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Responses of morphological characteristic and grain yield of maize cultivars to water stress at reproductive stage

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Key words: Morphological traits, maize, water stress, grain filling, yield.

Abstract

In order to evaluate some morphological and grain yield of maize cultivars (S704, BC678 and H500) under water stress at grain filling stage (no stress and stress), a factorial experiment (using RCB design) with three replicates was conducted in 2012 at Research Farm of Faculty of Agriculture, Payame Noor (PNU) university, East Azerbaijan, Iran. Results indicated plant height, cob leaf area, tassel weight and thereby grain yield per ha were decreased under water limitation at grain filling stage. As water stress occurred in reproductive stage leaf number per plant, stem diameter and cob diameter were not significant. As, stem diameter during water stress was not declined, this indicates that remobilization of assimilate was not occurred in this condition. S704 was superior cultivar in plant height, stem diameter, cob leaf area, tassel weight and consequence grain yield. No significant interaction between irrigation and cultivar indicated that S704 was superior cultivar in both well and limit water conditions. It is, therefore, essential to provide sufficient water during grain filling stage in order to prevent yield loss in maize cultivars.

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Introduction

Plants are exposed to a multitude of natural biotic and abiotic stresses. Drought is a major abiotic stress that severely affects food production worldwide. In some locations, naturally available water supplies do not allow the production of maximum yield from irrigable lands. In other regions, water resources are limited, leading to insufficient irrigation. These examples highlight the need for deficit irrigation management for different crops (Martin *et al.*, 1989). The most widely used criteria for selecting high yield performance are mean yield, mean productivity (aver-age yield performance under stress and non-stress conditions) and relative yield performance in drought-stressed and more favorable environments (Rashid *at al.*, 2003). Stability of grain yield for each genotype is estimated by the drought susceptibility index (DSI), derived from the yield difference between stress and non-stress environments (Blum *et al.*, 2005).

The water requirements of maize for all growing cycle vary from 500 to 800 mm (Brouwer and Heibloem, 1986). Narandra *et al.*, (2002) determined the ETc of corn at 354 mm. water stress has been an important effect on water consumption and corn yield. A positive linear relationship between yield and water use has been recognized by several authors (Istanbulluogu *et al.*, 2002; Fatih *et al.*, 2008). Doorenbos and Kassam (1979) established a relation between water applied and yield that can be used to predict yield per applied water unit.

Some morphological characters such as root length, spike number per m^{-2}, grain number per spike, number of fertile tillers per plant, 1000 grain weight, peduncle length, spike weight, stem weight, awn length and grain weight per spike of cereals tolerance to the moisture shortage in the soil (Plaut *et al.*, 2004).

Maize (*Zea mays* L.) is third most important cereal crop in the world agricultural economy and is a relevant source of food, feed, and industrial products. Being a C4 plant and having very high yield potential, it is called queen of cereals. Morphological traits are very important in production of yield and these characteristics can affected by environmental stress especially water stress during reproductive stage. Thus, this research was carried out to investigate the effect of water stress at reproductive stage on morphological traits and grain yield of maize cultivar.

Materials and methods

Field experiments

An experiment was conducted at the Research Farm of the Faculty of Agriculture, Payame Noor University (PNU), East Azerbaijan of Iran in 2012. The experimental design was factorial (bases RCB) with three replicates. Factors were two irrigation treatments (Non stress and water stress: well-watering and irrigation disruptions at grain filling stage on the bases of 50 and 90 mm evaporation from class A pan, respectively) and three maize cultivars (S704, BC678 and H500).

Treatment and managements

For determination of the best time of irrigation, 48 hours after irrigation at each stage during plant growth as daily and continuously soil sampled as randomly from rhizosphere by Agar for determination of soil water weight percent (1) (Alizadeh, 2010).Also, The content of water (2) that used in each stage calculated by Alizadeh (2010):

$$1) \quad = \frac{\text{wet soil weight (g)} - \text{dry soil weight (g)}}{\text{wet soil weight (g)}} \times 100$$

Soil water weight %

$$2) \quad V = \frac{(FC - \theta m) * Pb * Dr * A}{Ei} \times 100$$

Where V, FC, θm, Pb, A, Dr and Ei are content of water that used, soil wet weight percent in field capacity, soil wet weight percent before of irrigation, bulk density of soil (g/cm3), irrigated area (m3), depth of root activity and irrigation efficiency, respectively.

Grains of three maize cultivars were treated with 2 g kg-1 Benomyl and then were sown by hand on 8 May 2012 in 5-7 cm depth of a loam-clay soil. Each plot consisted of 4 rows of 5.4 m length, spaced 75 cm apart. Pre-plant fertilization accomplished on the bases soil analysis data (soil type was loam-clay with EC= 1.43 ds/m, PH= 7.5 and organic material= 0.72) as 100 kg/ha urea, 150 kg/ha $NH_4H_2PO_4$ and 100 kg/ha K_2SO_4. All plots were irrigated immediately after sowing and after seedling establishment, plants were thinned to 7.4 plants m^{-2} and at the same time, plots were fertilized with 200 kg/ha urea. Subsequent irrigations were carried out on the bases of 50 mm evaporation from class A pan up to grain filling stage. Thereafter, irrigation disruptions were applied according to the treatment. Hand weeding of the experimental area was performed as required.

Parameters studied

At maturity, the plants in 1 m^{-2} of each plot were harvested, and then plant height, leaf number per plant, stem diameter, cob leaf area, cob diameter, cob weight, tassel weight and grain yield were determined.

Statistical analysis

All the data were analyzed on the bases of experimental design, using SAS 9.1 software. The means of each trait were compered according to Duncan multiple range test at $p \leq 0.05$.

