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The influence of regular deficit irrigation applications on water use, yield, and quality components of two corn (*Zea mays* L.) genotypes

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ABSTRACT

The objective of the present study was to determine the mechanisms of tolerance of two corn (*Zea mays* L.) genotypes (Şafak and Ant-İ90) to water stress under five different irrigation treatments designated as full irrigation (I_{100}) with no water stress and slight (I_{75}), mild (I_{50}), severe water stress (I_{25}) and no irrigation (I_0) treatments. The results showed that different irrigation levels applied has statistically significant effect on yield components such as anthesis–silking interval, plant height, ear diameter, ear length, kernel number and 1000 grain weight, except for ear number. In both of the genotypes, water deficit stress significantly ($P \leq 0.01$) increased glucose, fructose, and sucrose contents while it decreased protein content. The maximum grain yield was obtained from Şafak genotype under full irrigation, slight, mild, severe and full water deficit stress as much as 9.35 t ha^{-1}, 8.34 t ha^{-1}, 7.89 t ha^{-1}, 5.56 t ha^{-1} and 3.63 t ha^{-1}, respectively. The highest water use was observed in I_{100} treatment as 738.1 mm for Şafak genotype, while the lowest was found in I_0 treatment as 260.0 mm for Ant-İ90 genotype. The highest water use efficiency was found in I_{50} as 15.7 kg ha^{-1} mm^{-1} for Şafak genotype, and the lowest one was found in I_0 as 5.5 kg ha^{-1} mm^{-1} for Ant-İ90. It was concluded that Şafak was more tolerant genotype to water stress than that of Ant-İ90.

1. Introduction

Corn (*Zea mays* L.) is the third most important cereal food crop of the world after wheat and rice. It ranks third among cereals following wheat and barley in Turkey. Total planting area and production of corn in Turkey was about 589 000 ha and 4200 000 t in 2011, respectively. Corn production is carried out mostly in Marmara (Marmora) in North Western, Ege (Aegean) in Western and Akdeniz (Mediterranean) in Southern Regions of Turkey (Tonk et al., 2011). It is one of the most important cereal crop grown principally during the summer season in West Mediterranean Region of Turkey.

Long-term average annual precipitation in the West Mediterranean region is about 1100 mm, falling more than 98% of it from October to May. Therefore, irrigation is needed at corn growing season to maintain and enhance crop growth and yield. Water deficit is a critical issue limiting corn growth by having impact on anatomical, morphological, physiological and biochemical processes (Setter et al., 2001).

Effects of deficit irrigation for corn were reported by some researchers. NeSmith and Ritchie (1992) reported that the reduction in maize yield exceeded 90% due to water deficit during the tasselling and silking stages. Vicente et al. (1999) reported that the reduction in grain yield was 70% and 90% in intermediate water stress and severe water stress, respectively, with grain yield fluctuating between 0.30 t ha^{-1} and 2.41 t ha^{-1} in severe stress. Pandey et al. (2000) reported that water stress reduced kernel number and weight, and yield. Stone et al. (2001) reported that water deficit reduces crop growth, canopy development, and morphological characteristics of corn plant. Viswanatha et al. (2002) stated that yield decreased with reduced irrigation water. Karam et al. (2003) pointed out that water deficiency significantly reduced dry matter accumulation. In this study, grain yield reduced to 37% due to a decline of 18% in kernel weight and of 10% in kernel number under water stress conditions. Oktem (2008) indicated that under conditions of water stress, the sweet corn plant decreased its leaf area index (LAI), yield and marketable ear number.

Deficit irrigation practices affect not only water use and yield but also quality parameters such as sugar and protein content. Various studies pointed to the role of soluble sugars in the protection of against stress. Mohammadkhani and Heidari (2008) reported that higher amount of soluble sugar and lower amount of starch were obtained from two maize (*Z. mays* L.) cultivars, named

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704 and 301, under water stress conditions. An experiment conducted by Shivakumar et al. (2011) revealed that crude protein decreased from 18.90% to 12.65% whereas sugars increased from 134.92 mg 100 g^{-1} to 250.17 mg 100 g^{-1} when baby corn irrigated during whole season as much as 1.0 and 0.6 of cumulative pan evaporation (CPE), respectively. Tarighaleslami et al. (2012) pointed out that corn grain protein is decreasing as water stress increased. Mugalkhod (2005) reported that drip irrigation scheduled at 100% of potential evapotranspiration (PE) registered higher crude protein content (16.73%) over all other irrigation schedules, whereas drip at 50% PE recorded lower crude protein content (12.52%) over other irrigation schedules. On the other hand, drip irrigation scheduled at 50% PE recorded higher crude fibre and reducing sugar (3.96% and 70.95 mg 100 g^{-1}, respectively), whereas drip irrigation scheduled at 100% PE recorded lower crude fibre and reducing sugar content (3.20% and 47.54 mg 100 g^{-1}, respectively). Sunder Singh (2001) revealed higher crude protein and vitamin C due to irrigation at 1.0 CPE (13.23% and 12.65 mg 100 g^{-1}, respectively) over 0.75 and 0.5 CPE (12.78% and 12.57 mg 100 g^{-1}; 12.11% and 12.44 mg 100 g^{-1}, respectively).

As seen from the studies cited above, there is a dilemma about the change in protein content as some of the studies reporting that protein content is increasing with an increase in water stress whereas some of them showing that protein content are decreasing as water stress decreased. Therefore, the present study was conducted to reveal the effect of deficit irrigation practices on water use, yield as well as sugar and protein contents of two corn genotypes under conditions of West Mediterranean Region in Turkey. The genotypes were selected because they are grown widely in the region.

