J. Agric. Sci. Mansoura Univ., 25 (2): 713 - 727, 2000.

GENOTYPIC DIFFERENCES AMONG 18 MAIZE POPULATIONS IN DROUGHT TOLERANCE AT DIFFERENT GROWTH STAGES

El-Ganayni, A.A.*; A.M. Al-Naggar * ; H.Y. El-Sherbieny ** and M.Y. El-Sayed**

*** Agron. Dept., Fac. of Agric., Cairo Univ., Giza, Egypt.**

**** FCRI, ARC., Giza, Egypt.**

ABSTRACT

Two field experiments were carried out during 1995 and 1996 to evaluate 18 white maize populations (3 local and 15 exotics) for their differences in drought tolerance under 5 moisture regimes in order to identify the best ones for future use in breeding programs. The 5 moisture regimes included: well watering (WW), stress at pre-flowering (BF), stress at flowering (FS), stress at post-flowering (AF) and severe stress (SS) at both flowering and post-flowering stages. A split-plot design with 3 replicates was used, where main plots were alloted for the moisture regimes, while sub-plots were for the maize populations. Fourteen traits were analyzed.

Drought stress caused significant reductions in grain yield and most of the studied traits, while days to 50 silking, anthesis-silking interval (ASI), leaf/air temperature, percentage of barrin stalks and leaf rolling traits were increased. Flowering stage was the most sensetive period with respect to grain yield. The local cultivar Giza-2 and the two exotic populations (DTP-1and DTP-2) bred for drought tolerance by CIMMYT were the most drought tolerant genotypes at all growth stages, based on their absolute, relative and potential yields. Drought tolerance of maize appears to be specific for a certain growth stage, but genotypes could be bred for tolerance at more than one growth stage. The most drought tolerant genotypes had a shorter ASI, lower leaf/air temperature , higher number of ears/plant, earlier flowering, lower leaf rolling and lower percentage of barren stalks, than those of the most susceptible genotypes.

Key Words: Zea mays, corn, maize genotypic differences, drought tolerance, stability, growth stages.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops in Egypt. Its total cultivated area is about 1.9 million feddan (1 feddan = 4200.78 m^2) in 1998 season, producing about .05 million tons grains (Report of the Central Adminst. Of Agric. Econ., Ministry of Agric., Egypt, 1998). Great attention was directed to raise up corn production, vertically and horizontally, to reach self-sufficiency. Water limitation either in the vally or in the newly-reclaimed lands, necessitates that maize breeders should pay more attention to develop maize genotypes of high yield under water stress.

The effect of water stress on maize was studied by many researchers and found to be varied according to the genotypes severity of water stress and plant growth stage. Several investigators emphasized the role of maize genotypes in drought tolerance. Tolerant genotypes were characterized by having shorter anthesis-silking interval (Bolanos and Edmeades, 1996), lower canopy temperature (Fischer *et al*. 1989) , higher number of ears per plant (Edmeades *et al*. 1993 and Ribaut *et al*, 1997) and higher number of kernels per ear (Hall *et al*., 1980 and Ribaut *et al*., 1997) than susceptible genotypes.

Maize crop was found to be particularly susceptible to drought several weeks before and after flowering (Chapman *et al.*, 1996). Losses in grain yield are particularly severe when drought stress occurs at those stages (Claassen and Shaw, 1970, Grant *et al*., 1989). Water stress at vegetative growth stages resulted in noticeable reductions in number of kernels/row (Stapleton *et al*., 1983) leaf area (Human *et al*., 1990) and grain yield (Ainer *et al.*, 1986). Flowering stage appeared to be the most critical period that affects yield.

The objectives of the present study were to examine the genotypic differences among several maize populations, in drought tolerance in order to identify the best ones for future use in breading programs, to study the effect of water deficit at different growth stages on some important maize attributes and to identify the most sensitive stage. Such information would help maize breeder when planning for developing drought tolerant genotypes.

MATERIALS AND METHODS

Two field experiments were carried out at Sids Agricultural Research Station, Agric. Res. Center (ARC), Egypt, during 1995 and 1996 seasons. The aim of the study was to evaluate 16 white maize populations under 5 soil moisture regimes. Maize populations were 3 locals (Giza-2 (G2) , Cairo - 1 (C-1) and American Early Dent, (AED) and 13 exotics: Weekley Prolific (WP) and Missouri (Mis) from USA, American White Flint (AWF) from Spain, Maiskaning (Mais) from Germany, Bianca Peria (BP) from Italy, Slouth Africa (SA) from South Africa Kitale Synthetic (KS) from Kenya, Synthetic La Posta (SLP) and Tepalcingo-5 (Tep 5) from Mexico, Mexican June (MJ) and White Dwarf Composite (WDC) from India, Adramet Skaja Beloja (ASB) from Russia and Pirsapak (Pir) from Pakistan. The soil moisture regimes were : 1- well watering (WW) or full irrigation, 2- pre-flowering water stress (BF), where the 3rd and 4th irrigations were skipped, preventing irrigation for 36 days at the late vegetative growth stage and during initiation and development of the inflorescence, 3- flowering stage (FS) water stress, where the 4th and 5th irrigations were skipped, preventing irrigation for 36 days at flowering stage, 4- post-flowering (AF) water stress, where irrigation was stopped after the 5th irrigation until harvest, preventing irrigation for 51 days at the grain filling stage and 5- severe stress (SS) , where the irrigation was stopped after the 4th irrigation until harvesrt, i.e. preventing irrigation for 63 days at both flowering and grain filling stages.

