4.2). Parent F-110 possessed maximum dominant genes for plant height followed by Y-330 while S-42 had maximum recessive genes for this trait. The remaining genotypes behaved intermediately.

#### **4.3.2 Days to tasseling**

Days to tasseling were partially adequate under both the conditions. As depicted by analysis of variance for this trait (Table 4.7a, b) significant value of a revealed that additive effects were under both normal and moisture deficit conditions. Under normal

**Table: 4.7-A ANOVA table of 6 x 6 diallel in *Zea mays* L for days to tasseling under normal condition**

Source	d.f.	M.S.	F. Value	Retesting Against	
				c	d
a	5	178.26	6.79819 <sup>NS</sup>		
b <sub>1</sub>	1	5.436	0.12872 <sup>NS</sup>		
b <sub>2</sub>	5	11.867	0.16760 <sup>NS</sup>		
b <sub>3</sub>	9	18.538	0.07140 <sup>NS</sup>		
b	15	15.441	0.48577 <sup>NS</sup>		
c	5	6.399	0.44316 <sup>NS</sup>		
d	10	8.637	0.21341 <sup>NS</sup>		
Total	35	35.446	1.14370		
a x blocks	10	26.202			
b <sub>1</sub> x blocks	2	42.231			
b <sub>2</sub> x blocks	10	70.805			
b <sub>3</sub> x blocks	18	8.949			
b x blocks	30	31.787			
c x blocks	10	14.440			
d x blocks	20	40.473			
Total x blocks	70	30.992			



**Table: 4.7-B ANOVA table of 6 x 6 diallel in *Zea mays* L for days to tasseling under moisture deficit condition**

Source	d.f.	M.S.	F. Value	Retesting Against _____	
				c	d
a	5	177.326	37.7316**	6,6260**	
b <sub>1</sub>	1	0.165	0.0206 <sup>NS</sup>		
b <sub>2</sub>	5	3.085	0.1591 <sup>NS</sup>		
b <sub>3</sub>	9	12.262	0.9433 <sup>NS</sup>		
b	15	8.396	0.5674 <sup>NS</sup>		
c	5	26.762	5.9950**		
d	10	6.032	0.4617 <sup>NS</sup>		
Total	35	34.477	3.0287		
a x blocks	10	4.700			
b <sub>1</sub> x blocks	2	8.005			
b <sub>2</sub> x blocks	10	19.392			
b <sub>3</sub> x blocks	18	12.999			
b x blocks	30	14.797			
c x blocks	10	4.464			
d x blocks	20	13.065			
Total x blocks	70	11.384			

**Table-:4.8 Components of variation for days to tasseling**

**A- Under normal condition**

<b>Components</b>	<b>Estimates</b>
E	10.97*±0.45
D	9.70* ±1.19
H <sub>1</sub>	-16.32* ±3.03
H <sub>2</sub>	-11.65* ±2.71
F	1.11*±2.92
h <sup>2</sup>	-5.09* ±1.82
√H <sub>1</sub> /D	1.30
Heritability (n.s)	0.50

**B-Under moisture deficit condition**

<b>Components</b>	<b>Estimates</b>
E	4.268*±0.57
D	16.30* ±1.51
H <sub>1</sub>	-5.09± 3.85
H <sub>2</sub>	-2.93±3.43
F	-4.14±3.70
h <sup>2</sup>	-2.34 ±2.31
√H <sub>1</sub> /D	0.56
Heritability (n.s)	0.72

Fig. 4.2 A. Graphical representation of days to tasseling under normal condition

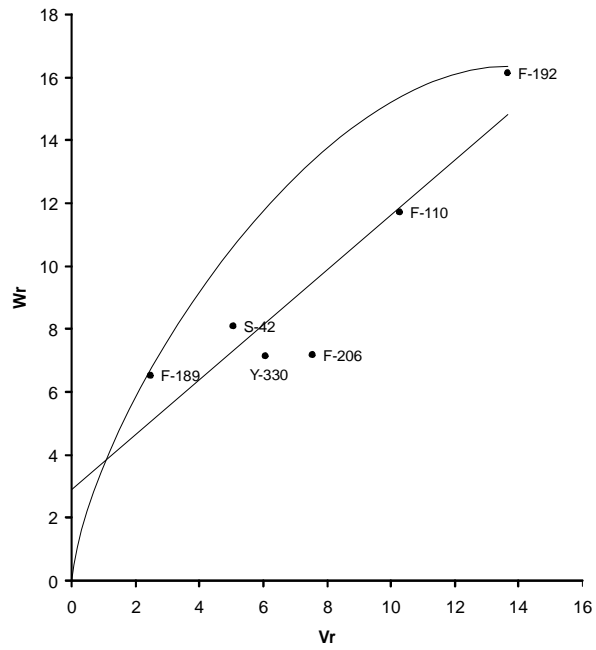
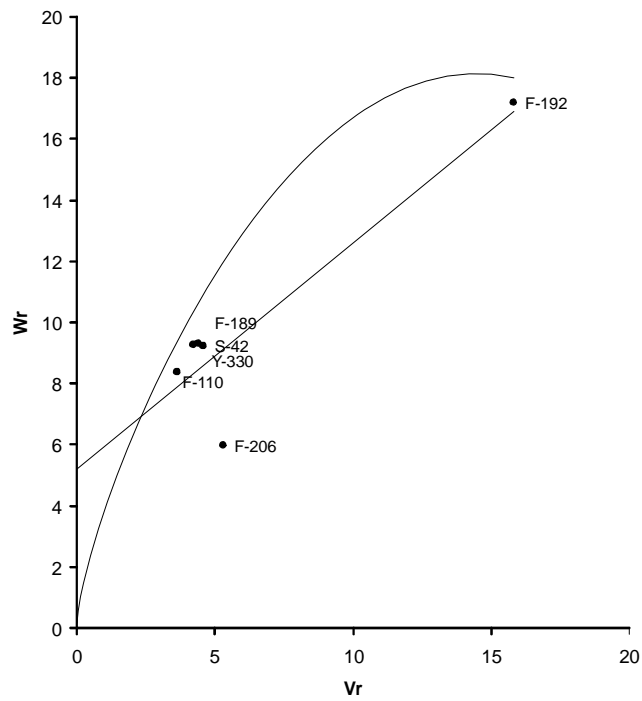


Fig. 4.2 B. Graphical representation of days to tasseling under moisture deficit condition



condition,  $b_3$  value was significant which reflected that specific gene effects were present. Non-significant values of  $c$  and  $d$  were indication of absence of maternal and reciprocal effects, respectively. Item  $b_1$ ,  $b_2$  and  $b$  were non-significant, so dominant gene effects were not present. Dominance gene distribution was in symmetrical manner and there was no directional dominance of genes.

Under moisture deficit conditions  $b$ ,  $b_1$ ,  $b_2$  and  $b_3$  values were non-significant which depicted that there were no dominance gene effects; directional dominance of genes was absent. Dominance gene distribution was in symmetrical manner and there was no specific gene effect. Significant value of  $c$  depicted that there was involvement of maternal effects. Non-significant values of  $d$  revealed the absence of reciprocal effects. Retesting of  $a$  value against  $c$  revealed that again it was significant and maternal effects did not influence this component.

Genetic component ( $D$  and  $H$ ) were significant under normal conditions suggesting that days taken to tasseling was under the control of both additive and dominant genetic effects (Table 4.8). Unequal values of  $H_1$  and  $H_2$  reflected different distribution of dominant and recessive genes. The value of  $F$  was positive and significant suggesting that positive and dominant genes were more frequent. Significant value of  $h^2$  indicated significant dominance effect due to heterozygous loci. Component  $E$  was significant which revealed that role of environment was significant for this trait.

Under moisture deficit conditions  $D$  was significant for days taken to tasseling which revealed that additive effects were important for the control of this trait. Unequal values of  $H_1$  and  $H_2$  indicated dissimilar distribution of positive and negative genes. Non-significant value of  $F$  indicated the lesser frequency of dominant genes. Non-significant value of  $h^2$  indicated that heterozygous loci had not important role in the expression of this trait. The value of  $\bar{m}$  mean degree of dominance was less than 1 (0.56) which revealed the additive type of gene action for this trait.

Graphical presentation revealed that additive type of gene action with partial dominance was involved (Fig. 4.3 A and B). Under normal conditions graph showed that inbred line F-189 carried maximum dominant genes for this trait and F-192 carried maximum recessive genes. Under moisture stress conditions F-206 had maximum dominant and F192 had maximum recessive genes. The results are in accordance with Zia and Chaudhry (1980) and Satyanrayana (1995) who found days to tasseling under control of partially dominant gene effects. Ramamurthy (1980), Saeed (1998), Setty (1975) and Tabassun (1989) revealed that this trait was under control of additive type of gene action.

Sharma and Bhalla (1990) reported dominant type of gene action for this trait. Karim (1979), Siddiqui (1988) Saleem *et al.* (2002) and Akbar (2008) found this trait under control of over-dominance type of gene action. Results may vary from breeding material to material or due to interaction of genes with the environment.

#### 4.3.3 Days taken to silking

As given in Table 4.9 A and B, days taken to silking is under control of additive type of gene action because value of *a* under both the conditions was significant. Non-significant values of *b*, *b*<sub>1</sub>, *b*<sub>2</sub> and *b*<sub>3</sub> depicted that there was no dominance type of gene action, directional dominance was absent, gene distribution was symmetrical and absence of specific gene effects. Values of *c* and *d* under both conditions were non-significant. This was evident from these values that there were no maternal and reciprocal effects.

Genetic component of variation were worked out for days taken to silking and are presented in Table 4.10A and B. Under normal conditions *D* and *H* values were significant which indicated the trait under control of additive and dominance type of gene action. Unequal values of *H*<sub>1</sub> and *H*<sub>2</sub> depicted the different distribution of dominant genes. Significant value of *h*<sup>2</sup> indicated the important effect of heterozygous loci for days taken to silking under moisture deficit conditions; however this value was non-significant under normal conditions. Negative and significant value of *F* under normal condition depicted the frequency of negative genes in parents. Degree of dominance revealed the involvement of additive gene action for inheritance of this trait. Heritability estimates in narrow sense under both conditions revealed that major portion of variation was transmitted towards progenies.

The results are in accordance with Naved (1979) and Zia and Chaudhry (1980). While Dhillon *et al.* (1976), Karim (1979), Siddiqui (1988), Saleem *et al.* (2002) and Akbar (2008) reported this trait to be under control of over-dominance type of gene action. Setty (1975), Khalid (1979), Bukhari (1986), Tabassum (1989), Saeed (1998) and Reddy (2004) declared this trait under the control of additive type of gene action. Sharma and Bhala (1990) found this trait under the control of dominance type of gene action.

Graph 4.3 A regarding days taken to silking under normal conditions showed that maximum dominant genes possessed by parent Y-330 and maximum recessive genes by F-192. Under moisture deficit condition (Fig 4.3 B) maximum dominant genes were possessed by F-189 and maximum recessive by F-192.

**Table: 4.9-A ANOVA table of 6 x 6 diallel in *Zea mays* L for days to silking under normal condition**

Source	d.f.	M.S.	F. Value	Retesting Against	
				c	d
a	5	159.728	14.2388**		
b <sub>1</sub>	1	6.676	0.3382 <sup>NS</sup>		
b <sub>2</sub>	5	6.194	0.2407 <sup>NS</sup>		
b <sub>3</sub>	9	11.043	1.4410 <sup>NS</sup>		
b	15	9.135	0.6303 <sup>NS</sup>		
c	5	3.854	0.3597 <sup>NS</sup>		
d	10	10.027	0.2925 <sup>NS</sup>		
Total	35	30.149	1.5750		
a x blocks	10	11.218			
b <sub>1</sub> x blocks	2	19.740			
b <sub>2</sub> x blocks	10	25.738			
b <sub>3</sub> x blocks	18	7.663			
b x blocks	30	14.493			
c x blocks	10	10.746			
d x blocks	20	34.275			
Total x blocks	70	19.142			

**Table: 4.9-B ANOVA table of 6 x 6 diallel in *Zea mays* L for days to silking under moisture deficit condition**

Source	d.f.	M.S.	F. Value	Retesting Against	
				c	d
a	5	157.610	5.10974**		
b <sub>1</sub>	1	4.169	0.89774 <sup>NS</sup>		
b <sub>2</sub>	5	4.739	0.08622 <sup>NS</sup>		
b <sub>3</sub>	9	19.668	0.68335 <sup>NS</sup>		
b	15	8.259	0.29497 <sup>NS</sup>		
c	5	4.619	0.31340 <sup>NS</sup>		
d	10	13.033	0.54482 <sup>NS</sup>		
Total	35	30439	1.20093		
a x blocks	10	30.845			
b <sub>1</sub> x blocks	2	4.644			
b <sub>2</sub> x blocks	10	54.965			
b <sub>3</sub> x blocks	18	15.612			
b x blocks	30	27.998			
c x blocks	10	14.739			
d x blocks	20	23.921			
Total x blocks	70	25.346			

**Table-:4.10 Components of variation for days to silking.**

**A- Under normal condition**

<b>Components</b>	<b>Estimates</b>
E	6.78*±0.35
D	13.52* ±0.92
H <sub>1</sub>	-10.62*±2.34
H <sub>2</sub>	-7.47*± 2.09
F	-5.11*±2.25
h <sup>2</sup>	-2.53± 1.41
√H <sub>1</sub> /D	0.89
Heritability (ns)	0.61

**B-Under moisture deficit condition**

<b>Components</b>	<b>Estimates</b>
E	9.02* ± 0.37
D	16.08*±0.98
H <sub>1</sub>	-17.48*±2.48
H <sub>2</sub>	-12.53* ±2.22
F	-3.38 ± 2.39
h <sup>2</sup>	-4.24*± 1.49
√H <sub>1</sub> /D	1.04
Heritability (ns)	0.55



Fig. 4.3 A. Graphical representation of days to silking under normal condition

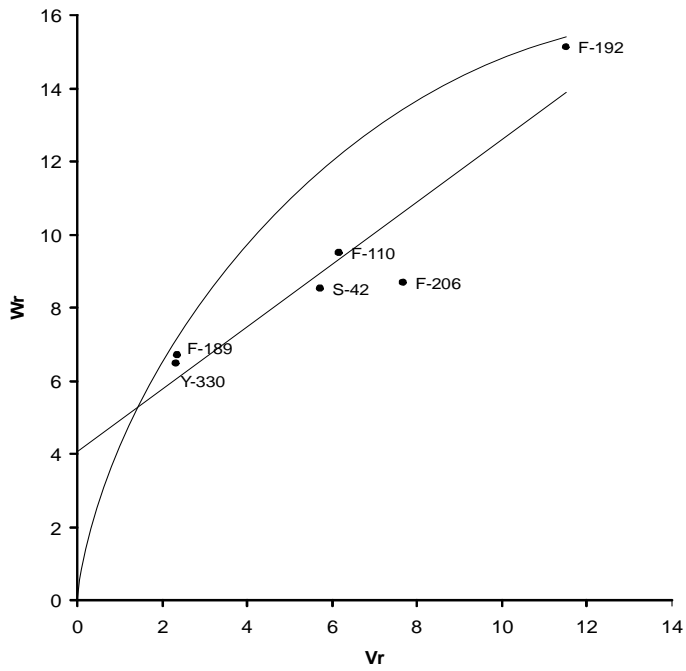
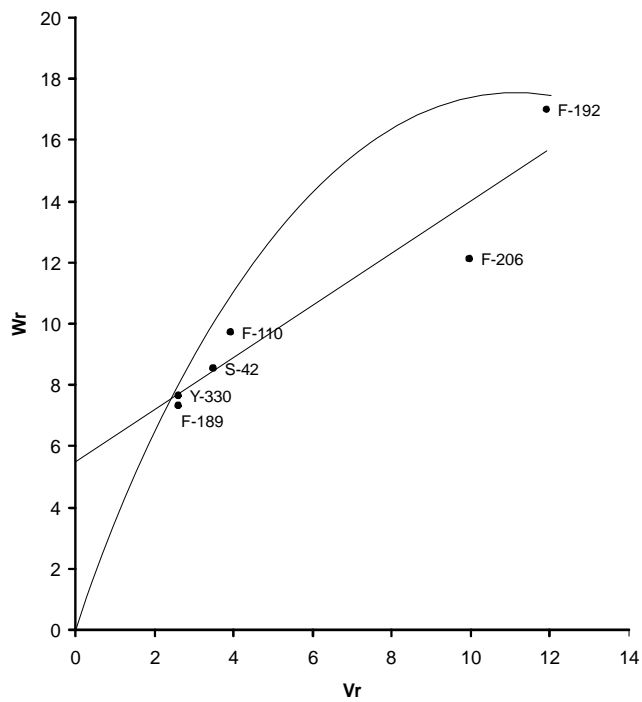


Fig. 4.3 B. Graphical representation of days to silking under moisture deficit condition



#### **4.3.4 Anthesis silking interval**

Additive dominance model for anthesis silking interval under normal conditions was found inadequate (Table 4.3). Therefore further genetic analysis was not performed (Hayman, 1954 a,b). However under moisture deficit conditions model was partially fit for this trait and thereby further genetic analysis was conducted. According to analysis of variance (Table 4.11) a and b components were significant suggesting the presence of both additive and dominant genetic effects, respectively. Significant variation due to  $b_3$  indicated the presence of important specific gene effects. Significant value of c revealed the presence of maternal effects. Importance of reciprocal effects was depicted by significant value of d. This required retesting of a, b and  $b_3$  items against c and d. After retesting of values of against c, it remained unchanged and still was significant. This depicted that there was no influence of maternal effects on a. Retesting of b and  $b_3$  values against d revealed that reciprocal effects influenced the values of b and  $b_3$  and these values turned to non-significant.

Regarding the components of variation for anthesis silking interval under moisture deficit conditions, it was observed (Table 4.12) that D and H ( $H_1$ ,  $H_2$ ) values were significant which revealed that there were additive as well as dominant genetic effects. Magnitude of D was higher than that of  $H_1$  which indicated the preponderance of additive model of gene action for this trait under moisture deficit conditions. Almost equal values of  $H_1$  and  $H_2$  displayed the similar distribution of dominant genes. Non-significant value of  $h^2$  indicated the absence of heterozygous loci effect. Mean degree of dominance ( $H_1/D$ )<sup>0.5</sup> was less than 1 (0.22) and revealed the partial dominance type of gene action. Significant value of E indicated the effect of environment in expression of the trait. High estimates of heritability in narrow sense (0.95) were observed for this trait. Graphical presentation (Fig. 4.4) also revealed the involvement of partial dominance for controlling the trait. Ahmad (2002) also found the similar results. Graph (Fig. 4.4) showed that inbred line F-110 had maximum dominant genes and F192 had maximum recessive genes.

#### **4.3.5 Days to maturity**

Additive dominance model was partially fit for days to maturity under both the conditions. Analysis of variance table (Table 4.13) revealed that under both the conditions a item was significant which indicated the importance of additive genetic effects. Non-significant value of b and  $b_1$  indicated the absence of dominance and directional dominance. Item  $b_2$  and  $b_3$  were also non-significant which indicated the symmetrical distribution of genes among the parents and absence of specific gene effects, respectively.

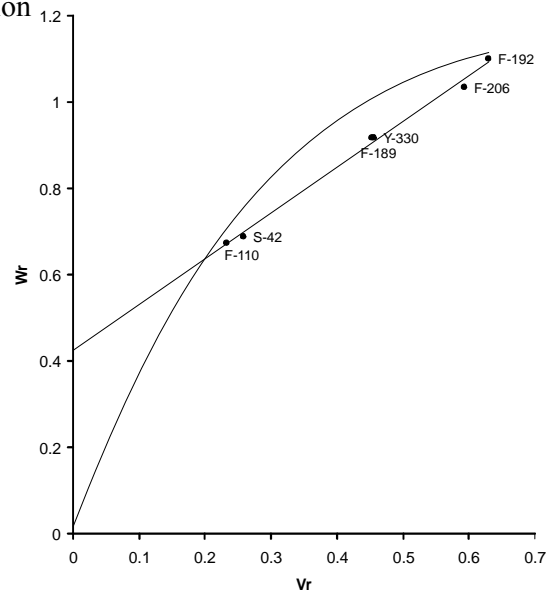
**Table: 4.11 ANOVA table of 6 x 6 diallel in *Zea mays* L for anthesis silking interval under moisture deficit conditions**

Source	d.f.	M.S.	F. Value	Retesting Against	
				c	d
a	5	14.5977	139.956**	28.9464**	
b <sub>1</sub>	1	0.1537	2.806 <sup>NS</sup>		
b <sub>2</sub>	5	0.1637	2.231 <sup>NS</sup>		
b <sub>3</sub>	9	0.2080	2.341*		0.1569 <sup>NS</sup>
b	15	0.1897	2.329**		0.1431 <sup>NS</sup>
c	5	0.5043	19.581**		
d	10	1.3257	18.797**		
Total	35	2.6175	35.547		
a x blocks	10	0.1043			
b <sub>1</sub> x blocks	2	0.0548			
b <sub>2</sub> x blocks	10	0.0734			
b <sub>3</sub> x blocks	18	0.0889			
b x blocks	30	0.0814			
c x blocks	10	0.0258			
d x blocks	20	0.0705			
Total x blocks	70	0.0736			

**Table-4.12 Components of variation for anthesis silking interval under moisture deficit condition**

Components	Estimates
E	0.026*±0.0047
D	1.94*±0.012
H <sub>1</sub>	0.092*±0.031
H <sub>2</sub>	0.073*±0.028
F	0.35*±0.03
h <sup>2</sup>	0.014±0.019
√H <sub>1</sub> /D	0.22
Heritability (n.s)	0.95

**Fig. 4.4 Graphical representation of anthesis silking interval under moisture deficit condition**



**Table: 4.13-A ANOVA table of 6 x 6 diallel in *Zea mays* L for days to maturity under normal condition**

Source	d.f.	M.S.	F. Value	Retesting Against	
				c	d
a	5	763.295**	24.8292**		
b <sub>1</sub>	1	0.018	0.0000 <sup>NS</sup>		
b <sub>2</sub>	5	8.076	0.0797 <sup>NS</sup>		
b <sub>3</sub>	9	22.601	0.2525 <sup>NS</sup>		
b	15	16.254	0.1433 <sup>NS</sup>		
c	5	9.259	0.1118 <sup>NS</sup>		
d	10	7.646	0.0477 <sup>NS</sup>		
Total	35	119.515	1.008		
a x blocks	10	30.742			
b <sub>1</sub> x blocks	2	389.030			
b <sub>2</sub> x blocks	10	101.329			
b <sub>3</sub> x blocks	18	89.509			
b x blocks	30	113.417			
c x blocks	10	82.795			
d x blocks	20	160.229			
Total x blocks	70	110.578			

**Table: 4.13-B ANOVA table of 6 x 6 diallel in *Zea mays* L for days to maturity under moisture deficit condition**

Source	d.f.	M.S.	F. Value	Retesting Against _____	
				c	d
a	5	557.289	4.47632**		
b <sub>1</sub>	1	1.836	0.04134 <sup>NS</sup>		
b <sub>2</sub>	5	5.572	0.14417 <sup>NS</sup>		
b <sub>3</sub>	9	25.096	0.39963 <sup>NS</sup>		
b	15	17.037	31.832 <sup>NS</sup>		
c	5	43.357	47.551 <sup>NS</sup>		
d	10	12.240	0.11472 <sup>NS</sup>		
Total	35	96.606	1.14687		
a x blocks	10	124.497			
b <sub>1</sub> x blocks	2	44.421			
b <sub>2</sub> x blocks	10	38.649			
b <sub>3</sub> x blocks	18	62.798			
b x blocks	30	53.523			
c x blocks	10	91.181			
d x blocks	20	106.695			
Total x blocks	70	84.234			

**Table-:4.14 Components of variation for days to maturity.**

**A- Under normal condition**

<b>Components</b>	<b>Estimates</b>
E	40.47*±0.66
D	30.89* ±1.74
H1	-95.31* ± 4.42
H2	-70.12 *±3.95
F	-65.62* ±4.26
h <sup>2</sup>	-22.48* ± 2.66
√H1/D	1.76
Heritability (n.s)	0.61

**B-Under moisture deficit condition**

<b>Components</b>	<b>Estimates</b>
E	34.21* ± 0.46
D	16.00* ± 1.21
H <sub>1</sub>	-78.64* ± 3.06
H <sub>2</sub>	-57.07* ±2.74
F	-56.08 *± 2.95
h <sup>2</sup>	-18.67* ± 1.84
√H1/D	2.22
Heritability (n.s)	0.56

Fig. 4.5 A. Graphical representation of days to maturity under normal condition

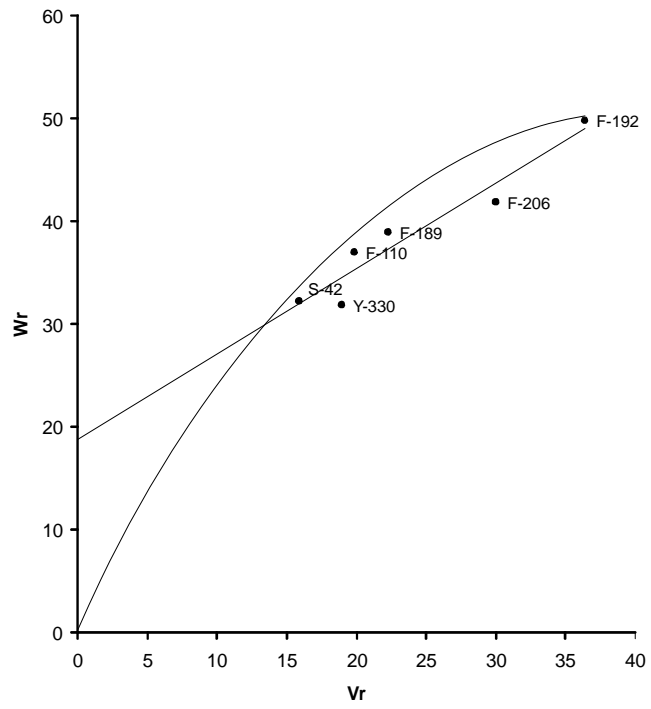
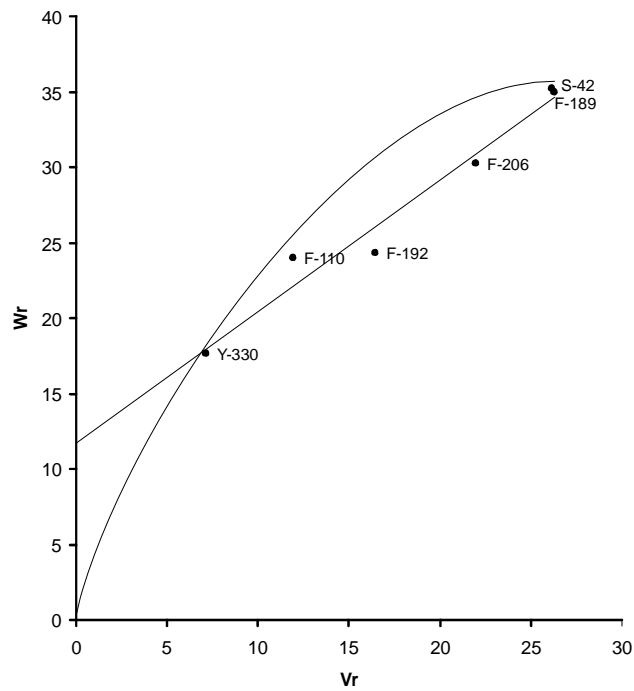


Fig. 4.5 B. Graphical representation of days to maturity under moisture deficit condition





Item c and d were non-significant under both the conditions which revealed the absence of maternal and reciprocal effects.

Genetic components of variation are presented in Table 4.14. The significant values of D and H reflected the presence of both additive and dominance type of genetic effects. However, the magnitude of  $H_1$  was much higher than that of D which revealed preponderance of dominance mode of gene action for days to maturity under normal and moisture deficit conditions. Unequal values of  $H_1$  and  $H_2$  displayed the dissimilar distribution of dominant genes. Negative and significant value of F under both the conditions indicated that negative genes were frequent in the parents. Significant values of  $h^2$  under both conditions indicated the important effects of heterozygous loci for this trait. Environmental variation (E) was significant under both the conditions which revealed that environment had influence on expression of the trait. Graphical presentation of data (Fig. 4.5 a and b) displayed the partial dominance type of gene action for days to maturity under normal and moisture deficit conditions. Zia and Chaudry (1980) also observed days to maturity under control of partially dominant gene effects. Khalid (1979), Bukhari (1986), Tabassum (1989) Setty (1975) and Akbar (2008) reported that tait was under control of additive type of gene action. Karim (1979) and Siddiqui (1988) worked out overdominance type of gene action for this trait. Sharma and Bhalla (1990) reported dominance type of gene action for days to maturity.

The intercept of regression line was positive under normal and moisture deficit conditions. Distribution of array points in the graph indicated that inbred line S-42 had the most dominant genes and F-192 had the most dominant genes for this trait under normal conditions. Under moisture deficit conditions Y-330 had most dominant genes and S-42 had maximum recessive genes. Remaining parents had intermediate positions containing dominant and recessive genes.

