An overview of conventional breeding for drought tolerance in *Zea mays*

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Abstract *Zea mays* is an important cereal crops through out world. It is highly affected by biotic and abiotic stresses like drought, heat, clod, insect/pest attack, fungal, viral and bacterial diseases. There is great loss of yield and productivity of maize due to water stress. The present review will provide its readers an opportunity to understand the breeding procedure to develop drought tolerant varieties and hybrids. Heritability, specific combining ability, dominance effects, heterosis provides a chance to develop hybrid while additive, general combining ability and genetic advance provide chance to develop synthetic variety for higher grain and fodder yield.
[Saif-ul-Malook, Qurban Ali, Muhammad Ahsan, Aamer mumtaz and Muhammad sajjad. **An overview of conventional breeding for drought tolerance in *Zea mays*.** *Nat Sci* 2014;12(10):23-37]. (ISSN: 1545-0740). http://www.sciencepub.net/nature. 3

Key words: *Zea mays*, drought, gene action, heritability, genetic advance, heterosis

Introduction

Agriculture is the main pillar of economy of Pakistan. It contributes 21% of the Grand Domestic Production (GDP) and directly or indirectly source of livelihood for 75% peoples in villages while over all accounts 45% of the manpower in Pakistan (Anonymous, 2012).

Maize (*Zea mays* L.) is an important cereal cr0p, belongs to family *Poaceae* of specialized tribe *Maydeae*. It is a monoecious and highly cross pollinated crop among the cereals. It ranked third after wheat and rice for its nutrition and uses (Cassamon, 1999). It has 500 byproducts but mostly used as food, feed, forage, green fuel (ethanol), vegetable oil and starch. It is a backbone of poultry feed industry. Maize grain constitutes about 10% protein, 72% starch, 5.8% fiber, 4.8% oil, 3.0% sugar and 1.7% ash (Chaudhary, 1983). A huge quantity of ethanol (52 thousand million liters) is produced in Pakistan against 28.9 million tons of the world production (Anonymous, 2012). It is grown in Pakistan at 1.083 million hectares with production of 4.271 million tones. Punjab contributes about 39% of total area under maize cultivation with 30% production of total produce in Pakistan while the major share belongs to Sindh and KPK with 56% area and 63% production. The average production of maize in Pakistan is 3672 kg/ha which is very low as compared to other countries (Anonymous, 2012).

Increasing population has enlarged the demand of food and energy which becomes necessary for the enhancement of maize production. Unluckily, ecological stresses such as water specific combining abilityrcity and high temperature stresses are going to confine the maize production (Mishra, 2012). Crop water requirement is a major factor that depends on existing environment (humidity and temperature) in which it is grown. Maize requires 1.3 to 45.6 mm of water per day (Adeniran *et al.*, 2014; saif-ul-malook, *et al.*, 2014). Water deficiency occurs in most part of the world every year having overwhelming effect on maize production (Ludlow and Muchow, 1990). Drought causes the reduction in CO_2/O_2 ratio in leaves that inhibit the photosynthesis. (Amin *et al.*, 2014). Drought is particularly severe in those countries, where irrigation water is often specific combining abilityrce and where rainfall represents the main source of crop-available water (Edmeades *et al.*, 1992). Water unavailability can impact maize production at all developmental stages, such as seedling, pre-flowering, flowering and grain-filling stages. There have been many reports of drought tolerance evaluation between different superior genotypes at the seedling stage (Liu *et al.*, 2004), which revealed the variation of drought tolerance among various genotypes. Different genes were encouraged and intricate in the drought stress response in many plants (Ingram and Bartels, 1996). These inducible genes play important role not only in drought tolerance but also in the regulation of gene expression and signal transduction in stress responses (Shinozaki and Shinozaki, 1997). Drought is the most complex trait to be improved through conventional breeding. Crop improvement through breeding against drought tolerance and yield stability is an important step for the solution of this problem. The genetic improvement can fill up the gap to 30% between realized and potential yield under drought (Edmeades *et al.*, 1999). Conventional breeding is long term and difficult process for improving yield under drought condition because field conditions are hard to manage properly. There is also a reduction in genetic variability and heredity of quantitative traits that equals an increase in biotic and abiotic stress (Blum, 1988). Reduction in yield due to drought mainly depends on two factors, the drought vulnerability of plant and over effects of yield prospective, that increase the number of chances that a plant performed better in well irrigation conditions will performed well under drought condition, even the yield reduction for that plant is large (Areous *et al*., 2005).

