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Assessment of Drought Tolerance Maize Hybrids at Grain Growth Stage in Mediterranean Area

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Abstract**—**Drought is one of the most serious problems posing a grave threat to cereals production including maize. Maize improvement in drought-stress tolerance poses a great challenge as the global need for food and bio-energy increases. Thus, the current study was planned to explore the variations and determine the performance of target traits of maize hybrids at grain growth stage under drought conditions during 2014 under Adana, Mediterranean climate conditions, Turkey. Maize hybrids (Sancia, Indaco, 71May69, Aaccel, Calgary, 70May82, 72May80) were evaluated under (irrigated and water stress). Results revealed that, grain yield and yield traits had a negative effects because of water stress conditions compared with the normal irrigation. As well as, based on the result under normal irrigation, the maximum biological yield and harvest index were recorded. According to the differences among hybrids were found that, significant differences were observed among hybrids with respect to yield and yield traits under current research.

Based on the results, grain weight had more effect on grain yield than grain number during grain filling growth stage under water stress conditions. In this concern, according to low drought susceptibility index (less grain yield losses), the hybrid (Indaco) was more stable in grain number and grain weight. Consequently, it may be concluded that this hybrid would be recommended for use in the future breeding programs for production of drought tolerant hybrids.

Keywords**—**Drought susceptibility index, grain filling, grain yield, maize, water stress.

I. Introduction

DROUGHT stress is considered one of the most common factors of limiting plant growth in arid and semi-arid regions [1]. The susceptibility of plants to drought stress varies in dependence of stress degree, different accompanying stress factors, plant species, and their developmental stages [2]. Acclimation of plants to water deficit is the result of different events, which lead to adaptive changes in plant growth and physic-biochemical processes, such as changes in plant structure, growth rate, tissue osmotic potential, and antioxidant defenses [3].

Maize crop plays an important role in the world economy and is valuable ingredient in manufactured items that affect a large proportion of the world population [4]. 20-25 percent of the planting area of maize is affected by drought pressure in the world [5]. Maize is one of the most important cereal crops in Turkey [6]. The cultivated area is about 0.60 million hectares and the production in Turkey are about 4.25 million tons and it covers about 95% of corn consumption in the country [7]. Grain yield reduction of maize due to the drought pressure is varied between 1% to 76% depending on the severity, timing, and stage of occurrence [8], [9].

Loss of yield is the main concern of plant breeders and they hence emphasize on yield performance under stress conditions. Thus, drought indices, which provide a measure of drought based on loss of yield under drought-conditions in comparison to normal conditions, have been used for screening drought/tolerant genotypes [10], [11]. Khalili et al. [12] reported that the yield decrease under drought stress at the reproductive stage was greater than that at the vegetative and grain filling stages. The flowering and grain setting stages appear to be the most sensitive stages to water stress. Limited irrigation at critical stages of growth and development may be crucial for recognition of tolerant maize hybrids. Limited irrigation at critical stages of growth and development may be crucial for recognition of tolerant maize hybrids. Thus, the objective of this research was to evaluate the performance of maize hybrids under water deficit stress at grain filling stage.

II. The Study Area

This project was performed in the experimental area of Agricultural Faculty in Cukurova University, Turkey.

III. Materials and Methods

A. Plant Material and Water Stress Treatments

Seven accessions of maize were chosen based on their morphological and agronomic diversity to formulate the representative core sample of the hybrids. Two factors (F) under current study, F1 hybrids, Sancia, Indaco, 71May69, Aaccel, Calgary, 70May82, 72May80 and F2, water stress control and deficit of water during the grain growth stage in Table I.

The experiment was laid out in strip-split design having four replications. Each plot was of 10 m length and 5.6 m width containing plant density (Intrarow: 70 cm, Interrow: 17 cm). In addition, in order to prevent adjacent treatments from overlapping with each other, 2 row was planted as marginal one between minor plots. Hybrids were sown on June 28, 2014. The regular tillage and agricultural operations of growing maize of the location were followed. All other agronomic practices were kept normal and uniform for all the treatments. Data on various yield components was collected by using standard procedures. During experiments,

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nitrogenous fertilizer was utilized within 2 times of planting, sowing 100 kg N and P2O5ha-1 (20-20-0) and V6-growth stage 200 kg N ha-1 (Urea). Planting was performed with drill.