In both seasons, a split plot design with three replications was used, where main plots were alloted to the 5 soil moisture regimes, while sub-plots were devoted for the 16 maize populations. Each sub-plot consisted of 4 ridges, 6 m long and 70 cm apart. Hills spaced 25 cm. The preceding crop was wheat and the kernels were planted in hills spaced 25 cm on the 15th

of June. The soil of the experimental field was clay, containing about 46% clay , 32% silt, 21% fine sand and 1% corse sand (according to the analysis done by Soil & Water Res. Inst., ARC, Egypt). Average temperature at Sids Station in July, August, September and October was 30.7, 29.8, 29.0 and 25.2 in 1995 and 30.3, 30.5, 29.8 and 24.8 in 1996, respectively (according to Meteorology and Climatic Res. Sec., Soil and Water Res. Inst., ARC, Egypt).

Fourteen traits were measured , viz. days to 50% silking, anthesis to silking interval (ASI), plant height (cm), ear height (cm), leaf area (LA) in cm^2 (according to Francis *et al*. (1969), leaf rolling (RL) scores from 1 to 5 where 1 is unrolled and 5 is tightly rolled, according to O'Toole and Moya (1978) , leaf air temperature ratio (L/AT) using Infrared thermoeter , Model 110 ALCS Microcomputer-Based AGRI-THERM, EVERST, Inter-science Inc., Ca, USA, percentage of barren plants (BP%), stay green trait (SG) soon after physiological maturity using a scale from 1 to 5 where 5 is completely green leaves and stems and 1 is completely dry, number of ears per 100 plants (E/P) , number rows/ear (R/E), number of kernels/row (K/R) , 100-kernel weight (KW) adjusted to 15.5 grain moisture and grain yield (g) per plant (GY/P) and per feddan (GY/F), adjusted to 15.5% grain moisture. Days to 50% silking, ASI, LP, BP%, SG, E/P and GY/F traits were recorded on a per plot basis. Leaf rolling and L/AT were measured at the plant age subjected to maximum drought stress.

Analysis of variance for each season was done. A combined analysis over the two seasons was performed. Least significant difference "L.S.D." test at 0.05 level of significance was used to compare the differences among means. Statistical analysis was carried out according to Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

I- Analysis of variance:

Analysis of variance revealed that highly significant differences existed among soil moisture (irrigation) regimes for all studied traits in both 1995 and 1996 seasons. The differences among genotypes (populations) were also highly significant ($P<0.01$) for all studied traits, except for leaf temperature in 1996 season, where differences were not significant.

Moisture regimes x population interactions were significant ($P<0.01$) for all studied traits in both seasons, except for ear height, leaf area, leaf rolling, leaf temperature, number of rows/ear, number of kernels/row and 100-kernel weight in 1996 season only.

Combined analysis of variance over seasons showed that highly significant differences existed among genotypes (populations) and soil moisture regimes for all studied traits. All genotypes x years, genotypes x moisture regimes, moisture regimes x years and genotypes x moisture regimes x years interactions were significant ($P<0.05$) or highly significant ($P<0.01$) for all studied traits, except moisture regimes x years interaction for ear height, number of ears/plant, number of rows/ear and 100-kernel weight;

genotypes x years interaction for days to 50% silking, anthesis to silking interval (ASI), ear height and leaf temperature; genotypes x moisture regimes interaction for leaf temperature and genotypes x moisture regimes x years interaction for days to 50% silking, ASI, plant and ear height and leaf area which were insignificant. Thus, the performance of genotypes varies with seasons and water supply, confirming previous results (El Sheikh, 1994).

B- Different responses of growth stages to drought:

A comparative summary of means of studied traits over all populations subjected to the five soil moisture regimes is presented in Table (1). For any given trait, the value under stress as a percentage of that under control may be considered as a simple expression of the relative drought resistance for the tested level of stress (Blum *et al*. 1989). In this sense, mean grain yield was significantly reduced by soil moisture stress at pre-flowering (BF) , flowering (FS), post-flowering (AF) stages and at severe stress (SS) conditions to 42, 33, 54 and 25%, respectively, over all populations. This indicates that, on average, among the developmental stages of flowering stage (FS) was the most sensitive stage to soil water deficit (67% reduction). The severe stress (SS) imposed during both flowering and grain filling stages exhibited the maximum reduction (75%) in grain yield, as expected. In this regard, our results are consistent to those reported by El-Zeiny and Kortam (1983), who found that critical periods for irrigation are flowering followed by grain-filling stages. On the other hand, Wilson (1968), mentioned that the post-flowering stage is the most critical one for water stress. He showed that drought 3 weeks before flowering, at silking stage and 3 weeks after flowering depressed grain yield by 15, 25 and 49%, respectively. Differences among results might be attributed to differences in other environmental conditions and/or in the genetic material used in different experiments.

Yield reductions due to drought imposed at different growth stges were accompanied by losses in all yield components: number of ears/plant, number of rows/ear, number of kernels/row and 100-kernel weight (Table 1). Reduction in each yield component, separately, was not as high as reduction in grain yield. As a yield component, maximum reduction was shown by number of ears/plant, it was reduced to 66, 47, 80 and 44% due to water stress at BF, FS, AF and SS, respectively as compared to control. Minimum reductions in yield components occurred in the number of rows/ear, which were 3, 4, a and 5% only due to the soil moisture stress at BF, FS, AF and SS, respectively. Maximum reduction in ears/plant were supported by the maximum increase occurred in the percentage of barren stalks which reached to 404, 557, 326 and 637% due to drought imposed at BF, FS, AF and SS, respectively, as compared to controls (Table 1). Our results are consistent with those reported by Guei and Wassom, 1992, Edmeades *et al*. 1993, Terrazas *et al*, 1995 and Ribaut *et al*., 1997). They suggested prolificacy as an important trait for drought tolerance.