A vast area of Pakistan is not suitable for agriculture due to different growth inhibiting constraints such as salinity and drought. Water shortage is a serious threat to our agriculture due to huge exploitation of new reservoirs. Agriculture consumes 70% of the world water. Maize is mainly affected by many biotic and abiotic factors. Drought badly affects plant growth from seedling to maturity (Areous *et al*., 2005). Drought is a second factor after soil infertility that causes reduction in maize grain yield. Maize is more susceptible to drought as compared to other cereals except barley (Banziger and Araus, 2007).

Drought causes reduction in leaf area, stem extension, root proliferation, low water use efficiency, disturbance in metabolism, enzyme activity, ionic balance and solute accumulation (Khan *et al*., 1995 and Farooq *et al*., 2002). It reduces chlorophyll contents resulted in less photosynthesis and ultimately reduction in crop yield (Athar and Ashraf, 2005). Water stress affects silking and extend the anthesis-silking-interval (ASI) leads to lower crop yield (Edmeades *et al*., 1992). Grain yield is a quantitative trait which depends on many factors such as plant height, plant vigor, efficient water availability, optimum nutrient availability, enhanced solar radiation interception and conversion of solar to chemical energy. Selection of genotype for water stress is complex due to genotype interaction with environment(Messmer,2006)

Seedlings traits

Eagles and Brooking (1981) and Fakorede and Ojo (1981) concluded that faster germinated populations contained higher germplasm proportion from conica race. Conica race have an advantage in the environments where germination rate was at the lowest level. Fakorede and Ayoola (1981) reported that a strong genetic relationship lies between selection of higher yielding maize genotypes and seedling vigour of maize. It was concluded that germination percentage, total dry matter, germination index, relative growth rate and growth rate as criteria for selection of seedling vigour after 30-days of germination. Jenison *et al*. (1981) concluded that vertical pull resistance, root spread and dry root weight were relatively same in performance in different environmental conditions and may be effective for the selection of higher yielding maize genotypes. It was also found that genotypes showed higher root dry weight were resistant to root worms. Szundy and Kovacs (1981) concluded that the heterozygosity increased the vigour of the maize seedling and can be used for the selection of higher yielding maize genotypes. Andrew (1982) concluded that the better germination percentage is greatly associated with the rapid relative root growth as compared to shoot relative growth and root/shoot length and weight ratio is the main source of this relationship. Eagles (1982) reported that the elite lines endosperm and embryo were of great importance as compared to the female parents in determining the differences of germination period and relative growth of maize seedlings. Gorny and Geiger (1982) performed an experiment to evaluate 11 days old seedlings of 35 elite lines and 24 single crossed hybrids of *Secale cereale* for seven traits related to shoot and root relative growth. It was concluded that the elite lines were generally had smaller means while larger vales of heritability as compared to the single crossed hybrid. It was concluded that germination percentage, rate of germination, fresh and dry weights are the traits that greatly contribute in cold tolerance in maize. Specific combining ability and general combining ability were significant for all cold tolerance traits while those reciprocal differences were significant but are not important in cold tolerance (Chapman and Drolsom 1983).

Eissa *et al*. (1983) conducted an experiment to compare the relative root growth, root fresh and dry weight and root length for 124 day-neutral F_3 cotton genotypes. The variability among different elite lines was significantly differing for all seed and seedling traits. It was concluded that the plants with long roots and higher relative root weight showed increasing trend of resistance to environmental stresses. Khidse *et al*. (1983) reported from an experiment that the non-additive genetic effects contributing for grain size and seedling vigour traits of sorghum, *viz*., seedling volume, plumule length, radicle length and root/shoot fresh and dry weights of maize seedlings. Pozzi *et al*. (1985) conducted an experiment on maize to assess cold tolerance on the basis of germination percentage; germination index and seedling dry weight. It was concluded that the accumulation of dry matter greatly varied among seedlings in maize genotypes. Seedling dry and fresh weights were useful traits for the selection of cold tolerance genotypes of maize. Stamp *et al*. (1986) reported that shoot fresh and dry weight, root fresh and dry weight were the traits that may predicate early field growth of six inbred lines of maize. Wallace *et al*. (1986)

reported that the germination rate at seedling stage and germination rate in field, stand and grin yield per plant are positively correlated with each other.