Results and Discussion

Analysis of variance of the data (Table 1) showed that the plant height, cob leaf area and weight, tassel weight and grin yield were significantly affected by irrigation and cultivar treatments. The effect of cultivar on stem diameter and interaction of irrigation × cultivar on cob weight was also significant. But, leaf number per plant and cob diameter was not significantly affected by both irrigation and cultivar.

Table 1. Analysis of variance of the data for morphological traits and grain yield of maize cultivars.

Source	df	height	Leaf number per plant	Stem diameter	Cob leaf area	Cob diameter	Cob weight	Tassel weight	yield
Replication	2	52.53	0.121	0.007	6664.99	0.085	204.65	22.23	3041915
Irrigation (a)	1	102.24**	0.011 ns	0.077 ns	107274**	0.001 ns	368.82**	134.04**	13036639**
Cultivar (b)	2	21.23**	0.086 ns	0.072*	26930.6**	0.014 ns	58.69**	25.01**	1253369**
a × b	2	3.07 ns	0.005 ns	0.002 ns	81.09 ns	0.074 ns	37.65**	11.73 ns	682794 ns
Error	10	3.7	0.11	0.017	3586.3	0.128	5.48	3.89	179452
CV%		0.88	2.53	5.26	8.28	11.38	6.4	7.57	6.18

*, ** and ns: significant at $p \leq 0.05$, $p \leq 0.01$ and no significant, respectively

The lowest plant height, cob leaf area, tassel weight and consequence grain yield were observed under water stress at grain filling stage (Table 2).

Canopy photosynthesis is reduced by moisture stress due to reduced stomatal conductance and reductions in leaf area. As moisture stress increases, stomata start closing as a mechanism to reduce transpiration. As a consequence, the entry of carbon dioxide is also reduced (Reddy *et al.*, 2003).

Leaf area expansion depends on leaf turgor, temperature and assimilates supply for growth, which are all affected by drought. Leaf and stem morphology are Altered by water stress. Continuous water deficit results in fewer and smaller leaves, which have smaller and more compact cells and greater specific leaf Weight (Chung *et al.*, 1997).

Pod and kernel development are progressively inhabited by drought stress due to in sufficient plant turgor and lack of assimilates. These stages can also be delayed by lack of soil water in the pod zone. Pod dry weights were significantly reduced by a 30-day water stress during the pod development stage (Meisner and Karnok, 1992). The number of pods per plant can be low due to increases in soil resistance caused by prolonged drought. Drought reduces pod yield primarily by decreasing the duration of the pod development phase. Water deficits during kernel or seed development reduce pod and seed weight shelling percentage is reduced by moisture stress during seed development (Janamatti *et al.*, 1986).

Table 2. Means of some morphological traits and grain yield of maize cultivars under water stress.

Irrigation	Height (cm)	Cob leaf area (m^2)	Tassel weight (g)	Yield per ha (kg)
Non stress	219.46 a	800.16 a	28.78 a	7695.9 a
Stress	214.7 b	645.76 b	23.32 b	5993.9 b

Different letter in each column indicate significant difference at $p \leq 0.05$

Table 3. Means of some morphological traits and grain yield of maize cultivars.

Cultivar	Height (cm)	Stem diameter	Cob leaf area (m^2)	Tassel weight (g)	Yield per ha (kg)
S704	219.25 a	2.633 a	795.81 a	28.34 a	7365.8 a
BC678	216.13 b	2.441 b	709.07 b	25.42 b	6658 b
H500	215.86 b	2.445 b	664.01 b	24.4 b	6510.9 b

Different letter in each column indicate significant difference at $p \leq 0.05$

The highest plant height, stem diameter, cob leaf area, tassel weight and grain yield was produced by S704 in comparison to other cultivar. These traits among BC678 and H500 were similar (Table 3). Yield difference among maize cultivars mainly resulted from differences in some morphological characteristic (Table 3). No significant interaction of irrigation and cultivar indicates that S704 was superior cultivar both under well and limited irrigation condition.

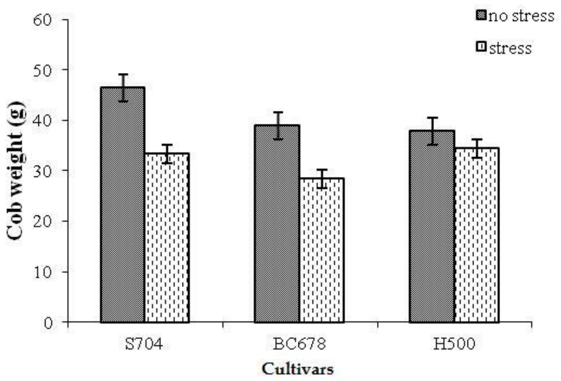

Fig. 1. change in cob weight of maize cultivarsunder water stress at reproductive stage

Cob weight of all cultivar as a result of water stress was lower than that of well watering condition. This reduction of cob weight under water stress for S704 and BC678 was significant. In contrast, reduction of cob weight in H500 was not significant (Figure 1). This result indicates that H500 in compared to S704 and BC678 was a stability cultivar in cob weight during well and stressed water condition.

Conclusion

As a result of this research maize is a sensitive crop to water stress at grain filling stage. However, water limitation occurred during grain filling, plant height, cob leaf area, tassel weight and consequence grain yield were significantly reduced. As, stem diameter at water stress condition was not declined, this indicates that remobilization of assimilate was not occurred in this condition for this crop. It is, therefore, essential to provide sufficient water during grain filling stage in order to prevent yield loss in maize cultivars.

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