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Response of maize cultivars to water stress at grain filling phase

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ABSTRACT

The current research was carried out to investigate field performance of three maize cultivars (S_{704}, BC_{678} and H_{500}) under non-stressed (performing 50 mm evaporation from class A evaporation pan) and stressed (performing 90 mm evaporation from class A evaporation pan) conditions at grain filling phase. Results showed that water stress during grain filling stage mainly had effects on grain weight rather than grain number per plant. Grain depth in cob and cob diameter under non-stressed condition was higher than those of water stressed condition, indicating that grain volume and especially grain yield were decreased by increasing waster stress. Maximum grain yield (7.3 ton/ha) was obtained by S_{704} in comparison with other cultivars (6.6 and 6.5 ton/ha for BC_{678} and H_{500}, respectively). Superiority of S_{704} was attributed to be more of 100 grain weight, row number per cob, grain number per cob, cob diameter and cob weight. This research suggests that there is considerable variation among studied genotypes in tolerance to water stress at grain filling stage. Thus, it is essential to provide sufficient water during grain filling stage in order to prevent yield losses in maize cultivars.

INTRODUCTION

Maize (*Zea mays* L.) is cultivated across a wide range of conditions, from extremely stressful to favourable conditions. Considering water as an important environmental factor regulating plant growth, development and yield (Manivannan et al. 2007) by providing inter cellular medium which most of the functions take place(Condon et al. 2002), drought is one of the major threats affecting maize production in tropical and subtropical regions or globally.

Several attempts have been made to optimize crop yields under water stressed conditions. Increasing crop tolerance to water stressed condition would be the most economical approach in order to enhance productivity and reduce agricultural use of fresh water resources. Plants usually react to water stress by demonstrating some morphological, physiological and biochemical responses (Xionget al. 2006; Gaoet al. 2008). The effect of water stress on plant growth and yield depends on plant's genotype, duration of stress, weather conditions, and growth stages of crops (Robertson and Holland 2004). Moderate to high drought stress can reduce plant biomass, number of pods and seeds, days to maturity, harvest index, seed yield and seed weight in common bean (Ghassemi-Golezani and Mardfar 2008), soybean (Demirtas et al. 2010) and pinto bean (Ghassemi-Golezani et al. 2010).

The flowering and pod setting stages appear to be the most sensitive stages to water stress (Nayyaret al. 2006; Ghobadiet al. 2006) indicating that water deficit during reproductive growth was more effective than one during vegetative growth of rapeseed. Limited irrigation at critical stages of growth and development may be crucial for recognition of tolerant maize varieties. Thus, the objective of this research was to evaluate the performance of maize cultivars under water deficit stress at grain filling stage.

MATERIALS AND METHODS

This research was performed at the Research Farm of the Faculty of Agriculture, Ajabshir branch of Payame Noor University (PNU),Iran in 2012. A factorial experiment based on randomized complete block (RCB) design with two factors and three replications was carried out in this investigation. Irrigation treatment was considered as first factor which included unstressed (performing 50 mm evaporation from class A evaporation pan) and

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stressed (performing 90 mm evaporation from class A evaporation pan) conditions at grain filling phase. Second factor included three maize cultivars of S_{704}, BC_{678} and H_{500}.

In order to determine the best time for irrigation, soil samples were taken from field daily after 48 hours of irrigation to evaluate gravimetric soil moisture content[1] and the volume of water required for irrigation[2](Alizadeh2010):

[1] $\Theta_m\% = [(\text{wet soil weight (g)} - \text{dry soil weight (g)}) / \text{dry soil weight (g)}] \times 100$

[2] $V= [(FC- \Theta_m) \times Pb \times Dr \times A]/Ei$

Where V implies the volume of water required for irrigation (cm^3), FC implies gravimetric soil moisture contents at field capacity, θ_m implies gravimetric soil moisture content before irrigation, Pb implies soil bulk density (g/cm^3), A implies irrigated area (cm^2), Dr implies depth of root activity (cm) and Ei implies irrigation efficiency (%).