#### **4.3.6 Grain yield per plant**

According to additive dominance model grain yield per plant was fully adequate under both normal and moisture deficit conditions. Further genet analysis was conducted as is given in Table 4.15 A and B. Under both conditions item a was significant which depicted the significance of additive gene effects. Significant value of b depicted the importance of dominance gene effects for grain yield per plant under normal and moisture deficit conditions. Significant value of  $b_1$  under both the conditions indicated the presence of directional dominance. Item  $b_2$  was also significant and depicted dissimilar gene distribution. Significant value of  $b_3$  indicated the effects of specific genes. Item c was

significant and indicated the presence of maternal effects. Similarly the value of  $d$  was significant reflecting presence of reciprocal effects under both the conditions. Retesting of  $a$  component against  $c$ , explained that additive effects of genes were not influenced by maternal effects and were still significant. After retesting  $b$ ,  $b_1$ ,  $b_2$  and  $b_3$  against  $d$  it was concluded that item  $d$  (reciprocal effects) influenced and these values became non-significant. Similar behaviour was observed under both conditions.

Estimates of components of variation are given in Table 4.16 A and B. Values of  $D$  and  $H$  were significant and indicated the presence of additive and dominant gene effects under normal and moisture deficit conditions. However, value of  $D$  was higher than that of  $H$  which depicted that additive gene effects were more important. Equal values of  $H_1$  and  $H_2$  indicated the similar distribution of dominant genes among the parents but behavior was changed under moisture stress conditions. Value of  $F$  under both the conditions was positive but non-significant displaying the frequency of dominant genes comparatively lesser than recessive genes. Mean degree of dominance under both the conditions was less than 1 (0.80 and 0.94) which indicated that dominance was partial. Estimates of heritability in narrow sense were 0.75 and 0.72 under both conditions, respectively, and indicated that major share of variation was transmitted to off-springs.

The results are in accordance with Khotyleva and Lemesh (1994), Bawzir (1983), Tabassum (1989) Saeed (1998) and Hussain (2009). According to Munir *et al.* (1977), Zia and Chaudhry (1980), Bukhari (1986), Singh *et al.* (2001), Tabassum (2004) Chen *et al.* (2002) and Akbar (2008) grain yield per plant was under control of over dominance type of gene action. Components  $h^2$  were significant under both conditions suggesting that heterozygous loci had an important role in the expression of grain yield per plant. Environmental variation ( $E$ ) was non-significant for grain yield per plant under both conditions.

Graphical presentation of data (Fig. 4.6 A and B) revealed that there was partial dominance for this trait under both the conditions. Distribution of array points indicated that inbred line F-206 contained maximum dominant genes followed by inbred line S-42 (Fig. 4.6 A). Inbred line F-110 had maximum recessive gene under normal conditions for grain yield per plant. Distribution of array points under moisture deficit conditions (Fig 4.6 B) indicated that inbred line F-206 had maximum dominant genes followed by inbred line F-192 while maximum recessive genes were contained by F-110. Other inbred lines were in intermediate position.

**Table: 4.15-A ANOVA table of 6 x 6 diallel in *Zea mays* L for grain yield per plant under normal condition**

Source	d.f.	M.S.	F. Value	Retesting Against _____	
				c	d
a	5	2929.14	55.6957**	113501**	
b <sub>1</sub>	1	664.78	6.3054**		2.1853 <sup>NS</sup>
b <sub>2</sub>	5	131.41	6.7544**		0.4453 <sup>NS</sup>
b <sub>3</sub>	9	342.16	17.8286**		1.1597 <sup>NS</sup>
b	15	292.09	11.7695**		0.9899 <sup>NS</sup>
c	5	258.07	11.6565**		
d	10	295.05	11.1019**		
Total	35	664.79	22.9992		
a x blocks	10	52.59			
b <sub>1</sub> x blocks	2	102.26			
b <sub>2</sub> x blocks	10	19.45			
b <sub>3</sub> x blocks	18	19.19			
b x blocks	30	24.82			
c x blocks	10	22.14			
d x blocks	20	26.58			
Total x blocks	70	28.91			

**Table: 4.15-B ANOVA table of 6 x 6 diallel in *Zea mays* L for grain yield per plant under moisture deficit condition**

Source	d.f.	M.S.	F. Value	Retesting Against _____	
				c	d
a	5	1933.06	63.2368**	8.7114**	
b <sub>1</sub>	1	647.17	21.1599**		3.3777 <sup>NS</sup>
b <sub>2</sub>	5	276.15	16.3138**		1.441 <sup>NS</sup>
b <sub>3</sub>	9	140.32	3.0976**		0.7323 <sup>NS</sup>
b	15	219.39	6.2930**		1.1450 <sup>NS</sup>
c	5	221.90	9.6774**		
d	10	191.60	6.6026**		
Total	35	456.62	14.7895		
a x blocks	10	30.57			
b <sub>1</sub> x blocks	2	30.58			
b <sub>2</sub> x blocks	10	16.93			
b <sub>3</sub> x blocks	18	45.30			
b x blocks	30	34.86			
c x blocks	10	22.93			
d x blocks	20	29.02			
Total x blocks	70	30.87			

**Table-:4.16 Components of variation for grain yield per plant .**

**A- Under normal condition**

<b>Components</b>	<b>Estimates</b>
E	10.23± 10.06
D	310.12*± 26.61
H <sub>1</sub>	196.66*±67.56
H <sub>2</sub>	174.28*±60.34
F	10.45 ± 65.01
h <sup>2</sup>	113.72*±40.62
√H <sub>1</sub> /D	0.80
Heritability (n.s)	0.75

**B-Under moisture deficit condition**

<b>Components</b>	<b>Estimates</b>
E	10.96 ± 9.71
D	203.31* ±25.68
H <sub>1</sub>	178.40*±65.19
H <sub>2</sub>	124.33*±58.24
F	46.23 ± 62.74
h <sup>2</sup>	113.76*±39.20
√H <sub>1</sub> /D	0.94
Heritility (n.s)	0.72

Fig. 4.6 A. Graphical representation of grain yield per plant under normal condition

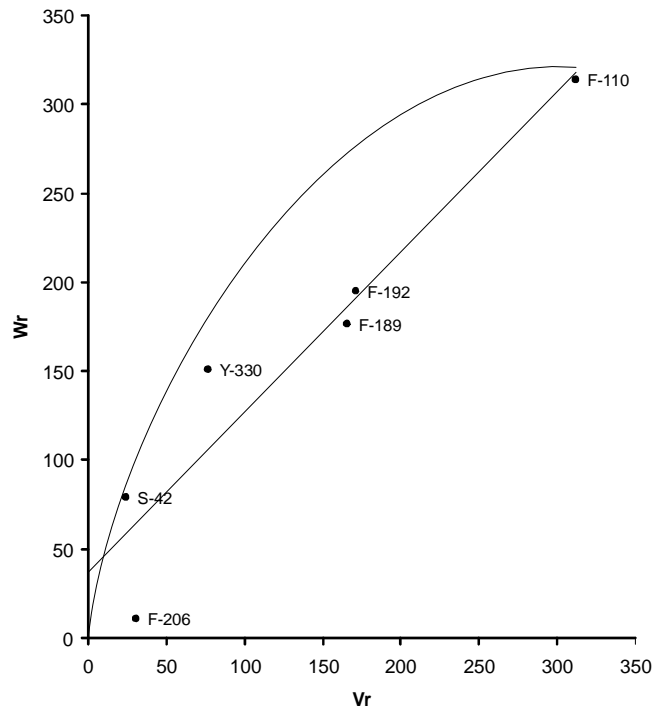
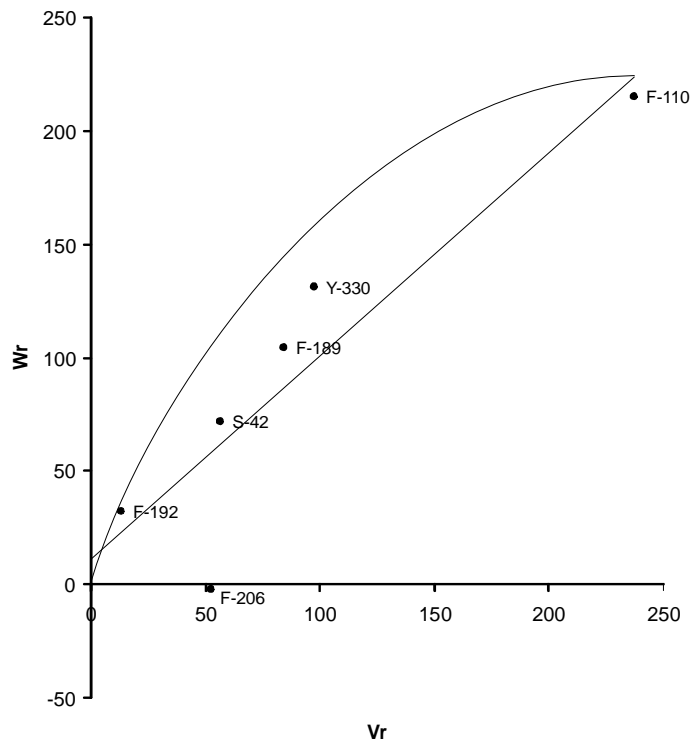


Fig. 4.6 B. Graphical representation of grain yield per plant under moisture deficit condition



#### 4.3.7 100-grain weight

According to additive dominant model 100-grain weight was partially adequate under both conditions. Under normal condition (Table 4.17A) a value for 100-grain weight was significant and indicated that additive gene effects were important. Significant value of  $b$  depicted the presence of dominant gene effects. Additive effects “ $a$ ” were much higher than those of dominant effects “ $b$ ” which indicated that additive effects were more effective. Significant values of  $b_1$ ,  $b_2$ , and  $b_3$  items indicated the presence of directional dominance, presence of asymmetrical gene distribution and important effect of specific genes. Similarly significant value of  $c$  and  $d$  exhibited the presence of maternal effect and did not influenced by maternal effects and remained significant. The value of  $b_1$ ,  $b_2$ , and  $b_3$  were retested against  $d$  and it was concluded that maternal effects influenced and these values rendered non-significant.

Under moisture deficit conditions (Table 4.17B) an item for 100-grain weight was involved in the inheritance of the trait. Items  $b_1$ ,  $b_2$ , and  $b_3$  were non-significant and indicated the absence of directional dominance, symmetrical gene distribution and absence of specific genes. Significant value of  $c$  indicated the importance of maternal effects. Reciprocal effects other than maternal were indicated from significant value of  $d$ . This required retesting of  $a$  item against  $c$ . After retesting  $a$  value remained significant and depicted that there was no influence of maternal effects on additive type of gene action.

Genetic components of variation for 100-grain weight are given in Table 4.18A and B. Under normal conditions (Table 4.18B) values of  $D$  and  $H$  were significant which indicated that additive dominant type of gene action was involved in the inheritance of the trait. However, the value of  $D$  was greater than double of  $H_1$  which indicated the additive type of gene action was more influential. Unequal values of  $H_1$  and  $H_2$  indicated the dissimilar distribution of positive and negative genes. Significant and positive value of  $F$  indicated the greater frequency of dominant genes. Significant value of  $h^2$  indicated that heterozygous loci had an important role in the expression of 100-grain weight. The environmental component ( $E$ ) was found non-significant. Mean degree of dominance under normal condition for this trait was 0.64 which depicted that there was partial dominance involved in the trait. Heritability in narrow sense was 0.79 which indicated that most of the variation was transmitted towards off-springs.

Under moisture deficit conditions  $D$  component was significant which indicated the involvement of additive type of gene action for this trait. Non-significant value of  $H_1$

**Table: 4.17-A ANOVA table of 6 x 6 diallel in *Zea mays* L for 100-grain weight under normal condition**

Source	d.f.	M.S.	F. Value	Retesting Against _____	
				c	d
a	5	112.64	286.767**	6.8294**	
b <sub>1</sub>	1	17.399	15.654**		1.8537 <sup>NS</sup>
b <sub>2</sub>	5	7.799	5.796**		0.8309 <sup>NS</sup>
b <sub>3</sub>	9	9.055	15.912**		0.9647 <sup>NS</sup>
b	15	9.193	10.639**		0.9794 <sup>NS</sup>
c	5	16.526	9.174**		
d	10	9.386	15.588**		
Total	35	25.106	29.332		
a x blocks	10	0.394			
b <sub>1</sub> x blocks	2	1.111			
b <sub>2</sub> x blocks	10	1.346			
b <sub>3</sub> x blocks	18	0.569			
b x blocks	30	0.864			
c x blocks	10	1.801			
d x blocks	20	0.602			
Total x blocks	70	0.856			



**Table: 4.17-B ANOVA table of 6 x 6 diallel in *Zea mays* L for 100-grain weight under moisture deficit condition**

Source	d.f.	M.S.	F. Value	Retesting Against _____	
				c	d
a	5	54.6756	28.6314**	4.5270**	
b <sub>1</sub>	1	7.6612	1.0184 <sup>NS</sup>		
b <sub>2</sub>	5	2.1068	0.5583 <sup>NS</sup>		
b <sub>3</sub>	9	4.3341	1.562 <sup>NS</sup>		
b	15	3.8135	1.1151 <sup>NS</sup>		
c	5	12.0769	8.0243**		
d	10	8.0625	7.0813**		
Total	35	13.4740	5.9130		
a x blocks	10	1.9096			
b <sub>1</sub> x blocks	2	7.5225			
b <sub>2</sub> x blocks	10	3.7738			
b <sub>3</sub> x blocks	18	2.7672			
b x blocks	30	3.4198			
c x blocks	10	1.5048			
d x blocks	20	1.1386			
Total x blocks	70	2.2787			

**Table-4.18 Components of variation for 100 grain weight.**

**A- Under normal condition**

<b>Components</b>	<b>Estimates</b>
E	0.32 ± 0.30
D	17.15* ± 0.78
H <sub>1</sub>	7.01* ± 1.98
H <sub>2</sub>	5.49* ± 1.77
F	6.23* ± 1.91
h <sup>2</sup>	3.04*± 1.19
√H <sub>1</sub> /D	0.64
Heritability (n.s)	0.79

**B-Under moisture deficit condition**

<b>Components</b>	<b>Estimate</b>
E	0.83* ± 0.17
D	7.33* ± 0.45
H <sub>1</sub>	0.79 ± 1.15
H <sub>2</sub>	0.88 ± 1.03
F	1.45 ± 1.10
h <sup>2</sup>	0.96 ± 0.69
√H <sub>1</sub> /D	0.33
Heritability (n.s)	0.73

Fig. 4.7 A. Graphical representation of 100-grain weight under normal condition

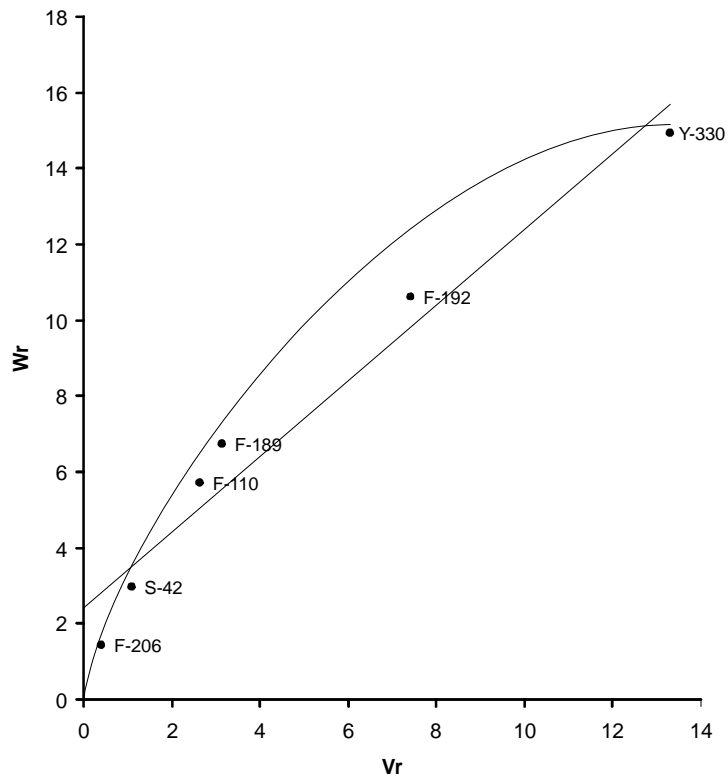
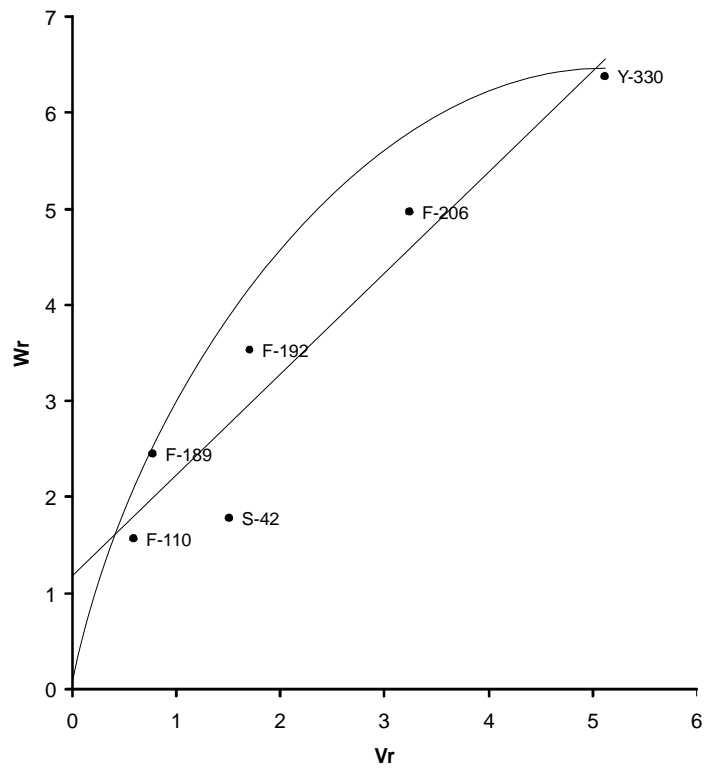


Fig. 4.7 B. Graphical representation of 100-grain weight under moisture deficit condition



indicated the absence of dominant type of gene action. Equal values of  $H_1$  and  $H_2$  indicated the similar distribution of positive and negative genes. Value of  $h^2$  was non-significant which depicted that there was no contribution of dominance effects due to heterozygous loci. Mean degree of dominance was less than 1 (0.33) which depicted that there was partial dominance for this trait. The regression line intercepted the  $W_r$  axis above the point of origin (Fig. 4.7 A and B) showing the presence of partial dominance in the expression of 100-grain weight under both conditions.

Chapman and McNeal (1971), Naveed (1979), Ramamurthy (1980), Bawzir (1983), Bukhari (1986), Wu (1987), Siddiqui (1988), Khotyleva and Lemesh (1989), Hosary and Sedhom (1990) and Tabassum (2007) reported that kernel weight was under control of additive and non-additive type of gene action. Zia and Chaudhry (1980), Malik *et al.* (1990), Saeed (1998), Malik *et al.* (2004) and Tabassum (2004) reported that 100-grain weight was under control of over-dominance type of gene action. The  $W_r/V_r$  graph (Fig. 4.7 A and B) indicated that under normal conditions inbred line F-206 had maximum dominant genes followed by S-42. Inbred line Y-330 had maximum recessive genes. Under moisture deficit conditions F-110 had maximum dominant genes for 100-grain weight followed by S-42 while inbred line Y-330 had maximum recessive genes while other inbred lines possessed intermediate position showing presence of both dominant and recessive genes.

#### **4.3.8 Ear leaf area**

Analysis of variance for ear leaf area (Table 4.10 A and B) revealed that under normal conditions a item was significant indicating the presence of additive type of gene action. Item b was non-significant which depicted the absence of dominant type of gene action. Similarly,  $b_1$  was non-significant thus there was no directional dominance. Value of  $b_2$  was also non-significant which indicated that gene distribution among the parents was symmetrical. Item  $b_3$  being non-significant indicated that there was no effect of specific genes. Item c and d were non-significant showing the absence of maternal and reciprocal effects.

Under moisture deficit conditions behaviour of the trait is given in Table 4.19B. According to the analysis of variance, items a and b were significant indicating the involvement of additive and dominant gene action. In the item  $b_1$  and  $b_2$  were non-significant showing the absence of directional dominance and presence of symmetrical gene distribution among the parents. Values of c and d were significant. It was depicted that maternal and reciprocal effects were present. After retesting of a and b items against

Table-:4.19-A ANOVA table of 6 x 6 diallel in *Zea mays* L for ear leaf area under normal condition

Source	d.f.	M.S.	F. Value	Retesting Against _____	
				c	d
a	5	11185.8	37.0678**	15.2796**	
b <sub>1</sub>	1	72.9	0.4126 <sup>NS</sup>		
b <sub>2</sub>	5	152.5	0.2903 <sup>NS</sup>		
b <sub>3</sub>	9	214.8	0.5477 <sup>NS</sup>		
b	15	184.6	0.4372 <sup>NS</sup>		
c	5	35.9	0.5479 <sup>NS</sup>		
d	10	167.3	1.1956 <sup>NS</sup>		
Total	35	1730.0	6.3278		
a x blocks	10	301.8			
b <sub>1</sub> x blocks	2	176.6			
b <sub>2</sub> x blocks	10	525.3			
b <sub>3</sub> x blocks	18	392.2			
b x blocks	30	422.2			
c x blocks	10	65.5			
d x blocks	20	139.9			
Total x blocks	70	273.4			

Table-:4.19-B ANOVA table of 6 x 6 diallel in *Zea mays* L for ear leaf area moisture deficit condition

Source	d.f.	M.S.	F. Value	Retesting Against_ ____	
				c	d
a	5	5412.52	50.8396**	15.2796**	
b <sub>1</sub>	1	502.07	2.7354 <sup>NS</sup>		
b <sub>2</sub>	5	127.71	1.7723 <sup>NS</sup>		
b <sub>3</sub>	9	161.08	3.6717**		1.2244 <sup>NS NS</sup>
b	15	592.69	3.0725**		1.0087
c	5	354.23	2.3932**		
d	10	290.16	3.4829**		
Total	35	1032.16	10.2212		
a x blocks	10	106.46			
b <sub>1</sub> x blocks	2	183.55			
b <sub>2</sub> x blocks	10	72.05			
b <sub>3</sub> x blocks	18	98.34			
b x blocks	30	95.26			
c x blocks	10	148.02			
d x blocks	20	83.31			
Total x blocks	70	100.98			

**Table-:4.20 Components of variation for ear leaf area**

**A- Under normal condition**

<b>Components</b>	<b>Estimates</b>
E	100.12* ± 0.01
D	1188.04*±11.05
H <sub>1</sub>	-110.04* ± 28.05
H <sub>2</sub>	-77.04* ± 25.06
	-54.34* ± 27.00
h <sup>2</sup>	.12* ± 16.87
√H <sub>1</sub> /D	0.30
Heritability (n.s)	0.88

**B-Under moisture deficit condition**

<b>Components</b>	<b>Estimates</b>
E	39.21*±6.31
D	585.88*±16.70
H <sub>1</sub>	118.95*±42.38
H <sub>2</sub>	116.66*±37.86
F	-0.21 ±40.79
h <sup>2</sup>	71.19*±25.48
√H <sub>1</sub> /D	0.45
Heritability (n.s)	0.81

Fig. 4.8 A. Graphical representation of ear leaf area under normal condition

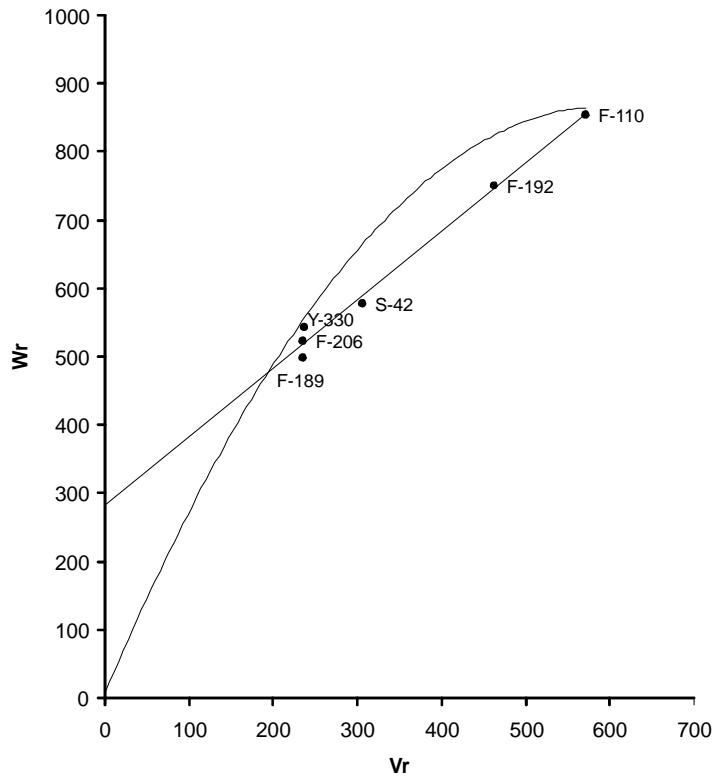
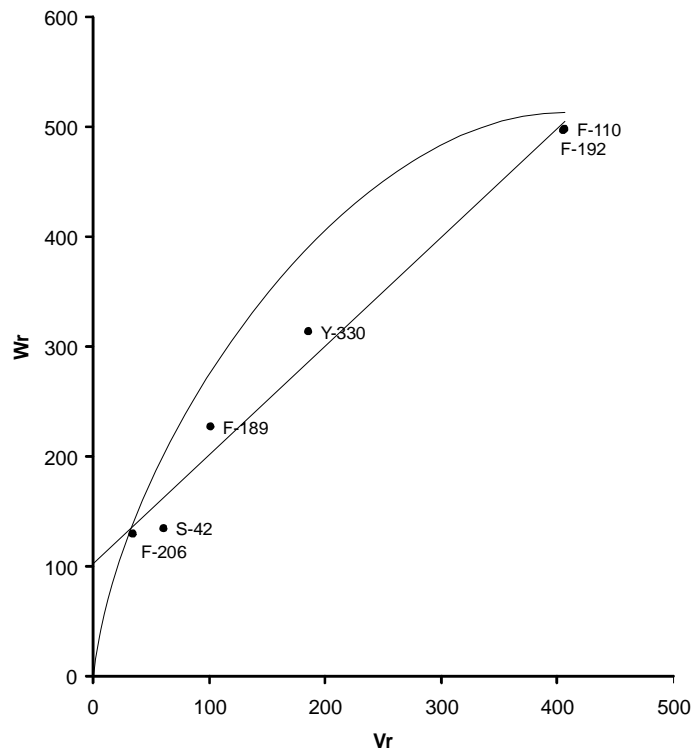


Fig. 4.8 B. Graphical representation of ear leaf area under moisture deficit condition





c and d respectively, it was concluded that item a remained unchanged. Thus maternal effects did not influence the additive type of gene action. When value of b and  $b_3$  was retested against d, these became non-significant. Therefore reciprocal effects influenced the b and  $b_3$  values.

Estimates of components of variation for ear leaf area are given in Table 20 (A & B). Under normal conditions additive variance (D) was significant showing the additive type of gene action. Value of  $H_1$  was also significant which showed the presence of dominant type of gene action for ear leaf area under normal conditions. Different distributions of dominant and recessive genes revealed by the unequal value of  $H_1$  and  $H_2$ . Value of F was significant which Table: 4.19 A. Analysis of variance of 6×6 diallel cross in maize for ear leaf area under (A) normal and (B) moisture deficit conditions indicated the greater frequency of dominant genes. Component  $h^2$  was significant and indicated that heterozygous loci had an important role in expression of ear leaf area. Mean degree of dominance was 0.30 which indicated partial dominance. High heritability estimates in narrow sense (0.88) revealed that maximum variation was transmitted by parents.

Under moisture deficit condition, D and H values were again significant showing the role of additive and dominant type of gene action. However, the value of D was much higher than those of  $H_1$  which depicted that additive aspect of gene action was influential. Almost equal values of  $H_1$  (118.95) and  $H_2$  (116.66) indicated similar distribution of dominant genes. Value of  $h^2$  component was significant displaying the fact that heterozygous loci had an important role in the expression of ear leaf area under moisture deficit condition. Mean degree of dominance was less than 1 (0.45) which depicted the presence of partial dominance. Higher estimates of heritability in narrow sense (0.81) were observed for ear leaf area under moisture deficit conditions.

The regression for ear leaf area intercepted the  $W_r$ -axis above the point of origin under both the conditions. It showed partial dominance. The results are in accordance with Kotyleva and Lemesh (1994) who also reported additive type of gene action for ear leaf area while Sharma and Bhalla (1990) Hussain(2009) reported additive type of gene action. Shakeel (1992), Yousaf (1992) Tabassum (2004) and Akbar (2008) reported over-dominance type of gene action for ear leaf area.

Distribution of array points (Fig. 4.8 A and B) indicated that most dominant genes under normal conditions were contained in F-189 followed by F-206 and Y-330. While F-110 had maximum recessive genes. Under moisture deficit conditions maximum dominant genes were possessed by inbred line F-206 followed by S-42. Inbred line F-110

had maximum recessive genes followed by F-192. Other inbred lines were placed at intermediate positions.