It was worthnoting that maximum reduction for number of kernels/row (22%) occurred when drought was imposed at pre-flowering stage. However, maximum reduction for grain weight (24%) happended when water deficit was imposed at post-flowering stage. This result is consistent with that reported by other workers (Moursi, 1997). Similarly, in wheat, certain drought treatments have been found to affect pollen viability, which in turn reduced seed number (Saini and Aspinall, 1981). This effect might also be one of the reasons of reduction in grain number of maize subjected to water stress regimes before and during flowering , which requires further investigations to substantiate it.

As expected, drought stress imposed after flowering stage (during the grain filling period) did not produce significant changes in the number of days to 50% silking, anthesis to silking interval (ASI) and in the plant and ear height. On the contrary, soil moisture deficit imposed prior to anthesis (BF), during flowering stage and the period including flowering and post-flowering stages (severe stress) caused significant delay in silking date by 7.4, 6.1 and 6.7 days, elongation in the anthesis to silking interval (ASI) by 5.4, 5.4 and 5.9 days, reductions in plant height by 23, 8 and 8% and in ear height by 25, 10 and 5%, respectively as compared to control.

These results agree with those reported by Edmeades *et al*. (1993) and Moursi (1997) who have demonstrated that drought stress in the pre-flowering phase can markedly delay flowering in maize. The elongation of anthesis to silking interval in maize was also reported by Herrero and Johanson (1981), Frederick *et al*., (1989) and Edmeades *et al*. (1993). Reduction in plant and ear height of maize due to water stress before flowering was also reported by Mahrous, (1991) and Atta Allah, (1996).

Leaf area was slightly declined when water was withheld at different development stages, with maximum decline (10%) when water was prevented at pre-flowering stage. Several researchers have also found that drought stress in maize caused reductions in leaf area (Shim and Lemon, 1968, and Atta Allah, 1996).

Leaf rolling score was significantly increased to 150, 154, 212 and 219 when drought imposed through the soil moisture regimes BF, FS, AF and SS, respectively, as compared to controls. It is obvious that post-flowering stage was the most sensitive to water stress for occurrence of leaf rolling. Moreover, maximum leaf rolling was exhibited by elongating the stress period to include both flowering and post-flowering stages.

Stay green trait (green leaf retention), which expresses the leaves that were still green when plants reached physiological maturity, was significantly reduced when plants were subjected to flowering (FS), post-flowering (AF) and severe water stress (SS) to 94, 81 and 82%, respectively, as compared to controls. It is worthy to note that reduction in the green leaf retention was more pronounced when water stress was experioenced after anthesis. In other words, for green leaf retension, the post-flowering (grain filling) stage was more sensitive to water stress than pre-flowering and flowering stages. El-Bakry (1998) reached to a similar conclusion in sorghum.

The physiological trait leaf to air temperature, increased significantly as a result of experiencing water deficit to 114, 113, 117 and 117% when stress imposed in the irrigation treatments BF, FS, AF and SS, respectively, as compared with the controls. The most sensitive growth stage for the increase of leaf temperature by water stress was post-flowering (grain filling) stage. Increase in leaf temperature is related to decreased transpirational cooling (Gates, 1964), which is a consequence of stomatal closure.

Summarizing the above mentioned results indicates that flowering stage was the most sensitive stage to water deficit, where the reduction in grain yield (67%), number of ears per plant (53%) and the increase in percentage of barren stalks (57%) were at maximum. The pre-flowering stage was the most sensitive to water stress for the delay in silking date (7.4 days), reduction in plant and ear heights (23 and 25%, respectively), leaf area (10%) and number of kernels/row (22%). However, the grain filling stage was the most sensitive one to water stress for the increase in leaf rolling (112 %) and leaf temperature (17%) and the reduction in stay green trait (19%) and grain size (24%). Pre-flowering and flowering stages were equal in sensitivity to water deficit effect on anthesis to silking interval and number of rows/ear. Both of them when water stressed elongated the anthesis to silking interval by 5.4 days and reduced number of rows/ear by 4% as compared to controls. Moreover, the severe stress, experienced from the beginning of flowering stage until maturity showed maximum reductions in grain yield (75%), ears/plant (56%), rows/ear (5%) and maximum increments in ASI (28%) , leaf rolling (319%), leaf temperature (17%) and percentage of barren stalks (537%) as compared to controls.

C- Differential response of genotypes to drought:

The effect of drought stress on grain yield of each gentotype (population) was assessed by to variables: absolute yield under stress and yield under stress as a percent of control as a drought tolerance index) (Table 2). When an advantage in both absolute yield under stress and relative yield was taken as an index of drought resistance in its agronomic definition, the local population, Giza-2 followed by the CIMMYT'S drought tolerant populations DTP-1 and DTP-2 at all four studied drought stresses (BF, FSm AS and SS) could be regarded as the most drought resistant genotypes under the conditions of this experiment. In the same manner, the populations Syn. La Posta and Tepalcino-5 at pre-flowering stage, South Africa at flowering stage, American Flint at post-flowering stage and Pirsabak under sever stress could be considered as the most drought resistant genotypes under these respective soil moisture regimes (Table 2).