TABLE I
IRRIGATION DATE AND AMOUNT IN MAIZE

Irrigation No	Date	Control, mm	Deficit irrigation, mm
1	30.06.2014	48	48
2	11.07.2014	48	48
3	24.07.2014	48	48
4	06.08.2014	48	48
5	16.08.2014	48	24
6- (Pollination)	23.08.2014	48	24
7	30.08.2014	48	24
8	06.09.2014	48	24
9	14.09.2014	48	24
Total		432	312

B. Plant Sampling and Measurements

- Measurements: grain weight (mg), grain number per m^2, grain yield (t ha^{-1}), biomass (t ha^{-1}) and harvest index (%).
- Estimation of Drought Susceptibility Index: A drought susceptibly index (DSI) for grain yield and its components was calculated according to Fischer and Maurer [13].
- Statistical analysis: All data collected for both seasons were subjected to analysis of variance according to Gomez and Gomez [14]. Treatment means were compared using Duncan Multiple Range Test [15]. All statistical analysis performed using analysis of variance technique by "MSTAT-C" computer software package 1990.

IV. RESULTS AND DISCUSSION

Detailed discussions on the results presented in this chapter have been made under the following heads.

A. Agronomic Traits

Observations of yield traits for plants are summarized in Table II. Data showed that for yield components of maize hybrids were significantly affected by irrigation treatments. Data in Table II indicated that water stress lead to a significant reduction in seed weight and seed per m^2. The results showed that the stress resulted in higher value for normal irrigation compared with the water stress treatment. According to The hybrids, the results showed significant differences in grain yield and yield traits. The hybrids 71May69 and Calgary had higher values of grains per m^2 under the stressed treatment. In this concern, 70May82 and Aaccel more positive effect of grain weight. These results agree with [16], which reported that irrigation disruption at grain filling stage causes a decrease in the leaf area duration and photosynthate mobilization to seeds and thereby decreasing grain weight. Similar results were reported by [17] that kernel number per plant is moisture stress-dependent and concluded that kernel number decrease is the primary effect of water deficit on corn grain yield. Zinselmeier et al. [18] stated that the drought effect on number of grains and grain weight, grain yield was reduced.

TABLE II
MEANS OF GRAIN WEIGHT, SEEDS PERM^2, AS INFLUENCED BY WATER STRESS IN MAIZE HYBRIDS

Factor	Grain weight (mg)	Grains per m^2	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
			Irrigation (A)		
Control	258 a	4985	12.72 a	2271 a	56.0 a
Stress	232 b	4586	10.50 b	1954 b	53.7 b
F. test	**	NS	**	**	*
			Hybrid (B)		
Sancia	236 bc	4869 bc	11.30 b	2082	54.2 bc
Indaco	271 a	4614 bc	12.52 a	2280	54.8 abc
71 May 69	232 bc	4972 ab	11.45 ab	2036	56.2 ab
Aaccel	263 ab	4453 bc	11.65 ab	2054	56.6 a
Calgary	223 c	5478 a	12.12 ab	2198	55.1 abc
70May82	257 ab	4310 c	11.12 b	2075	53.3 c
72May80	234 bc	4802 bc	11.13 b	2060	54.1 bc
F. test	**	**	*	NS	*
			Interaction		
A x B	NS	NS	NS	NS	NS

*, ** and NS indicate P < 0.05, P < 0.01 and not significant, respectively. Means within the same column of each factor followed by a common letter are not significantly different at the 5% level, according to Duncan's multiple range test.

B. Grain Yield

According to the results for grain yield show that decreased significantly with under water stress and a greater yield was observed in indaco, 71May69, Aaccel and Calgary in Table II. Grain yield is the result of the expression and association of several plant growth components. The deficiency of water leads to severe decline in yield of crop plants probably by disrupting leaf gas exchange properties which not only limited the size of the source and sink tissues but the phloem loading, assimilate translocation and dry matter portioning are also impaired [19]. Pandey et al. [20] reported that yield reduction (22.6–26.4%) caused by deficit irrigation was associated with a decrease in kernel number and weight. The grain filling stage it had the maximum effect on this trait, showing the severe effects of drought stress at this stage of growth, results that are in agreement with [21].