#### **4.3.9 Leaf temperature**

Leaf temperature is partially adequate according to additive dominance model (Table 4.3 A and B). Analysis of variance is given in table 4.21 A and B. Under normal conditions item *a* was significant showing that additive type of gene action was involved in the inheritance of leaf temperature. Hussain (2009) reported that leaf temperature was under control of both additive and dominance type of gene action. Value of  $b_1$  was significant which indicated that directional dominance was present. Items  $b_2$  and  $b_3$  was non-significant which depicted that mean dominance deviation of  $F_1$  from their mid parent values within each array did not differ over arrays because all the parents contained considerably similar dominant genes. There was symmetrical gene distribution among the parents. The  $b_3$  item was a test of the part of dominance deviation which was equal to each of  $F_1$ . Absence of important specific gene effects was indicated by non significant value of  $b_3$  item. Non- significant value of *c* indicated the absence of maternal effects. Item *d* was non-significant which revealed the absence of reciprocal effects.

Under moisture deficit conditions an item was significant which indicated that additive type of gene action was involved for leaf temperature. Non- significant value of item *b* indicated the absence of dominance type of gene action. Item  $b_1$  was also non-significant showing the absence of directional dominance. Symmetrical distribution of gene among the parents was evident from non- significant value of  $b_2$ . Item  $b_3$  was non-significant indicating the absence of specific gene effects for leaf temperature in maize under moisture deficit conditions. Value of *c* was non-significant and indicated the absence of maternal effects. Similarly non-significant value of *d* depicted the absence of reciprocal effects.

Estimation of genetic components of variation (Table 4.22 A and B) displayed the significance of additive variation (*D*) for leaf temperature under normal conditions. Value of  $H_1$  was non-significant which depicted the absence of dominant variation. Unequal values of  $H_1$  and  $H_2$  indicated the different distribution of dominant and recessive genes among the parents. Value of *F* was significant but negative and indicated that negative genes were present frequently. Value of  $h^2$  was significant under normal conditions depicting important effects of heterozygous loci. Mean degree of dominance was less than 1 (0.59) depicting the presence of partial dominance. Heritability estimates in narrow sense were 0.60 depicting the transmission of variation from parents to off-springs.

**Table: 4.21-A ANOVA table of 6 x 6 diallel in *Zea mays* L for leaf temperature under normal condition**

Source	d.f.	M.S.	F. Value	Retesting Against _____	
				c	d
a	5	48.0667	59.7107**		
b <sub>1</sub>	1	17.0667	8.6640**		
b <sub>2</sub>	5	1.1333	0.2446 <sup>NS</sup>		
b <sub>3</sub>	9	7.7333	1.4001 <sup>NS</sup>		
b	15	6.1556	1.2336 <sup>NS</sup>		
c	5	2.0000	0.6766 <sup>NS</sup>		
d	10	1.4000	0.6200 <sup>NS</sup>		
Total	35	10.1905	3.0686		
a x blocks	10	0.8050			
b <sub>1</sub> x blocks	2	1.9698			
b <sub>2</sub> x blocks	10	4.6334			
b <sub>3</sub> x blocks	18	5.5234			
b x blocks	30	4.9898			
c x blocks	10	2.9560			
d x blocks	20	2.2580			
Total x blocks	70	3.3209			

**Table: 4.21-B ANOVA table of 6 x 6 diallel in *Zea mays* L for leaf temperature under moisture deficit condition**

Source	d.f.	M.S.	F. Value	Retesting Against _____	
				c	d
a	5	43.8667	18.2305**		
b <sub>1</sub>	1	1.0667	0.0777 <sup>NS</sup>		
b <sub>2</sub>	5	2.0833	0.2811 <sup>NS</sup>		
b <sub>3</sub>	9	12.1500	1.7868 <sup>NS</sup>		
b	15	8.0556	1.0790 <sup>NS</sup>		
c	5	7.0000	0.8483 <sup>NS</sup>		
d	10	2.6500	0.2866 <sup>NS</sup>		
Total	35	11.6762	1.5584		
a x blocks	10	2.4062			
b <sub>1</sub> x blocks	2	13.7282			
b <sub>2</sub> x blocks	10	7.4117			
b <sub>3</sub> x blocks	18	6.7999			
b x blocks	30	7.4657			
c x blocks	10	8.2514			
d x blocks	20	9.2466			
Total x blocks	70	7.3640			

**Table-:4.22 Components of variation for leaf temperature.**

**A- Under normal condition**

<b>Components</b>	<b>Estimates</b>
E	1.19* ± 0.14
D	3.48*± 0.36
H <sub>1</sub>	1.19 ± 1.30
H <sub>2</sub>	1.73* ±0.82
F	-2.00*±0.88
h <sup>2</sup>	2.50*±0.55
√H <sub>1</sub> /D	0.59
Heritability (n.s)	0.60

**B-Under moisture deficit condition**

<b>Components</b>	<b>Estimates</b>
E	2.86* ±0.17
D	0.91* ±0.46
H <sub>1</sub>	-1.80 ± 1.17
H <sub>2</sub>	-0.35 ± 1.05
F	-4.46 *± 1.13
h <sup>2</sup>	-1.39*± 0.70
√H <sub>1</sub> /D	1.40
Heritability (n.s)	0.41

Fig. 4.9 A. Graphical representation of leaf temperature under normal condition

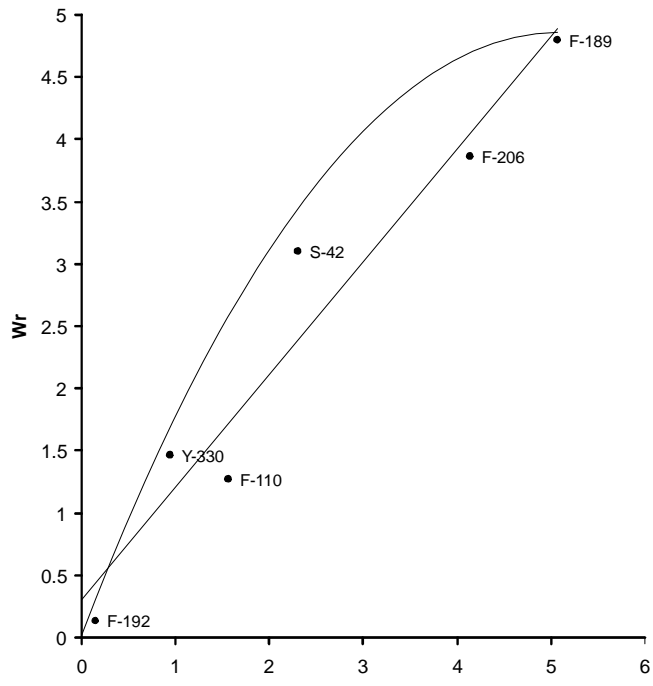
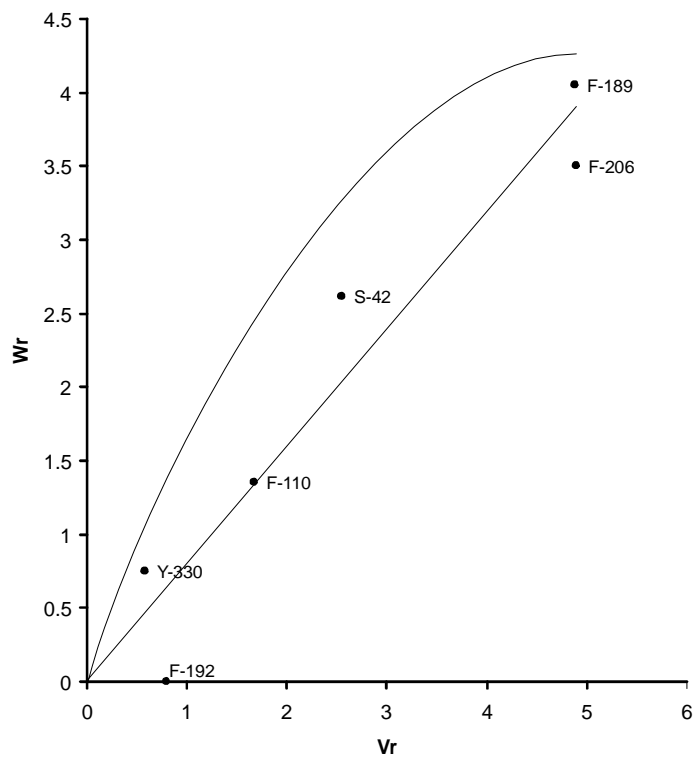


Fig. 4.9 B. Graphical representation of leaf temperature under moisture deficit condition



Under moisture deficit condition D was significant indicating the additive value for the leaf temperature  $H_1$  was non-significant indicating the absence of dominance variation. Unequal values of  $H_1$  and  $H_2$  depicted different gene distribution among the parents. Value of F was significant and negative showing the prevalence of negative genes in greater number. Value of  $h^2$  was significant depicting important effects of heterozygous loci. Heritability in narrow sense was 0.41 for leaf temperature under moisture stress conditions. The results were in agree with Hussain (2009). Graphical presentation of data (Fig. 4.9 A and B) revealed that regression line intercepted the  $W_r$ -axis above the point of origin showing the presence of partial dominance for expression of the leaf temperature under normal conditions. Under moisture deficit conditions (Fig 4.9 B) the regression line intercepted the  $W_r$ -axis at the origin depicting the complete dominance for this trait.

According to the graph (Fig. 4.9A), maximum dominant genes were contained by genotype F-189 and maximum recessive genes by F-192 under normal conditions. Under moisture deficit conditions, maximum dominant genes for leaf temperature maximum genes were contained by F-192 followed by Y-330. Maximum recessive genes for said trait were possessed by genotype F-189.

#### **4.3.10 Relative water loss**

According to additive-dominance model relative water loss was partially adequate under normal and moisture deficit conditions (Table 4.2 A and B). Analysis of variance table (Table 4.23A) under normal conditions revealed that a was significant showing the additive type of gene action for the trait. Hussain (2009) reported additive and dominance type of gene action for trait under discussion. Value of b was non-significant which indicated the absence of dominance type of gene action. The items  $b_1$ ,  $b_2$  and  $b_3$  were non-significant. These indicated that directional dominant deviation was absent, and symmetrical gene distribution among the parents. Non-significant value of  $b_3$  indicated the absence of specific gene effects. Non-significant values of c and d depicted the absence of maternal and reciprocal effects, respectively.

Under moisture deficit conditions, the analysis of variance (Table 4.23B) revealed that there was significant value of a indicating the involvement of additive type of gene action. The value of b,  $b_1$  and  $b_3$  were non significant showing the absence of dominant type of variation, directional dominance and specific gene effects. Value of  $b_2$  was significant showing the symmetrical gene distribution among the parents. Items c and d were non-significant and thus there was no need to retest the values of a and  $b_2$ .

**Table: 4.23-A ANOVA table of 6 x 6 diallel in *Zea mays* L for relative water loss under normal condition**

Source	d.f.	M.S.	F. Value	Retesting Against _____	
				c	d
a	5	672.039	14.4889**		
b <sub>1</sub>	1	2.579	0.3434 <sup>NS</sup>		
b <sub>2</sub>	5	22.115	0.5464 <sup>NS</sup>		
b <sub>3</sub>	9	26.983	1.3592 <sup>NS</sup>		
b	15	23.340	0.9244 <sup>NS</sup>		
c	5	2.866	0.0970 <sup>NS</sup>		
d	10	2.947	0.0768 <sup>NS</sup>		
Total	35	107.260	3.2869		
a x blocks	10	46.383			
b <sub>1</sub> x blocks	2	7.512			
b <sub>2</sub> x blocks	10	38.641			
b <sub>3</sub> x blocks	18	19.778			
b x blocks	30	25.248			
c x blocks	10	29.560			
d x blocks	20	38.370			
Total x blocks	70	32.632			



**Table: 4.23-B ANOVA table of 6 x 6 diallel in *Zea mays* L for relative water loss under moisture deficit condition**

Source	d.f.	M.S.	F. Value	Retesting Against _____	
				c	d
a	5	604.264	91.327**		
b <sub>1</sub>	1	22.759	0.6354 <sup>NS</sup>		
b <sub>2</sub>	5	27.778	2.6681*		
b <sub>3</sub>	9	10.169	0.8416 <sup>NS</sup>		
b	15	16.778	1.2876 <sup>NS</sup>		
c	5	8.068	1.3967 <sup>NS</sup>		
d	10	2.934	0.1491 <sup>NS</sup>		
Total	35	95.548	7.3436		
a x blocks	10	6.631			
b <sub>1</sub> x blocks	2	35.816			
b <sub>2</sub> x blocks	10	10.411			
b <sub>3</sub> x blocks	18	12.082			
b x blocks	30	13.107			
c x blocks	10	5.776			
d x blocks	20	19.676			
Total x blocks	70	13.011			

Table: 4.24 Components of variation for relative water loss.

A- Under normal condition

Components	Estimates
E	0.64* ± 0.97
D	0.05*±2.57
H <sub>1</sub>	0.79 ± 6.53
H <sub>2</sub>	72± 5.83
F	81* ± 6.28
h <sup>2</sup>	99 ± 3.92
√H <sub>1</sub> /D	0.46
Heritability (n.s)	0.78

B-Under moisture deficit condition

Components	Estimates
E	4.69* ±0.49
D	53.84* ± 1.30
H <sub>1</sub>	4.93 ± 3.31
H <sub>2</sub>	1.88 ± 2.96
F	-8.69* ±3.18
h <sup>2</sup>	1.61 ± 1.99
√H <sub>1</sub> /D	0.30
Heritability (n.s)	0.86

Fig. 4.10 A. Graphical representation of relative water loss under normal condition

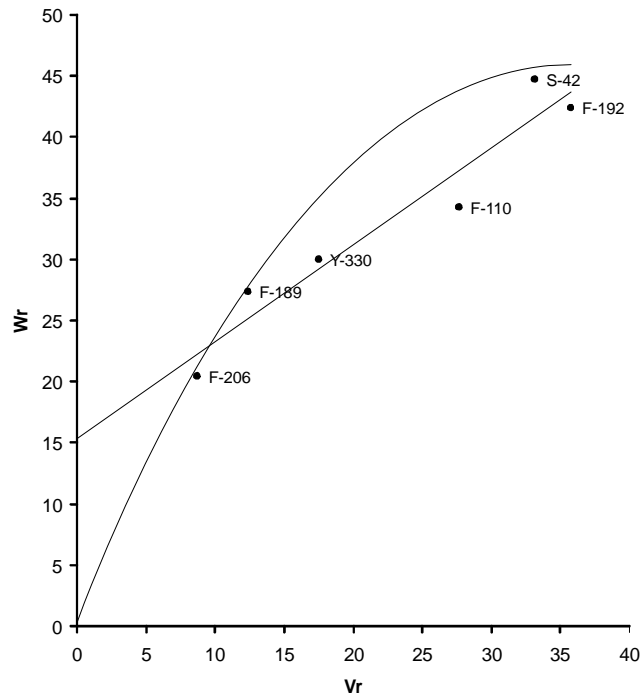
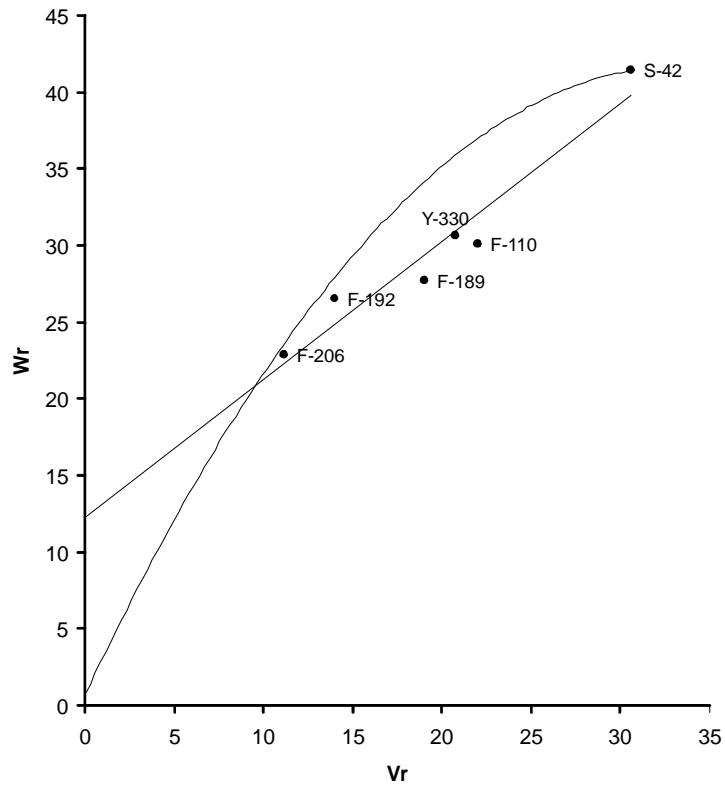


Fig. 4.10 B. Graphical representation of relative water loss under moisture deficit condition



Genetic components of variation were estimated to Hayman (1954b) and are presented in Table 4.24 A and B. Under normal conditions value of D was significant showing the importance of additive genetic effects. Non-significant value of  $H_1$  indicated the absence of dominant genetic effects. Unequal values of  $H_1$  and  $H_2$  displayed the dissimilar distribution of dominant genes. The value of F was significant but negative which indicated that negative genes were frequent. The value of  $h^2$  was non-significant but negative which confirmed less frequency of dominant genes.

Mean degree of dominance was less than 1 (0.46) which depicted the partial dominance. High value of heritability in narrow sense revealed that genetic variation was due to additive genes. Under moisture deficit conditions (Table 4.24 B) the value of D was significant indicating that additive gene effects were important. Values of  $H_1$  and  $H_2$  were unequal and revealed the different distribution of dominant genes. The value of F was negative and significant showing the higher frequency of negative genes. Non-significant value of  $h^2$  was observed and it was indicated that effect of heterozygous loci was not important for relative water loss. Mean degree of dominance was less than 1 (0.30) which revealed that there was not much dominance involved in the inheritance of the trait. High estimates of heritability in narrow sense (0.86) were revealed for the trait under moisture deficit conditions. Regression line (Fig-10 (A&B)) intercepted the  $W_r$ -axis above the point of origin. It was depicted that under both the conditions, there was involvement of partial dominance. According to Fig. 4.10A, under normal conditions, maximum dominant genes were contained by inbred line F-206 and maximum recessive genes were contained by genotype S-42 and F-192 equally. Under moisture deficit conditions Fig. 4.10B) maximum dominant genes were again contained by F-206 while inbred line S-42 had maximum recessive genes.

#### **4.3.11 Cell membrane thermostability**

Analysis of variance for cell membrane thermostability is presented in Table 4.25(A &B). Under normal conditions (Table 4.25A) item a was significant showing the additive type of gene action. Hussain (2009) reported additive and dominance type of gene action for trait under discussion. The value of  $b_1$  was also significant indicating the importance of directional dominance. The values of item b,  $b_2$  and  $b_3$  were non-significant. The non-significant value of b depicted the absence of dominance type of gene action. Non-significant value of  $b_2$  indicated the symmetrical gene distribution of genes. Item  $b_3$  being non-significant depicted unimportance of specific gene effects. The items c and d were non-significant indicating the absence of maternal and reciprocal

**Table: 4.25-A ANOVA table of 6 x 6 diallel in *Zea mays* L for cell membrane thermo-stability under normal condition**

Source	d.f.	M.S.	F. Value	Retesting Against _____	
				c	d
a	5	484.500	75.0492**		
b <sub>1</sub>	1	205.350	25.8829**		
b <sub>2</sub>	5	11.700	0.6947 <sup>NS</sup>		
b <sub>3</sub>	9	16.767	0.8417 <sup>NS</sup>		
b	15	27.650	1.5280 <sup>NS</sup>		
c	5	2.200	0.1228 <sup>NS</sup>		
d	10	1.600	0.1266 <sup>NS</sup>		
Total	35	81.836	5.5124		
a x blocks	10	6.456			
b <sub>1</sub> x blocks	2	7.934			
b <sub>2</sub> x blocks	10	16.843			
b <sub>3</sub> x blocks	18	19.920			
b x blocks	30	18.095			
c x blocks	10	17.911			
d x blocks	20	12.634			
Total x blocks	70	14.866			

**Table: 4.25 –B ANOVA table of 6 x 6 diallel in *Zea mays* L for cell membrane thermo-stability under moisture deficit condition**

Source	d.f.	M.S.	F. Value	Retesting Against _____	
				c	d
a	5	396.967	25.38**		
b <sub>1</sub>	1	176.817	1262.56**		
b <sub>2</sub>	5	23.433	1.45 <sup>NS</sup>		
b <sub>3</sub>	9	49.233	4.91**		
b	15	49.139	4.31**		
c	5	7.200	0.87 <sup>NS</sup>		
d	10	4.500	0.27 <sup>NS</sup>		
Total	35	80.083	6.09		
a x blocks	10	15.644			
b <sub>1</sub> x blocks	2	0.140			
b <sub>2</sub> x blocks	10	16.163			
b <sub>3</sub> x blocks	18	10.026			
b x blocks	30	11.412			
c x blocks	10	8.303			
d x blocks	20	16.968			
Total x blocks	70	13.160			

**Table-:4.26 Components of variation for cell membrane thermo- stability.**

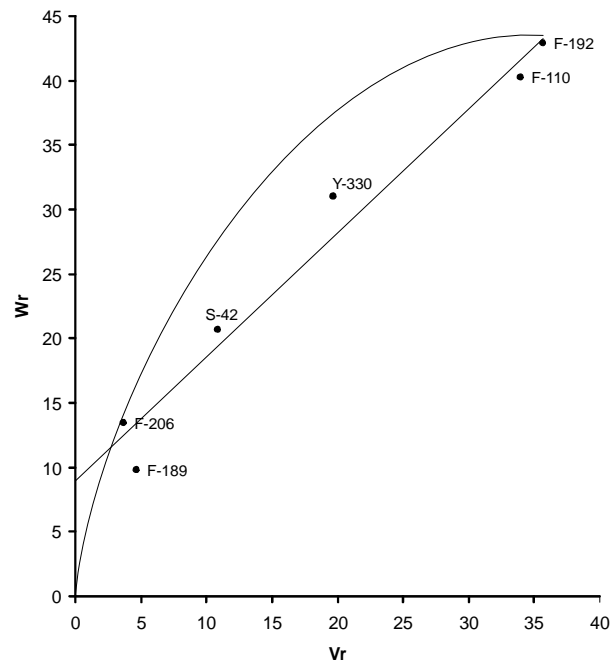
**A- Under normal condition**

<b>Components</b>	<b>Estimates</b>
E	5.28 *±0.70
D	48.89* ±1.84
H <sub>1</sub>	6.95 ±4.68
H <sub>2</sub>	7.87 ±4.18
F	-4.11 ±4.50
h <sup>2</sup>	35.09*±2.18
√H <sub>1</sub> /D	0.38
Heritability (n.s)	0.78

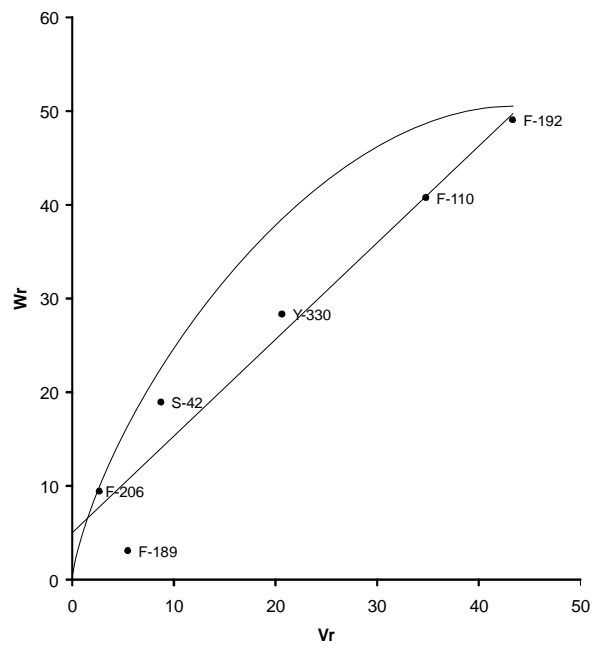
**B-Under moisture deficit condition**

<b>Components</b>	<b>Estimates</b>
E	4.65 ± 1.24
D	6.04* ±3.29
H <sub>1</sub>	25.56*±8.35
H <sub>2</sub>	23.45*±7.46
F	15.60*±8.04
h <sup>2</sup>	30.16*±5.02
√H <sub>1</sub> /D	0.68
Heritability (n.s)	0.67

Fig. 4.11 A. Graphical representation of cell membrane thermo stability under normal condition



4.11 B. Graphical representation of cell membrane thermo stability under moisture deficit condition





effects. Under moisture deficit conditions (Table 4.25B) item a was significant indicating the importance of additive type of gene action. Item b was also significant depicting the involvement of dominance type of gene action. However the value of b was very low as compared to item a. Therefore additive type of gene action was important. Value of  $b_1$  was significant which meant that there was directional dominance involved in the inheritance of cell membrane thermo stability under moisture deficit conditions. Non significant value of  $b_2$  depicted the symmetrical distribution of dominant genes among the parents. Item  $b_3$  was significant showing the importance of effects of specific genes. Items c and d were non significant thus there were no maternal and reciprocal effects.

Genetic components of variation were estimated according to Hayman (1954b) and are presented in Table 4.26 (A&B). Under normal condition, value of D was significant showing the importance of additive genetic effects. The value of  $H_1$  was non-significant showing the absence of dominant genetic effects. Equal values of  $H_1$  and  $H_2$  displayed the similar distribution of dominant genes of positive and negative effects. A negative and non- significant value of F indicated that negative gene effects were not frequent. The significant value of  $h^2$  indicated the important effect of heterozygous loci for cell membrane thermostability. Lesser value of mean degree of dominance indicated the partial dominance involved in the inheritance of the trait under discussion. Heritability in narrow sense was 78%. Under moisture deficit conditions, both D and  $H_1$  were significant showing additive and dominance genetic effects involved in the inheritance of cell membrane thermo-stability. Equal values of  $H_1$  and  $H_2$  depicted the similar distribution of dominant and recessive genes among the parents. Positive and significant value of F indicated the higher frequency of positive genes. Significant value of  $h^2$  indicated the important effect of heterozygous loci for this trait. Mean degree of dominance was less than 1 (0.68) which indicated the involvement of partial dominance.

Graphical presentation of data (Fig. 4.11 A and B) revealed that regression line intercepted the  $V_r$ -axis above the point of origin under both conditions which confirmed additive type of gene action. According to the Fig. 4.11 A and B, under both the conditions, maximum dominant genes were contained by inbred line F-189 followed by F-206 and maximum recessive genes by F192.