It is very interesting that the Egyptian variety Giza-2 stressed at all 4 moisture regimes (BF, FS, AF and SS) excelled also in its potential yield (control), reaching a yield level higher than 25 ardabs per feddan under full irrigation. Moreover, the exotic drought tolerant populations DTP-1 and DTP-2 stressed at all 4 moisture treatments (BF, FS, AF and SS) excelled also in their potential yield reaching a yield level greater than 19 ardabs/fed under well watering.

The genotypes Giza-2, DTP-1 and DTP-2 excelled in absolute yields under stress (imposed at BF, FS, AF and SS treatments) and under full irrigaiton (their potential yield). These genotypes also exhibited high relative yields at all stresses.

In many cases, those genotypes excelled in their absolute yields under stress are different from those excelled in their relative yields to control. However, rank correlation coefficients computed between absolute and relative yield at each stress were significant and positive. (r = 0.73, 0.83, 0.55 and 0.82 between absolute and relative yield at each of BF, FS, AF and SS soil moisture treatments). While, rank correlation coefficients computed between the potential yield (absolute yield under well watering) and the relative yield at either BF, FS, AF or SS compared to control were insignificant and very small in magnitude (r = -0.27, -0.16, -0.24 and – 0.04, respectively). This demonstrates that there was no positive correlation between drought tolerance and absolute grain yield under WW conditions. Ribaut *et al* (1997) reached to similar conclusion. Based on these results, it appears that absolute yield under stress and relative yield to control (drought tolerance) may be independent characters. However, genotypes even characterized by high absolute yield under stress, high relaive yield to control and high potential yield could be indentified in this experiment.

Comparisons of environmental variations in yield must be viewed as a form of adaptation to environmental conditions (Jordan *et al*., 1983). When this form of adaptation is examined in the manner suggested by Finlay and Wilkinson (1963), two points appear clear. First, genotypic differences in yield are significant and both high yielding and low yielding genotypes can be identified. Second, genotypic response to environmental factors, which affect yield also differ as described by the regression (bi) values in Table (2). Each of the regression (bi) value compares the response of an individual genotype against the mean response of genotyupes being compared. For example, not only did Giza-2, DTP-1 and DTP-2 have a high average yield, but the yield also increased proportionately when they were grown under conditions which promoted higher yields (under well watering). Entries characterized by regression coefficients (b values) of about 1.0 have average genetic stability over all environments, but Giza-2, DTP-1 and DTP-2 had the highest coefficient for the test (b = 1.41, 1.40 and 1.39, respectively) which indicated high response to improving environments. In contrast, Cairo-1 and Dwarf Composite had low average yield and the response to improved environments was also lower than average (b = 0.8 and 0.60, respectively).

Therefore, the possibility exists to select genotypes on the basis of either absolute yield or adaptive response. Genotypes exhibiting larger than average adaptive response may be preferred over those with a high but stable yield (Jordan *et al*., 1983), of the genotypes tested, Giza-2, DTP-1 and DTP-2 were superior in both characteristics.

A second point illustrated by these data is that high absolute yield and high response (regression coefficient) are not always coupled as suggested by data in Table (2). In this instance, Weekly Prolific gave the fourth highest environmental response (b=1.35) even though its absolute average yield was intermediate. Rank correlation coefficients computed between b values and each of absolute and relative yield were very small in magnitude and insignificant. Based on these results, it appears that absolute and relative yield and genotypic stability or adaptability may be independent characters.

Correlation coefficients calculated between the ranks of genotypes in their absolute yields under stress (at BF, FS, AF and SS) and the potential absolute yield (under full irrigation treatment) were positively significant, but with low magnitudes. Therefore, selection for yield improvement under WW conditions only, would not be necessarily very effective for yield improvement under drought. Similar conclusion was reached by Ribaut *et al*. (1997). Moreover, correlation coefficients among the rankings of genotypes in their absolute yields under the four types of stresses BF, FS, AF and SS were also positive and significant, but with low magnitudes. This also indicates weak consistency of absolute yield response of certain genotype between each two stress treatments and between the control treatment and each of the stress treatments (BF, FS, AF and SS). Furthermore, rank correlation coefficient computed between the relative yields to controls under each two stresses were insignificant or significant but with very low magnitudes. Drought tolerance of maize appears to be a growth stage-specific trait, i.e. tolerance at each growth stage is independent from tolerance at another growth stage. Therefore, maize breeder should focus his breeding efforts for drought tolerance on a specific growth stage.

To describe the differences between drought resistance (R) and susceptible (S) genotypes, the studied traits were averaged for two groups of genotypes differing in drought resistance by definition, namely in both absolute and relative grain yield under drought stress (Table 3). The drought resistant genotypes were the populations Giza-2, DTP-1 and DTP-2 while the drought susceptible genotypes were the population Dwarf Conposite, Syn La Posta and Weekly Prolific.

On the average, genotypes classified as the most drought resistance, in terms of absolute and relative yield, had a lower period to 50% silking, shorter ASI, lower ratio of leaf to air temperature, lower leaf rolling, lower percentage of barren stalks and higher number of ears/plant, plant height, ear height, leaf area, scores of stay green, row/ear, kernels/row, kernel weight and grain yield all of which indicated a better plant water status, as compared with the most susceptible genotypes.