Ochesanu and Cabulea (1988) evaluated 42 F_1 hybrids between inbred lines from a set of diallel crosses for root length, seminal and crown roots, number and volume of roots, fresh and dry weight of roots. It was concluded that root volume and root fresh and dry weights played a significant role in selection of high yielding maize genotypes. Rehman *et al*. (1988) concluded that the general combining ability and specific combining ability effects for seedling traits were highly significant and can be used for selecting high yielding maize genotypes. The range of heterosis was found to be 27.1% for root branching traits and 137.8% for mesocotyl root traits. Hussain (1989) reported from an experiment that the genotypic coefficient of variation was maximum for shoot weight while minimum for root-to-shoot weight ratio. The broad-sense heritability was highly significant for germination percentage, root and shoot fresh weights and root length. Mehdi and Ahsan (2000a) estimated higher values of coefficient of variation for fresh and dry root and shoot weights. Moderate broad-sense heritability was found shoot fresh weight, root dry weight and shoot length. All traits were positively and significantly correlated with each other. Mehdi and Ahsan (2000b) reported that higher genotypic coefficient of variation was found for dry root weight and fresh shoot weight. Higher broad-sense heritability was found for root dry weight, shoot fresh weight and shoot length. Shoot fresh weight showed higher and positive phenotypic correlation with all other traits. Mehdi *et al.* (2001) reported highly significant differences among S1 maize families and drought treatment for all traits studied except dry root weight which is non-significant among treatments. The value of coefficient of variation for fresh shoot weight was found to higher than fresh root weight, dry root weight and dry shoot weight. Broad sense heritability estimates ranging between 54.27 – 83.99 percent for seedling traits. Khan *et al*. (2004) evaluated maize genotypes for seedling traits under normal and drought conditions. Higher genotypic coefficients of variance were observed for dry shoot weight, dry root weight, emergence percentage, fresh shoot weight and fresh seedling weight. Aslam *et al*. (2006) reported that cell membrane stability, stomata conductance and survival rate of maize seedlings may be used to select drought resistant maize genotypes. Ahsan *et al*. (2010) evaluated twenty five genotypes for the determination of physio-genetic behavior of maize under drought conditions. Fresh shoot length and fresh root weight were directly associated with fresh shoot weight while positively correlated with fresh shoot weight. It was suggested that increased fresh shoot length, fresh root weight and decreased stomata frequency and epidermal cell size may be useful criteria for selection under drought conditions. Ali *et al*. (2011a,d) concluded that root length, root dry weight, leaf temperature, root density and shoot dry weight were significantly correlated with each other at genotypic and phenotypic levels and hence may be used as selection criteria for higher yielding maize genotypes. Root length, leaf temperature, root dry weight, root density and shoot dry weight were the traits that supposed to contribute greater shoot length of seedlings (Ali *et al*. 2011b,c). Ali *et al.* (2012a,b) evaluated the growth related seedling traits of maize accessions. It was reported that high values of heritability and genetic advance for fresh root and fresh shoot length and fresh root-to-shoot length ratio indicated that selection can be mad on the basis of these traits for higher yielding maize genotypes under drought conditions. Chohan *et al*. (2012) reported partial dominance effect for cell membrane thermo-stability and net photosynthetic rate at seedling stage under drought conditions. Khodarahmpour (2012) evaluated four germination traits of maize hybrids under four levels of osmotic potential. It was reported that germination and growth was reduced due to water shortage. The mean germination time become high with decreased in osmotic potential. Hybrid Simon gave better performance under drought. Higher heterosis and heterobeltiosis was found for root length, shoot length, fresh root and shoot weight (Ali *et al.* 2013; Ali *et al.* 2014a,b,c).

Grain yield traits

Diem and Dolinka (1983) reported significant and positive correlation for cob length and number of grains per row as compared to cob diameter and number of grain rows per cob. Inoue and Okabe (1983) studied several traits were positively and significantly correlated with grain yield and stability of these quantitative traits. Ahmad (1984) concluded that a positive and non-significant correlation was found between grain yield per plant and number of grains per row, number of grain rows per cob and 100-seed weight. Number of grain per rows showed negative and non-significant correlation with both number of grain row per cob. Akhtar *et al*. (1985) and Javed (1987) reported a positive and significant genotypic and phenotypic correlation of grain yield with plant height, cobs per plant and 100-seed weight. Najeebullah (1987) found that a positive and significant correlation was showing by grain yield and its contributing traits and concluded that cobs per plant, grain rows per cob, grain per cob, 100-seed weight and plant height had direct effect on grain yield. Koscielniak and Dubert (1985) performed an experiment for maize seedling and maturity traits. It was concluded that 79-95% of maize yield variations and seedling traits were positively correlated with each other. Martiniello (1985) reported that the early vigour in maize greatly responded for selection of higher yielding genotypes but germination rate and moisture contents were not significant at harvesting. The hybrid was compared with their parents for relative growth traits at 10-30 days of planting. The increase in total dry matter was greater in hybrids as compared to their parents. The dry matter of hybrid was two times as compared to *Zea diploperennis* and sweet corn Ever green (Magoja and Palacios 1987).