#### **4.3.12 Photosynthetic rate**

Additive dominance model for photosynthetic rate was fully adequate under normal condition (Table 4.2 A) and partially adequate under moisture deficit condition (Table 4.2 B). Analysis of variance for leaf photosynthetic rate under normal conditions

**Table: 4.27-A ANOVA table of 6 x 6 diallel in *Zea mays* L for leaf photosynthetic rate under normal condition**

Source	d.f.	M.S.	F. Value	Retesting Against	
				c	d
a	5	113.262	109.260**		
b <sub>1</sub>	1	11.034	98.406**		
b <sub>2</sub>	5	1.995	1.730 <sup>NS</sup>		
b <sub>3</sub>	9	6.886	9.544**		
b	15	5.532	6.707**		
c	5	11.967	22.620**		
d	10	5.824	8.577**		
Total	35	21.925	28.431		
a x blocks	10	1.037			
b <sub>1</sub> x blocks	2	0.112			
b <sub>2</sub> x blocks	10	1.153			
b <sub>3</sub> x blocks	18	0.722			
b x blocks	30	0.825			
c x blocks	10	0.529			
d x blocks	20	0.579			
Total x blocks	70	0.771			

**Table: 4.27-B ANOVA table of 6 x 6 diallel in *Zea mays* L for leaf photosynthetic rate under moisture deficit condition**

Source	d.f.	M.S.	F. Value	Retesting Against	
				c	d
a	5	68.4617	89.7561 <sup>NS</sup>		
b <sub>1</sub>	1	1.6745	0.4900 <sup>NS</sup>		
b <sub>2</sub>	5	1.3052	0.7111 <sup>NS</sup>		
b <sub>3</sub>	9	5.2356	9.7145 <sup>**</sup>		
b	15	3.6880	3.1712 <sup>**</sup>		
c	5	6.1005	11.8828 <sup>**</sup>		
d	10	6.5140	10.4388 <sup>**</sup>		
Total	35	14.035	16.4055		
a x blocks	10	0.7628			
b <sub>1</sub> x blocks	2	3.4174			
b <sub>2</sub> x blocks	10	1.8354			
b <sub>3</sub> x blocks	18	0.5389			
b x blocks	30	1.1630			
c x blocks	10	0.5134			
d x blocks	20	0.6240			
Total x blocks	70	0.8590			

**Table-:4.28 Components of variation for photosynthetic rate.**

**A- Under normal condition**

<b>Components</b>	<b>Estimates</b>
E	0.40*± 0.18
D	15.72* ± 0.46
H <sub>1</sub>	3.06*±1.18
H <sub>2</sub>	2.89*±1.05
F	3.44 ± 3.13
h <sup>2</sup>	1.82*±0.71
√H <sub>1</sub> /D	0.44
Heritability (n.s)	0.85

**B-Under moisture deficit condition**

<b>Components</b>	<b>Estimates</b>
E	0.33*±0.099
D	8.74* ±0.26
H <sub>1</sub>	1.87* ±0.67
H <sub>2</sub>	1.80 *±0.60
F	1.31*± 0.64
h <sup>2</sup>	0.13± 0.40
√H <sub>1</sub> /D	0.46
Heritability (n.s)	0.83

Fig. 4.12 A. Graphical representation of photosynthetic rate under normal condition

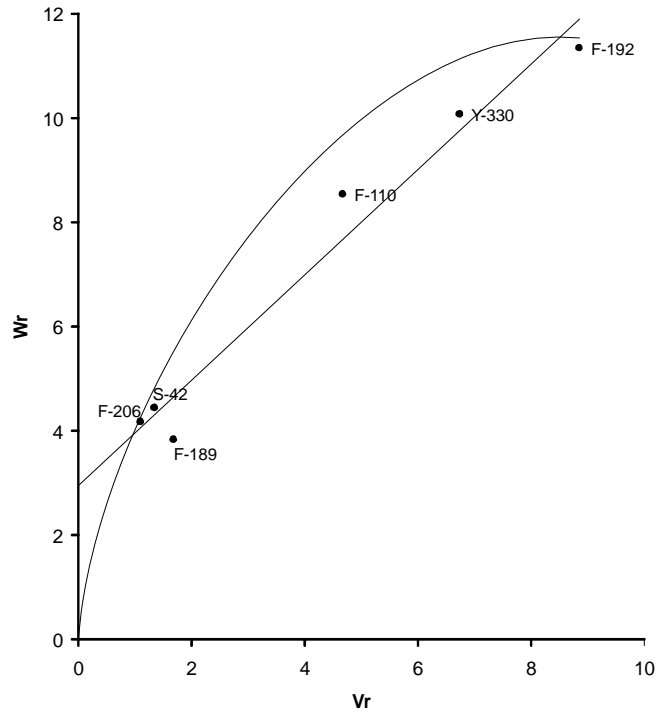
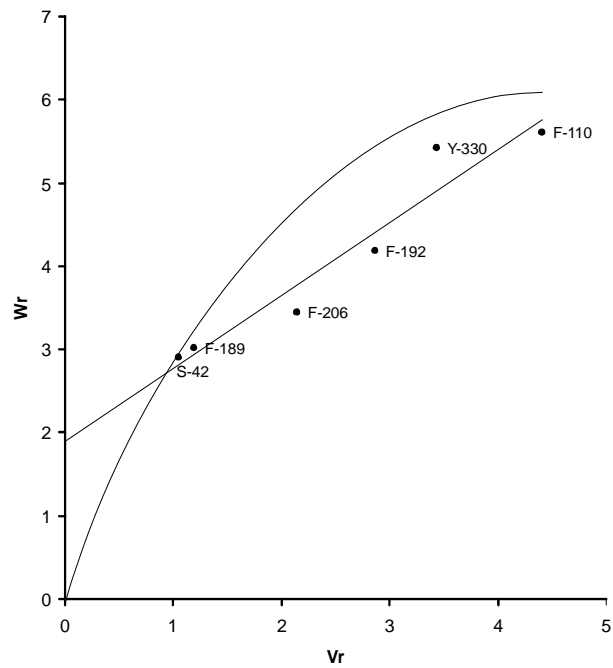


Fig. 4.12 B. Graphical representation of photosynthetic rate under moisture deficit condition



(Table 4.27 A) displayed that variation due to both a and b items was significant which depicted the importance of both additive and dominant genetic effects. However, value of item a was much higher as compared with value of b which again displayed importance of additive genetic effects. Significant value of  $b_1$  under normal conditions indicated the importance of directional dominance. Non-significant value of  $b_2$  indicated that mean dominance deviation of the  $F_1$  from their mid parent values within each array did not differ over arrays because there was symmetrical gene distribution. Value of  $b_3$  was significant showing the effect of specific genes. Under normal conditions c and d values were significant showing the presence of maternal and reciprocal effects. Values of a and b were retested against c and d, respectively. After retesting against item “c”, a value remained unchanged depicting no influence of maternal effects. After retesting against d, the values of  $b_1$ ,  $b_3$  and b became non-significant showing the influence of reciprocal effects.

Genetic components of variation were estimated according to Hayman (1954b) and is presented in Table 4.28 A and B. Under normal conditions table revealed that both D and H were significant showing the involvement of both additive and dominance mode of gene action. However, the value of D was much higher as compared to  $H_1$  showing the importance of additive mode of gene action. Equal values of  $H_1$  and  $H_2$  indicated the similar distribution of dominant genes among the parents. Positive but non-significant value of F displayed the lesser frequency of positive genes. Significant value of  $h^2$  depicted the important effect of heterozygous loci for leaf photosynthetic rate under normal conditions. Mean degree of dominance (0.44) revealed partial dominance in the inheritance of the trait under discussion.

Under moisture deficit conditions again D and  $H_1$  components were significant showing the importance of additive and dominant type of gene action involved in the inheritance of the leaf photosynthetic rate. Value of D was much higher as compared to  $H_1$  showing the importance of additive genetic effect. Equal values of  $H_1$  and  $H_2$  displayed the similar distribution of dominant genes. Positive and significant value of F revealed that positive genes were frequent. Non-significant value of  $h^2$  indicated that effect of heterozygous loci was not important for leaf photosynthetic rate. Mean degree of dominance value (0.46) confirmed the additive effects of genes.

Graphical presentation of the data (Fig. 4.12) revealed that the regression line intercepted the  $W_r$ -axis above the point of origin under both the conditions indicating the partial dominance involved in the inheritance of the leaf photosynthetic rate.

According to the Fig. 4.12 A it was concluded that under normal condition, maximum dominant genes for leaf photosynthetic rate were contained by inbred lines F-206 and F-189 followed by S-42 and maximum recessive genes were contained by inbred line F-192. Under moisture deficit conditions (Fig. 4.12 B) S-42 genotype had maximum dominant genes for leaf photosynthetic rate followed by inbred line F-110 which had maximum recessive genes for the trait under discussion.

#### **4.4 COMBINING ABILITY ANALYSIS**

Analysis of variance for all the traits under normal and moisture deficit conditions (Table 4.29 A and B) displayed significant mean squares for general and specific combining abilities and reciprocal effects for all the trait under normal and moisture deficit conditions. Estimates of components of variations (Table 4.30 A and B) depicted greater GCA variance ( $\delta^2_g$ ) as compared to SCA variance ( $\delta^2_s$ ) indicating the additive genetic effects for all the traits. Significant mean squares due to reciprocal effects explained the involvement of significant reciprocal differences. A greater GCA variance than SCA variance indicated the preponderance of additive gene action. Under normal moisture conditions, days to tasseling, days to maturity, 100-grain weight and leaf temperature were under control of both additive and non-additive type of gene action. However under moisture deficit conditions, days to tasseling, days to maturity, grain yield per plant and cell membrane, thermo stability were under both types of gene action.

##### **4.4.1 Plant height**

According to Table 4.30 A and B, estimates of components of variation depicted greater GCA variance ( $\delta^2_g$ ) as compared to SCA ( $\delta^2_s$ ) indicating the involvement of additive genetic effect for plant height under normal as well as under moisture deficit conditions. Khalid (1979), Wu (1987), Paul and Debanth (1999), Nigussie and Zelke (2001), Vicente *et al.* (2001), Yuan *et al.* (2003), Malik *et al.* (2004) and Rezaei *et al.* (2005) also found plant height under control of additive type of gene action. However Dehghanpour *et al.* (1996) and Prakash and Ganguli (2004) concluded that plant height was under control of non-additive type of gene action.

Mahmood *et al.* (1990) Choukan (1999), Lemos *et al.* (1999), Revilla *et al.* (1999), Ogunbodede (2000), Ahmad (2002), Gribincea (2002) and Tabassum (2007) reported that plant height was under control of both additive and non-type of gene action. The conclusion was varied due to difference in breeding material as well as environment under which these studies were conducted.

**Table 4.29 A. Mean squares for GCA, SCA and reciprocal effects of *Zea mays* L 6x6 diallel under normal condition.**

<b>MEAN SQUARE</b>				
<b>Traits</b>	<b>GCA (df=5)</b>	<b>SCA (df=15)</b>	<b>Reciproca (df=15)</b>	<b>Error (df=70)</b>
<b>Plant height(cm)</b>	1584.21**	194.64**	19.52**	107.97
<b>Days to tasseling (n)</b>	59.37**	5.14**	2.63**	10.33
<b>Days to silking(n)</b>	53.24**	3.04**	2.65**	6.38
<b>Anthesis silking interval(n)</b>	0.0531**	0.2945**	0.200**	0.00258
<b>Days to maturity(n)</b>	254.43**	5.41**	2.72**	36.85
<b>Grains yield per plant (g)</b>	976.36**	97.36**	94.24**	9.63
<b>100-grain weight (g)</b>	37.62**	3.06**	3.92**	0.285
<b>Ear leaf area(cm<sup>2</sup>)</b>	3729.03**	61.46**	41.16**	91.18
<b>Leaf temperature</b>	16.02**	2.05**	0.5333**	1.10
<b>Relative Water loss</b>	224.01**	7.78*	0.9733**	10.87
<b>Cell membrane thermo stability%</b>	161.50**	9.21**	0.600**	4.94
<b>Photosynthetic rate(μmol/m<sup>2</sup>)</b>	37.75**	1.84**	2.62**	2.62



**Table 4.29 B. Mean squares for GCA, SCA and reciprocal effects of *Zea mays* L 6x6 diallel under moisture deficit condition.**

<b>MEAN SQUARE</b>				
<b>Traits</b>	<b>GCA (df=5)</b>	<b>SCA (df=15)</b>	<b>Reciproca (df=15)</b>	<b>Error (df=70)</b>
<b>Plant height(cm)</b>	1351.88**	155.83**	53.75**	57.68
<b>Days to tasseling (n)</b>	59.10**	2.79**	4.31*8	3.79
<b>Days to silking(n)</b>	25.54**	2.75**	3.41**	8.44
<b>Anthesis silking interval(n)</b>	4.86**	0.0632**	0.3506**	0.0245
<b>Days to maturity(n)</b>	185.71**	5.68**	7.53**	28.07
<b>Grains yield per plant (g)</b>	644.34**	73.12**	67.23**	10,29
<b>100-grain weight (g)</b>	18.22**	1.27**	3.13**	0.7595
<b>Ear leaf area(cm<sup>2</sup>)</b>	1804.10**	97.58**	103.84**	33.67
<b>Leaf temperature</b>	14.62**	2.68**	1.36**	2,45
<b>Relative Water loss</b>	201.42**	5.62**	1.54**	4.33
<b>Cell membrane thermo stability%</b>	132.32**	16.37**	1.80**	4.38
<b>Photosynthetic rate(μmol/m<sup>2</sup>)</b>	22.82**	1.22**	2.12**	0.2862

**Table 4.30 A. Estimates of genotypic variance and its components relative to reciprocal, SCA and GCA effects in *Zea mays* L 6x6 diallel under normal condition.**

<b>Traits</b>	<b>O<sup>2</sup>g</b>	<b>O<sup>2</sup>s</b>	<b>O<sup>2</sup> r</b>	<b>O<sup>2</sup>e</b>
<b>Plant height(cm)</b>	116.03	50.32	-44.22	107.97
<b>Days to tasseling (n)</b>	4.50	-3.01	-3.85	10.33
<b>Days to silking(n)</b>	4.17	-1.93	-1.86	6.38
<b>Anthesis silking interval(n)</b>	-1.93	0.1695	9.87	0.00258
<b>Days to maturity(n)</b>	20.66	-18.25	-17.06	36.85
<b>Grains yield per plant (g)</b>	73.48	50.94	42.30	9.63
<b>100-grain weight (g)</b>	2.88	1.61	1.81	0.285
<b>Ear leaf area(cm<sup>2</sup>)</b>	305.55	-17.25	-25.01	91.18
<b>Leaf temperature</b>	1.16	0.5486	-0.2868	1.10
<b>Relative Water loss</b>	18.01	-1.79	-4.95	10.87
<b>Cell membrane thermo stability%</b>	12.70	2.47	-2.17	4.94
<b>Photosynthetic rate(μmol/m<sup>2</sup>)</b>	2.99	0.9214	1.18	2.62

**Table 4.30 B. Estimates of genotypic variance and its components relative to reciprocal, SCA and GCA effects in *Zea mays* L 6x6 diallel under moisture deficit condition.**

<b>Traits</b>	<b>O<sup>2</sup>g</b>	<b>O<sup>2</sup>s</b>	<b>O<sup>2</sup>r</b>	<b>O<sup>2</sup>e</b>
<b>Plant height(cm)</b>	99.93	56.98	-1.96	57.68
<b>Days to tasseling (n)</b>	4.68	-0.5782	0.2593	3.79
<b>Days to silking(n)</b>	4.13	-3.30	-2.52	8.44
<b>Anthesis silking interval(n)</b>	0.4003	0.0224	0.1630	0.0245
<b>Days to maturity(n)</b>	14.94	-13.00	-10.27	28.07
<b>Grains yield per plant (g)</b>	47.77	36.48	28.47	10.29
<b>100-grain weight (g)</b>	1.41	0.2971	1.18	0.7595
<b>Ear leaf area(cm<sup>2</sup>)</b>	142.38	37.10	35.08	33.67
<b>Leaf temperature</b>	0.9953	0.1338	-0.5439	2.45
<b>Relative Water loss</b>	16.31	0.7482	-1.39	4.33
<b>Cell membrane thermo stability%</b>	9.69	6.96	-1.29	4.38
<b>Photosynthetic rate(μmol/m<sup>2</sup>/s)</b>	1.80	0.5476	0.9195	0.2862

Table 4.31 A showed that four of the parental genotypes had negative general combining ability effects and two parents had positive general combining ability effects. Maximum value of GCA effects (19.665) were observed for S-42 and considered to be the best general combiner for plant height. Parental inbred line Y-330 with value of -15.115 was the poorest general combiner. In case of single crosses, positive SCA was observed in 9 crosses. The most useful combinations were S-42 x F-189 (16.903), F-92 x S-42 (6.620) and P110 x F-189 (6.583). Cross F-189 x F-206 had maximum negative value of specific combining ability (-18.513) followed by F-110 x S-42 (-17.780). Positive reciprocal effects were shown by four crosses. F-206 x S-42 showed maximum value of 9.287 reciprocal effects. Negative reciprocal effects were exhibited by eleven crosses. Maximum negative value of -4.398 was shown by cross Y-330 x F-189. Analysis of variance for plant height indicated significant mean of squares due to both GCA and SCA effects revealing the importance of both additive as well as non-additive genetic effects under moisture deficit condition. Reciprocal effects were also significant. According to Table 4.31 B, under moisture deficit condition, three of the parents showed positive GCA effects. Parental line S-42 had maximum GCA effects (17.522).

Three parents showed negative GCA effects and inbred line Y-330 had maximum negative value (14.937). Among crosses nine combinations gave positive SCA effects. Most useful combination was F-189 x Y-330 with SCA value 17.019. Six of the crosses showed negative SCA effects and maximum negative value was shown by cross S-42 x Y-330 (-15.073). Among reciprocals seven crosses showed positive value with highest value of 11.00 by cross F-206 x F-192. Eight crosses showed negative reciprocal effects with maximum negative value of -10.572 shown by cross S-42 x F-110.

#### **4.4.2 Days to tasseling**

According to table 4.29 (A& B), mean squares for GCA and SCA effects were significant for days to tasseling. Reciprocal effects were also significant under both conditions. According to table 4.30 A and B estimates of variance of components were greater for GCA variance ( $\delta^2g$ ) as compared to SCA ( $\delta^2s$ ). Though both additive and non-additive genetic effects were significant but additive genetic effects were more important as compared to non-additive. Prakash and Ganguli (2004), Tallei and Kachaksaraei (1999) and Rana and Venod (2001) reported similar results. Ahmad (2002), Barati *et al.* (2004), and Naved (1979), concluded that both additive and non-additive genetic effects were important for this trait.

**Table 4.31: GCA, SCA and reciprocal effects for plant height under**

**A. Normal condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-3.416</u>	1.491	6.620	-0.017	-5.600	2.204
<b>F-110</b>	-2.310	<u>-4.516</u>	-17.780	6.583	2.500	5.304
<b>S-42</b>	1.000	-0.500	<u>19.665</u>	16.903	-11.180	-3.106
<b>F-189</b>	-3.500	-1.000	-1.500	<u>-0.198</u>	2.778	-18.513
<b>Y-330</b>	-1.000	1.000	-2.500	-4.398	<u>-15.115</u>	11.403
<b>F-206</b>	0.500	-0.500	9.257	-1.000	-3.000	<u>3.581</u>

SE<sub>GCA</sub> = 4.2420

SE<sub>SCA</sub> = 9.4855

SE<sub>Reciprocal</sub> = 10.3908

**B. Moisture deficit condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-4.997</u>	0.742	4.487	-2.878	-4.054	0.1000
<b>F-110</b>	6.552	<u>-0.731</u>	-8.006	-5.323	0.181	11.431
<b>S-42</b>	-2.500	-10.572	<u>17.522</u>	5.757	-15.073	2.366
<b>F-189</b>	0.347	1.167	3.500	<u>2.734</u>	17.019	-16.131
<b>Y-330</b>	-0.500	-6.000	-2.000	1.810	<u>-14.937</u>	4.540
<b>F-206</b>	11.000	-3.917	-0.882	6.500	-2.500	<u>0.409</u>

SE<sub>GCA</sub> = 3.1005

SE<sub>SCA</sub> = 6.9331

SE<sub>Reciprocal</sub> = 7.5948

Table 4.32: **GCA,SCA and reciprocal effects for days to tasseling under**

**A. Normal condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-0.837</u>	-0.163	0.087	-1.413	1.062	2.920
<b>F-110</b>	-0.500	<u>-1.665</u>	-1.585	1.415	-2.500	0.748
<b>S-42</b>	0.667	-0.500	<u>-1.415</u>	1.165	0.670	-1.002
<b>F-189</b>	0.500	0.500	-0.500	<u>0.585</u>	0.170	-2.002
<b>Y-330</b>	1.017	0.001	-1.500	-1.000	<u>-0.920</u>	-0.997
<b>F-206</b>	2.500	-1.500	-1.000	2.000	-0.500	<u>4.252</u>

SE<sub>GCA</sub> = 1.3121

SE<sub>SCA</sub> = 2.9341

SE<sub>Reciprocal</sub> = 3.2141

**B. Moisture deficit condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-1.925</u>	0.283	-1.047	-0.880	-0.503	3.551
<b>F-110</b>	2.167	<u>-0.445</u>	0.806	-0.361	0.065	-0.429
<b>S-42</b>	1.500	-0.500	<u>-1.782</u>	0.976	0.047	-1.092
<b>F-189</b>	1.000	0.001	-1.000	<u>0.551</u>	0.381	-0.759
<b>Y-330</b>	2.900	0.355	-1.000	-1.667	<u>-0.520</u>	0.776
<b>F-206</b>	2.000	-1.500	-0.500	-0.167	-2.078	<u>4.120</u>

SE<sub>GCA</sub> = 0.7953

SE<sub>SCA</sub> = 1.7784

SE<sub>Reciprocal</sub> = 1.9481

Table 4.32 A and B showed the combining abilities effects for days to tasseling under normal and moisture deficit conditions.. Under normal condition, two inbred lines displayed positive GCA effects. F-206 inbred line showed maximum value of GCA effects (4.252) and hence it was good general combiner. Four parents showed negative value of GCA effects. Among them F-110 showed -1.665 value of GCA being poor general combiner. Eight crosses showed positive SCA effects for days to tasseling. F-192 x F-206 showed maximum positive value (2.920) of SCA indicating most useful combination. F-110 x Y-330 showed maximum negative value (-2.500) of SCA being poor combiner. Seven crosses showed positive reciprocal effects. Maximum reciprocal effects were shown by F-206 x F-192 (2.500) followed by F-206 x F-189 (2.000). Eight combinations showed negative reciprocal effects. Among them Y-330 x S-42 showed maximum negative value of reciprocal effects (-1.500) followed by F-206 x F-110.

Under moisture deficit condition mean squares for GCA, SCA and reciprocal effects were significant. However, estimates of variance were greater than that of SCA. According to Table 4.32 B, two parents showed positive GCA and parent F-206 was good general combiner with a value of 4.120 followed by F-189 with GCA value of 0.551. Among crosses eight combinations showed positive SCA effects. Most useful combination was F-192 x F-206 with a SCA value of 5.551 followed by S-42 x F-189 (0.976). Seven of the crosses showed negative value of SCA effects. Maximum value of SCA was shown by S-42 x F-206 (-1.092) followed by F-192 x S-42 (-1.047). Seven combinations showed positive reciprocal effects. Y-330 x F192 combination showed maximum value (2.900) followed by F-110 x F-192 (2.167) and F-206 x F-192 (2.000). Eight combinations showed negative values. Y-330 x F-189 gave maximum negative value (-1.667) followed by F-206 x F-110 (-1.500). The comparison of combining ability under both conditions revealed that all the parents had consistency in expression of their GCA effects. Combinations S-42 x F-189, S-42 x Y-330 and F-189 x Y-330 showed positive SCA effects while crosses F-192 x F-189, S-42 x F-206 and F-189 x F-206 showed negative SCA effects under both the conditions.

#### **4.4.3 Days to silking**

Estimation of components of variation (Table 4.30) showed that GCA variance ( $\delta^2g$ ) was greater than SCA ( $\delta^2s$ ) indicating preponderance of additive gene effects. Newton and Eagle (1991), Tallei and Kochaksaraei (1999) Choukan (1999), Ogunbodede (2000), Revilla *et al.* (1999), Nigussie and Zellke (2001), Rana and Venod (2001) and Reddy (2004) reported that additive effects were important in genetic control

of days to silking. Vicente (2001), Ahmad (2002), Saleem *et al.* (2002) and Barati *et al.* (2004) concluded that both additive and non-additive gene effects were important for days to silking.

Table 4.33 (A & B) displayed the combining ability effects for days to silking under normal and moisture deficit conditions. Under normal condition two parental lines expressed positive GCA effect. Inbred line F-206 was good general combiner with GCA effect of 4.063 followed by F-189 having GCA value 0.389. Four inbred lines showed negative GCA effects and inbred line S-42 was poorest general combiner with GCA value of -1.487 followed by F-110 (-1.327). Among crosses seven combinations showed positive value of SCA effects. Combination F-192 x F-206 was good specific combination with SCA value of 2.639 followed by combination S-42 x F-189 (1.153). Eight crosses had negative value of SCA effects. Combination F-110 x S-42 was poorest with most negative value of SCA effects (-2.131), followed by Y-330 x F-206 (-1.514). Out of fifteen, six crosses had positive reciprocal effects. Combinations F-206 x F-192 (2.500), F-206 x F-189 (2.000) were important. Nine crosses had negative reciprocal effects. Combination Y-330 x S-42 gave most negative value of reciprocal effects (-1.500).

Under moisture conditions (Table 4.33 B) showed that five parental inbred lines showed negative GCA effects and inbred line F-206 was good general combiner with GCA effect (4.106). Inbred line S-42 showed negative value of GCA effect (-1.575). Six combinations out of fifteen, displayed positive value of SCA effects. Combination F-192 x F-206 was most useful with value of 2.742 followed by S-42 x F-189 (1.655). Nine crosses showed maximum negative SCA effects (-1.525) followed by F-189 x F-206 (-1.355). For days to silking eight combinations showed positive value of reciprocal effects. F-206 x F-192 showed highest positive value (2.500) as reciprocal effects followed by F-206 x F-189 (1.500). Seven crosses showed negative value of reciprocal effects. Maximum negative value of reciprocal effect was shown by five combinations i.e. Y-330 x S-42, Y-330 x F-189, F-206 x F-110, F-206 x S42 and F-206 x Y-330.

Comparison of specific combining ability effects for days to silking under normal and moisture deficit conditions (Table 4.33 A and B) depicted that four inbred lines maintained their negative GCA effects under both the conditions. F-206 inbred line showed positive GCA effects under both conditions. Inbred line F-189 showed positive value of GCA effects under normal where as under moisture deficit conditions it showed



Table 4.33: **GCA,SCA and reciprocal effects for days to silking under**

**A. Normal condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-1.146</u>	0.029	-0.066	-0.687	-0.262	2.639
<b>F-110</b>	-0.500	<u>-1.327</u>	-2.131	0.493	0.039	-0.139
<b>S-42</b>	0.158	-1.000	<u>-1.487</u>	1.153	0.535	-0.520
<b>F-189</b>	0.500	0.500	-1.000	<u>0.389</u>	0.160	-1.396
<b>Y-330</b>	-0.043	1.163	-1.500	-1.000	<u>-0.493</u>	-1.514
<b>F-206</b>	2,500	-0.542	-1.000	2.000	-1.000	<u>4.063</u>

SE<sub>GCA</sub> = 1.0311

SE<sub>SCA</sub> = 2.3058

SE<sub>Reciprocal</sub> = 2.5259

**B. Moisture deficit condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-1.409</u>	0.017	-0.326	-0.840	-0.350	2.742
<b>F-110</b>	-1.000	<u>-0.668</u>	-0.484	10.086	0.603	-0.498
<b>S-42</b>	0.020	0.001	<u>-1.575</u>	1.655	0.156	-1.091
<b>F-189</b>	0.500	1.167	0.172	<u>-0.311</u>	-0.107	-1.355
<b>Y-330</b>	1.077	-0.520	-1.500	-1.500	<u>-0.142</u>	-1.525
<b>F-206</b>	2.500	-1.500	-1.500	1.500	-1.500	<u>4.106</u>

SE<sub>GCA</sub> = 1.1866

SE<sub>SCA</sub> = 2.6534

SE<sub>Reciprocal</sub> = 2.9066

negative value of GCA effects. Six combinations maintained their positive value of SCA effects under both conditions.

#### 4.4.4 Anthesis silking interval (ASI)

Table 4.29 A and B showed that mean squares for GCA, SCA and reciprocal effects were significant for anthesis silking interval under normal and moisture deficit conditions which depicted that both additive and non-additive effects were involved. Table 4.30 revealed that a greater value of GCA variance ( $\delta^2g$ ) as compared to SCA ( $\delta^2s$ ) under normal conditions which depicted that additive genetic effects were more important for this trait. Ahmad (2002) and Parsad *et al.* (1988) reported that both additive and non-additive gene effects played role for anthesis-silking interval. Choukan (1999), Nigussie and Zellke (2001) and Tallei and Kochaksaraei (1999) found that additive genetic effects were important for anthesis-silking interval. Table 4.34 (A) revealed that for anthesis-silking interval under normal conditions three inbred lines were with positive GCA effects (F-192, S-42 and Y-330). Inbred line F-110, F-189 and F-206 showed negative GCA effects. Among crosses seven out of fifteen showed positive SCA effects. Combination F-189 x F-206 showed highest positive value of SCA effects (0.449) followed by F-192 x F-189 (0.368) and F-189 x Y-330 (0.363). Eight combinations showed negative value of SCA effects. F-192 x F-206 showed maximum negative value of SCA effects (-0.712) followed by F-110 x F-189(-0.571) and F-192 x Y-330 (-0.299), Reciprocal effect for anthesis-silking interval under normal conditions depicted that nine combinations expressed positive value of reciprocal effects. Maximum value of reciprocal effects were shown by combination Y-330 x F-192 followed by S-42 x F-192 (0.002). Six crosses showed negative value of reciprocal effects.

Under moisture deficit conditions three parental inbred lines showed positive GCA effects. Inbred Lines F-192 and Y-330 maintained their positive GCA effects under moisture deficit conditions (0.420, 0.292). Parental lines F-110, S-42 and F-189 showed negative GCA effects (-0.429, -0.153 and -0.406, respectively). Inbred line F206 gave maximum value of GCA effects (0.815) and stood first as general combiner. Among crosses, four combinations showed positive value of SCA effects. F-192 x Y-330, F-192 x F-206, F-110 x F-189 and S-42 x F-189 showed value of SCA effect, 0.0123, 0.274, 0.217 and 0.274, respectively. Nine combinations showed negative value of SCA effects. F-192 x F-110 was poor combiner with a negative value (-0.157) of SCA effects. Reciprocal effects under moisture deficit conditions were positive for eight combinations. Maximum value of reciprocal effects (0.353) was shown by cross F-206 x F-192 followed

Table 4.34: **GCA,SCA and reciprocal effects for anthesis silking interval under**

**A. Normal condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	0.049	0.267	0.203	0.368	-0.299	-0.712
<b>F-110</b>	0.001	-0.012	-0.238	-0.571	-0.238	0.349
<b>S-42</b>	0.002	-0.500	0.054	-0.138	0.196	-0.218
<b>F-189</b>	0.001	0.001	-0.500	-0.113	0.363	0.449
<b>Y-330</b>	0.500	-0.500	0.001	0.001	0.054	-0.217
<b>F-206</b>	0.001	0.001	-0.500	-0.001	-0.500	-0.033

$SE_{GCA} = 0.0207$

$SE_{SCA} = 0.0463$

$SE_{Reciprocal} = 0.0507$

**B. Moisture deficit condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	0.420	-0.157	-0.094	-0.152	0.0123	0.274
<b>F-110</b>	0.013	-0.429	-0.041	0.217	-0.041	-0.174
<b>S-42</b>	-0.428	-0.445	0.153	0.274	-0.151	-0.115
<b>F-189</b>	-0.500	1.020	0.183	-0.946	-0.025	-0.047
<b>Y-330</b>	0.333	0.001	0.100	-0.500	0.292	-0.144
<b>F-206</b>	0.353	-0.517	-0.355	0.001	-0.102	0.815

$SE_{GCA} = 0.0639$

$SE_{SCA} = 0.1430$

$SE_{Reciprocal} = 0.1566$

by Y-330 x F-192 (0.333). Seven combinations showed negative value of reciprocal effects. Maximum negative value of reciprocal effects were shown by F-206 x F-110 (-0.517).