Duration to 50% silking was earlier in the drought resistant (R) than in the drought susceptible (S) genotypes by 6.0, 11.5, 8.0 and 13.7 days at BF, FS, AF and SS, respectively. Anthesis to silking interval was 1.7, 7.1, 1.0 and 7.9 days longer in the drought susceptibel genotypes than in the drought resistant genotypes. This may resulted in greater floral asynchrony, which may cause reduction in number of fertilized kernels and subsequently in the grain yield of the susceptible genotypes.

Barren stalks was greater in susceptible than in resistant genotypes by 3.25, 4.50, 5.40 and 2.50 folds at BF, AF and SS, respectively. Moreover, number of ears/plant was appreciably greater in the resistant than in the susceptible genotypes by 32, 176, 57 and 103% at the formentioned stress

in the same order.

Mean leaf temperature divided by air temperature was lower in resistant than in susceptibel genotypes (Table 3). Mean leaf temperature was lower in resistant than in susceptible genotypes by nearly 0.6, 1.1, 1.0 and 2.2ºC at BF, FS, AF and SS, respectively (data not shown), most likely in accord with the respective difference between resistant and susceptible genotypes in plant water deficit.

REFERENCES

Ainer, N.G., M.A. Metwally and H.M. Eid (1986): Effect of drought condition at different growth on yield, yield components, consumptive use and water use efficiency of corn (*Zea mays* L.). Annals Agric. Sci., Moshtohor, Zagazig Univ.

Atta Allah, S.A.A. (1996): Effect of irrigation intervals and plant densities on growth, yield and its components of some maize varieties. Proc. 7th Conf. Agron. Mansoura Univ., 9-10 Sept., 59-70.

Blum, A., J. Mayer and G. Golan (1989): Agronomic and physiological assessments of genotypic variation for drought resistance in sorghum. Australina J. of Agric. Res., 40: 49-61.

Bolanos, J., G.O. Edmeades (1996): The importance of the anthesis-silking interval in breeding for drought tolerance in tropical maize. Field Crops Res., 48: 65-80.

Chapman, S.C., G.O. Edmeades and J. Crossa (1996): Pattern asnalysis of grains from selection for drought tolerance in tropical maize population. In plant adaptation and crop improvement (Ed. by Cooper, M. and Hammer, G.L.), Walling Ford, UK, CAB INTERNATIONAL, 513-527.

Claassen, M.M. and R.H. Shaw (1970) : Water deficit effect on corn I. Vegetative components. Agron. J., 62: 649-652.

Edmeades, G.O., J. Bolanos, M. Hwernandez and S. Hello (1993): Causes for silk delay in a low land tropical maize population. Crop Sci., 33: 1029-1035.

El-Bakry, M.H.I. (1998): Studies on breeding for drought tolerance in grain sorghum *(Sorghum bicolor* L. Moench). Ph.D. Thesis, Fac. Agric., Cairo Univ., Egypt.

El-Sheikh, M.A. (1994): Response of two maize varieties to plant densities and irrigation treatments. J. Agric. Sci., Mansoura Univ. 19 (2): 413-422.

El-Yazal, M.N.S. (1976): Evaluation of critical irrigation periods for corn during its different physiological stage. Ph.D. Thesis, Fac. Agric., Al Azhar Univ., Egypt.

El- Zeiny, H.A. and M.A. Kortam (1983): The effect of water supply on growth and yield of corn (*Zea mays* L.) plants. Egypt. J. Agron., 8 (1-2): 63-72.

Finlay, K.W. and G.N. Wilkinson (1963) : The analysis of adaptation in plant breeding. Aust. J. Agric. Res., 14: 472-754.

Fischer, R.A., G.O. Edmeades and E.G. Johanson (1989): Selection for the improvement of maize yield under moisture deficits. Field Crops Res., 22: 227-243 (C.F. Plant Breed Abst., 60: 3158).

Francis, G.A., J. N. Rutger and A.F.E. Palmer (1969): A rapid method for plant leaf area estimation in maize (*Zea mays* L.). Crop Sci., 9:537-539.

Frederick, J.R., J.D. Hesketh, D.B. Peters and F.E. Below (1989): Yield and reproductive trait responses of maize hybrids to drought stress. Maydica, 34 (4): 3190328.

Gates, D.M. (1964): Leaf temperature and transpiration. Agron. J. 56: 273-277.

Grant, R.F., B.S. Jackson, J.R. Kiniry and G.F. Arkin (1989): Water deficit timing effect on yield components in maize. Agron. J., 8 (1): 61-65.

Guei, R.G. and C.E., Wassom (1992): Inheritance of some drought adaptive traits in maize: I. Interrelationship between yield, flowering and ears per plant. Maydica, 37: 157-164 (C.F. Maize Abst., 9 : 2903).

Hall, A.J., D.H. Ginzo, J.H. Lemcoff and A. Sorians (1980): Influence of drought during pollen shedding on flowering, growth and yield in maize. Z.Acker and Pflanzenbau, 149: 284-298.

Herrero, M.P. and R.R. Johanson (1981): Drought stress and its effect on maize reproduction systems, Crop Sci., 21: 105-108.

Human, J.J., W. H. DuPreez and L.P. DaBruyn (1990): The influence of plant water stress on net photosynthesis and leaf area of two maize (*Zea mays* L.) cultivars. Jour. Of Agron. And Crop Sci., 164 (3): 194-201.