C. Biological Yield

The resulted in irrigated treatment higher biomass, compared with the stressed treatment in Table II. Moreover, there is significant different between hybrids in biomass yield. The highest of biological yield was achieved in control with compare water stress treatments. In this concern, the hybrids Indiaco and Calgary were achieved the best value of biomass yield. These results agree with [22], which reported that biomass was reduced by moisture stress. Stone et al. [23] stated that yield was related strongly to biomass especially that accumulated after silking and reported that biomass was reduced by moisture stress.

D. Harvest Index

The physiological efficiency of a crop to convert dry matter into economic yield is determined by the harvest index. The results show that water stress leas to a decrease in dry material yield and grain yield, so the harvest index does not differ so much. The highest of harvest index was achieved in control with significant differences from other treatment in Table II. According to hybrids, Aaccel, Indaco, Calgary and 71May69 produced the highest values compared with other hybrids in harvest index. The decrease in harvest index under water deficit stress showed the fact that both grain yield decreased under drought stress, but grain yield decreased more that decreased harvest index. With drought, stress had decreased seed yield and harvest index. Therefore, difference between hybrids in control was little and under drought stress, this difference had expanded. These results are in line with the findings of [24] and [25] that skipping irrigation at different crop growth stages significantly influenced different maize hybrids for the parameter of harvest index.

E. Drought Susceptibility Index

The drought susceptibility index (DSI) estimates the rate of change for each hybrid in yield, between the stress and non-stress conditions relative to the mean change for all hybrids. Values of DSI lower than 1 denotes low drought susceptibility (or drought tolerance) and values higher than 1 indicate high drought susceptibility or poor yield in Fig. 1.

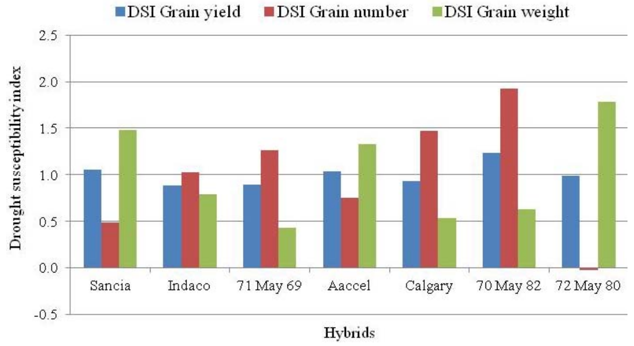

Fig. 1 The drought susceptibility index for grain yield, grain number and grain weight

Depending on the mean DSI value based on grain yield, varieties could be ordered according to water stress tolerance as follow; Indaco, 71May69, Calgary and 72May80, respectively. From the result of DSI (less grain yield losses) this hybrids (Indaco) was more stable in grain number and grain weight. Additionally, it is less grain yield losses under drought stress. Using DSI, Indaco was selected as more stable hybrid in grain growth stages of stress (Fig. 1). Indaco yield was relatively high in all conditions. This finding is consistent with that reported by [26]. Fayaz and Arzani [27] reported cultivars with low DSI values are drought tolerance because they have lesser reduction in grain yield under stress compared with non-stress condition. Moreover, [28] indicated that genotypes with low DSI values might represent a valuable genetic resource for enlarging the genetic variation of barley breeding programs for drought tolerance.

V. CONCLUSION

This result indicated that grain weight had more effect on grain yield than grain number during grain filling growth stage under water stress conditions. Accordingly, drought susceptibility stress index for grain weight could be recommended in future breeding programs for a selection as criteria in identifying high yielding hybrids under stress conditions. In this concern, the low drought susceptibility index (less grain yield losses) the hybrid (Indaco) was more stable in grain number and grain weight. Consequently, it may be concluded that this hybrid would be perform better under conditions of poor water supply and it could be recommended for use in future breeding programs for production of drought tolerant hybrids.

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