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Yield and quality of sweet corn under deficit irrigation

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ABSTRACT

The present study was conducted to determine the effects of different irrigation levels (I_{100}: full irrigation; I_{85}: 15% deficit; I_{70}: 30% deficit; I_{55}: 45% deficit and I_{40}: 60% deficit) on yield and yield components, sugar and protein content of fresh sweet corn during the years of 2011 and 2012. Experiments were carried out in a randomized complete-block design with three replications.

The lowest and the highest plant water consumptions (E_t) were found in I_{40} (240–406 mm) and I_{100} (348–504 mm) treatments in both years. Water deficit affected on maize fresh ear yields, yield components, quality and water use efficiencies. The lowest fresh ear yields (11515.7 and 10952.3 kg ha^{-1}) were determined in I_{40} treatments in both years, respectively. The highest fresh ear yields (14857.7 and 14712.7 kg ha^{-1}) were obtained from I_{100} treatments in 2011 and 2012 years, respectively.

Maize fresh ear yields were significantly affected by water deficits. Low irrigation levels decreased the ear yields. However, it was clearly observed that I_{70} treatment could be a water-saving treatment without a significant decrease in yield. In addition, the highest protein content and sugar amount was also observed in I_{70} treatment. I_{70} treatment seems to have lowest impact on yield and higher quality for sweet corn.

1. Introduction

Water stress affects crop growth and productivity in many ways. Most of the time, it has negative impacts on production, but crops have different and often complex mechanisms to react against water deficit. Several crops and genotypes develop different degrees of drought tolerance, drought resistance or compensatory growth to deal with such a stress period. The highest crop productivity is achieved for high-yielding varieties with optimal water supply and high soil fertility levels, but under conditions of limited water supply crops will adapt to water stress and can produce well with less water (FAO, 2002). In some cases, the deficit irrigation as an on farm strategy may provide water savings with little lost in yield at dry areas (Fereres and Soriano, 2006). Therefore, it is important to know the crop evapotranspiration and yield response to water deficit applied at different growth stages under cropping and irrigation conditions similar to the one experienced by farmers in practice (Rong, 2012).

The water use efficiency (*WUE*) has an important correlation between plant water use and dry matter accumulation (Bauer, 1966). Deficit irrigation practices are different than traditional water supply practices. The main objective of deficit irrigation is to increase the *WUE* of a crop by eliminating irrigations that have little impact on yield. The manager needs to know allowable level of transpiration deficiency without significant reduction in crop yields. The deficit irrigations yield reduction should be smaller than benefits gained from the saved water which could be normally for other crops under traditional irrigation practices (Kirda, 2010).

Evapotranspiration (ET_c), or crop water use is the water removed from the soil by evaporation from the soil surface and transpiration by the plant. Evaporation can account for 20–30% of growing season ET_c for corn. Transpiration is the last step in a continuous water pathway from the soil, into the plant roots, through the plant stems to leaf surfaces and into the atmosphere. Approximately 70–80% of crop water use is resulted from plant transpiration. The amount of daily corn water use varies with atmospheric conditions: air temperature, humidity, solar radiation and wind speed. Higher ET_c caused by high air temperatures, low humidity, clear skies and high wind speed, but lower ET_c will result from high humidity, clear skies and low wind speed (Kranz et al., 2008).

Water loss by evapotranspiration is very high during the growing season in the semi arid regions. Therefore, irrigation is needed during the growing season to maintain and enhanced crop growth, yield and quality (Yilmaz et al., 2010). Irrigation is an important factor influencing grain quality in cereals (Seleiman et al., 2011). Researches on corn revealed that 368 l water is needed to produce 1 kg of dry matter (House, 1985). The water supply has a significant effect in grain filling period (Ying, 2000; Adrienn and Janos,

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2012). Smaller grains and consequently decreased dry matter yields results from drought during grain filling period (Andrade et al., 2005).

The present study was conducted to determine the effects of different irrigation water deficits (I_{100}: full irrigation; I_{85}: 15% deficit; I_{70}: 30% deficit; I_{55}: 45% deficit and I_{40}: 60% deficit) on yield and yield components, sugar and protein content of fresh sweet corn in two vegetation seasons in Isparta, Turkey.

2. Materials and methods

2.1. Experimental site

The experiment was conducted during the growing seasons of 2011 and 2012 at the Experimental Station of the Faculty of Agriculture in Suleyman Demirel University, Isparta, Turkey. Isparta Province is located at a 37°45′ N latitude, 30°33′ E longitude and 1050 m altitude with semi-arid climate characteristics and total annual precipitation of 524.4 mm. In the study, Lumina F_1 hybrid sweet corn variety was used as the plant material.

2.2. Climatic data of the experimental area

Meteorological data for the growing seasons are provided in Table 1. The long-term annual mean temperature, relative humidity, total annual precipitation, wind speed and sunshine duration per day in the area were 12.4 °C, 55%, 524.4 mm, 2.4 m s^{-1} and 7.6 h, respectively. During the vegetative periods (from April to end of August) of the years 2011 and 2012, an average temperature of 18.5 and 19.2 °C, total precipitation of 162.4 and 214.1 mm and an average relative humidity of 56.2 and 50.8% were recorded, respectively. While, average temperature and relative humidity data of maize growing seasons were similar to long-term meteorological data, except two years precipitations were higher than long-term averages.