Jordan, W.R., R.L. Monk, F.R. Miller, D.T. Resenow, L.E. Clark and P. J. Shoes (1983): Environmental physiology of epiculticular wax load.. Crop Sci., 23: 552-558.

Mahrous, N.M. (1991): Performance of some corn cultivars under some water stress treatments. Bull. Fac. Agric., Cairo Univ., 42 (4): 1117-1132.

Moursi, A.M. (1997): Studies on drought tolerance in maize. M.Sc. Thesis. Fac. Agric., Zagazig Univ., Egypt.

Nesmith, D.S. (1991): Growth response of corn (*Zea mays* L.) to intermittent soil water deficit. Dissertation Abst. Inter., B. Sci., In En., 51 (9): 4114 (C.F. Field Crop Abst., 44: 7924, 1992).

O’Toole, J.C. and T.B. Moya (1978): Genotypic variation in maintenance of leaf water potential in rice. Crop Sci., 18:873-876.

Ribaut, J.M. , C. Jiang, D. Gonzalez-de-Leon, G.O. Edemeas, D.A. Hoisington (1997): Identification of quantitative trait loci under drought conditions in tropical maize. II. Yield components and marker-assisted selection strategies. Theor. Appl. Genet. , 94:887-896.

Saini, H.S. and D. Aspinall (1981): Effect of water deficit on sporogensis in wheat (*Triticum aestivum* L.) Ann. Pot., 48: 623-633.

Shim, J.H. and E.R. Lemon (1968): Photosynthesis under field conditions. XI. Soil-plant water relations during drought stress in corn. Agron. J., 60: 337-343.

Snedecor, G.W. and W.G. Cochran (1980): Statistical method 7th Edit., Iowa State Univ. Press, Ames. U.S.A.

Stapleton, A.R., R.J. Wogent and D. L. Jurner (1983): Corn growth and nitrogen uptake under irrigation fertilized conditions. Irrig. Sci., 4 (1) : 1-15.
Terrazas, J.M.,W. Velasco, G. Avial, L.G. Avila and P.L.M. Cespedes (1995): Response to irrigation and water stress conditions during the first stage of crop development in full-sib families of a maize variety from the highland zone. Memorias de al III. Reunion Latino Am,ericana YXVI Reunion de la Zona Anddina de Investigadores en maize. Cochabamba, Santa Cruz, Bolivia, Tomo I., 249-266, 10 ref.
Westgate, M.E. and J. S. Boyer (1986): Reproduction at low silk and pollen water potentials in maize. Crop Sci., 26: 951-459.
Wilson, J.H. (1968): Water relations of maize I. Effect of seven soil moisture stress imposed at different stages of growth on grain yields of maize. Khod. J. Agric. Res., 6:103-105 (C.F. Field Crops Abst., 32:2346).

الأختلافات الوراثية بين 18 عشيرة ذرة شامية فى قدرتها على تحمل الجفاف فى بعض مراحل النمو المختلفة

عــادل عبد الحليم الجناينى* ، أحمد مدحت النجار * ، حمدى الشربينى ** و محمد يحيى السيد**

*** قسم المحاصيل - كلية الزراعة - جامعة القاهرة - جيزة .**
**** معهد بحوث المحاصيل الحقلية - مركز البحوث الزراعية - الجيزة.**

أجريت تجربتـان حقليتـان خـلال موسـمى 1995و 1996 لتقييم 18 عشيرة ذرة بيضـاء (3 محلية ، 15 مستوردة) من حيث الاختلافات فى القدرة على تحمل الجفاف تحت خمسة أنظمة من الاجهاد المائى بهدف تحديد أفضلها للاستخدام فى برامج التربية . وكانت أنظمة الاجهاد المائى : 1- الرى الكامل 2- الاجهاد المائى فى مرحلة قبل التزهير , 3- الاجهاد المائى فى مرحلة التزهير ، 4- الاجهاد المائى فى مرحلة ما بعد التزهير 5- الاجهاد المائى الشديد فى مرحلتى التزهير وما بعد التزهير معا . وقد أستخدم تصميم القطع المنشقة فى ثلاث مكررات ، حيث وزعت معاملات الاجهاد المائى على القطع الرئيسية بينما وزعت العشائر فى القطع المنشقة وتم قياس 14 صفة .

تسبب الاجهاد المائى فى جميع مراحل النمو موضع الدراسة فى حدوث نقص معنوى فى محصول الحبوب والصفات المؤثرة ، كماحدثت زيادة فى نسبة النباتات الذكر وعدد الايام حتى خروج الحريرة والفترة من نثر حبوب اللقاح حتى خروج الحريرة وكذلك درجة حرارة الورقة ودرجة التفاف الاوراق . واتضح أن مرحلة التزهير هى أكثر المراحل حساسية للاجهاد المائى يليلها مرحلة ما قبل التزهير ثم مرحلة ما بعد التزهير ، وكان النقص فى المحصول أعلى ما يمكن نتيجة الاجهاد المائى الشديد الذى تعرضت له النباتات فى مرحلتى التزهير وما بعد التزهير معا .