Ahmad (1989) estimated positive and significant genotypic and phenotypic correlation of grain yield and its contributing traits including cobs per plant, number of grains per cob, number of grain rows per cob, plant height and 100-seed weight. Path coefficient analysis also showed that number grain rows per cob had direct effect on grain yield per plant. Smith and Smith (1989) reported that heterosis can be used for maintenance of germplasm and pedigree similarities among maize hybrids. Altaf (1990) found a positive and significant genotypic and phenotypic correlation between grain yield per plant and its contributing traits. Number of grains per cob showed maximum direct effect on grain yield per plant. Beck *et al*. (1990) estimated general combining ability and specific combining ability for 10 parents in diallel crossing ways and concluded that general combining ability was significant for all of the traits while specific combining ability was not significant for all traits. Debnath and Sarkar (1990) estimated general combining ability and specific combining ability for 9 inbred lines of maize and concluded that the F_1 hybrids showed good general combining ability effects for grain yield per plant and grain per row. Hebert (1990) concluded that early vigor, leaf emergence and grain yield related traits can be used for selecting high yielding maize genotypes. The early growth rate can be used in silage maize breeding programs as good indicator for higher dry matter yield. Qadir (1990) reported positive and significant genotypic and phenotypic correlation between grain yield per plant and cobs per plant, plant height, grain rows per cob, 100-seed weight, cob length and diameter. Reddy and Joshi (1990) concluded that the selection for higher grain yielding genotypes of maize directly affect to decrease husk senescence and the days taken for silking while plant height and cob length increased. The cobs per plant increase the grain yield per plant.

Nevado and Cross (1990) reported that general combining ability and specific combining ability mean ratios indicated that it may be easier for the selection of higher yielding maize progenies for number of grain rows per cob, 100-seed weight, grains per row and grain yield. Higher general combining ability effects showed that grain yield may be used as selection criteria in maize. Martinez *et al*. (1990) reported from five hybrid maize progenies while using ICA-V-507 and ICA-V-506 as check varieties that ICA-V-155 × MB515 and ICA-V-453 × MB515 had higher grain yields. General combining ability and specific combining ability effects of S_2 differing in average leaf expansion rate and were evaluated for germination percentage, seedling vigor and leaf emergence after 25 days of sowing. specific combining ability were found to be related with maternal effects for germination percentage, leaf emergence and seedling vigour (Cross 1991). Ivankhenko and Klimo (1991) concluded that grain rows per cob and 100-seed weight may be used as selection criteria for higher yielding maize genotypes. Iqbal (1991) reported general combining ability and specific combining ability effects for grain yield of maize in 6 × 6 diallel set of crosses and concluded that the general combining ability and specific combining ability effects were highly significant for grain yield and it contributing traits. Jadhav *et al*., (1991) concluded that grain yield showed positive and significant correlation with cobs per plant, plant height, cob weight, leaves per plant and grain yield per cob. Tarutina *et al*. (1991) estimated general combining ability and specific combining ability by conducting an experiment on six inbred lines and 15 hybrids during 1^{st} year and 8 inbred lines and 28 hybrids during 2^{nd} year and concluded that additive gene action was more dominant over the dominance gene action for grain yield per plant, 100-seed weight, grain rows per cob and grains per cob.

Ajala (1992) concluded that seedling vigour, early maturity, higher standability and higher yielding traits related to grain yield can be used to select higher yielding maize genotypes. Dash *et al*. (1992) reported from path coefficient analysis that plant height, cob diameter, cob length, and 100-seed weight were the major traits that contribute for grain yield and selection for higher yielding maize genotypes. Dronavalli and Kang (1992) estimate specific combining ability and general combining ability effects for grain yield per plant, germination percentage, root and shoot lengths, dry matter, root and shoot dry weights and vigour index. General combining ability effects were more important as compared to specific combining ability effects for all grain yield related traits but for root length both general combining ability and specific combining ability were important and equally significant.