Comparison of combining ability effects for anthesis silking interval under normal and moisture deficit conditions depicted that inbred line F-206 showed negative value of SCA effect(-0.033) under normal conditions and under moisture deficit condition, where as under moisture deficit condition it showed positive value (0.815) of SCA under normal conditions. Inbred line S-42 showed positive value of SCA effects (0.054) under normal conditions and under moisture deficit conditions it showed negative value (-0.153). Under normal conditions F-189 x F-206 showed 0.449 value of SCA effects, while under moisture deficit conditions its value changed to negative (-0.047). Cross F-192 x F-206 showed negative value SCA effects (-0.712) and under moisture deficit condition value changed to positive (0.274). For reciprocal effects Y-330 x F-192 maintained its positive value under both the conditions.

#### **4.4.5 Days to maturity**

Table 4.29 A and B depicted that mean squares of GCA, SCA and reciprocal effects regarding days to maturity were significant under both the conditions. Table 4.30 depicted that GCA variance ( $\delta^2g$ ) was greater as compared to SCA variance ( $\delta^2s$ ). It was clear that additive gene effects were important under both the conditions. Akbar (2008) found that days to maturity was under control of additive gene effects. Table 4.35 A depicted the GCA, SCA and reciprocal effects under normal conditions. Three parental inbred lines showed positive value of GCA effects (S-42, F-189, F-206) with value of GCA variance ( $\delta^2g$ ) 3.952, 2.025 and 5.315, respectively. F-206 stood first as general combiner. Inbred line Y-330 showed maximum negative value of GCA effects (-6.923) followed by F-110 (-2.723) and F-192 (-1.645). Eight out of fifteen combinations showed positive value of SCA effects. F-192 x F-206 was most efficient combination with a SCA value of 3.135 followed by S-42 x Y-330 (2.609) and F-192 x F-189 (1.258). Seven crosses showed maximum negative value of SCA effects (-2.754) followed by F-192 x Y-330 (-2.160) and F-192 x S-42 (-1.668). Twelve out of fifteen showed positive values of reciprocal effects. F-206 x F192 showed maximum positive value of reciprocal effects followed by F-206 x S-42 (1.527). Three crosses Y-330 x F-192, F-189 x S-42 and Y-330 x F-189 showed negative reciprocal effects (-2.867, -0.662 and -0.500, respectively).

Under moisture deficit conditions (table 4.35 B) three parental inbred lines showed positive value of GCA effects. F-206 had maximum value of GCA effects

Table 4.35: **GCA,SCA and reciprocal effects for days to maturity under.**

**A. Normal condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-1.645</u>	0.006	-1.668	1.258	-2.160	3.135
<b>F-110</b>	0.500	<u>-2.723</u>	0.409	-0.831	0.784	0.046
<b>S-42</b>	0.500	0.500	<u>3.952</u>	-0.350	2.609	0.765
<b>F-189</b>	0.500	0.333	-0.662	<u>2.025</u>	-0.464	-0.702
<b>Y-330</b>	-2.867	0.001	0.500	-0.500	<u>-6.923</u>	-2.754
<b>F-206</b>	2.667	0.500	1.527	0.500	0.500	<u>5.315</u>

SE<sub>GCA</sub> = 2.4758

SE<sub>SCA</sub> = 5.5421

SE<sub>Reciprocal</sub> = 6.0711

**B. Moisture deficit condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-3.157</u>	0.244	-0.910	-3.171	2.402	1.467
<b>F-110</b>	0.598	<u>-0.910</u>	0.255	1.455	0.655	-1.753
<b>S-42</b>	-0.505	-0.250	<u>3.227</u>	0.265	-1.254	2.776
<b>F-189</b>	-2.540	0.667	1.720	<u>0.110</u>	-0.732	1.082
<b>Y-330</b>	-3.000	0.500	-0.595	1.467	<u>-4.923</u>	-1.907
<b>F-206</b>	2.360	2.333	3.667	3.088	0.500	<u>5.652</u>

SE<sub>GCA</sub> = 2.1632

SE<sub>SCA</sub> = 4.8371

SE<sub>Reciprocal</sub> = 5.2988

(5.652) followed by S-42 (3.227) and F-189 (0.110). Inbred line Y-330 showed maximum negative value of GCA effects (-4.923) followed by F-192 (-3.157) and F-110 (-0.910). Among nine of fifteen crosses showed positive value of SCA effects. Combination S-42 x F-206 was most useful with maximum positive values of SCA effects (2.776) followed by F-192 x Y-330 (2.402) and F-110 x F-189 (1.455). Six combinations showed negative SCA effects. F-192 x F-189 showed maximum negative value (-3.171) followed by Y-330 x F-026 (-1.907) and F-110 x F-206 (-1.753). Ten crosses out of fifteen showed positive reciprocal effects. F-206 x S-42 showed maximum value of reciprocal effects (3.667) followed by F-206 x F-189 (3.088) and F-206 x F-192 (2.360).

Comparison of combining ability effects for days to maturity under two conditions depicted that parental lines showed same behaviour under both conditions regarding GCA effects. F-206 was most promising inbred line under both the conditions with positive value of 5.315 and 5.652 respectively. Among crosses, F-192 x F-189 showed positive value of SCA effects (1.258) under normal conditions and under moisture deficit conditions its value changed to negative (-3.171). Maximum value of reciprocal effects (2.667) was shown by F-206 x F-192 under normal conditions, while under moisture deficit conditions cross F-206 x S-42 showed maximum value of reciprocal effects (3.667).

#### **4.4.6 Grain yield per plant**

Table 4.29 A and B showed that mean squares for GCA, SCA and reciprocal effects were significant regarding grain yield per plant under normal and moisture deficit conditions. Table 4.30 A and B regarding estimates of variance components showed that GCA variance ( $\delta^2_g$ ) were greater as compared to SCA variance ( $\delta^2_s$ ), but difference was negligible. So it was concluded that for grain yield per plant, both additive and non-additive gene effects were important. However, additive gene action was more important than non-additive. Nigussie and Zellke (2001), Joshi *et al.* (1998), Lin and Chen (1986), Beck *et al.* (1990), Ogunbodede (2000), Yuan *et al.* (2003) and Rezaei *et al.* (2005) reported that grain yield per plant was controlled by additive gene action. Naved (1979), Choukan (1999), Lemos *et al.* (1999), Mandal *et al.* (2001), Shreenivasa and Singh (2001), Ahmad *et al.* (2002), Chen *et al.* (2002), Gribincea (2002) and Barati *et al.* (2004)

Table 4.36: **GCA,SCA and reciprocal effects for grain yield per plant under**

**A. Normal condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-3.327</u>	-6.890	0.511	12.738	0.446	1.739
<b>F-110</b>	-1.567	<u>-8.549</u>	6.400	-4.373	0.835	14.128
<b>S-42</b>	-1.500	-0.500	<u>2.116</u>	-0.755	1.419	-8.144
<b>F-189</b>	2.000	2.667	2.383	<u>-2.610</u>	-3.771	3.139
<b>Y-330</b>	0.667	-1.500	0.730	0.500	<u>-4.652</u>	-1.034
<b>F-206</b>	0.367	-25.200	4.573	0.417	-5.032	<u>17.022</u>

SE<sub>GCA</sub> = 1.2671

SE<sub>SCA</sub> = 2.8335

SE<sub>Reciprocal</sub> = 3.1039

**B. Moisture deficit condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-8.209</u>	5.303	-3.340	-1.220	0.732	-5.753
<b>F-110</b>	-1.382	<u>-5.392</u>	2.581	0.343	-3.085	12.214
<b>S-42</b>	-2.745	-1.150	<u>5.154</u>	-1.640	5.569	-1.720
<b>F-189</b>	1.000	1.947	-3.843	<u>-1.711</u>	-0.604	4.841
<b>Y-330</b>	-1.000	2.000	-0.800	-0.495	<u>-1.663</u>	2.201
<b>F-206</b>	-1.000	-20.217	3.270	-4.575	-5.167	<u>11.822</u>

SE<sub>GCA</sub> = 1.3096

SE<sub>SCA</sub> = 2.9285

SE<sub>Reciprocal</sub> = 3.2080

found that grain yield per plant was under control of both additive and non-additive gene action.

Table 4.36 A revealed that two inbred lines out of six were good general combiner. F-206 showed GCA effects (17.012) followed by S-42 (2.116). Five inbred lines showed negative value of GCA effects. Maximum negative value of GCA effects F-110 (-8.549) followed by Y-330 (-4.652) and F-192 (-3.327). Under normal conditions, nine crosses showed positive value of SCA effects. F-110 x F-206 showed greater value of SCA effects (14.128) followed by F-192 x F-189 (12.738) and F-110 x S-42 (6.400). Six crosses showed negative value of SCA effects. Cross S-42 x F-206 showed maximum value of SCA effects (-8.144) followed by F-192 x F-110 (-6.890) and F-110 x F-189 (-4.373). Eight of the crosses showed positive value of reciprocal effects. F-206 x S-42 showed maximum value of reciprocal effects (4.573) followed by F-189 x S-42 (2.383) and F-189 x F-110 (2.667). Under moisture stress conditions again two inbred lines showed positive values of GCA effects. Maximum positive value of GCA effects (11.822) was shown by F-206 followed by S-42 (5.154). F-192 showed maximum negative value of GCA effects (-8.209) followed by F-110 (-5.392). Eight crosses were observed as positive combinations, Maximum value of SCA effects (12.214) was shown by F-110 x F-206 followed by S-42 x Y-330 (5.569) and F-192 x F-110 (5.303). Only three crosses showed positive value of reciprocal effects. Maximum value of reciprocal effects (3.270) was shown by F-206 x F-110 followed by Y-330 x F-110 (2.000) and F-189 x F-110 (1.947). Maximum negative value of reciprocal effects (3.270) was observed in cross F-206 x Y-330 (-5.167) followed by F-206 x F-189 (-4.575) and F-189 x S-42 (-3.843).

Comparison of GCA, SCA and reciprocal effects for grain yield per plant under normal and moisture deficit conditions depicted that inbred line F-206 and S-42 observed positive value of GCA effects under both the conditions. Inbred lines F-192, F-110, F-189 and Y-330 showed negative value of GCA effects under both the conditions. Cross F-110 x F-206 had positive (maximum) value of SCA effects (14.128 and 12.214) under normal and moisture deficit conditions. Crosses F-192 x S-42, F-192 x F-189, F-192 x F-206 and F-110 x Y-330 changed their values of SCA effects from positive to negative.



#### 4.4.7 100-grain weight

Regarding the 100-grain weight of 6 x 6 diallel crosses under normal and moisture deficit conditions, mean squares for GCA, SCA and reciprocal effects are presented in table 4.29 A and B. All the mean squares were significant under normal and moisture deficit conditions. This was depicted that both additive and non-additive gene actions were involved in the inheritance of the trait under discussion. However, table 4.30 depicted that GCA variance ( $\delta^2_g$ ) were greater as compared to SCA variance ( $\delta^2_s$ ) indicating the importance of additive type of gene action. Khotyleva and Lemesh (1994), Munir *et al.* (1977), Bawzir (1983), Tabassum (1989), Ramamurthy (1980), Siddiqui (1988) and Tabassum (2007) reported that kernel weight was under control of additive and non-additive type of gene action, while Ahmad (2002), Malik (1990), Yousaf (1992), Malik *et al.* (2004) and Tabassum (2004) reported over-dominance type of gene action for grain weight. Altinbs and Tosun (1998), Dubey *et al* (2000), Prakash and Ganguli (2004) and Barati *et al.* (2004) concluded that additive gene effects were significant for grain weight. Table 4.37 A depicted three inbred lines (S-42, F-189 and F-206) had positive values of GCA effects (1.214, 1.847 and 2.459) regarding 100-grain weight under normal conditions. Inbred line Y-330 had maximum negative value of GCA effects (-2.125) followed by F-192 (-1.711) and F-110 (-0.510). So it was noted that F-206 was good general combiner with respect to 100-grain weight. Nine of the crosses showed positive value of SCA effects and six had negative value of SCA effects. Maximum value of SCA effects (1.807) was shown by cross S-42 x Y-330 followed by F-192 x F-206 (1.790) and Y-330 x F-206 (1.602). Maximum negative value of SCA effects was shown by S-42 x F-206 (-1.736) followed by F-110 x S-42 (-0.601) and F-192 x F-189 (-0.591). Twelve crosses showed positive values of reciprocal effects. Maximum value of reciprocal effects was shown by cross F-206 x F-192 (2.898) followed by S-42 x F-192 (2.500) and F-189 x F-110 (2.000). Maximum negative value of reciprocal effects (-2.125) was shown by cross F-206 x F-189.

Under moisture stress conditions only two inbred lines showed positive value of GCA effects. S-42 showed 1.914 and F-189 showed 0.997. Y-330 showed maximum negative value of GCA effects (-1.224) followed by F-189 (-1.085) and F-206 (-0.498). Among crosses seven out of fifteen had positive value of SCA effects. Maximum negative value of SCA effects (-1.406) was shown by cross F-110 x S-42. Twelve crosses had positive value of reciprocal effects. Maximum value was shown by cross F-189 x F-192 (2.580) followed by S-42 x F-192 (2.028). F-110 x F-192 had maximum negative

Table 4.37: **GCA,SCA and reciprocal effects for 100-grain weight under**

**A. Normal condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-1.711</u>	-0.053	0.433	-0.599	-1.428	1.790
<b>F-110</b>	-0.137	<u>-0.510</u>	-0.601	0.272	0.904	0.022
<b>S-42</b>	2.500	0.333	<u>1.214</u>	0.048	1.847	-1.736
<b>F-189</b>	1.355	2.000	0.500	<u>1.847</u>	0.387	-0.197
<b>Y-330</b>	-1.133	0.500	0.500	0.387	<u>-2.125</u>	1.602
<b>F-206</b>	2.898	1.320	1.500	-2.125	-0.500	<u>2.459</u>

SE<sub>GCA</sub> = 0.2180

SE<sub>SCA</sub> = 0.4876

SE<sub>Reciprocal</sub> = 0.5341

**B. Moisture deficit condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-1.085</u>	0.620	-0.256	-0.246	-0.084	-0.238
<b>F-110</b>	-0.527	<u>-0.104</u>	-1.406	0.330	0.838	-0.161
<b>S-42</b>	2.028	-0.167	<u>1.914</u>	-0.585	1.381	1.154
<b>F-189</b>	2.580	1.652	0.245	<u>0.997</u>	0.299	0.132
<b>Y-330</b>	-0.298	0.222	0.500	1.500	<u>-1.224</u>	-0.454
<b>F-206</b>	0.125	1.667	2.000	0.030	0.453	<u>-0.498</u>

SE<sub>GCA</sub> = 0.3558

SE<sub>SCA</sub> = 0.7956

SE<sub>Reciprocal</sub> = 0.8715

value (-0.527) of reciprocal effects. Comparing the combining ability estimates under both conditions S-42 and F-192 proved stable for positive GCA effects. Similarly inbred lines F-192, F-110 and Y-330 retained their negative GCA effects. Inbred line F-206 behaved differently. Its GCA effects were positive under normal conditions and negative under moisture deficit conditions. Cross S-42 x F-189 showed positive value (0.048) under normal conditions and negative under moisture stress conditions. F-110 x F-192 and Y-330 and F-192 showed negative reciprocal effects under both the conditions.

#### 4.4.8 Ear leaf area

Table 6.29 showing mean squares for GCA, SCA and reciprocal effects depicted that all effects were significant for ear leaf area under both the conditions, and there by trait was found under control of both the additive and non-additive gene action. However, value of mean square for GCA effects were much more as compared to SCA effects suggesting that additive genetic effects were more important. Similarly, Table 4.30 regarding estimates of variance components of variation also depicted that value of GCA variance ( $\sigma_g^2$ ) was more than that of SCA variance ( $\sigma_s^2$ ), displaying that additive gene effects were important in controlling the trait. Khotyleva and Lemesh (1994) and Malik *et al.* (2004) also reported additive and non-additive genetic effects for the trait. However Singh *et al.* (2000) and Akbar (2008) reported non-additive effects for leaf area.

Table 3.38 A depicted that three parental inbred lines showed positive GCA effects. Inbred line F-206 showed maximum value of GCA effects (28.647) followed by S-42 (8.884) and F-189 (5.657). Maximum value of negative GCA effects was shown by F-192 (-14.476). Only seven crosses out of fifteen showed positive SCA effects. F-192 x F-189 showed maximum value of SCA effects (8.816) followed by F-110 x S-42 (0.338) and F-110 x F-206 (5.575) F-192 x F-110 showed maximum negative value of SCA effects (-8.937). Only three crosses had positive value of reciprocal effects. F-206 x S-42 had maximum value of reciprocal effects (15.113) followed by Y-330 x F-192. Maximum negative reciprocal effects (-4.145) were shown by F-189 x S-42.

Under moisture deficit conditions (table 4.38 B) inbred line F-206 had maximum GCA effects (17.858) followed by S-42 (7.923) and F-189 (5.829). Maximum negative GCA effect was presented by F-110 (-11.894). Eight combinations had positive SCA effects. F-192 x S-42 showed maximum SCA effects (11.258) followed by F-192 x F-206 (8.154) and F-192 x S-42 (7.089). F-192 x F-110 had maximum negative value of SCA effects (-9.927). Six crosses had positive reciprocal effects. F-206 x S-42 had maximum

Table 4.38: **GCA,SCA and reciprocal effects for ear leaf area under**

**A. Normal condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-14.476</u>	-8.937	-0.412	8.816	0.759	2.825
<b>F-110</b>	-2.792	<u>-14.726</u>	8.338	5.566	1.009	5.575
<b>S-42</b>	-1.000	-0.500	<u>8.884</u>	-7.852	-3.901	-1.401
<b>F-189</b>	1.000	-1.500	-4.145	<u>5.657</u>	-0.173	-0.040
<b>Y-330</b>	4.700	-1.437	-3.000	-0.500	<u>-13.986</u>	-2.662
<b>F-206</b>	-1.000	-3.500	15.133	-1.607	-0.998	<u>28.647</u>

SE<sub>GCA</sub> = 3.8983

SE<sub>SCA</sub> = 8.7170

SE<sub>Reciprocal</sub> = 9.5490

**B. Moisture deficit condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-10.225</u>	-9.927	7.089	6.446	-5.998	8.154
<b>F-110</b>	2.167	<u>-11.894</u>	11.258	2.383	3.005	5.735
<b>S-42</b>	-1.000	-1.500	<u>7.923</u>	-4.149	-3.645	-8.994
<b>F-189</b>	11.737	-2.500	-1.185	<u>5.829</u>	-0.551	-1.233
<b>Y-330</b>	9.500	2.167	-1.000	-1.000	<u>-9.491</u>	4,420
<b>F-206</b>	3.000	-1.575	21.500	-7.333	1.000	<u>17.858</u>

SE<sub>GCA</sub> = 2.3689

SE<sub>SCA</sub> = 5.2971

SE<sub>Reciprocal</sub> = 5.8027

reciprocal effects (21.500) and F-206 x F-189 had maximum negative value of reciprocal effects (-7.333).

Comparison of combining ability estimates regarding the leaf area under normal and moisture deficit conditions depicted that parental genotypes retained their positive or negative GCA effects under both the conditions. F-206 showed maximum GCA effects under both the conditions. Similarly, F-110 showed maximum negative value of GCA (-14.726). Cross F-192 x Y-330 showed positive value of SCA effects (0.759) under normal conditions while under moisture deficit conditions its value was negative (-5.998). F-192 x S-42 and Y-330 x F-206 showed negative value of GCA effects under normal conditions and positive under moisture stress.

#### **4.4.9 Leaf temperature**

Table 4.29 regarding the mean squares for GCA, SCA and reciprocal effects showed that both GCA and SCA effects were significant. Estimates of variance components relative to GCA and SCA (Table 4.30) showed that under both the conditions GCA variance ( $\delta^2g$ ) was greater than that of SCA variance ( $\delta^2s$ ). It was concluded that both the additive and non-additive gene effects were important and additive gene action was more important for controlling the leaf temperature. Hussain (2009) reported that mean squares of GCA effects were greater than those of SCA effects indicating the importance of additive genetic effects for leaf temperature under normal and moisture stress conditions.

Table 4.39 A depicted that under normal conditions parental genotype F-192 displayed maximum value of GCA effects (2.028) being best general combiner followed by Y-330 (0.361). S-42 was poorest general combiner with a GCA effects of -1.306 followed by F-206 (-0.639). Seven crosses displayed positive SCA effects. F-110 x F-206 had maximum value of SCA effects (1.972) followed by F-192 x F-189 (1.722) and S-42 x Y-330 (1.139). F-189 x F-206 had maximum negative value of SCA effects (-1.972) and S-42 x Y-330 (-1.111). Eight of the combinations showed positive value of reciprocal effects. Y-330 x F-192 had maximum value of reciprocal effects (0.500).

Under moisture stress conditions (Table 4.39 B), three parental genotypes showed positive value of GCA effects (1.944) followed by F-110 (0.194) and Y-330 (0.193). Five crosses displayed positive value of SCA effects. F-192 x F-189 had maximum value of SCA effects (1.806) being best combination followed by F-110 x F-206 (1.805) and S-42

Table 4.39 **GCA,SCA and reciprocal effects for leaf temperature under**

**A. Normal condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>2.028</u>	-0.194	-0.028	1.722	-0.444	0.556
<b>F-110</b>	-0.500	<u>0.111</u>	-0.111	0.139	-1.028	1.972
<b>S-42</b>	1.000	0.001	<u>-0.556</u>	-0.694	1.139	0.139
<b>F-189</b>	0.001	-0.500	0.001	<u>-1.306</u>	0.889	-1.111
<b>Y-330</b>	0.500	0.001	-0.500	-0.500	<u>0.361</u>	0.278
<b>F-206</b>	0.500	-1.000	-0.500	-0.500	0.001	<u>-0.639</u>

SE<sub>GCA</sub> = 0.4295

SE<sub>SCA</sub> = 0.9604

SE<sub>Reciprocal</sub> = 1.052

**B. Moisture deficit condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	1.944	-0.194	-0.28	1.806	-1.694	1.056
<b>F-110</b>	0.001	0.194	-0.028	-0.444	-0.444	1.805
<b>S-42</b>	1.500	-0.500	-0.472	-1.278	1.222	0.472
<b>F-189</b>	0.500	-0.500	0.001	-1.306	1.056	-1.694
<b>Y-330</b>	1.500	0.001	-1.000	-1.000	0.193	-0.694
<b>F-206</b>	0.500	-1.500	-0.500	-0.500	0.001	-0.556

SE<sub>GCA</sub> = 0.6396

SE<sub>SCA</sub> = 1.4302

SE<sub>Reciprocal</sub> = 1.5667

x Y-330 (1.222). F-189 x F-206 cross had highest negative value of SCA effects (-1.694) being poorest combination. Seven crosses showed positive reciprocal effects and eight combinations showed negative value.

By comparing the combining ability effects for leaf temperature under normal and moisture stress conditions it was concluded that parental genotypes displayed similar GCA effects under both the conditions. F-110 x F-189 displayed positive value of SCA effects (0.139) under normal conditions and negative (-0.444) under moisture deficit conditions.

#### **4.4.10 Relative water loss**

Relative water loss under normal and moisture stress conditions were analyzed and given in Table 4.40 for GCA, SCA and reciprocal effects. Table 4.29 A and B regarding mean squares for GCA, SCA and reciprocal effects depicted that all were highly significant under both the conditions for this trait. Estimates of variance components (Table 4.30) depicted that GCA variance ( $\delta^2g$ ) was greater than SCA variance ( $\delta^2s$ ). It was concluded that additive genetic effects were important for controlling the trait under discussion.

Table 4.40 (A) depicted GCA, SCA and reciprocal effects under normal conditions. Three parents out of six displayed positive GCA effects. F-206 showed maximum value of GCA effects (5.688) and was best general combiner followed by F-189 (3.022) and S-42 (2.605). Negative value of GCA effects was shown by Y-330 (-4.985) followed by F-192 (-3.466) and F-110 (-2.864). Among crosses six combinations displayed positive value of SCA effects. F-192 x F-206 showed maximum value of SCA effects (3.716) being best combination followed by F-110 x F-189 (1.781) and F-110 x F-206 (1.614). F-192 x F-110 showed greater value of SCA effects (-3.231) being poorest combination. Ten combinations showed positive reciprocal effects. F-189 x F-192 had highest positive value of reciprocal effects. F-189 x F-192 had highest positive value of reciprocal effects (1.500). Highest negative value was displayed by Y-330 x F-189 and F-189 x S-42 (-1.000).

Under moisture stress conditions (Table 4.4 B) again three parental genotypes displayed positive GCA effects. F-206 showed highest value (4.554) being best general combiner followed by F-189 (3.287) and S-42 (3.176). Negative GCA effects was shown by Y-330 (-4.625) followed by F-110 (-3.325) and F-192 (-3.106) Nine crosses showed

Table 4.40: **GCA,SCA and reciprocal effects for relative water loss under**

**A. Normal condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-3.466</u>	-3.231	-0.200	-0.117	-0.336	3.716
<b>F-110</b>	0.500	<u>-2.864</u>	-2.303	1.781	1.474	1.614
<b>S-42</b>	0.001	0.500	<u>2.605</u>	1.312	-1.682	0.145
<b>F-189</b>	1.500	0.001	-1.000	<u>3.022</u>	0.901	-1.772
<b>Y-330</b>	0.275	-1.313	0.001	-1.000	<u>-4.985</u>	-0.265
<b>F-206</b>	0.001	-0.500	0.500	0.001	-0.500	<u>5.688</u>

SE<sub>GCA</sub> = 1.3464

SE<sub>SCA</sub> = 3.0107

SE<sub>Reciprocal</sub> = 3.2981

**B. Moisture deficit condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>3.106</u>	-0.3m70	-0.200	-2.311	0.601	0.699
<b>F-110</b>	0.158	<u>-3.315</u>	1.990	1.899	0.339	1.122
<b>S-42</b>	0.500	0.500	<u>3.176</u>	-1.408	-1.680	0.444
<b>F-189</b>	0.500	-0.500	-0.500	<u>3.287</u>	1.280	1.000
<b>Y-330</b>	0.500	-1.972	-0.500	-0.500	<u>-4.625</u>	0.912
<b>F-206</b>	1.697	-0.980	-1.167	0.500	0.500	<u>4.584</u>

EGCA = 0.8501

SE<sub>SCA</sub> = 1.9010

SE<sub>Reciprocal</sub> = 2.0825



positive value of SCA effects. Highest SCA effects were displayed by F-110 x F-189 (1.899) followed by F-189 x Y-330 (1.280) and F-110 x F-206 (1.122). F-192 x F-189 showed highest negative SCA effects (-2.311) followed by S-42 x Y-330 (-1.680). Eight combinations showed positive reciprocal effects. F-206 x F-192 displayed highest reciprocal effects (1.697) followed by F-110 x F-192 (1.158). Y-330 x F-110 showed highest negative reciprocal effect (-1.972).

Comparison of combining ability effects for relative water loss under moisture stress conditions depicted that parental genotype behaved similarly with respect to GCA effects under both conditions. F-206 proved to be best general combiner under both conditions. Similarly, Y-330 was poorest general combiner under both conditions. S-42 x F-189 showed positive SCA effects under normal (1.312) and negative (-1.408) under moisture stress conditions. F-192 x Y-330, F-189 x F-206 and Y-330 x F-206 displayed negative SCA effects under normal and positive under moisture stress conditions.

#### **4.4.11. Cell membrane thermo stability**

Estimates of variance components and mean squares for GCA, SCA and reciprocal effects (Table 4.29 and 4.30) depicted that fore mentioned effects were significant for cell membrane thermo stability. It was observed that value of GCA variance ( $\delta^2g$ ) was greater than that of SCA variance ( $\delta^2s$ ) indicating the involvement of additive type of gene action for controlling the cell membrane thermo stability.