وبالنسبة للعشائر ، فقد تميزت عشائر جيزة 2 (المستنبط محليا) وDTP-1, DTP-2 المستنبطتان لتحمل الجفاف بواسطة (CIMMYT) بأنها أفضل العشائر تحملا للجفاف فى جميع مراحل النمو حيث أظهرت أعلى محصول مطلق ونسبى تحت ظروف الاجهاد فى حين أعطت أعلى محصول أيضا تحت ظروف الرى الكامل . وقد أشارت النتائج الى أن صفة التحمل للجفاف تبدو كصفة متخصصة لمرحلة نمو معينة بالرغم من إمكانية تربية تراكيب وراثية معينة تتحمل الجفاف فى أكثر من مرحلة نمو . وقد أظهر التحليل الاحصائى أن اكثر التراكيب الوراثية تحملا للجفاف تتميز بفترة أقصر بين نثر حبوب اللقاح وخروج الحريرة وبدرجة حرارة ورقة أقل وبعدد اكبر من الكيزان على النبات وبتبكير فى النضج ودرجة أقل من التفاف الاوراق وبنسبة أقل من النباتات الذكر مقارنة باكثر التراكيب الوراثية حساسية للجفاف .
أنظمة للاجهاد المائى وذلك على 18 عشيرة نباتية من الذرة الشامية (3 محلية و 5 مستوردة) ولقد إستخدم فى الدراسة تصميم القطع المنشقة فى (3) مكررات ، حيث وزعت معاملات الاجهاد المائى على القطع

الرئيسية، وكانت المعاملات كما يلى 1- المقارنة 2- الاجهاد قبل التزهير 3- الاجهاد أثناء التزهير 4- الاجهاد بعد التزهير 5- الاجهاد الشديد أثناء التزهير وإمتلاء الحبوب فى حين خصصت القطع الفرعية للعشائر –وأجريت الدراسة على (14) صفة .

ولقد بينت النتائج أن الفروق بين معاملات الأجهاد الرطوبى وكذا بين العشائر ، قد بلغت حدود المعنوية في أغلب الحالات .

ولقد إتضح أن أعلى تأثير للاجهاد الرطوبى يقع عندما يتعرض النبات للاجهاد المائى الشديد ، متبوعا بالاجهاد أثناء التزهير، ثم بالاجهاد قبل التزهير وأخيرا الاجهاد بعد التزهير. وبالنسبة للصفات ، فلقد تبين أن التفاف الورقة، نسبة النباتات الذكر %، عدد الحبوب فى الصف ، ومحصول الحبوب/فدان قد تأثرت معنويا بالاجهاد المائى فى جميع مراحل النمو. ولقد سجل أعلى نقص على عطاء كل من نسبة النبات الذكر % ، الفترة بين إنتشار حبوب اللقاح وظهور الحريرة والتفاف الورقة على الترتيب. وعلى النقيض من ذلك فإن صفات عدد الصفوف/كوز ، مساحة الورقة ، عدد الحبوب/صف ، الفترة بين إنتشار حبوب اللقاح وظهور الحريرة ، ووزن المائة حبة على التوالى قد أظهرت مقاومة عالية للاجهاد الرطوبى ، الذى أحدث نقصا فى محصول الفدان من الحبوب بنحو 5ر61% .

ولقد أظهرت النتائج أن الصنف المحلى جيزة (2) قد تفوق معنويا فى محصول الفدان على باقى العشائر متبوعا ب DTP-1 ثم DTP-2 حيث بلغ متوسط إنتاجية الاصناف الثلاثة تحت ظروف الاجهاد الرطوبى 6ر11 ، 6ر9 ، 4ر9 أردب/فدان على التوالى .

ولقد أرتبط التفوق السابق بالقياسات الاقل على صفات التزهير ASI ، نسبى حرارة الورقة الى حرارة الهواء ، درجة التفاف الورقة ، نسبة النباتات الذكر - كذلك ارتبط هذا التفوق بزيادة عدد الكيزان على النبات .

الا أنه بالنظر الى قدرة إحتمال الاجهاد الرطوبى فإن .S.L.P فأن الصنف Syn la Posta ، أحد أقل الاصناف المختبرة إنتاجا للحبوب /فدان (7ر4 أردب /فدان) ، قد بين بجلاء إرتفاع قدرته على تحمل الاجهاد الرطوبى قياسا على الصنف جيزة (2) ، مما قد يعطى للصنف الاول ميزة وأهمية فى برامج تربية الذرة لمقاومة الجفاف .

ولقد أعطت الدراسة إستخلاصا محددا مؤداه أن إحتمال الذرة الشامية الظاهرة للاجهاد الرطوبى تتوقف على مرحلة النمو ، وان من الممكن التربية لمقاومة الجفاف فى اكثر من مرحلة واحدة للنمو الصفات النباتية والتراكيب الوراثية المعرضة للاجهاد الرطوبى .

Table (1): Means (absolute and relative) of the studied traits under well watering (WW), stress berfore flowering (BF) stress at flowering (FS) , stress after flowering (AF), and severe stress (SS). Data combined over 1995 and 1996.