Rehman *et al*. (1992) found that the agronomic traits were positively associated with each other while the quality traits were negatively associated with agronomic traits as well with each other. Juvik *et al*. (1993) reported from an experiment that simple mass selection can improve the grain yield and field emergence in maize. It was concluded that the grain yield and quality can be improved by simple selection. Camacho (1994) reported that leaf area, root volume, longest root length, seedling length, fresh root and shoot weights, root and shoot dry weights, root dry weight to shoot dry weight ratio and total biomass per seedlings may be used for the selection of higher yielding maize genotypes. Elhosary *et al*. (1994) concluded that general combining ability effects were significant in both years of study while the specific combining ability effects were significant for grain rows per cob, plant height, grains per cob, 100-seed weight and grain yield per plant. Rehman *et al*. (1994) found that the extant of dominance was higher then additive gene action. Heterosis and broad sense heritability for adventitious roots and root dry weight was found to be 2.54%, 103.52%, 88% and 88% respectively. Significant differences were found among maize genotypes at seedling stage for germination percent by Herandez and Carballo (1997).

Sedhom (1994) reported significant interactions among general combining ability for plant height, cobs per plant, grain rows per cob and cob length. The higher specific combining ability effects were fond for 100-seed weight, plant height, grains per cob and grain yield peer plant. Lee *et al*. (1995) reported that the inbred lines showed significant differences for 100-seed weight, grain rows per cob, cobs per plant, grains per cob and grain yield per plant. The hybrids showed higher general combining ability effects for 100-seed weight. Bolanos and Edmeades (1996) found that the grain yield is greatly affected by water stress. The genetic variability of grain yield and its contributing traits was increases due to increase in water stress. Chen *et al*. (1996) reported genetic association of leaf rolling rate, stomatal conductance, anthesis-silking interval, number of leaves, plant height, harvest index and leaf angles with drought resistance. Heritability estimates under drought conditions were low as compared to normal conditions. Flower *et al*. (1996) concluded that leaf area and plant height varied greatly under different environments. Singh and Mishra (1996) concluded that lines exhibited higher general combining ability effects as compared to specific combining ability effect for grain yield and its related traits. Balderrama *et al*. (1997) concluded that higher general combining ability effects were recorded for grain yield per plant. Chapman *et al*. (1997a) reported that the improvement in the grain yield can be obtained through selection of higher yielding maize genotypes. Chapman *et al*. (1997b) studied that the selection for grain yield under normal water condition may not be helpful to increase the grain yield under water deficit conditions. Singh *et al*. (1997) estimated that positive genotypic correlation was found to be significant for germination rate, seedling growth rate and 100-seed weight with field emergence. Germination rate also showed positive genotypic correlation with seedling growth rate and 100-seed weight. Tusuz and Balabanli (1997) reported that plant height and cob length showed low broad sense heritability while grain yield was positively and significantly correlated with plant height and cob length.

Kahkim *et al*. (1998) concluded that grain yield had a positive and significant genotypic correlation with cobs per plant, plant height, number of grain per cob, number of grain rows per cob, cob length, 100-seed weight and grain oil contents. Mather *et al*. (1998) reported significant gene effects were recorded for cobs per plant, grain rows per cob, grains per cob and grain yield per plant. San-vicente *et al*. (1998) and Ali *et al*. (2014d) found that significant general combining ability effects were recorded for all traits while specific combining ability effects were significant for plant height and grain yield per plant. Singh *et al*. (1998) concluded from an experiment that moderate estimates of heritability and genetic advance; positive and significant genotypic correlation was found for grain yield per plant with plant height, cob length, grains per cob, 100-seed weight and number of cobs per plant. Almeia *et al*. (1999) concluded that the grain yield and total dry matter per plant were not significantly differ among maize genotypes. The crude proteins were higher for all genotypes but no significantly differ for other chemical components. Golob and Plestenjak (1999) reported that the grain nutritive values of each selected maize genotype significantly differ from each other. Khatun *et al*. (1999) reported that a positive and significant correlation was shown by grain yield per plant with 100-seed weight, number of grain per cob and cob diameter. Mehdi and Ahsan (1999) reported green fodder yield was positive and significantly correlated with number of leaves per plant and plant height. Ravilla *et al*. (1999) estimated significant general combining ability and specific combining ability effects were found for plant height, days to silking and grain yield per plant. Torun *et al*. (1999) reported from correlation and path coefficient analysis that grains per cob, cobs per plant, cob length, and 100-seed weight had significant direct effects on grain yield.