Seeds broadcasting were done manually during early May 2012 in 5-7 cm depth of a loam-clay soil considering 4 rows of 5.4 m length for each plot. Pre-plant application of fertilizers including 100 kg/ha urea, 150 kg/ha NH_4H_2PO4 and 100 kg/ha K_2SO_4 accomplished based on soil analysis reporting soil texture of clay-loam with EC= 1.43 dS/m, pH= 7.5 and organic matter= 0.72 %. All plots were irrigated immediately after sowing and seedling establishment, plants were thinned to 7.4 plants per m^2, and plots were fertilized with 200 kg/ha urea at the same time, Subsequent irrigations were carried out on the bases of 50 mm evaporation from class A evaporation pan up to grain filling stage. Thereafter, irrigation disruptions were applied according to the treatments. Hand weeding of the experimental area was performed as required.

At maturity, the plants in 1 m^2 of each plot were harvested, and then grain yield and yield component were determined. All the data were analysed on the bases of experimental design, using SAS 9.1 software. The means of each treatment were compared according to Duncan multiple range test at $p \leq 0.05$.

RESULTS

Analysis of variance of the data for yield and yield components of maize cultivars showed that 100 grain weight($p \leq 0.05$), grain weight per cob($p \leq 0.01$), grain number per row and cob ($p \leq 0.05$), cob diameter and length($p \leq 0.05$), cob weight per plant and per m^2($p \leq 0.01$), and grain yield per ha ($p \leq 0.01$)were significantly affected by irrigation and cultivar. The effect of irrigation treatments on grain depth in cob was also significant ($p \leq 0.01$). Row number per cob was only affected by cultivar. The interaction of irrigation × cultivar was significant ($p \leq 0.05$) for grain weight per cob and grain number per row.

Means of 100 grain weight, grain number per cob, cob diameter and length, grain depth in cob, cob weight per plant and m^2 and grain yield per ha were decreased under water stress. Water deficit at grain filling stage had the most effect on grain weight than that of number of grain. As, grain depth in cob under well watering condition was more in comparison to water limitation condition, indicating that grain volume, length and weight decreased by increasing water stress (Table 1).

Maximum cob diameter and length, cob weight per plant and m^2 and grain yield per ha were obtained from S_{704} in comparison to BC_{678} and H_{500}. However, 100 grain weight, row number per cob and grain number per cob among S_{704} and BC_{678} was similar (Table 2).

Grain weight per cob under water stress condition was lower than well watering condition in all cultivars. Maximum grain weight per cob under non stress condition was showed in S_{704}, followed by BC_{678} and H_{500}, respectively. But, under water stress condition maximum grain weight per cob after S_{704}, was followed by H_{500} and BC_{678}, respectively (Figure 1).

Grain number per row in all cultivars under water stress at grain filling phase was lower than well watering. In non-stress condition, grain number per row of S_{704} and BC_{678} was similar, while, in water stress condition this trait of BC_{678} and H_{500} was similar (Figure 2).

DISCUSSION

Leaf senescence of maize due to water stress at reproductive stages can potentially reduce grain yield. Since there is a linear relationship between LAI and light interception (Ghasemi-Golezaniet al. 2008), reduction of this growth index can reduce photosynthesis, plant biomass, yield components and consequently grain yield (Table 1). Similar results were reported for maize (Bismillah Khan et al.2001).

Water stress at grain filling phase had great effects on grain weight (Table 1). Since in this research plants during flowering stage had well watering, thereby number of grain in plants was not significant. Irrigation disruption at grain filling stage causes a decrease in the photosynthate mobilization to seeds and thereby decreasing grain weight. Similar results were reported by Sadeghipour (2008), Ghassemi_Golezaniet al. (2010) and Ghassemi-Golezani and Lotfi (2012).

Table 1: Comparison of means of yield component and grain yield of maize under water stress at reproductive stage.