2. Materials and method

The study was conducted at the research field of the Bati Akdeniz Agricultural Research Institute in Antalya, Turkey, during June–September 2011. The research area was located at a latitude of 36 56′N and a longitude of 30 53′E, and an altitude of 28 m. The climate of the region is typically Mediterranean, i.e. mild and rainy in winter and dry and hot in summer. The climatic variables for experimental year and long-term means for June–September are given in Table 1.

The soil of the research area is clay–loam in texture, unsalted and rich in calcium carbonate and alkali. Some physical and chemical properties of field soil and irrigation water are given in Tables 2 and 3, respectively. The electrical conductivity (EC) of irrigation water was 0.46 dS m^{-1} and the sodium adsorption ratio was 0.34 which does not risk for growing corn plants (Ayers and Westcot, 1985) (Table 3).

Two corn genotypes and five irrigation levels were examined in the study. Şafak and Ant-İ90 corn genotypes were used as a crop material. Fertilizer applications were based on soil analysis results and all of the plots received the same amount of total fertilizer. The recommended dose of 75 kg ha^{-1} pure N, P and K (15, 15, 15 composite) before sowing and additional nitrogen dose of 115 kg ha^{-1} was applied as ammonium nitrate, which is 50% of total nitrogen, when the plant reach to 0.4–0.5 m in height. The corn seeds were planted on June 1, 2011 with 0.70 × 0.20 m spacing.

Regular deficit irrigation treatments consisted of full irrigation (I_{100}) with no water stress and slight (I_{75}), mild (I_{50}), severe water stress (I_{25}) and no irrigation (I_0) treatment. The amount of water applied in full irrigation treatment (I_{100}) was calculated as the amount of water necessary to replenish to the field capacity in the upper 90 cm soil profile depth. The quantity of irrigation water applied to the other treatments was decreased stepwise as 0%, 25%, 50% and 75% of water applied to the treatment I_{100}. When 40% of the amount of available soil moisture in the upper 0.90 m soil depth in full irrigation treatment (I_{100}) was consumed the plants were irrigated. Irrigation intervals ranged from 7 days in the initial stage to 4 days in the mid-season stage. Crops were irrigated 12 times throughout growing season. In each irrigation, about 51.5 mm water was applied to full irrigation treatment. The soil–water content measurements were taken gravimetrically one day before irrigation until harvest in three replications for all treatments. Plant and soil water measurements and observations were started 16 days after planting, and were terminated on the harvest date. The plots were irrigated with drip irrigation method. The PE drip lines with 16 mm diameter with in-line drippers at 0.20 m intervals. The average discharge of the drippers was 2 L h^{-1} at 1.0 bars of pressure with one drip line for each crop row.

Water use (*WU*) was calculated using the soil water balance method for the growing season. The equation can be written as (Doorenbos and Kassam, 1979)

$$WU = I + P - D \pm \Delta W$$

where *WU* is the water use (mm), *I* is the irrigation water applied (mm), *P* is the amount of precipitation (mm), *D* is the deep percolation (mm) and ΔW is the change in soil water storage (mm). Since the amount of irrigation water was only sufficient to bring the water deficit to field capacity, deep percolation was neglected. The soil water measurements with gravimetric sampling were done just before sowing, before each irrigation events and lastly at the harvest to determine soil water storage. Soil samples were taken at 0.30 m increments over 0.90 m depth at midway over a centrally located row of plants of every plot.

Water use efficiency (*WUE*) is defined as grain yield (*Y*, kg ha^{-1}) divided by the water use (*WU*, mm) during the growing season while irrigation water use efficiency (*IWUE*) is defined as the ratio of yield (*Y*, kg ha^{-1}) to the amount of irrigation water (*I*, mm) applied throughout the season:

$$WUE = Y/WU$$

$$IWUE = Y/I$$

The experiment was performed as a randomized complete block design (RCBD) with three replications. The crop was harvested on September 11, 2011. 1000 kernel weight, grain yield, grain number, sugar components, protein content, and some vegetative properties were evaluated. Analysis of variance (ANOVA) was used to evaluate the effects of different deficit irrigation treatments on the yield and yield components of corn genotypes and the Duncan's multiple range tests was used to compare the averages (Gomez and Gomez, 1984).

3. Results and discussion

Amount of irrigation water applied, water use, water use efficiency and irrigation water use efficiency data were given Table 4. A total of 128.6 mm of water was applied equally to all treatments between 01 and 26 June 2011 for germination. The first treatment irrigation was carried out on June 26, and the final application was done on September 9, 2011. Water use (*WU*) varied from 260 mm.0 to 737.1 mm for Ant-İ90 variety and 123.3 mm to 738.1 mm for Şafak variety among the different treatments. The amount of water applied to I_{100}, I_{75}, I_{50}, I_{25}, and I_0 treatments in 14 irrigations were 722.2 mm, 573.8 mm, 425.4 mm, 277.0 mm, and 128.6 mm, respectively. For Ant-İ90 variety, compared to I_{100} treatment, reductions in the yield were determined as 14%, 18%, 38% and 81% for I_{75}, I_{50}, I_{25} and I_0 treatments, respectively. Similar results were noted for Şafak variety. Since the rainfall received during the corn growing season (11 mm) was not significant, the crop water consumption