Arya, *at al*. (2000) reported that the stem diameter is increased at 2^{nd} internode by decreasing plant population density. Borrell *et al*. (2000) found that the leaf area reduced up to 67% due to water stress. Bromely *et al*. (2000) concluded that the estimates of heterosis greatly effected on bulking the inbred lines heaving association with different heterotic groups. Nass *et al*. (2000) estimated significant general combining ability and specific combining ability effects were found for all agronomic traits. Pandey *et al.* (2000) concluded that increasing the moisture stress was major cause of decrease in crop growth rate, leaf area, shoot dry matter, plant height and harvesting index. Rameeh *et al*. (2000) estimated higher and significant general combining ability and specific combining ability effects for grains per row, grains per cob, 100-seed weight and grain yield per plant. Umakanth *et al*. (2000) reported positive and significant correlation of grain yield with plant height, 100-seed weight and cobs per plant. Vaezi *et al*. (2000) reported that grain yield of maize was positively and significantly correlated with cob diameter, cob circumference and grain rows per cob. Zelleke (2000) reported that significant specific combining ability effects were shown by plant height, days taken to tasseling, silking, grain rows per cob, cobs per plant and grain yield per plant.

Desai and Singh (2001) concluded that the hybrids K305 × CML66 and CML40 × SY8-2 showed highest heterosis 14-19% for grain yield respectively. The inbred lines CML-66 and CM-40 showed higher general combining ability effects for grain yield while higher specific combining ability effects were found for NC-2. Khan *et al.* (2001a) estimated maximum number of leaves per plant, plant height and stem diameter under normal field moisture conditions while decreased due to increase in moisture stress. Khan *et al.* (2001b) reported that stem diameter, plant height, leaf area, cobs per plant, cob diameter, grain rows per cob, 1000-seed weight and grain yield per plant decreased significantly under water stress conditions. Nigussie and Zelleke (2001) concluded that specific combining ability effects were significant for plant height, days taken to tasseling, days taken to silking and grain yield per plant. The mid parent heterosis showed a range of -11.6-21.9% for grain yield per plant. Vales *et al*. (2001) estimated significant general combining ability and specific combining ability effects for cobs per plant, grain rows per cob, plant height, 100-seed weigh and grain yield per plant in three synthetic maize populations. Akhtar (2002) determined heterosis, general combining ability and specific combining ability, genetic advance and heterobeltiosis for different maize seedling traits in 10 inbred lines and F_1 hybrids. A reasonable value of heterosis and heterobeltiosis was found for all seedling traits while maximum for MO-17 × CML-299-2, MS-211 × 935006, MO-17 × F-107 and MS-211 × F-107 for root and shoot fresh and dry weights, root length, branches-root and root-shoot weight ratio. Banziger *et al*. (2002) reported that the increase in the leaf length, increased nutrient and water uptake, greater reserve food materials during grain filling stage, cobs per plant and grain yield per plant was positively associated with each other and with water stress tolerance ability in maize. Bruce *et al*. (2002) evaluated that average yield was increased due to better nitrogen application, tolerance to water deficient environment, continual sensitivity to input supply and better weed control. Pollination and early grain filling was much sensitive and highly effected due to drought. It was cleared that tropical germplasm exposed less number of spikelets, early vigorous silking and decreased anthesis-silking interval (ASI) after selection to drought tolerant superior maize genotypes. New molecular marker and ample gene expression profiling method gave the chances for continuous crop breeding that give positive results under variable environments. Farshadfar *et al*. (2002) calculated additive gene action for relative transpiration arte, leaf water retention, grain yield and cobs per plant. Jeanneau *et al*. (2002) studied that plant growth, photosynthetic rate, reproductive stage, grain filling and grain yield per plant were reduced due to water stress on maize. Alvi, *et al*. (2003) estimated heterosis for 8 F_1 hybrids of maize and evaluate on the basis of cob length, cob diameter, cobs per plant, plant height, grain rows per cob, 1000-seed weight and grain yield per plant. Maximum value of heterosis was found for F-113 × F-107 for cob length, cob diameter, cobs per plant, 1000-seed weight and grain yield per plant. Aguiar, *et al*. (2003) estimated general combining ability and specific combining ability for single-crosses of maize inbred lines. The higher specific combining ability effects were found for grain yield, ear height, plant height, prolificacy and ear placement. general combining ability effects and genotype vs. environment interactions were significant for all traits.

Gautam (2003) estimated specific combining ability and general combining ability effects for cob length, cobs per plant, 100-seed weight, plant height and grain yield per plant in 15 f_1 maize hybrids. general combining ability and specific combining ability effects were significant for all traits while highly significant for hybrid × year interactions for days taken to maturity and plant height. Mehmood *et al*. (2003) concluded that maximum 1000-seed weight was recorded for H6, minimum days taken to 50% silking for H6, H9 and H8 whereas, check hybrids showed latest maturity. It was suggest that the hybrid H10 may be commercially used as hybrid for Peshawar maize growing areas. Qayyum *et al*. (2003) suggested that significant genetic variation, heritability and better performance of various quantitative traits under water stress may be helpful to improve grain yield. Bhatnagar *et al*. (2004) concluded that the general combining ability effects were non-significant for grain yield while highly significant for other agronomic traits and grain quality traits.