Traits	Unstressed control	Absolute value Stressed at					Relative value Stressed at			
	WW	BF	FS	AF	SS	L.S.D.	BF	FS	AF	SS
1- Days to 50% silking	62.50	69.90	68.60	62.70	69.20	1.37	112	110	100	111
2- ASI (days)	2.20	7.60	7.60	2.20	8.10	1.26	346	346	100	368
3- Plant height (cm)	250.30	193.50	231.30	247.80	230.60	4.66	77	92	99	92
4- Ear height (cm)	145.10	109.20	131.10	145.00	137.50	3.16	75	90	100	95
5- Leaf area (cm^2)	708.50	639.80	676.20	698.30	681.90	22.46	900	95	99	96
6- Leaf rolling (score)	1.57	2.36	2.44	3.32	3.44	0.17	150	154	212	219
7- Lear air temperature (ratio)	0.84	0.96	0.95	0.98	0.98	0.02	114	113	117	117
8- Barren stalks (%)	5.34	21.57	29.76	17.39	34.01	0.54	404	575	326	637
9- Stay green (score)	1.28	1.40	1.20	1.04	1.05	0.09	109	94	81	82
10- No. ears/100 plant	89.41	59.11	42.18	71.58	39.50	4.44	66	47	80	44
11- No. of rows/ear	13.74	13.34	13.25	13.56	13.05	0.36	97	96	99	95
12- No. of Ker nels/ row	35.57	27.71	29.72	31.89	28.84	1.93	78	84	90	81
13- 100-Ker nel weight (gm)	31.26	31.71	29.48	23.88	28.82	1.12	102	95	76	92
14- Grain yield (Arb/fed.)	15.59	6.53	5.12	8.35	3.94	0.74	42	33	54	25

Table (2): Mean grain (Ard/fed.) of studied maize populations (in absolute and relative values) under the five soil moisture regimes, combined over 1995 and 1996 .

Populations	Unstressed Control	Absolute value Stressed at				Relative value to control (%) Stressed at				Stability Mean	Parameters b_i
	WW	BF	FS	AF	SS	BF	FS	AF	SS		
1- Weekly prolific	17.64	3.35	3.55	9.78	2.15	19	20	55	12	7.29	1.35
2- American flint	14.69	7.94	4.13	8.87	4.49	54	28	60	31	8.02	0.91
3- Maiskining	17.23	4.36	3.89	8.47	2.97	25	23	49	17	7.38	1.25
4- Bianca Peria	14.15	3.84	3.06	8.83	2.89	27	22	62	20	6.55	1.02
5- South Africa	14.26	4.57	7.74	7.98	4.59	32	54	56	32	7.83	0.77
6- Missouri	16.58	3.77	5.78	7.67	3.01	32	35	46	18	7.36	1.14
7- Kital Syn.	15.21	6.40	3.58	5.98	4.43	42	24	39	29	7.12	0.99
8- Syn. La Posta	10.13	9.61	2.03	5.17	2.04	95	20	51	20	5.80	0.66
9- Mexican Junes	15.27	8.01	2.37	7.00	2.28	52	16	46	15	6.99	1.14
10- Dwrf Composite	7.95	2.80	2.70	5.87	1.02	35	34	74	13	4.07	0.60
11- Adramet S.B.	12.90	4.03	2.81	6.83	3.89	31	22	53	30	6.09	0.84
12- Pirsabak	16.36	7.60	6.94	9.70	5.77	46	42	59	35	9.27	0.95
13- Giza-2	25.40	12.63	11.04	14.68	7.94	50	43	58	31	14.34	1.41
14- American Early	16.51	5.74	4.98	6.57	3.51	35	30	40	20	7.46	1.10
15- Tepalcinco-5	15.82	8.86	3.90	8.59	2.94	36	25	54	19	8.02	1.08
16- Cairo –1	12.18	6.31	4.31	7.19	3.41	52	35	59	28	6.68	0.08
17- DTP-1 *	19.04	8.98	9.69	11.53	7.79	47	52	61	41	11.46	--
18- DTP-2*	19.25	8.73	9.40	9.53	5.78	45	49	50	30	10.54	--

L.S.D. 0.05 for
Moist-regimes (M) = 0.74
Population (P) = 0.72

M x P = 2.75

* Means of DTP-1 and DTP-2 are estimated from only one year (1996).

Table (3): Studied traits averaged over the best 3 yielding genotypes and the poorest 3 yielding genotypes at each soil moisture stress.

Traits	Stress at BF		Stress at FS		Stress at AF		Stress at SS	
	Resistant (R)	Susceptable (S)	Resistant (R)	Susceptable (S)	Resistant (R)	Susceptable (S)	Resistant (R)	Susceptable (S)
1- Days to 50% silking	66.20	72.20	61.80	73.30	59.70	67.70	62.30	76.00
2- ASI (days)	5.20	6.90	2.50	9.60	1.30	2.30	3.40	11.30
3- Plant height (cm)	177.00	168.00	231.00	197.00	245.00	217.00	224.00	191.00
4- Ear height (cm)	106.00	100.00	127.00	90.00	139.00	108.00	134.00	117.00
5- Leaf area (cm^2)	661.00	592.00	681.00	670.00	708.00	704.00	684.00	681.00
6- Leaf rolling (score)	0.95	0.97	0.92	0.95	0.96	0.99	0.92	0.99
7- Lear air temperature (ratio)	1.45	1.62	1.02	1.50	1.97	2.50	2.23	2.70
8- Barren stalks (%)	1.40	1.30	1.57	1.27	1.22	1.04	1.35	1.05
9- Stay green (score)	8.38	27.15	9.30	41.80	4.37	23.45	16.97	42.97
10- No. ears/100 plant	0.74	0.56	0.69	0.25	0.39	0.95	0.57	0.28
11- No. of rows/ear	14.00	13.00	14.00	13.00	14.00	13.00	14.00	13.00
12- No. of Ker nels/ row	29.00	26.00	32.00	26.00	33.00	29.00	31.00	22.00
13- 100-Ker nel weight (gm)	31.10	30.70	32.20	27.00	23.50	21.60	29.30	27.60
14- Grain yield (Arb/fed.)	10.10	3.40	10.10	2.80	11.90	6.40	7.20	2.50