2.3. Soil structure

Soil at a depth of 60 cm was sampled before the experiment and subjected to a physicochemical analysis. Some physical and chemical characteristics of the experimental soils are provided in Table 2. The soil had 19.8 kg ha^{-1} NH_4^+ nitrogen, 22 kg ha^{-1} P_2O_5 potassium and 850 kg ha^{-1} K_2O levels. The soil was alkaline (pH: 7.9) and limy (1.3% $CaCO_3$).

2.4. Sowing and fertilization

Sowing was performed on 9th and 5th of May in 2011 and 2012, respectively. Row spacing was 70 cm and on-row plant spacing was 20 cm. Each plot had a size of 25.2 m^2 with 6 rows. Seeds were sown at 5–6 cm depths using a dibbler. Experiments were conducted in a randomized complete block design with three replicates.

Nitrogen, phosphorus and potassium fertilizers were applied to the rows at a rate of 200 kg ha^{-1}, 100 kg ha^{-1} and 100 kg ha^{-1} in the form of ammonium sulphate, P_2O_4 and KCl, respectively. The total quantity of phosphorus and potassium fertilizers was applied during the time of sowing. Nitrogen was applied in three equal amounts at the time of sowing, 10 cm seedling height and 35–40 cm height stages.

2.5. Irrigation

Irrigation water was supplied from a well using a pump. The water was classified as C_1S_1 with a sodium risk and a low electrical conductance (USSL, 1954). The 16 mm diameter lateral pipes carrying 2 L h^{-1} water had inline drippers with 33 cm spacing. Soil water contents were measured by the gravimetric method from the soil samples taken from soil depths with 30 cm increments in each plot at planting, before irrigations, and at the final harvesting date.

Experimental plots were irrigated by a sprinkler irrigation system at the beginning for a uniform plant establishment. Irrigation was carried out two times during this stage. After the emergence of maize seedlings, irrigations were performed by drip irrigation to irrigate a soil profile of 0–90 cm to field capacity. Subsequent irrigations were applied according to the prescribed irrigation rates with 7 day intervals. In present study, irrigation treatments were arranged according to five different deficit rates (K_n) of available soil water as follows:

1. $I_{100:}$ full irrigation and K_1: 1.00
2. I_{85}: 85% of full irrigation and K_2: 0.85
3. I_{70}: 70% of full irrigation and K_3: 0.70
4. I_{55}: 55% of full irrigation and K_4: 0. 55
5. I_{40}: 40% of full irrigation and K_5: 0.40

Amounts of irrigation water for treatments were computed by using Eq. (1).

$$I_r = W_{sd} \times K_n \quad (1)$$

where, I_r – the irrigation water (mm); W_{sd} – soil water deficit before the irrigation (mm); and K_n – the rate of water deficit.

The plant water consumption (E_t) was estimated using Eq. (2) (James, 1988):

$$E_t = I_r + P + C_r - D_p - R_f \pm \Delta_s \quad (2)$$

where E_t – plant water consumption (mm), I_r – irrigation water (mm), P – the precipitation (mm), C_r – the capillary rise (mm), D_p – the deep percolation losses (mm), R_f – the runoff losses (mm), and Δs – the moisture storage in soil profile (mm). D_p and R_f values were neglected because irrigation was done by drip irrigation and the water was applied for field capacity and its low doses. The problem of ground water in the area was not available. Therefore, C_r was ignored.

The irrigation water use efficiency (*IWUE*) and simple water use efficiency or plant water consumption efficiency (*WUE*) were calculated via Eqs. (3) and (4) (Howell et al., 1990; Ertek et al., 2006):

$$IWUE = \left(\frac{E_y}{I_r}\right) \times 100 \quad (3)$$

$$WUE = \left(\frac{E_y}{E_t}\right) \times 100 \quad (4)$$

where, *IWUE* – the irrigation water use efficiency (t ha^{-1} mm^{-1}), E_y – the marketable yield (t ha^{-1}), *WUE* – the water use efficiency (t ha^{-1} mm^{-1}).

Moreover, Eq. (5) was used to determine the contribution of different irrigation water levels on plant water consumption (Howell et al., 1990; Ertek et al., 2006):

$$I_{rc} = \left(\frac{I}{E_t}\right) \times 100 \quad (5)$$

where I_{rc} is the compensation rate of E_t by irrigation water applied (%).

Eq. (6) was used to determine yield-response factor (K_y) (Doorenbos and Kassam, 1979; Ertek et al., 2012).

$$\left(1 - \frac{Y}{Y_m}\right) = K_{yEt}\left(1 - \frac{E_t}{E_{tm}}\right) \quad (6)$$

where Y – the real yield (t ha^{-1}), Y_m – the maximum yield (t ha^{-1}), E_{tm} – the maximum plant water consumption (mm), K_{yEt} – the yield-response factor for E_t.