Malik *et al*. (2004) reported higher heterosis for cobs per plant, plant height, grain rows per cob, cobs per plant, 100-seed weight, cob weight and grain yield per plant. The mean mid-parent and higher parent was found for grain yield per palnt 17.2% and 2.8%, respectively. Fan *et al*., (2004) concluded from genetic similarities and specific combining ability effects of 45 F_1 hybrids, the 10 quality protein maize genotypes were divided into 3 groups of different heterosis. The present study provided fruitful information about quality protein maize genotypes.

Prakash *et al*. (2004) estimated general combining ability and specific combining ability effects for days taken to 50% tasseling, plant height, cobs per plant, grain rows per cob, cob length, cobs per plant, 100-seed weight, cob weight, leaf area and grain yield per plant. Non-additive gene action was found for all traits except for cob length, days taken to 50% tasseling and grain rows per cob that showed additive type of gene action. Zhou *et al*. (2004) estimated higher general combining ability and specific combining ability effects for grain rows per cob, cob length, cobs per plant, plant height, 100-seed weight, cob weight, leaf area and grain yield per plant. Zhen *et al*. (2005) reported that additive gene action was found for grain rows per cob, cob length, cobs per plant, 100-seed weight and cob weight. Non-additive gene action was found for cob tip length, grain weight percentage and grain yield per plant. Vafias *et al*. (2005) concluded that heterosis calculated through three way crosses was acceptable for yield traits in maize as compared to the single cross hybrids. The half-sibs and hybrids showed significant specific combining ability and higher value of heterosis for 100-seed weight, cobs per plant, cob diameter and grain yield per plant. Hader (2006) reported that leaf area might be useful indirect factor to improve maize yield. Kefale and Ranamukhaarachchi (2006) reported that moisture deficiency through out growth significantly reduced the vegetative growth and increase the time to tessling of three maize cultivars thus grain yield was significantly affected due to drought. Muraya *et al*. (2006) estimated higher heterosis and significant specific combining ability and general combining ability effects in S_1 maize lines for days taken to 50% tasseling, plant height, cobs per plant, grain rows per cob, cob length, 100-seed weight, cob weight, leaf area and grain yield per plant. General combining ability: specific combining ability ratio was ≥1 for all agronomic traits except 100-seed weight.100-seed weight showed additive type of gene action. Abdelmula *et al*. (2007) found that grain yield was decreased due to water stress at reproductive stage while there was no effect on vegetative traits. G-3 genotype performed better than others and PR-1 was susceptible to drought at D3 level. A positive and significant correlation was observed between leaf area index and leaves per plant while positive but non-significant correlation was recorded between grain yield per plant with plant height and stem diameter. Grzesiak *et al*. (2007) studied that direct effects of water stress on maize seedling caused the reduction in dry matter of seedlings, leaf water potential, chlorophyll contents and leaf injury index. Ojo *et al*. (2007) reported from an experiment on maize inbred lines that general combining ability and specific combining ability effects were non-significance for grain yield traits. The F_1 hybrids showed higher values of heterosis for most of the yield relating traits including cob length, cobs per plant, 100-seed weight, cob weight and grain yield per plant. Saleem *et al*. (2007) reported significant differences among maize genotypes for days taken to 50% tasseling and silking, cobs per plant, cob length, cob weight, grain rows per cob, plant height, flag leaf area, biomass per plant, total dry matter, 100-grain weight and grain yield per plant. Positive and significant genotypic correlation was found between plant height, flag leaf area, biomass per plant, total dry matter, 100-grain weight and grain yield per plant. The maximum positive direct effects of cobs per plant, cob length, cob weight, grain rows per cob, plant height, flag leaf area, 100-grain weight on grain yield per plant were also found. Wang *et al*. (2007) studied that the use of coronatine caused significant increase in stem diameter, shoot weight, root length, stomata conductance, transpiration rate and photosynthesis rate in maize genotypes.