Table 4.41 (A) depicted that under normal conditions three of the parental genotypes showed positive value of GCA effects. F-206 had highest value of GCA effects (4.500) being best general combiner with reference to cell membrane thermo stability followed by F-189 (3.667) and S-42 (1.417). Genotype F-192 exhibited negative value of GCA effects (-4.00) followed by Y-330 (-2.833) and F-110(-2.750). Nine crosses showed positive value of SCA effects for trait under discussion. Highest value of SCA effects (2.917) was displayed by F-192 x F-189 being best combination followed by F-110 x F-189 (2.667) and Y-330 x F-206 (1.917). Six out of fifteen combinations showed negative value of SCA effects. F-110xY-330 had negative value of SCA effect (-1.633) being poorest combination. Only four combinations showed positive value of reciprocal effects. Combinations F-206 x F-192, F-206 x F-110, F-206 x S-42 and F-206 x F-189 showed positive reciprocal effects. Eleven combinations showed negative value of reciprocal effects. S-42 x F-110 displayed highest negative value of reciprocal effects (-1.000). Under moisture deficit conditions (Table 4.41 B), again three genotypes displayed positive value of GCA effects. Genotype S-42 had highest value of GCA effects (17.522)

Table 4.41: GCA, SCA and reciprocal effects for cell membrane thermo stability  
under

**A. Normal condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-4.000</u>	-0.667	1.167	2.917	0.117	1.083
<b>F-110</b>	-0.500	<u>-2.750</u>	1.417	2.667	-1.833	1.833
<b>S-42</b>	-0.500	-1.000	<u>1.417</u>	0.500	-0.001	-0.333
<b>F-189</b>	-0.500	-0.500	-0.500	<u>3.667</u>	-0.250	-1.583
<b>Y-330</b>	-0.500	-0.500	-0.500	-0.500-	<u>2.833</u>	1.917
<b>F-206</b>	0.500	0.500	0.500	0.500	-0.500	<u>4.500</u>

SE<sub>GCA</sub> = 0.9081

SE<sub>SCA</sub> = 2.036

SE<sub>Reciprocal</sub> = 2.2244

**B. Moisture deficit condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	-3.778	-0.722	-0.139	4.611	1.528	1.528
<b>F-110</b>	-0.500	-2.361	2.944	3.194	-2.889	1.111
<b>S-42</b>	1.000	0.500	1.556	0.278	-0.306	-1.306
<b>F-189</b>	-0.500.	0.500	-0.500	3.306	-2.056	-3.056
<b>Y-330</b>	-0.500.	-0.500	0.001	0.001	-2.611	3.861
<b>F-206</b>	1.000	3.000	-0.500	0.500	--0.500	3.889

SE<sub>GCA</sub> = 0.8550

SE<sub>SCA</sub> = 1.9119

SE<sub>Reciprocal</sub> = 2.0944

followed by F-189 (2.734) and F-206 (0.409). Y-330 showed negative value (-14.937) and was poorest general combiner followed by F-192 (-4.997) and F-110 ((0.731). Nine of the single crosses had positive value of SCA effects. F-189 x Y-330 combination was best with highest value of SCA effects (17.019) followed by F-110 x F-206 (11.473) and S-42 x F-189 (5.757). F-189 x F-206 showed highest negative value of SCA effects (-16.131) and was poorest combination followed by S-42 x Y-330 (-15.073) and F-110 x S-42 (-8.006). Seven combinations showed positive value of reciprocal effects. Highest positive value of reciprocal effects was shown by F-206 x F-192 (11.000) followed by F-110 x F-192 (6.552) and F-206 x F-189 (6.500). Maximum negative value of reciprocal effects (-10.572) was exhibited by cross S-42 x F-110 followed by Y-330 x F-110 (-6.000). and F-205 x F-110 (-3.917).

Comparison of combining ability effects regarding cell membrane thermostability under normal and moisture deficit conditions depicted that genotype F-189 showed negative value of GCA effects (-0.198) under normal and positive (2.734) under moisture stress conditions. Rest of the parental inbred lines retained their negative or positive GCA effects accordingly. Among crosses, F-110 x F-189 showed positive value of SCA effects under normal condition (6.583) but under moisture stress conditions it displayed negative SCA effects (-5.323). Combination S-42 x F-206 had negative value of SCA effects (-3.106) under normal condition and it exhibited positive value of SCA effects (2.366) under moisture deficit condition. Reciprocal effects for S-42 x F-192, Y-330 x F-110 and F-206 x S-42 were positive under normal conditions and turned negative under moisture stress conditions. Value of reciprocal effects for combinations, F-110 x F-192, F-189 x F-192, F-189 x F-110, F-189 x S-42, Y-330 x F-189 and F-206 x F-189 were negative under normal conditions and became positive under moisture deficit conditions. Akbar (2008) and Hussain (2009) reported that cell membrane thermostability was under the control of non-additive type of gene action.

#### **4.4.12 Photosynthetic rate**

Regarding the photosynthetic rate Table 4.29 A and B depicted that mean squares for GCA, SCA and reciprocal effects were significant under normal and moisture stress conditions. It was deduced that both additive and non-additive genetic effects were important. However, Table 4.30 displayed that estimates of variance components relative to GCA variance ( $\delta^2g$ ) were greater than that of SCA variance ( $\delta^2s$ ) indicating the importance of additive gene action in relation to photosynthetic rate under normal and moisture stress conditions.

Table 4.42: **GCA,SCA and reciprocal effects for photosynthetic rate under**

**A. Normal condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	-1.819	-0.959	0.404	2.124	-0.701	0.654
<b>F-110</b>	0.500	0.119	0.476	0.020	-0.181	0.363
<b>S-42</b>	-2.500	-1.500	0.756	-1.117	1.015	-0.099
<b>F-189</b>	-1.500	0.001	-1.167	2.035	0.235	-1.033
<b>Y-330</b>	-0.127	1.667	-0.500	1.000	-2.430	0.932
<b>F-206</b>	-1.000	-1.000	0.155	-0.500	-1.000	1.339

$SE_{GCA} = 0.2070$

$SE_{SCA} = 0.4628$

$SE_{Reciprocal} = 0.5070$

**B. Moisture deficit condition**

Parents	<b>F-192</b>	<b>F-110</b>	<b>S-42</b>	<b>F-189</b>	<b>Y-330</b>	<b>F-206</b>
<b>F-192</b>	<u>-1.988</u>	-1.424	0.863	1.041	0.022	-0.534
<b>F-110</b>	1.000	<u>0.467</u>	-0.863	0.271	0.400	1.270
<b>S-42</b>	-2.000	-0.622	<u>0.180</u>	-0.128	0.317	-0.109
<b>F-189</b>	-1.500	-0.520	-0.500	<u>1.503</u>	-0.135	-0.098
<b>Y-330</b>	0.667	2,500	0.523	0.001	<u>-1.312</u>	0.717
<b>F-206</b>	0.193	0.167	-0.500	-0.500	-0.500	<u>1.150</u>

$SE_{GCA} = 0.2184$

$SE_{SCA} = 0.4884$

$SE_{Reciprocal} = 0.5150$

Under normal conditions (Table 4.42 A) showed that for photosynthetic rate, four of parental genotypes showed positive value of GCA effects. Genotype F-189 had highest value of GCA effects (2.035) being best general combiner followed by F-206 (1.339) and S-42 (0.756). Genotype Y-330 (-2.430) and F-189 (-1.819) had negative GCA effects. F-189 had highest value of GCA effects. Combination F-192 x F-189 showed positive value of SCA effects (2.124) and was best combination followed by Y-330 x F-206 (0.932) and F-192 x F-206 (0.654). combination S-42 x F-189 had negative value of SCA effects (-1.117) being poorest combination followed by F-189 x F-206 (-1.033) and F-192 x F-110 (-0.959). Five out of fifteen combinations showed positive value of reciprocal effects. Y-330 x F-110 showed maximum value of reciprocal effects (1.667) followed by Y-330 x F-189 (1.000) and F-110 x F-192 (0.500). Combination S-42 x F-192 had highest negative value of reciprocal effects (-2.500) followed by S-42 x F-110 (-1.500) and F-189 x F-192.

Under moisture deficit conditions four parental genotypes showed positive value of GCA effects. Genotype F-189 was best general combiner with a value of 1.503 followed by F-206 (1.150) and F-110 (0.467). Inbred line F-192 had negative value of GCA effects (-1.988) being poorest general combiner followed by Y-330 (-1.312). Regarding the SCA effects for the trait under discussion, eight inbred lines showed positive value. Combination F-192 x S-42 was best combination with a value of 0.863 followed by Y-330 x F-206 (0.717) and S-42 x Y-330 (0.312). Cross F-192 x F-110 had negative value of SCA effects (-1.424) and was poorest combination followed by F-189 x F-206 (-1.098) and F-110 x S-42 (-0.863). As far as reciprocal effects were concerned, seven combinations showed positive value. Y-330 x F-110 showed maximum value of reciprocal effects (2.500) followed by F-110 x F-192 (1.000) and Y-330 x F-192 (0.667). Combination S-42 x F-192 had negative value of reciprocal effects (-2.000) followed by F-189 x F-192 (-1.500) and S-42 x F-110 (0.622).

Comparing the combining ability effects for photosynthetic rate under normal and moisture stress conditions, it was observed that parental lines F-192 and Y-330 showed positive value GCA effects under both the conditions. Rest of the parents showed negative GCA effects under both conditions. Crosses F-192 x F-206, F-110 x S-42 and F-189 x Y-330 displayed positive SCA effects under normal conditions and negative under moisture stress. Genotypes/crosses F-192 x Y-330 and F-110 x Y-330 had negative value of SCA effects under normal and positive under moisture stress conditions. Reciprocal

effects of crosses F-189 x F-110 and F-206 x S-42 were positive under normal but negative under moisture stress condition.

#### **4.5 Mean performance of parental genotypes and their crosses**

Table 4.43 showed that under normal conditions maximum height was shown by F-206 followed by F-189. Lowest value of plant height was displayed by F-110. Under moisture deficit conditions, highest value was shown by F-192. Generally plant height decreased under moisture stress conditions. Among crosses, maximum plant height was shown by F-206 x S-42 under both the conditions. For days to tasseling highest mean value was observed by cross F-192 x Y-330 under normal irrigation conditions. Under moisture deficit conditions maximum value was exhibited by F-206 and F-192 x Y-330. Generally days to tasseling decreased under moisture deficit conditions.

Table 4.44 depicted that days to silking and anthesis silking interval increased under moisture deficit conditions. Maximum value of days to silking was exhibited by F-206 under normal irrigation conditions. Anthesis silking interval ranged from 1 to 2 under normal and from 4.11 to 7.01 under moisture deficit conditions. Table 4.45 showed that for days to maturity, cross F-110 x F-206 displayed maximum value under normal irrigation conditions and minimum value was displayed by cross F-192 x F-189. Under normal irrigation conditions maximum grain yield was given by cross F-189 x F-206 and minimum value of grain yield was displayed by genotype F-192. Under moisture deficit condition, minimum value of grain yield was displayed by cross F-192 x S-42. Table 4.46 showed that maximum value of 100 grain weight was displayed by cross F-192 x F 206 under normal irrigation conditions. Under moisture deficit conditions cross F-100 x F-192 showed maximum value of 100 grain weight. As for as leaf area was concerned, maximum value was experienced by F-206 under normal conditions. Y-330 displayed maximum value of leaf area under moisture deficit conditions.

Table 4.47 displayed the mean values for cell membrane thermo stability and photosynthetic rate. Regarding the cell membrane thermo stability under normal conditions, maximum value was shown by cross Y-330 x F-189, F-206 and Y-330. Under moisture stress conditions, F-206 showed maximum value of cell membrane stability.

As far as photosynthetic rate was concerned maximum value was displayed cross F-206 x F-189, under normal and moisture deficit conditions.

On observing the overall results, it has been concluded that on growing the maize genotypes under moisture stress condition, generally plant height, days to maturity, 100-grain weight, days to tasseling, cell membrane thermo stability, photosynthetic rate,

leaf area and grain yield per plant decreased. While days to silking and anthesis silking interval increased under water deficit condition. Similar results were also reported by Tabassum (2004), Aslam (2007), and Hussain(2009).

General and specific combining abilities estimates along with reciprocal effects revealed significant mean squares for all the characters studied. A greater GCA variance than SCA indicated the preponderance of additive type of gene action. Inbred lines S-42, F-206, and F-189 were good general combiners for most of the traits. These parents can be exploited to produce high yielding and moisture stress tolerant maize hybrids for enhancing production in the moisture deficit environment. Parental inbred lines with good positive GCA for grain yield (F-206 and S-42), negative GCA for days to silking and days to maturity (S-42 and Y-330) and moderate plant height (Y-330) may extensively be exploited in hybridization program. The crosses F-192  $\times$  F-189 and F-110  $\times$  F-206 exhibited good SCA effects with outstanding mean performance for grain yield under moisture stress condition. The better performing combinations can be utilized for developing high yielding maize hybrids as well as for exploiting hybrid vigour.

**Table: 4.43 Mean values of parental genotypes and their crosses for plant height and days to tasseling**

Genotype	Traits					
	Plant height			Days to tasseling		
	Normal	Stress	% change	Normal	Stress	% change
<b>F192</b>	158.38	137.00	-13.50	69.33	66.00	-3.48
<b>F192XF110</b>	191.00	150.00	-21.47	68.67	66.00	-3.88
<b>F192XS42</b>	160.00	130.69	-18.32	69.00	68.00	-1.45
<b>F192XF189</b>	142.00	111.00	-21.83	70.49	69.21	-1.82
<b>F192XY330</b>	170.00	142.00	-16.47	79.00	77.00	-2.53
<b>F192XF206</b>	164.00	133.70	-18.48	67.33	65.00	-3.59
<b>F110XF192</b>	168.00	133.33	-20.64	71.00	69.00	-2.82
<b>F110</b>	151.00	114.00	-24.50	68.71	65.00	-5.71
<b>F110XS42</b>	171.00	142.68	-16.56	72.00	71.00	-1.39
<b>F110XF189</b>	202.00	165.00	-18.32	70.00	68.00	-2.86
<b>F110XY330</b>	158.00	121.00	-23.42	67.00	66.00	-1.49
<b>F110XF206</b>	196.56	154.90	-21.19	71.00	70.00	-1.41
<b>S42xF192</b>	150.20	142.11	-5.38	69.00	68.00	-1.45
<b>S42x110</b>	151.00	129.00	-14.57	75.00	73.00	-2.67
<b>S42</b>	164.00	123.00	-25.00	72.00	70.00	-2.78
<b>S42xF189</b>	163.00	124.00	-23.93	68.00	65.00	-4.41
<b>S42xY330</b>	189.00	155.00	-17.99	67.33	63.00	-6.44
<b>S42XF206</b>	167.00	130.00	-22.16	68.00	66.00	-2.94
<b>F189XF192</b>	144.00	112.00	-22.22	68.45	63.41	-7.37
<b>F189XF110</b>	169.00	120.00	-28.99	74.00	73.00	-1.35
<b>F189XS42</b>	165.00	154.84	-6.16	68.33	66.00	-3.54
<b>F189</b>	170.00	131.00	-22.94	70.00	69.00	-1.43
<b>F189XY330</b>	149.00	126.00	-15.44	65.00	68.00	-4.62
<b>F189XF206</b>	172.00	150.51	-12.49	75.00	74.00	-1.33
<b>Y330XF192</b>	205.00	158.00	-22.93	71.00	70.00	-1.41
<b>Y330XF110</b>	163.00	125.00	-23.31	70.00	68.00	-2.86
<b>Y330XS42</b>	177.98	156.67	-11.98	73.00	71.00	-2.74
<b>Y330XF189</b>	158.99	138.49	-12.89	71.33	71.00	-0.47
<b>Y330</b>	153.00	116.00	-24.18	73.00	71.33	-3.29
<b>Y330XF206</b>	170.00	128.00	-24.71	74.00	73.16	-1.58
<b>F206XF192</b>	155.60	127.10	-18.32	66.00	64.00	-3.03
<b>F206XF110</b>	160.00	135.00	-15.63	69.00	68.00	-1.45
<b>F206XS42</b>	215.00	181.00	-15.82	68.00	66.00	-2.94
<b>F206XF189</b>	159.00	142.51	-10.37	72.00	71.00	-1.39
<b>F206XY330</b>	137.00	103.00	-24.82	70.00	69.00	-1.43
<b>F206</b>	177.00	134.00	-24.29	79.00	77.00	-2.53



**Table: 4.44 Mean values of parental genotypes and their crosses for days to silking and anthesis - silking interval**

Genotype	Traits					
	Days to silking			Anthesis to silking interval		
	Normal	Stress	% change	Normal	Stress	% change
<b>F192</b>	69.00	71.00	2.90	2.00	5.02	151.17
<b>F192XF110</b>	69.40	70.77	1.97	2.00	4.92	145.76
<b>F192XS42</b>	71.00	72.00	1.41	2.00	4.00	100.00
<b>F192XF189</b>	70.00	73.24	4.62	2.00	6.35	217.33
<b>F192XY330</b>	80.00	82.00	2.50	1.00	7.04	604.00
<b>F192XF206</b>	66.00	71.33	8.08	1.00	4.11	311.00
<b>F110XF192</b>	72.00	74.33	3.24	1.00	5.04	404.00
<b>F110</b>	71.33	73.33	2.81	1.00	5.00	400.00
<b>F110XS42</b>	74.00	75.00	1.35	2.00	4.87	143.67
<b>F110XF189</b>	71.00	74.00	4.23	1.00	4.54	353.67
<b>F110XY330</b>	69.00	71.00	2.90	2.00	5.27	163.33
<b>F110XF206</b>	73.00	74.00	1.37	1.00	5.34	433.67
<b>S42xf192</b>	71.00	72.00	1.41	2.00	4.00	100.00
<b>S42x110</b>	77.00	78.00	1.30	2.00	5.00	150.00
<b>S42</b>	73.00	75.00	2.74	1.00	6.04	504.00
<b>S42xF189</b>	70.00	73.00	4.29	2.00	5.00	150.00
<b>S42xY330</b>	69.09	70.73	2.38	2.00	5.78	189.00
<b>S42xF206</b>	70.00	71.00	1.43	2.00	5.00	150.00
<b>F189XF192</b>	70.09	71.08	1.42	1.00	5.68	468.00
<b>F189XF110</b>	75.00	77.00	2.67	1.00	6.33	533.33
<b>F189XS42</b>	68.00	71.33	4.90	2.00	5.00	150.00
<b>F189</b>	71.00	72.00	1.41	1.00	3.00	200.00
<b>F189XY330</b>	69.00	74.37	7.79	2.00	5.00	150.00
<b>F189XF206</b>	75.08	79.00	5.22	2.00	5.91	195.33
<b>Y330XF192</b>	73.00	73.66	0.90	2.00	4.17	108.50
<b>Y330XF110</b>	72.00	74.00	2.78	2.00	5.07	153.33
<b>Y330XS42</b>	75.00	77.00	2.67	2.00	6.11	205.67
<b>Y330XF189</b>	73.00	75.00	2.74	2.00	5.00	150.00
<b>Y330</b>	73.00	75.00	2.74	2.00	5.00	150.00
<b>Y330XF206</b>	75.00	78.00	4.00	2.00	6.24	212.17
<b>F206XF192</b>	68.00	70.00	2.94	1.97	6.02	206.27
<b>F206XF110</b>	71.00	73.00	2.82	2.10	4.52	114.74
<b>F206XS42</b>	70.00	71.00	1.43	2.00	5.00	150.00
<b>F206XF189</b>	73.00	74.00	1.37	1.00	3.02	202.00
<b>F206XY330</b>	72.00	75.00	4.17	2.00	6.00	200.00
<b>F206</b>	81.00	84.00	3.70	1.98	7.01	254.21

**Table: 4.45 Mean values of parental genotypes and their crosses for days to maturity and grain yield per plant**

Genotype	Traits					
	Days to maturity			Grain yield per plant		
	Normal	Stress	% change	Normal	Stress	% change
<b>F192</b>	120.00	106.45	-11.29	59.87	53.46	-10.70
<b>F192XF110</b>	125.00	108.33	-13.33	78.00	54.00	-30.77
<b>F192XS42</b>	126.00	100.92	-19.90	85.00	51.00	-40.00
<b>F192XF189</b>	110.27	101.00	-8.40	73.33	53.00	-27.73
<b>F192XY330</b>	133.33	116.00	-13.00	96.00	60.00	-37.50
<b>F192XF206</b>	126.00	112.00	-11.11	79.67	64.33	-19.25
<b>F110XF192</b>	122.67	111.00	-9.51	67.33	58.33	-13.38
<b>F110</b>	115.00	105.00	-8.70	66.33	55.00	-17.09
<b>F110XS42</b>	127.00	115.00	-9.45	77.60	61.57	-20.66
<b>F110XF189</b>	128.83	115.00	-10.73	81.33	61.10	-24.88
<b>F110XY330</b>	124.00	106.13	-14.41	79.81	71.40	-10.54
<b>F110XF206</b>	135.42	125.00	-7.69	95.77	81.67	-14.72
<b>S42xf192</b>	118.00	105.60	-10.51	69.67	58.67	-15.79
<b>S42x110</b>	131.00	119.61	-8.69	98.17	73.52	-25.11
<b>S42</b>	120.00	109.00	-9.17	86.50	70.33	-18.69
<b>S42xF189</b>	119.00	105.26	-11.55	63.00	56.22	-10.76
<b>S42xY330</b>	124.00	109.34	-11.82	81.00	59.49	-26.56
<b>S42xF206</b>	125.00	106.00	-15.20	89.00	53.00	-40.45
<b>F189XF192</b>	116.00	107.00	-7.76	72.00	55.00	-23.61
<b>F189XF110</b>	128.00	111.28	-13.06	95.27	62.00	-34.92
<b>F189XS42</b>	125.00	112.50	-10.00	80.67	66.63	-17.40
<b>F189</b>	122.00	109.67	-10.11	62.00	54.43	-12.20
<b>F189XY330</b>	115.00	104.00	-9.57	69.33	51.00	-26.44
<b>F189XF206</b>	126.00	110.33	-12.43	128.00	102.00	-20.31
<b>Y330XF192</b>	130.15	111.56	-14.28	76.57	68.79	-10.16
<b>Y330XF110</b>	123.00	107.32	-12.75	78.35	73.00	-6.83
<b>Y330XS42</b>	132.37	117.67	-11.11	86.62	75.13	-13.27
<b>Y330XF189</b>	119.00	102.67	-13.73	68.67	59.66	-13.12
<b>Y330</b>	130.00	113.43	-12.74	97.33	82.67	-15.07
<b>Y330XF206</b>	119.00	108.00	-9.24	96.57	80.67	-16.47
<b>F206XF192</b>	120.00	103.33	-13.89	65.00	51.00	-21.54
<b>F206XF110</b>	118.00	107.00	-9.32	53.00	35.00	-33.96
<b>F206XS42</b>	130.00	115.00	-11.54	85.00	72.00	-15.29
<b>F206XF189</b>	129.00	111.00	-13.95	68.00	58.00	-14.71
<b>F206XY330</b>	112.00	100.67	-10.12	73.00	55.00	-24.66
<b>F206</b>	134.00	119.32	-10.96	104.41	75.00	-28.17

**Table: 4.46 Mean values of parental genotypes and their crosses for hundred grain weight and ear leaf area**

Genotype	Traits					
	Hundred grain weight			Ear leaf area		
	Normal	Stress	% change	Normal	Stress	% change
<b>F192</b>	23.15	19.33	-16.50	373.07	326.33	-12.53
<b>F192XF110</b>	28.00	23.00	-17.86	407.00	360.00	-11.55
<b>F192XS42</b>	25.28	23.17	-8.37	415.00	370.00	-10.84
<b>F192XF189</b>	19.17	17.74	-7.46	391.00	340.00	-13.04
<b>F192XY330</b>	31.00	18.73	-39.57	430.00	375.00	-12.79
<b>F192XF206</b>	26.00	20.67	-20.51	416.00	362.00	-12.98
<b>F110XF192</b>	28.00	23.30	-16.77	407.00	350.00	-14.00
<b>F110</b>	24.33	20.16	-17.15	384.86	340.00	-11.66
<b>F110XS42</b>	28.86	21.33	-26.09	430.00	366.34	-14.81
<b>F110XF189</b>	28.00	23.00	-17.86	416.55	364.63	-12.46
<b>F110XY330</b>	27.00	23.00	-14.81	402.00	350.00	-12.94
<b>F110XF206</b>	29.00	25.00	-13.79	465.27	395.00	-15.10
<b>S42xf192</b>	26.00	22.00	-15.38	405.00	351.00	-13.33
<b>S42x110</b>	28.00	21.09	-24.68	446.66	371.33	-16.86
<b>S42</b>	27.00	18.71	-30.72	425.00	370.00	-12.94
<b>S42xF189</b>	23.43	20.39	-12.98	378.66	322.00	-14.96
<b>S42xY330</b>	23.00	18.94	-17.64	409.00	362.00	-11.49
<b>S42xF206</b>	22.57	18.01	-20.23	413.00	346.53	-16.10
<b>F189XF192</b>	21.43	18.33	-14.46	381.60	321.00	-15.88
<b>F189XF110</b>	25.20	18.48	-26.66	432.00	369.00	-14.58
<b>F189XS42</b>	25.33	21.00	-17.11	417.00	365.00	-12.47
<b>F189</b>	24.00	20.00	-16.67	410.00	355.00	-13.41
<b>F189XY330</b>	23.33	19.72	-15.50	387.74	335.67	-13.43
<b>F189XF206</b>	26.21	18.00	-31.32	437.00	369.49	-15.45
<b>Y330XF192</b>	27.00	22.51	-16.63	424.84	367.00	-13.61
<b>Y330XF110</b>	26.00	22.00	-15.38	408.00	352.00	-13.73
<b>Y330XS42</b>	26.00	21.00	-19.23	435.00	352.00	-19.08
<b>Y330XF189</b>	23.00	19.00	-17.39	406.00	353.00	-13.05
<b>Y330</b>	29.00	21.03	-27.48	449.87	386.00	-14.20
<b>Y330XF206</b>	28.00	17.80	-36.43	427.00	368.00	-13.82
<b>F206XF192</b>	22.00	18.00	-18.18	382.00	330.00	-13.61
<b>F206XF110</b>	24.00	20.00	-16.67	375.00	320.00	-14.67
<b>F206XS42</b>	28.00	24.00	-14.29	437.00	370.00	-15.33
<b>F206XF189</b>	27.00	22.00	-18.52	421.00	365.00	-13.30
<b>F206XY330</b>	18.00	16.00	-11.11	391.00	340.00	-13.04
<b>F206</b>	29.00	19.00	-34.48	467.00	383.35	-17.91

**Table: 4.47 Mean values of parental genotypes and their crosses for cell membrane thermo stability and photosynthetic rate**

Genotype	Traits					
	Cell membrane thermostability			Photosynthetic rate		
	Normal	Stress	% change	Normal	Stress	% change
<b>F192</b>	67.00	59.00	-11.94	23.00	18.00	-21.74
<b>F192XF110</b>	73.00	65.00	-10.96	22.00	17.00	-22.73
<b>F192XS42</b>	77.00	70.00	-9.09	26.00	19.00	-26.92
<b>F192XF189</b>	68.00	61.00	-10.29	20.08	17.33	-13.69
<b>F192XY330</b>	77.00	69.00	-10.39	24.33	18.77	-22.88
<b>F192XF206</b>	74.00	69.00	-6.76	25.00	19.33	-22.67
<b>F110XF192</b>	78.00	71.00	-8.97	27.33	21.67	-20.73
<b>F110</b>	67.00	58.00	-13.43	24.33	22.00	-9.59
<b>F110XS42</b>	79.00	72.00	-8.86	26.00	23.00	-11.54
<b>F110XF189</b>	80.00	71.00	-11.25	25.67	21.00	-18.18
<b>F110XY330</b>	73.00	65.00	-10.96	24.00	19.65	-18.11
<b>F110XF206</b>	81.00	70.00	-13.58	27.31	20.67	-24.33
<b>S42xf192</b>	75.00	65.00	-13.33	26.00	20.00	-23.08
<b>S42x110</b>	82.00	71.00	-13.41	27.00	21.00	-22.22
<b>S42</b>	78.00	71.00	-8.97	24.00	20.00	-16.67
<b>S42xF189</b>	68.00	60.00	-11.76	22.00	16.00	-27.27
<b>S42xY330</b>	74.00	63.00	-14.86	27.00	21.00	-22.22
<b>S42xF206</b>	78.00	71.00	-8.97	29.00	22.00	-24.14
<b>F189XF192</b>	69.00	62.00	-10.14	20.34	16.00	-21.32
<b>F189XF110</b>	76.00	67.00	-11.84	26.33	18.38	-30.20
<b>F189XS42</b>	76.00	68.00	-10.53	28.00	20.58	-26.51
<b>F189</b>	79.00	70.00	-11.39	27.33	22.71	-16.93
<b>F189XY330</b>	68.00	59.00	-13.24	21.00	17.00	-19.05
<b>F189XF206</b>	78.00	66.00	-15.38	28.00	22.67	-19.05
<b>Y330XF192</b>	81.00	72.00	-11.11	28.00	22.00	-21.43
<b>Y330XF110</b>	74.00	65.00	-12.16	25.00	18.61	-25.57
<b>Y330XS42</b>	80.00	71.00	-11.25	27.00	21.67	-19.75
<b>Y330XF189</b>	76.00	65.00	-14.47	24.00	20.00	-16.67
<b>Y330</b>	81.00	70.00	-13.58	28.00	22.00	-21.43
<b>Y330XF206</b>	79.00	72.00	-8.86	26.00	21.00	-19.23
<b>F206XF192</b>	62.00	52.00	-16.13	20.00	16.00	-20.00
<b>F206XF110</b>	66.00	58.00	-12.12	25.67	21.00	-18.18
<b>F206XS42</b>	75.00	68.00	-9.33	26.00	20.00	-23.08
<b>F206XF189</b>	78.00	70.00	-10.26	29.00	23.00	-20.69
<b>F206XY330</b>	69.00	61.00	-11.59	19.00	16.00	-15.79
<b>F206</b>	81.00	72.00	-11.11	27.00	22.00	-18.52

## CHAPTER V

### SUMMARY

Studies pertaining to gene action and combining ability analysis regarding six maize inbred lines along with their all possible combinations were conducted under normal and moisture deficit conditions in the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. Germplasm was collected from various research organizations working on maize crop. Fifty inbred lines were screened against moisture deficit conditions. Six inbred lines i.e. F-192, F-110, S-42, F-189, Y-330 and F-206 were selected and crossed in a complete diallel fashion. The parents and all possible combinations were sown for evaluation in a triplicate randomized complete block design under normal and moisture deficit conditions. Data for plant height, days to tasseling, days to silking, anthesis silking interval, days to maturity, grain yield per plant, 100-grain weight, ear leaf area, leaf temperature, relative water loss, cell membrane thermo stability and photosynthetic rate were recorded from both the sets. Analysis of variance was conducted for gene action and combining ability analysis was performed. It revealed that material had significant variation for all the traits. Additive dominance formula was fully or partially fit for all the parameters except anthesis-silking interval under normal irrigation conditions. Value of item  $a$  was statistically significant for six traits under normal irrigation conditions while both  $a$  and  $b$  were statistically significant for four parameters. Additive and dominant gene action were significant for grain yield per plant, anthesis silking interval, ear leaf area, plant height, cell membrane thermo stability and photosynthetic rate while gene action was additive for days to tasseling, days to silking, days to maturity, 100-grain weight, leaf temperature and relative water loss. Maternal effects for yield, 100-grain weight and photosynthetic rate were significant under normal irrigation conditions while under maternal effects were important for days to tasseling, anthesis silking interval, grain yield per plant, 100-grain weight, ear leaf area and photosynthetic rate moisture deficit condition.