Irrigation	100 GW	GN/C	CD	CL	GDC	CW/P	CW/M^2	GY/ha
Non stress	259.24 a	563.41 a	4.52 a	15.01 a	6.89 a	151.17 a	1118.69 a	7695.9 a
Water stress	189.68 b	453.61 b	4.12 b	12.69 b	5.4 b	112.57 b	833.03 b	5993.9 b

100 GW (grain weight), GN/C (grain number per cob), CD (cob diameter), CL (cob length), GDC (grain depth in cob), CW/P (cob weight per plant), CW/M^2 (cob weight per m2) and GY/ha (grain yield per ha).
Different letters in each column indicate significant difference at P≤0.05

Table 2: Comparison of means of yield component and grain yield of maize cultivars

Cultivar	100 GW	RN/C	GN/C	CD	CL	CW/P	CW/M^2	GY/ha
S_{704}	244.18 a	16.31 a	534.91 a	4.57 a	15.9 a	145.94 a	1079.89 a	7365.8 a
BC_{678}	234.02 ab	16.18 a	507.45 ab	4.21 b	13.4 b	126.27 b	934.43 b	6658 b
H_{500}	195.19 b	15.20 b	483.17 b	4.18 b	12.25 c	123.41 b	913.26 b	6510.9 b

100 GW (100 grain weight), RN/C (row number per cob), GN/C (grain number per cob), CD (cob diameter), CL (cob length), GDC (grain depth in cob), CW/P (cob weight per plant), CW/M2 (cob weight per m2) and GY/ha (grain yield per ha).
Different letters in each column indicate significant difference at P≤0.05

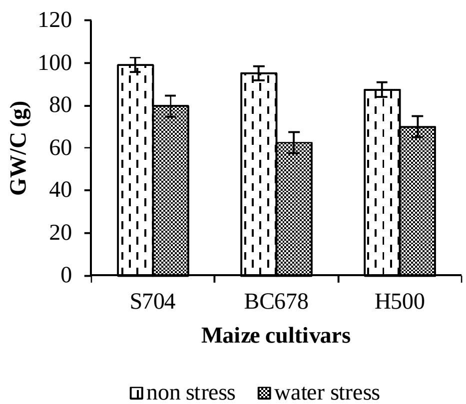

Figure 1: Changes in GW/C (grain weight/cob) of three maize cultivars under water stress at grain filling stage.

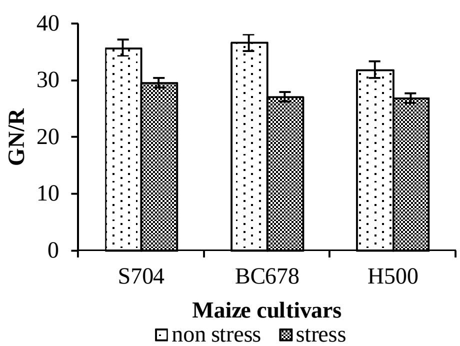

Figure 2: Changes in G.N/R (grain number/row) of three maize cultivars under water stress at grain filling stage.

Grain depth in cob was declined under water limitation condition (Table 1), indicating that grain volume, length and weight decreased by increasing water stress. Khanzadaet al. (2001), found that pod length in guar genotypes decreased significantly with application of water stress when compared with control. Qadiret al. (1999) also found that water stress reduced the spikelets per spike in wheat.

The highest and the lowest grain number, weight and yield were produced by S_{704} and H_{500}, respectively. The superiority of S_{704} was attributed to more 100 grain weight, row number per cob, grain number per cob, cob diameter and length and cob weight per plant (Table 2).

Water disruption during grain filling stage can lead to severe loss in yield and yield components of maize cultivars. Results in this research indicated that grain weight had more effect on grain yield than grain number. This study suggests that there is considerable variation between maize genotypes in tolerance to water stress, and that maximizing the number and weight of grains are important traits for maintaining stable and high grain yields under water deficit conditions.

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