Ahsan *et al*. (2008) estimated that the leaf morpho-physiological traits including leaf venation, cell membrane thermo-stability, leaf area, stomata frequency and stomata size were significantly differ from each other. A positive correlation was found for cell membrane thermo-stability, leaf area, stomata frequency with stomata size. Grain yield showed positive direct effect and significant positive correlation with stomata size and frequency. Akbar and Saleem (2008) reported that the specific combining ability, general combining ability and reciprocal effects of grain yield and its contributing traits were highly significant at low and high temperatures except general combining ability effects for 100-seed weight that were non-significant. Akbar *et al*. (2008) found that specific combining ability and general combining ability ratio showed that there was non-additive type of gene action among grain yield and its contributing traits. The 935006 inbred line showed higher value of general combining ability for grain yield per plant followed by F165-2-4 and R2304-2. Amler (2008) studied that ratio of dry matter contents of grain to dry matter contents of stover (silage maize ripeness index) is one of the most useful tool to determine the yield and silage quality and harvesting date of maize. Derera *et al*. (2008) found significant general combining ability effects for grain yield per plant in maize. Monneveux *et al*. (2008) studied that secondary morpho-physiological traits, cobs per plant, grains per cob, anthesis interval, leaf rolling, leaf senescence and grain yield per plant may be used as selection criteria for developing drought resistant maize genotypes. Zhang *et al.* (2008) revealed that maize inbred showed significant reduction in yield under drought. The anthesis end siliking interval (ASI) was prolonged compared with the control with a smaller leaf area, thinner stalk, shorter and smaller ears, lengthened barren ear tip, a decline in plant height and ear position, reduced grain number per ear and grain weight, which led to yield decline index.

Akbar *et al*. (2009) estimated general combining ability and specific combining ability effects for various physiological and grain yield traits of maize under normal and higher temperature conditions. The higher general combining ability and specific combining ability effects were shown by days taken to 50% maturity, 100-seed weight, cobs per plant, turgor potential and stomata size. The F_1 hybrid 935066 × R2304-2, R2304-2 × 935006 followed by F165-2-4 × R2304-2 and F165-2-4 × 935006 showed higher specific combining ability, reciprocal effects and higher grain yield per plant. Hussain *et al.* (2009) reported that plant height, leaf area, grin yield per plant and harvest index under normal and drought conditions indicated additive gene action with partial dominance. However, kernel per row and seed index were found to be controlled by additive type of gene action. Uddin *et al*. (2010) studied the yield and yield component in five maize synthetic cultivars at Chialas Agriculture Farm. Number of cobs per plant and 100 grain weight showed positive correlation with grain yield. Number of cobs per plant had strong positive correlation with 100 grain weight on the basis of study cultivars jalal and azam were recommended for general cultivation in cropping zone in district diamer. Wali *et al*. (2010) reported that grain yield per plant of male parent was higher than the female parent, 78.01g and 70.66g respectively. The significant interactions of line × tester variance were estimated for all characters except shelling percentage, circumference, fodder yield and ear length and significant interactions were also found for grain rows per cob, grains per row, 100-seed weight and grain yield. Yousufzai *et al*. (2009) reported that stomata conductance was positively and significantly correlated with grain yield and flag leaf area. It was concluded that stomata conductance and flag leaf area can be used as criteria for the selection of higher yielding maize genotypes.

Farhad *et al*. (2011) evaluated maize hybrid for drought tolerance. FH 421, FH 810, Pioneer 32-F-10, Pioneer 32-W-86, Monsanto 919, Monsanto 6525, NK 8441 and SS 5050 maize hybrid for evaluation of drought tolerance were used. Monsanto 919 provided better performance for plant height, leaf area, water potential, osmotic potential, turgor potential and minimum relative saturation deficit. FH 810 was drought sensitive. Leaf water content was correlated with osmotic potential under drought condition. Correlation studies showed that plant height and leaf area directly and indirectly related with grain yield under drought conditions. Saleem *et al*. (2011) reported significant differences among maize genotypes under drought. W-64-TMS and PB-7-1 inbred lines showed high genetic variation and heritability so these can be used for breeding program under drought conditions. Moradi *et al*. (2012) evaluated eight hybrids for yield performance on the basis of grain yield, stress tolerant index, stress susceptibility index, tolerance index and mean productivity. The results showed that H6 gave better performance in irrigated conditions while H8 gave good result in drought conditions. It was concluded that H8 and KSC704 performed best under drought conditions. Ahsan *et al*. (2013) reported additive gene action for all yield related traits except stomata frequency and stomata size for which complete and over dominance effects were found. Ali *et al*. (2014d,e); Javeed *et* al. (2014) and Waseem *et* al. (2014) found significant correlation for grains per cob, 100-grain weight, grain rows per cob and grain yield per plant.

Conclusion

It was concluded from prescribed that selection for the development of higher yield maize grain and fodder yield hybrid and synthetic variety may be helpful on the basis of cobs per plant, cob length, cob weight, grain rows per cob, plant height, flag leaf area, green fodder yield, dry matter yield, 100-grain weight and grain yield per plant.

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9/3/2014