As far as genetic components of variation were concerned, additive gene action was significant for relative water loss, plant height, leaf temperature and cell membrane thermo stability under normal conditions. Both additive and dominance type of gene action were involved for days to tasseling, days to silking, days to maturity, grain yield per plant, 100-

grain weight, ear leaf area and photosynthetic rates. Additive and dominance type of gene action were significant for days to silking, anthesis silking interval, days to maturity, grain yield per plant, ear leaf area, cell membrane thermo stability and photosynthetic rate under moisture deficit condition.

Graphical presentation for gene action depicted that most of the traits including grain yield per plant displayed partial dominance under normal and moisture deficit conditions. Leaf temperature showed partial dominance under normal and complete dominance under moisture stress conditions. Inbred line F-206 was nearest to the origin and had maximum dominant genes for grain yield per plant. Similar was the case for hundred grain weight under normal conditions. Maximum dominant genes were also contained by inbred line F-206 for leaf area and days to tasseling under moisture stress condition.

Combining ability analysis depicted that mean squares for GCA, SCA and reciprocal effects were highly significant for all the parameters under normal and moisture deficit conditions. Estimates of variance components due to GCA were greater than those of SCA for all the parameters under normal irrigation AND moisture deficit conditions. Higher estimates of variance of GCA indicated the involvement of additive type of gene action. Reciprocal effects were found highly significant for all the traits under normal and moisture deficit conditions. According to analysis inbred line F-206 was best general combiner for most of the traits including grain yield per plant under both the conditions. Genotype F-110 was poorest general combiner for grain yield per plant under both the conditions. Combination F-110 x F-206 showed best performance for grain yield per plant under both the conditions. Combinations F-192 x F-189 and F-110 x S-42 were second and third for yield per plant under normal irrigation conditions, respectively. . Parents with good positive gca for yield (F-206 and S-42), negative gca for days to silking and days to maturity (S-42 and Y-330) and moderate plant height may extensively be used in hybridization program.

## **LITERATURE CITED**

- Aggarwal, P.K. and S.K, Sinha. 1983. Relationship between mother shoot and tillers as a criterion of selection for wide or specific adaptability to drought in maize. *Zacker-Planzenb, Planzenb*, 152:310-320.
- Ahmad, A. 2002. Genetics of growing degree days, yield and its components in maize. Ph. D thesis, Department of Plant Breeding and Genetics, UAF, Faisalabad.
- Akbar, M. 2008. Genetic control of high temperature tolerance in *Zea mays L.* Ph.D. Thesis, Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan.
- Alam, A.N., 1985. Evapo-transpiration and yield of corn as related to irrigation timing during silking. Dissertation Abst. International, B-46(6):1749B-1750B, Colorado State Univ; Foricollins, U.S.A.
- Altinbs, M. and M. Tosun. 1998. A study on utilizing combining ability covariance in hybrid maize (*Zea mays L.*) breeding. *Anadolu*. 8 (2): 90-100.
- Aminzadeh, G\_ and A. G. Eshghi. 2006. Evaluation of drought resistance in new lines and cultivarsof bred wheat. (Abstract). The first international conference on the theory and practices inbiological water saving (ICTPB). 21-25 May, Beijing-China.<http://www.conferene.ac.cn/ictpb.htm>
- Ana, C. V. D., J. B. M. Filho and M. R. B. Alleoni.1997. Diallel cross analysis for young plants of brachytic maize (*Zea mays L.*) varieties. *Braz. J. Genet.* 20 (3):
- Anonymous. 2011. Pakistan Bureau of Statistics, Government of Pakistan, Statistical Division.
- Aslam, M. 2007. Assesment of physio-genetic traits for drought tolerance in maize. Ph.D. Thesis, Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan.
- Azhar, F.M. and T. McNeilly, 1988. The genetic basis of variation for salt tolerance in *Sorghum bicolor L.* Moench seedlings. *Pl. Breed.*1010:114-121.
- Banziger M, Edmeades GO, Beck D, Bellon M (2000) Breeding for drought and nitrogen stress tolerance in maize: From theory to practice. CIMMYT, Mexico .p.68.

- Barati, A., K. Safikhani, G. Nematzadeh, G. A. Kianoosh and R. Chogan, 2004. General and specific combining abilities of five maize inbred lines for different traits in diallel crosses. *Pajouhesh-va-Sazandegi-In- Agronomy-and-Horticulture*. 62: 9-17.
- Bassetti, P. and Westgate, M.E. (1994). Floral asynchrony and kernel set in maize quantified by image analyses. *Agronomy Journal* 86, 933-703.
- Bawzir, A.A.A. 1983. Study on combining ability and nature of gene action in F1 diallel cross in grain sorghum. *Agric. Res. center, Aden., FAO*. 658-66.
- Beck D, Betran FJ, Banziger M, Ribaut JM, Willcox M, Vasal SK, Ortega A (1996) Progress in developing drought and low soil nitrogen tolerance in maize. In: Wilkinson DB (ed) *Proceedings of the 51st Annual Corn & Sorghum Research Conference*. Washington ASTA, pp 85-111
- Begg J. E. and N. C. Turner. 1976. Crop water deficit. *Adv. Agron.* 28: 161-217.
- Betran, F.J., D, Beck, M. Banziger and G.O. Edmeades. 2003. Genetic analysis of inbred and hybrids grain yield under stress and non stress environments in tropical maize. *Crop Sci.* 43:807-817.
- Bhatnagar S., F. j. Betran and L. W. Roomey. 2004. Combining abilities of quality protein maize inbreds. *Crop Sci.* 44: 1997-2005.
- Bijagare, M.N., S.B. Ghuge and V.S. Hudge. 1994. Effect of moisture stress on seed germination in sorghum. *Ann. Pl. Physiol.* 8:39-41.
- Blum A., L. Shpiler, G. Gozlan and J. Mayer. 1989. Yield stability and canopy temperature of wheat genotypes under drought stress. *Field Crops Res.* 22: 289-296.
- Blum, A. and A. Ebercon. 1981. Cell membrane stability as a measure of drought and heat tolerance in wheat. *Crop Sci.*, 21: 43-47.
- Bolanos, J. and G.O. Edemeades. 1993. Response in reproductive behavior. *Field Crops Res.* 31: 253-268.
- Bolanos, J. and G.O. Edemeades. 1996. The importance of anthesis silking interval in breeding for drought tolerance in maize. *Field Crops Research.* 48(1):65-80.
- Borrell AK, Hammer GL, Douglas ACL (2000a) Does maintaining green leaf area in sorghum improve yield under drought? I. Leaf growth and senescence. *Crop Science* 40: 1026-1037
- Boyer J. S. 1982. Plant productivity and environment. *Science* 218: 443-448.



- Boyle, M.G., Boyer, J.S., and Morgan, P.W . (1991). Stem infusion of liquid culture medium prevents reproductive failure of maize at low water potential. *Crop Science* 31, 1246-1252.
- Bradford K. J. and T. C. Hsiao. 1982. Physiological responses to moderate water stress. In *Water Relations and Carbon Assimilation. Physiological Plant Ecology II*, Lange, O. L., P. S. Nobel, C. B. Osmond and Ziegler, H. (eds). *Encyclopedia of Plant Physiology* n.s. 12B, Springer-Verlag, Berlin-Heidelberg. pp. 263-324.
- Bray E. A. 2000. Response to abiotic stresses. In *Biochemistry and Molecular Biology of Plants* (Gruissem, W. et al., eds), pp. 1158-1249, American Society of Plant Physiologists.
- Bruce W. B., G. O. Edmeades and T. C. Barker. 2002. Molecular and physiological approaches to maize improvement for drought tolerance *J. Exp. Bot.* 53: 13-25.
- Bukhari, S.H.1986. Diallel analysis of yield and yield components in maize. M.Sc. thesis, Deptt. Pl. Br. Genet., Univ. Agri. Faisalabad, Pakistan.
- Burke, J.J. 2007. Evaluation of source leaf responses to water-deficit stresses in cotton using a novel stress bioassay. *Plant Physiol.* 143:108.
- Buttrose M. S. and J. G. Swift. 1975. Effects of killing by heat or desiccation on membrane structure in pea roots. *Aust. J. Plant Physiol.* 2: 225-233.
- Çakir, R. 2004. Effect of water stress at different development stages on vegetative and reproductive growth of corn. *Field Crops Res.* 89:1-16.
- Campos, H., M. Cooper, J.E. Habben, G.O. Edmeades and J.R. Schussler. 2004. Improving drought tolerance in maize: A view from industry. *Field Crops Res.* 90:19-34.
- Carvalho,R.C.,A.Cunha and J.M.Silva, 2010. Photosynthesis by six Portuguese maize cultivars during drought stress and recovery *Acta Physiol Plant* DOI 10.1007/s11738-010-0555-1
- Castonguay, Y. and A.H.Markhart.1992. Leaf gas exchange in water stressed common bean arid tepary bean. *Crop Sci.* 32:980-986.
- Chapman, S. C., J. Crossa, K. E. Basford, P. M. Kroonenber. 1997. Genotypes environment effects and selection for drought tolerance in tropical maize. Three-mode pattern analysis. *Euphytica.* 95(1): 11-20.
- Chapman, S. R. and F. H. McNeal. 1971. Gene actions for yield components and plant height in maize. *Crop Sci.* 11: 284-286.

- Chazen O. and P. M. Newmann. 1994. Hydraulic signals from the roots and rapid cell wall hardening in growing maize leaves are primary responses to polyethylene glycol induced water deficits *Plant Physiol.* 104: 1385-1392.
- Chen, Y.H., W. A. Zhu, W. L. Cheng; Z. X. Qian, W. J. Yu, B. J. Wen, Y.H. Chen, W. AZ, W. L. C, X. Q. Zhang; J.Y. Wu and J.W. Bai. 2002. Analysis of combining ability and heterosis among 8 maize populations including Goldqueen. *J. Maize Sci.* 10(4): 10-12.
- Choukan, R. 1999. General and specific combining ability of ten maize inbred lines for different traits in diallel crosses. *Seed and Plant. Iran.* 15(3): 280-295.
- Clarke, J.M., 1987. Use of physiological and morphological traits in breeding programmes to improve drought resistance of cereals. In: J.P. Srivastava, E. Porcedo, E. Acevedo & S. Varma (Eds.), *Drought Tolerance in Winter Cereals*, pp 171–190. John Wiley & Sons, New York.
- Claasen, M. M. and R. H. Shaw. 1970. Water deficit effects on grain. II. Grain components. *Agron. J.* 62: 652-655.
- Cowan I. R. and G. D. Farquhar. 1977. Stomatal functioning in relation to leaf metabolism and environment, in *Integration of Activity in the Higher Plants*, edited by D. H. Jennings, pp. 471-505, Cambridge Univ. Press, New York.
- Dahlan M., M. Mejaya and S. Blamet. 1997. Maize losses due to drought in Indonesia and sources of drought tolerance and escape. In: Symposium “Developing drought and low nitrogen tolerant maize. Poster No. 18. Symposium Abst. Published in 1997.
- Dai, J.Y.; W.L. Gu, X. Y. Shen, B. Zheng, H. Qi and S. F. Cai. 1990. Effect of drought on the development and yield of maize at different growth stages. *J. Shenyang, Agric. U.niv.* 21: 181-185.
- Dass, S., P. Arora, M. Kumari and P. Dharma. 2001. Morphological traits determining drought tolerance in maize. *Ind. J. Agri. Res.* 35:190-193.
- Dehghanpour, Z., B. Ehdai, M. Moghaddam, B. Griffing and B.I. Hayman. 1996. Diallel analysis of agronomic characters in white endosperm corn. *J. Genet. Pl. Br.* 50(4): 357-365.
- Dexter S. T. 1956. Evaluation of crop plants for winter hardiness. *Adv. Agro.* 8: 203-209.
- Dhillon, B. S. and J. Singh and D. Singh .1976. Genetic analysis of grain yield and maturity in maize populations. *Maydica.* 21(3): 129-133.
- Doorenbos J., A. K. Kassam. 1979. Yield response to water, irrigation and drainage Paper 33. FAO, United Nations, Rome p. 176.

- Dubey, R.B., V.N. Joshi and N.K. Pandiya. 2001. Heterosis and combining ability for quality, yield and maturity traits in conventional and non-conventional hybrids of maize. *Ind. J. Genet.*, 61(4): 353-355.
- DuPlessis D. P. and F. J. Dijkhuis. 1967. The influence of time lag between pollen shedding and silking on the yield of maize. *South African Journal of Agricultural Sci.* 10: 667-674.
- Duvick, D. N. 1997. What is yield? In: Edmeades, G.O., Banziger, B., Mickelson, H.R., Pena-Valdivia, C.B. (Eds.), *Developing drought and low N maize*. CIMMYT, EL Batan, Mexico, 9-pp. 332-335.
- Edmeades, G.D., M. Banziger, J.R. Schussler and H. Campos. 2004. Improving abiotic stress tolerance in maize: a random or planned process, In proceedings of the Aruel, R.Hllauer international symposium on Plant Breeding. Mexico, 17-22 August 2003, Iowa State University Press, (In press).
- Edmeades, G.O., Banziger, M., and Ribaut, J.-M. (2000). Maize improvement for drought-limited environments. In "Physiological bases for maize improvement" (Otegui, M.E. and Slafer, G.A ., eds.), pp. 75-111
- Edmeades G. O., J. Bolanos, M. Hernandez and S. Bello. 1993. Causes for silk delay in lowland tropical maize. *Crop Sci.* 33: 1029-1035.
- Edwards EJ, Still CJ (2008) Climate, phylogeny and the ecological distribution of C4 grasses. *Ecol Lett* 11:266–276
- Elemery, M.I., A.s.A. Gouda and M.A. Kalifa. 1995. Seed germination and seedling vigour for measuring drought tolerance of some maize (*Zea mays* L.) genotypes. *Ann. Agric. Sci. Cairo.* 40:639-655.
- Feng Y. S., X. M. Li and L. Boersma. 1994. Roles of osmotic adjustment and turgor potential in leaf area expansion. *Physiologia Plantarum*, 90: 1-8.
- Ferrat, I. L. and C. J. Lovatt. 1999. Relationship between relative water content, nitrogen pools and growth of *Phaseolus vulgaris* L. and *P. acutifolius* A. Grag during water deficit. *Crop. Sci.* 39: 467-475.
- Fokar, M., H.I. Nyuyen and A. Blum. 1998. Heat tolerance in spring wheat. I. Genetic variability and heritability of cellular thermotolerance. *Euphytica*, 104: 1-8.
- Franks S. J., S. Sim and A. E. Weis. 2006. Rapid evolution of flowering time by an annual plant in response to a climate fluctuation. *PNAS* 104: 1278-1282.
- Fredrick, J. R., J. D. Hesketh, D. B. Peters, F. E. Below. 1989. Yield and reproductive trait responses of maize hybrids to drought stress. *Maydica*, 34:319-328.

- Frensch J. and T. C. Hsiao. 1994. Transient response of cell turgor and growth of maize roots as affected by change in water potential. *Plant Physiol.* 104: 247-254.
- Ghannoum O (2009) C4 Photosynthesis and water stress. *Ann Bot.* 103:635–644
- Grant, R.F., Jackson, B.S., Kiniry, J.R., and Arkin, G.F. (1989). Water deficit timing effects on yield components in maize. *Agronomy Journal* 81, 61-65.
- Gribincea, V. 2002. Cercetari-de-Genetica-Vegetala-si-Animala. 2002. Study of genetic determinism of some quantitative traits in maize. 7: 159-165.
- Griffing, B. 1956. Concept of general and specific combining ability in relation to diallel/crossing systems. *Aust. J. Biol. Sci.* 9:463-493.
- Grzesiak, S. 2001. Genotypic variation between maize (*Zea mays* L.) single cross hybrids in response to drought stress. *Acta Physiologiae Plantarum.* 23:443-456.
- Gu, W. L., J. Y. Dai, X. Y. Shen, C. Wang. 1989. Drought resistances of maize at different growth stages. *Plant Physiology Communications*, 3: 18-21.
- Hayman, B.I. 1954a. The theory and analysis of diallel crosses. *Biometrics*, 10:235-45.
- Hayman, B.I. 1954b. The theory and analysis of diallel crosses. *Genetics*, 39:789-809.
- Herrero M. P. and R. R. Johnson. 1981. Drought stress and its effect on maize reproductive system. *Crop Sci.* 21: 105-110.
- Herrero, M. P. and R. R. Johnson. 1980. High temperature stress and pollen viability of maize. *Crop Sci.* 20:796-800.
- Hirayama, H., Y. Wada and H. Neato. 2006. Estimation of drought tolerance based on leaf temperature in lipland Rice Breeding. *Breeding Science.* 56:47-54.
- Hoogenboom, G., M. G. Huck and C.M.Peterson.1987 Root growth rate of soybean as affected by drought stress. *Agron J.* 79:607-614.
- Hosary, A. A. and S. A. Sedhom. 1990. Diallel analysis of yield and other agronomic characters in maize (*Zea mays* L.) *Annals Agric. Sci. Moshtohor.* 28(4): 1987-1998.
- Hsiao T. C. 1973. Plant responses to water stress. *Ann. Rev. Plant Physio.* 24: 519-570.
- Hussain, I. 2009. Genetics of drought tolerance in maize. Ph.D. Thesis, Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan.
- Ibrahim, H.M. and S.Q. James. 2001. Genetic control of high temperature tolerance in wheat as measured by membrane thermol stability. *Crop Sci.* 41:1405-1409.

- Idso S. B., R. J. Reginato, D. C. Reicosky and J. L. Hatfield. 1981. Determining soil induced plant water potential depressions in alfalfa by means of infrared thermometry. *Agron. J.* 73: 826-830.
- Jana, S. 1975. Genetic analysis by means of diallel graph. *Heredity*: 35: 1-19.
- Jing, J.H., T.C. Hsiao. 1987. Effects of water stress and re-watering after water stress on leaf elongation rate of maize. *Acta Phytophysiologicapinica*, 13:51-57.
- Jinks, J. L. 1954. The analysis of continuous variation in a diallel crosses of *Nicotiana mstica* L. varieties. *Genetics*, 39:767-788.
- Jongdee B., S. Fukai, and M. Cooper. 2002. Leaf water potential and osmotic adjustment as physiological traits to improve drought tolerance in rice. *Field crop Res.* 76: 153-163.
- Joshi, V.N., N.K. Pandiya and R.B. Dubey. 1998. Heterosis and combining ability for quality and yield in early maturing single cross hybrids of maize (*Zea mays* L.). *Ind. J. Genet. Pl. Br.* 58(4): 519-524.
- Kamara, A. Y., A. Minker, B. Badu-Apraku and O. Ibikunle. 2003. Reproductive and stay green traits responses of maize hybrids, improved open pollinated varieties and farmer's local varieties to terminal drought stress. *Medical.* 4891:29-37.
- Karim, A.1979. Diallel analysis for yield and yield components in F1 of maize. M. Sc. Thesis, Deptt. P.B.G., Univ. Agri. Faisalabad, Pakistan.
- Kebede, H., P.K. Subudhi, D.T. Rosenow and H.T. Nguyen. 2001. Quantitative trait loci influencing drought tolerance in grain sorghum (*sorghum bicolor* L. moench). *TAG Theoretical and Applied Genetics* 103:266-276.
- Khalid, M. N., M. A. Chaudhry and A. Khaliq. 1979. Diallel analysis for plant height and its components in F1 of maize. M. Sc. Thesis, Deptt. Pl .Breed. Genet., Univ. Agri. Faisalabad, Pakistan.
- Khan, H. R. and F. L. Stoddard. 2005. Genotype variation physiological attributes related to droughttolerance in faba bean. (Abstract) The 2nd International Conference on Integrated Approachesto Sustain and Improve Plant Production Under Drought Stress .Inter, Drought-II. September24 to 28. Rome-Italy.
- Khotyleva,. L. V; Lemesh, V. A. 1994. Genetic control of morphological and physiological characters of the seedlings in maize. *Tsitologiya-i; Genetika.* 28(5): 55-59.
- Kiesselbach, T. A. 1999. The structure and reproduction of corn. Cold Spring Harbor Laboratory Press, New York.

- Kirda C., S. Topcu, H. Kaman, A. C. Ulger, A. Yazici, M. Cetin, and M. R. Derici. 2005. Grain yield response and N-fertiliser recovery of maize under deficit irrigation. *Photosynthetica* 19: 312-319.
- Kleidon A. 2004. Optimized stomatal conductance of vegetated land surfaces and its effects on simulated productivity and climate *Geophys. Res. Lett.* 31: 1029-39.
- Kramer, P.J. 1980. Drought stress and the origin of adaptation. In N.C. Turner, and P.J. Kramer (ed.) *Adaptation of Plants to water and High Temperature Stress*. John Wiley and Sons, New York. P. 7-19.
- Latimer J. G. 1990. Drought or mechanical stress affects broccoli transplant growth and establishment but not yield. *HortScience* 25:1233-1235.
- Lawlor D. W. and D. C. Uprety. 1993. Effects of water stress on photosynthesis of crops and the biochemical mechanism. In *Photosynthesis, Photoreactions to plant Productivity*, Abrol, Y. P., P. Mohanty and Godvindjce (eds.), Oxford and IBH Publ. Co., PVT Ltd. New Delhi, pp. 421-445.
- Lee E. A., A. Ahmadzadeh, and M. Tollenaar. 2005. Quantitative genetic analysis of the physiological processes underlying maize grain yields. *Crop Sci.* 45: 981-987.
- Lee, E.A. and M. Tollenaar. 2007. Physiological basis of successful breeding strategies for maize grain yield. *Crop Sci.* 47(S3):S202-S215.
- Lemcoff JH, Chimenti, CA, Davezac TAE. 1998. Osmotic adjustment in maize (*Zea mays* L.): Changes with ontogeny and its relationship with phenotypic stability. *Journal of Agronomy and Crop Sciences.* 180, 241-247.
- Lemos, M. A., G. Gama, S.N. Parentoni, A.C. Oliveira, FJB. Reifschneider, JPO.Santos, JN. Tabosa and AC. Oliveir. 1999. General and specific combining ability in single hybrids of sweet corn. *Ciencia-e-Agrotecnologia.* 23(1): 48-56.
- Levitt, J. 1980. *Response of plants to environmental stress*. Second Edition, Vols.I and II. Academic Press, New York and London.
- Lin, S. F. and C. Chen. 1986. Studies of combining ability for major agronomic characters in maize (*Zea mays* L.) *J. Agric. Association, China.* 136: 6-14.
- Lopez-Castaneda C. and R. A. Richards. 1994. Variation in temperate cereals in rainfed environment. III. Water use and water-use efficiency. *Field Crops Res.* 39: 85-98.
- Lyndon R .F. 1990. *Plant development: the cellular basis*. Academic Division of Unwin Nyman Ltd. London, UK.

- Mabhaudhi, T., 2009. Responses of maize (*Zea mays* L.) landraces to water stress compared with commercial hybrids. Thesis (M.Sc.Agric.) - University of KwaZulu-Natal, Pietermaritzburg.
- Magorocosho, C., K. V. Pixley and P. Tongoona. 2003. Selection for drought tolerance in two tropical maize populations. *Afr. Crop. Sci. J.* 11(3): 151-161.
- Mahajan, V., A. S. Kehra, B. S. Dhillon and V. K. Sexena, 1991. Interrelationship of yield and other traits in maize in monsoon and winter seasons. *Crop Improvement.* 17(2): 128-132.
- Mahmood, I. M., M. A. Rashed, E. M. Fahmy and M. F. A. Dheaf. 1990. Heterosis and combining ability and type of gene action in a 6x6 diallel of maize. Proceedings of the 3rd conference of Agricultural Development Research held at Ain Sham Univ. Chairo, Egypt on 22-24 December, 1990. *Annal Agric. Sci. Chairo. Special Issue.* 307-307.
- Mahmood, N. 1998. Genetic performance of bread wheat genotypes under normal and late plantings. Ph.D. thesis, Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan.
- Maiti, R. K., L. E. D. Amaya, S. L. Cardona, A. M. O. Dimas, M. De LaRosa-Ibarra and H. De Leon Castillo, 1996. Genotypic variability in maize cultivars for resistance to drought and salinity at seedling stage. *J. PI. Physio.*, 148:741-744.
- Malik, S. I., H.N. Malik, N. M. Minhas And M. Munir. 2004. General and specific combining ability studies in maize diallel crosses. *Int. J. Agri. Biol.* 6(5): 856-859.
- Malik, M.A. 1990. Genetic analysis of quantitative characters in maize (*Zea mays* L.) diallel crosses. M.Sc. Thesis, Deptt. Pl. Br. Genet. Univ. Agri. Faisalabad, Pakistan. Mandal, S., H.K
- Mandal, D K Verma and S.A Akhtar. 2001. Combining ability analysis for grain yield and components traits in maize (*Zea mays* L.). *J. Interacademia, India.* 5 (2):132-137.
- Martineau J. R., J. E. Specht, J. H. Williams and C. Y. Sullivan. 1979. Temperature tolerance in soybeans. I. Evaluation of technique for assessing cellular membrane thermostability. *Crop Sci.* 19: 75-78.
- Martiniello, P. 1983. Outline of major components of maize breeding programs for a semiarid region (Capitana Plain: South Italy). *Gen. Agri.* 37:361-390.
- Mather, K. and J.L. Jinks. 1982. Introduction to Biometrical Genetics. Chapman & Hill Ltd. London.

- Matin, M.A., J.H. Brown and H. Ferguson. 1989; Leaf water potential, relative content and diffusive resistance as screening techniques for drought resistance in Barley. *Agifbn.; J. N.* 81:100-105.
- Matsuura A., S. Inanaga and Y. Sugimoto. 1996. Mechanisms of interspecific differenceds among four gramineous crops in growth response to soil drying. *Japanese J. Crop Sci.* 65:352-360.
- McKee, G.W.1964. A coefficient for computing leaf area in hybrid corn. *Agron. J.* 56:240-241.
- Morgan J. M. and A. G. Condon. 1986. Water use, grain yield and osmoregulation in wheat. *Australian Journal of Plant Physiol.* 13: 523-532.
- Morizet, T., M. Pollucsk and D. Togola. 1983, Drought tolerance in four maize varieties (*FieldCropsAbst.*39:306,1986),
- Moussa, I. and S.M. Abdel-Aziz. 2008. Comparative response of drought tolerant and drought sensitive maize genotypes to water stress.[Online]. *Australian Journal of Crop Science* 1:31.
- Mungo S. N. and K. Njoroge. 1997. Alleviating the effect of drought on maize production in the moisture stress area of Kenya through escape and tolerance. Oral presentation – 19. In: Symposium “ Developing drought and low nitrogen tolerant maize. Poster No. 18. Symposium Abst. Published in 1997.
- Munir, M. S. D. Shah and M. Aslam, 1977. Gene action controlling yield and its components in maize. *Pak. J. Agic. Sci.* 14(1): 63-68.
- Mwanamwenge, J., S.P. Loss, K.H.M. Siddique and P.S. Cocks. 1999. Effect of water stress during floral initiation, flowering and podding on the growth and yield of faba bean (*vicia faba L.*). *Eur. J. Agron.* 11:1-11.
- Naved, A. 1979. Genetic analysis of yield ant its economic characters in maize. M. Sc. Thesis, Deptt. Pl. Br. Genet., Univ. Agri. Faisalabad, Pakistan.
- Nagy, Z. Tuba, F.Z. Soldos and L. Erdei. 1995. CO<sub>2</sub> exchange and water relation responses of sorghum and maize during water and silt stress. *J. Pl. Physio.* 145:539-544.
- NeSmith D. S. and J. T. Ritchie. 1992. Effects of soil water deficit during tassel emergence on development and yield components of maize. *Field Crops Res.* 28: 251-256.



- Neyestani, E. and M, Azimzadeh. 2003. Study of drought tolerance of 15 lentil varieties. Iranian Journal of Agriculture. Vol.5. No.1:61-69.
- Newton, S. D. and H. A. Eagle. 1991. Development traits affecting time to low ear moisture in maize. Plant breed. 106(1): 58-67.
- Nielsen (Bob) R. L.. 2005. Chat n Chew Café. Corny News Network, Purdue Univ.
- Nigussie, M. and H. Zelleke. 2001. Heterosis and combining ability in a diallel among eight elite maize populations. Afr. Crop Sci. J. 9(3): 471-479.
- Niklas K. J. 1991. Biomechanical responses of *Chamaedorea* and *Spathiphyllum* petioles to tissue dehydration Ann. Bot. 67: 67-76.
- Nir I., S. Klein, and A. Poljakoff-Mayber. 1969. Effects of moisture stress on submicroscopic structure of maize roots. Aust. J. Biol. Sci. 22:17-33.
- Ofori, E. & Kyei-Baffour, N., 2008. Chapter 13C: Agrometeorology and Maize.
- Ogunbodede, B. A., S. R. Ajibade and S. A. Olakojo. 2000. Heterosis and combining ability for yield and yield related characters in some Nigerian local varieties of maize (*Zea mays*). Moor J. Agric. Res. 1(1): 37-43.
- Oregan, B.P., W.A. Cress and J. Staden. 1993. Root growth, water relation of drought resistant I and drought sensitive maize cultivars in response to water stress. South African Journal Botany 59:98-104.
- Passioura J. B., A. G. Condon and R. A. Richards. 1993. Water deficits, the development of leaf area and crop productivity. In Water Deficits, Plant Responses from Cell to Community, J. A. C. Smith and H. Griffiths (eds). BIOS Scientific publ. Oxford, pp. 253-2640.
- Paul, K.K and S.C. Debanth. 1999. Combining ability analysis in maize (*Zea mays* L.). Pak. J. Sci. Ind. Res., 42(3): 141-144.
- Perez, V. J. C., H. Ceballos, S. Pandey and A. C. Diaz, 1996. Analysis of diallel crosses among Columbian land races and improved population of maize. Crop Sci. 3592:572-578.
- Petcu, E. and M. Terbea. 1996. Dynamics of the free proline content in maize plants under drought conditions. Analcle instituii de cercetari pentru cereale si plante Mechnicse, Fundulea 63. 163-272 (Crop Physiol, Abst. 29 (6): 4707, 1997).
- Prakash, S and D.K. Ganguli. 2004. Combining ability for various yield component characters in maize (*Zea mays* L.). J. Res. Birsa Agric. Univ. 16(1): 55-60.
- Prasad, R. S. Singh and R. S. Paroda. 1988. Combining ability analysis in a maize diallel. Ind. J. Genet. 48(1): 19-23.

- Ouattar, S., R. J. Jones, R. K. Crookston and M. Kajeiou. 1987. Effect of drought on water relations of developing maize kernels. *Crop Science*, 27:730-735
- Prasad, P.V.V., S.A. Staggenborg, Z. Ristic. 2008. Impacts of drought and/or heat stress on physiological, developmental, growth, and yield processes of crop plants. P. 1-55. In *Advances in agricultural systems modeling. Ser. 1. ASA, CSSA, and SSSA, Madison, WI*
- Ramadan, H.A., S.N. Al-Niemi. and T.T.Hamdan.1985. Water stress, soil type and phosphorus effects on corn and soybean, 1. Effect ;on growth. *Iraqi J. Agri. Sci, "Sanco" 3 "*: 1237-.144.
- Ramamurthy, A. 1980. Genetic analysis of yield and economic characters in maize diallel crosses. M.Sc. Thesis, Deptt. Pl. Br. Genet., Univ. Agri. Faisalabad. Pakistan.
- Rana, M. K. and K.Venod. 2001. Combining ability for yield and its components and phonological characters in maize. *New Botanist*. 28(1): 39-44.
- Reddy, S. R. 2004. *Agronomy of field crops*. Kalyani publishers, India. 195-252.
- Revilla, P., A. N. Butro., R. A. Malvar and A.S. Orda. 1999. Relationship among kernel weight, early vigor and growth in maize. *Crop Sci*. 39(3): 654-658.
- Reynolds M. P., A. K. Mujeeb and M. Sawkins 2005. Prospects for utilizing plant-adaptive mechanisms to improve wheat and other crops in drought and salinity prone environments. *Annals of Applied Biology* 146: 239-259.
- Rezaei, A.H., B. Yazdisamadi, A. Zali, A. M. Rezaei, A. Tallei, H. Zeinali. 2005. An estimate of heterosis and combining ability in corn using diallel crosses of inbred lines. *Iranian J. Agric. Sci*. 36(2 ): 385-397.
- Rijsberman FR (2006) Water scarcity: Fact or fiction? *Agricultural Water Management* 80:5-22
- Rosegrant, M.W., N. Leach and R.V. Gerpacio. 1999. Alternative future for world cereal and meat consumption. Summer meeting of the Nutrition Society. Guildford, UK. 29 June- 2July 1998. *Proc. Nutr. Soc*. 58:1-16.
- Rosenow, D.T. and L.E. Clark. 1981. Drought tolerance in sorghum. p. 18-31. In *Drought tolerance in sorghum. Proceedings of the 36th annual corn and sorghum research conference, 1981*.
- Sacks M.M., W.K. Silk and P. Burman. 1997. Effect of water stress on cortical cell division rates within the apical meristem of primary roots of maize. *Plant Physiology*. 114:519-527.

- Sadalla M. M., J. F. Shanahan and J. S. Quick. 1990. Heat tolerance in winter wheat. I. Hardening and genetic effects on membrane thermostability. *Crop Sci.* 30: 1243-1247.
- Sadiq, M., F. Baig and N. A. Baig. 1989. Water in maize varieties under water stress conditions. *Pak. J. Agri. Sci.* 26(1) 8, 1989.
- Saeed, M. T. 1998. Estimates of gene effects for some important plant traits in maize diallel crosses. M. Sc. thesis, Deptt. Pl. Breed. Genet. Univ. Agri. Faisalabad, Pakistan.
- Saini H. S. and M. E. Westgate. 2000. Reproductive development in grain crops during drought. *Advances in Agronomy* 68: 59-96.
- Saleem, M., K. Shahzad, M. Javed, A. Ahmed. 2002. Genetic analysis for various quantitative traits in maize (*Zea mays* L.) inbred lines. *International J. Agric. and Bio.* 4(3): 379-382.
- Saneoka H, Moghaieb REA, Premachandra GS, Fujita K (2004). Nitrogen nutrition and water stress effects on cell membrane stability and leaf water relations in *Agrostis palustris* Huds. *Environ. Exp. Bot.* 52, 131-138
- Satyanarayana, E. 1995. Genetic analysis of flowering period in Rabi maize (*Zea mays* L.). *Himachal. J. Agric. Res.* 29(3): 213-218.
- Schussler, J.R. and Westgate, M.E. (1995). Assimilate flux determines kernel set at low water potential in maize. *Crop Science* 35, 1074-1080.
- Setty, A. H. 1975. Genetic architecture of yield and its components in maize diallel crosses. *Mesore Agric. Sci.* 9(2): 356-357.
- Shakil, Q. 1992. Genetic analysis for quantitative characters in diallel crosses of maize inbred lines. M.Sc. Thesis, Deptt. Pl. Br. Genet. Univ. Agric. Faisalabad, Pakistan.
- Sharma, J. K. and S. K. Bhalla. 1990. Combining ability for drought tolerant traits in maize. *Crop Improvement.* 1792: 144-149.
- Shiralipour, A. and S. H. West. 1984. Inhibition of specific protein synthesis in maize seedlings during water stress. *Proc. Soil and Crop Sci. Soc. Florida.* 43:102-106.
- Shreenivasa, A. D. and R. D. Singh. 2001. Combining ability studies for some morphological and biochemical traits related to drought tolerance in maize. *Ind. J. Genet.* 61:34-36.
- Siddiqui, N.A. 1988. Genetic analysis of yield its components in maize diallel crosses. M.Sc. Thesis, Deptt. of Pl. Br. Genet., Univ. Agri. Faisalabad, Pakistan.
- Smirnoff N. 1993. The role of active oxygen in the response of plants to water deficit and desiccation. *New Phytologist* 125: 27-58.

- Singh. A. K, J. P. Shahi, J K Singh and R.N. Singh. 2001. Genetic control of some traits in maize (*Zea mays* L.). Crop Improvement. 28(1): 56-61.
- Singh, R.K. and B.D. Chaudhary. 1985. Biometrical methods in Quantitative Genetic Analysis.; Kalyani Pub., Ludhiana, New Delhi, Revised Ed. pp. 102-118.
- Singh, R D., T. Yadav, J. S. Bhat and T. Yadav. 2000. Combining ability analysis in varietal crosses of maize. New Botanist. 27(1): 29-36.
- Sinsawat, V. J. Pandey, P. Leipner, P. Stamp and Y. Fracheboud. 2004. Effect of heat stress on the photosynthetic apparatus in maize (*Zea mays* L.) grown at control or high temperature. Environ. and Experimental Bot. 52: 123-129.
- Shabir, G. and M. Saleem. 2002. Gene action for protein content of maize grain in diallel cross. Pak. J. Seed Tech., 1(2): 53-56.
- Shaw R. H. 1977. Water use and requirement of maize, a review. Agrometeorology of the Maize Crop, 480. World Met. Organization Publication pp. 119-134.
- Steduto P. 1996. Water use efficiency. In Sustainability of Irrigated Agriculture, Pereira, L. S. R. A. Feddes, J. R. Gilley and B. Lesaffre (eds.) NATO Advanced Research Workshop. Kluwer Academic Publ., pp. 193-209.
- Steel, R.G.D., J.H. Torrie and D.A. Dickey. 1997. Principles and procedures of statistics: McGraw Hill Book Co., New York, USA.
- Stout D. G. and G. M. Simpson. 1978. Drought resistance of sorghum bicolor. I. Drought avoidance mechanism related to leaf and water status. Can. J. Plant Sci. 58: 213-224.
- Sullivan C. Y. 1972. Mechanism of heat and drought resistance in grain sorghum and method of measurements. In: Rao N. G. P., L. R. House (eds) Stress Physiology in crop plants. John Wiley & Sons, New York, pp. 263-281.
- Tabassum, M. I. 1989. A study of gene action for economic characters in maize (*Zea mays* L.). M.Sc (Hons.) Thesis, Deptt. Pl. Breed. Genet. Univ. Agri. Faisalabad, Pakistan.
- Tabassum, M. I. 2004. Genetics of physio-morphological traits in *Zea mays* L. under normal and water stress conditions. Ph.D Thesis, Deptt. P.B.G., Univ. Agri., Faisalabad, Pakistan.
- Tabassum, M. I., M. Saleem, M. Akbar, M. Y. Ashraf and N. Mehmood. 2007. Combining ability studies in maize under normal and drought conditions. J. Agric. Res. 45(4): 261-268.

- Talleei, A. and H. N. K. Kochaksaraei. 1999. Study of combing ability and cytoplasmic effects in maize diallel crosses. *Iranian J. Agri. Sci.* 30(4): 761-769.
- Tollenaar M., D. E. McCullough and L. M. Dwyer. 1994. Physiological basis of the genetic improvement of corn. In: Slafer, G. A. (Ed.), *Genetic Improvement of Field Crops* Marcel Dekker, New York, pp. 183-236.
- Tollenaar M., J. Ying and D. N. Duvick. 2000. Genetic gain in corn hybrids. In: *Proceedings of the 55<sup>th</sup> Annual Research Conference on Corn and Sorghum*, Chicago, IL, December 6-8, 2000. American Seed Trade Association, Washington, DC, pp. 53-62.
- Tangpremsri T., S. Fukai and K. S. Fischer. 1995. Growth and yield of sorghum lines extracted from a population for differences in osmotic adjustment. *Australian J. Agric. Res.* 46: 61-74.
- Thakur, P.S. and V.K. Rai. 1984. Water stress effects on maize growth responses of two differentially drought sensitive maize cultivars during early stage of growth. *Indian Journal of Ecology*, 11:92-98.
- Trachse, S. 2009. Genetic analysis of root morphology and growth of tropical maize and their role in tolerance to desiccation, aluminum toxicity and high temperature. Thesis Doctor of Sciences . Dipl. Ing.-Agr. ETH Zurich
- Tuinstra, M.R., E.M. Grote, P.B. Goldsbrough and G. Ejeta. 1997. Genetic analysis of post-flowering drought tolerance and components of grain development in sorghum bicolor (L.) moench. *Mol. Breed.* 3:439-448.
- Turner N. C. and J. E. Begg. 1981. Plant water relations and adaptation to stress. *Plant and Soil* 58: 97-131.
- Turner N. C. and M. M. Jones. 1980. Turgor maintenance by osmotic adjustment: a review and evaluation. In *Adaptation of Plants to Water and High Temperature Stress*, Turner N. C. and P. J. Kramer (eds). Wiley Interscience, New York, pp. 87-103.
- Valentovic, P., M. Luxova, L. Kolarovic and O. Gasparikova. 2006. Effect of osmotic stress on compatible solutes content, membrane stability and water relations in two maize cultivars. *Plant Soil Environ.*, 52(4): 186-191.
- Vazan, S., Z. Ranji., M. H. Tehrani., A. GHlavand. and M. S. SHariatpanahi. 2005. Study of proline variations in related to abscisic acid, stomatal conductivity, and plasma membrane stability indifferent genotypes of *Beta vulgaris* L. under drought stress

- and non-stress conditions. *Iranian Journal of Agronomy and Plant Breeding*. Vol.1. No.1:27-37
- Vega C. R. C., F. H. Andrade, B. O. Sadras, S. A. Uhart and O. R. Valentinuz. 2001. Seed number as a function of growth: A comparative study in soybean, sunflower and maize. *Crop Sci.* 41: 748-754.
- Vicente, F. S., A. Bejarano, Crossa. J. Marin. 2001. Heterosis and combining ability of tropical yellow endosperm maize populations. *Agronomia Tropical*, Maracay. 51(3): 301-318.
- Vicente, F.S., S.K. Vasal, S.D. Mclean, S.K. Ramanujam and M. Barandiaran. 1999, Behaviour of tropical early maize lines j under drought conditions. *Agronomia tropical (Maracay)* 49(2): 135-154.
- Whitehouse, R.N.H, T.B. Thompson and M.A.M: Dovalle Robiero. 1958. Studies on the breeding of self pollinated cereals. The use of diallel cross analysis in yield prediction. *Euphitica*, 7:147-169.
- Weerathorn, P.A. Soldati and P.Stamp. 1992. Shoot and root growth of tropical maize seedling at different moisture regimes. *Maydica*, 37:209-215.
- Westgate M. E. and J. S. Boyer. 1985. Carbohydrate reserves and reproductive development at low leaf water potentials in maize. *Crop Sci.* 25: 762-769.
- Wilson, N. D., D. E. Weibel and R.W, Me New. 1978. Diallel analysis of grain yield. Percent protein yield in sorghum. *Crop Sci.* 18:491-495.
- Wu ,G.H. 1987. Analysis of genetic effects for quantitative characters at different developmental states in maize. *Genetics.* 18(2): 69-69.
- Xu, X. and W.L. Bland. 1993. Resumption of water uptake by sorghum after water stress. *Agron. J.* 85(3):697-702.
- Xu, Z.Z., G.S. Zhou, Y.L. Wang, G.X. Han and Y.J. Li. 2008. Changes in chlorophyll fluorescence in maize plants with imposed rapid dehydration at different leaf ages. *J. Plant Growth Regul.* 27:83-92.
- Yang, C.M. and W.M. Hsiang. 1992. Growth and reproduction of maize response to soil water deficits." 1. Changes of growth when stress and recovery occurring at the vegetative stage in the controlled environment, *J. Agri. Res. Chi.* 41(2):132-139.
- Yang J., J. Zhang, Z. Wang and Q. Zhu. 2001a. Activities of starch hydrolytic enzymes and sucrose phosphate synthase in the stems of rice subjected to water stress during grain filling. *Journal of Experimental Botany* 52: 2169-2179.

- Yang J., J. Zhang, Z. Wang and Q. Zhu. 2001b. Remobilization of carbon reserves in response to water-deficit during grain filling of rice. *Field Crops Research* 71: 47-55.
- Yang J., J. Zhang, Z. Wang, L. Liu and Q. Zhu. 2003. Post anthesis water deficits enhance grain filling in two line hybrid rice. *Crop Sci.* 43: 2099-2108.
- Yedeneov, G. I. and N. A. Pancova. 1886. Genetic control of quantitative characters in maize, contents of dry matter in ears at harvest. *Genetika, USSR.* 24(2): 642-656.
- Yousaf, M. 1992. Genetic analysis of yield and yield components in maize diallel crosses. M.Sc. Thesis, Deptt. of Pl. Br. Genet., U. A. Faisalabad.
- Yuan, D. H. W., G. Wei, L. DeXiang; L. JunJie, L. Qiang; H. DY; G.W. Wu, DX. Long, J. Lu and Q. Liu. 2003. Analysis of combining ability and hereditary parameters of main quantitative characters of 10 maize inbred lines. *J. Maize Sci. China.* 11(1): 26-29.
- Zhang, D.S. and G.R. Wang. 1991. Analysis of the combining ability of main photosynthetic and agronomic characteristics of *Zea mays* L. *Journal of Shandong Agricultural University*, 22(3):212-220.
- Zia, M. K. and A. R. Chaudhry. 1980. Gene action for yield and its components in maize. *Pak. J. Agric. Sci.* 17(2): 87-92.
- Zinselmeier, C., B.R. Jeong and J.S. Boyer. 1999. Starch and the control of kernel number in maize at low water potentials. *Plant Physiol.* 121:25-36.

**Appendix: 1. Meteorological Data Agro met center, University of Agriculture,  
Faisalabad for January, 2009.**

DATE	TEMPERATURE			RAIN FALL
	MAX	MIN.	Avg.	
	°C	°C	°C	mm
1	21.0	07.0	14.0	00.0
2	22.0	04.0	13.0	00.0
3	22.0	08.0	15.0	00.0
4	18.0	08.5	13.3	00.0
5	17.5	06.0	11.8	<b>03.5</b>
6	18.0	05.0	11.5	00.0
7	18.0	04.0	11.0	00.0
8	17.5	03.5	10.5	00.0
9	18.0	04.0	11.0	00.0
10	17.0	03.5	10.3	00.0
11	20.5	06.0	13.3	00.0
12	20.0	05.0	12.5	00.0
13	20.0	06.0	13.0	00.0
14	20.5	06.5	13.5	00.0
15	22.0	08.5	15.3	00.0
16	20.0	12.0	16.0	<b>02.6</b>
17	15.0	10.5	12.8	<b>02.7</b>
18	19.5	11.0	15.3	<b>01.9</b>
19	17.5	08.5	13.0	<b>02.6</b>
20	18.0	06.5	12.3	00.0
21	19.5	05.5	12.5	00.0
22	21.0	05.5	13.3	00.0
23	22.0	05.5	13.8	00.0
24	22.0	07.5	14.8	00.0
25	23.0	11.0	17.0	00.0
26	19.5	11.0	15.3	<b>00.2</b>
27	16.5	11.0	13.8	00.0
28	19.5	08.5	14.0	00.0
29	21.0	08.5	14.8	00.0
30	22.0	09.0	15.5	00.0
31	21.0	10.0	15.5	00.0
<b>AVERAGE:</b>	19.6	07.3	13.5	<b>total=13.5</b>
<b>5 YEARS :</b>	19.6	6.01	12.81	21.13
<b>10 YEARS:</b>	18.79	6.2	12.5	15.07



**Appendix: 2. Meteorological Data Agro met center, University of Agriculture,  
Faisalabad for February, 2009.**

DATE	TEMPERATURE			RAIN FALL
	MAX	MIN.	Avg.	
	°C	°C	°C	mm
1	23.0	08.5	15.8	00.0
2	23.0	08.0	15.5	00.0
3	22.0	09.0	15.5	00.0
4	23.0	11.5	17.3	00.0
5	23.5	12.5	18.0	00.0
6	19.5	09.5	14.5	00.0
7	20.0	07.0	13.5	00.0
8	20.5	06.0	13.3	00.0
9	22.5	09.5	16.0	00.0
10	20.0	09.0	14.5	00.0
11	18.5	09.5	14.0	<b>00.7</b>
12	20.0	09.0	14.5	00.0
13	21.0	10.0	15.5	00.0
14	22.0	11.0	16.5	<b>16.2</b>
15	21.0	07.5	14.3	00.0
16	20.5	08.0	14.3	00.0
17	21.5	08.5	15.0	00.0
18	22.5	10.0	16.3	00.0
19	23.0	10.5	16.8	00.0
20	20.0	11.0	15.5	<b>01.3</b>
21	22.0	12.5	17.3	<b>T</b>
22	25.0	12.0	18.5	00.0
23	22.0	07.0	14.5	00.0
24	26.0	14.0	20.0	00.0
25	24.0	12.0	18.0	00.0
26	24.5	12.5	18.5	<b>T</b>
27	24.0	11.0	17.5	00.0
28	25.0	11.0	18.0	00.0
<b>AVERAGE:</b>	22.1	09.9	16.0	<b>18.2(total)</b>
<b>5 YEARS :</b>	22.8	9.9	16.4	23.7
<b>10 YEARS:</b>	20.5	8.1	14.3	15

**Appendix: 3. Meteorological data Agro met center, University of Agriculture,  
Faisalabad for March, 2009.**

DATE	TEMPERATURE			RAIN FALL
	MAX	MIN.	Avg.	
	°C	°C	°C	mm
1	25.0	12.0	18.5	00.0
2	27.0	12.5	19.8	00.0
3	27.5	15.5	21.5	00.0
4	26.0	13.0	19.5	00.0
5	28.0	13.0	20.5	00.0
6	27.5	13.0	20.3	00.0
7	29.0	16.0	22.5	00.0
8	26.0	13.5	19.8	00.0
9	28.0	08.0	18.0	00.0
10	25.0	12.0	18.5	00.0
11	27.0	10.0	18.5	00.0
12	27.5	11.5	19.5	00.0
13	28.5	12.0	20.3	00.0
14	31.0	14.0	22.5	00.0
15	30.0	15.0	22.5	00.0
16	29.5	14.5	22.0	00.0
17	31.0	15.0	23.0	00.0
18	29.5	15.5	22.5	00.0
19	31.0	17.0	24.0	00.0
20	30.0	16.0	23.0	00.0
21	29.0	14.5	21.8	<b>01.2</b>
22	28.0	15.0	21.5	00.0
23	28.0	15.0	21.5	00.0
24	29.0	18.5	23.8	00.0
25	24.5	14.5	19.5	<b>04.5</b>
26	24.5	13.5	19.0	00.0
27	27.0	16.5	21.8	00.0
28	22.5	14.5	18.5	<b>04.3</b>
29	21.0	14.0	17.5	<b>04.0</b>
30	27.0	14.0	20.5	00.0
31	27.5	16.5	22.0	00.0
<b>AVERAGE:</b>	27.5	14.0	20.8	<b>total=14.0</b>
<b>5 YEARS :</b>	29.4	14.77	22.01	25.38
<b>10 YEARS:</b>	28.83	14.09	21.44	17.84

**Appendix: 4. Meteorological Data Agro met center, University of Agriculture,  
Faisalabad for April, 2009.**

DATE	TEMPERATURE			RAIN FALL
	MAX	MIN.	Avg.	
	°C	°C	°C	mm
1	29.5	17.5	23.5	00.0
2	34.0	18.0	26.0	00.0
3	30.5	18.0	24.3	<b>T</b>
4	31.5	18.0	24.8	00.0
5	30.5	20.0	25.3	00.0
6	30.0	17.0	23.5	<b>03.8</b>
7	25.0	16.0	20.5	<b>02.6</b>
8	29.5	15.5	22.5	<b>13.4</b>
9	23.5	15.0	19.3	<b>02.1</b>
10	26.0	14.5	20.3	00.0
11	30.0	14.5	22.3	00.0
12	33.5	19.5	26.5	00.0
13	35.0	21.0	28.0	00.0
14	35.0	23.5	29.3	00.0
15	37.0	20.5	28.8	<b>T</b>
16	32.0	18.0	25.0	00.0
17	33.0	17.0	25.0	00.0
18	34.0	18.0	26.0	00.0
19	36.0	20.0	28.0	00.0
20	39.0	23.5	31.3	<b>01.0</b>
21	37.5	23.5	30.5	<b>T</b>
22	34.5	20.0	27.3	00.0
23	35.0	18.0	26.5	00.0
24	35.0	17.5	26.3	00.0
25	35.0	17.5	26.3	00.0
26	37.0	19.0	28.0	00.0
27	38.5	19.0	28.8	00.0
28	38.5	23.0	30.8	00.0
29	38.5	25.0	31.8	00.0
30	39.5	24.0	31.8	00.0
<b>AVERAGE:</b>	33.5	19.1	26.3	<b>Total=22.9</b>
<b>5 YEARS :</b>	37.36	20.44	28.86	7.16
<b>10 YEARS:</b>	36.93	20.21	28.55	6.89

**Appendix: 5. Meteorological Data Agro met center, University of Agriculture,  
Faisalabad for May, 2009.**

DATE	TEMPERATURE			RAIN FALL
	MAX	MIN.	Avg.	
	°C	°C	°C	mm
1	40.5	23.5	32.0	00.0
2	41.5	24.0	32.8	00.0
3	40.5	25.0	32.8	00.0
4	39.0	20.0	29.5	<b>08.4</b>
5	32.0	20.0	26.0	<b>00.7</b>
6	31.0	19.0	25.0	00.0
7	32.5	23.0	27.8	00.0
8	36.0	24.0	30.0	00.0
9	37.0	24.0	30.5	00.0
10	40.0	22.0	31.0	00.0
11	37.0	22.5	29.8	00.0
12	37.5	21.5	29.5	00.0
13	39.0	23.0	31.0	00.0
14	42.0	25.5	33.8	00.0
15	43.0	23.0	33.0	00.0
16	41.0	28.0	34.5	00.0
17	42.0	27.5	34.8	00.0
18	43.0	27.0	35.0	00.0
19	44.0	30.5	37.3	00.0
20	45.0	29.5	37.3	00.0
21	41.5	28.0	34.8	00.0
22	44.0	27.0	35.5	00.0
23	43.0	27.0	35.0	00.0
24	42.0	27.0	34.5	00.0
25	42.0	26.0	34.0	00.0
26	37.0	23.0	30.0	00.0
27	40.0	25.0	32.5	00.0
28	43.0	25.0	34.0	00.0
29	43.0	25.0	34.0	00.0
30	43.0	26.0	34.5	00.0
31	40.0	27.0	33.5	00.0
<b>AVERAGE:</b>	<b>40.1</b>	<b>24.8</b>	<b>32.4</b>	<b>9.1(Total)</b>
<b>5 YEARS :</b>	<b>40.0</b>	<b>25.1</b>	<b>32.6</b>	<b>27.2</b>
<b>10 YEARS:</b>	<b>39.6</b>	<b>24.3</b>	<b>32.0</b>	<b>20.0</b>

**Appendix: 6. Meteorological Data Agro met center, University of Agriculture,  
Faisalabad for June, 2009.**

DATE	TEMPERATURE			RAIN FALL
	MAX	MIN.	Avg.	
	°C	°C	°C	mm
1	39.0	25.5	32.3	00.0
2	38.5	28.0	33.3	00.0
3	40.5	23.0	31.8	<b>05.2</b>
4	40.0	29.0	34.5	00.0
5	42.0	30.0	36.0	00.0
6	41.0	26.0	33.5	00.0
7	38.0	25.0	31.5	00.0
8	40.5	24.5	32.5	00.0
9	41.5	24.0	32.8	00.0
10	41.5	25.0	33.3	00.0
11	42.5	25.0	33.8	00.0
12	42.0	29.0	35.5	00.0
13	41.0	31.0	36.0	00.0
14	41.5	31.0	36.3	<b>04.4</b>
15	37.0	27.5	32.3	00.0
16	35.0	23.5	29.3	00.0
17	34.0	24.0	29.0	00.0
18	36.0	25.5	30.8	00.0
19	39.5	25.0	32.3	00.0
20	40.5	21.5	31.0	00.0
21	41.5	25.0	33.3	00.0
22	42.0	27.0	34.5	00.0
23	45.0	28.0	36.5	00.0
24	45.0	27.0	36.0	00.0
25	43.5	30.5	37.0	00.0
26	37.0	26.0	31.5	00.0
27	43.5	31.0	37.3	00.0
28	45.0	29.5	37.3	00.0
29	45.0	32.0	38.5	00.0
30	43.0	29.5	36.3	00.0
<b>AVERAGE:</b>	40.7	27.0	33.8	<b>9.6 (Total)</b>
<b>5 YEARS :</b>	40.36	27.76	34.08	57.56
<b>10 YEARS:</b>	40.32	27.91	34.125	58.29