Effect of irrigation frequencies on yield characteristics of dent corn (*Zea mays indentata*) and water–yield relationships under semi-arid region

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Received : April 2003

ABSTRACT

The study was conducted to determine the best irrigation frequency and water–yield relationship for dent corn (*Zea mays L. indentata*) irrigated by furrow irrigation system under semi-arid conditions in 1998 and 1999 at Sanliurfa, Turkey. Water was applied to corn as 100% 90%, 80% and 70% of evaporation from Class A Pan corresponding to 2-, 4-, 6-, and 8-day irrigation frequencies, respectively. In both the years, maximum grain yield was observed at application of 10% deficit irrigation and 4-day irrigation frequency, while minimum yield was at application of 30% deficit irrigation and 8-day irrigation frequency. Total water-use efficiency (TWUE), irrigation water-use efficiency (IWUE) and crop response factor \( k_y \) values were determined. Yield characteristics were affected negatively by 30% deficit irrigation and 8-day irrigation frequency.

**Key words:** Corn, Deficit irrigation, Irrigation frequencies, Water saving

Irrigation is one of the important factors in agricultural practices. Optimal crop production is dependent on the time and amount of irrigation. Yildirim *et al.* (1996) studied the effects of sufficient and reduced soil moisture on grain yield and determined that the highest yield obtained was 10.85 tonnes/ha with sufficient irrigation and the lowest yield obtained was 3.47 tonnes/ha with reduced irrigation and crop response factor for total growing season was reported to be 0.97. It was also reported that the grain yield, in short-irrigation intervals, increased linearly with increasing amount of water applied and the highest total water-use efficacy (TWUE) at ET: ETo ratio of 0.7 was 1.9 kg/m³ (Lyle and Bordovsky, 1995). Oktem *et al.*, (2003) reported that deficit irrigation affected negatively yield of sweet corn and TWUE varied between 1.04 and 1.38, irrigation water-use efficacy (IWUE) ranged from 1.19 to 1.66, crop response factor from 0.76 to 1.29.

The objective of our research was to determine which irrigation treatment is the most efficient with furrow irrigation for corn in semi-arid region and determine water–yield relationships.

**MATERIALS AND METHODS**

The study was conducted during 1998 and 1999 at the Research Field of the Faculty of Agriculture, Harran University, Sanliurfa, Turkey. The research field is located in Harran Plain (Altitude: 465 m; 37°08’ north and 38°46’ east) where the climate varies form arid to semi-arid.

The research field soil was clay and contained high alkaline matter (pH 7.3 to 7.4), the organic matter in the surface of soil was 1.1% and was 0.8% at deeper parts of the soil. Field capacity of the soil was 32.7% on dry basis, the permanent wilting point was 21.18% and the volumetric weight of the soil was 1.37 g/cm³. During June, July and August for both treatment years, the temperatures were above 40°C, while the relative humidity was below 50%.

In this study, ‘Dracma dent’ hybrid corn variety was used. The experiment was laid out in randomized block design with 3 replicates. Each plot consisted of 4 rows in 5 length. The plants were grown 70 cm apart between the rows with 20 cm spacing in each rows. There were 5 m distances among each plots. Around each plots were terrace with soil for prevent to surface runoff.

The seeds were sown on 21 June 1998 [Day of Year (DOY): 172] in the first year and on 26 June 1999 (DOY: 177) in the second year. At sowint 80 kg/ha pure N, P, K (20-20-0 composite) was applied to each plots followed by 160 kg N/ha as urea when the plant reached to 30-40 cm height. When kernel humidity declined to 15%, ears of 2 rows in the centre of each plot were harvested manually on 27 October 1998 (DOY 300) and on 11 November 1999 (DOY 315). Analysis of variance (ANOVA) was conducted on the data and Least Significant Differene (LSD) tests were employed to determine differences.
among treatments using MSTATCTM statistical analysis software package.

**Irrigation treatments and methods**

First irrigation water was applied to all treatments using sprinkler during 1998 and 1999 to bring the soil water content in 0-90 cm soil depth up to the level of field capacity. Irrigation treatments were started using furrow irrigation system when the water content of soil decreased to 50% of available soil water. Irrigation treatments were started using furrow irrigation system when the water content of soil decreased to 50% of available soil water. Irrigation water was applied as 100% (IF2 treatment), 90% (IF4 treatment), 80% (IF6 treatment) and 70% (IF8 treatment) of evaporation from Class A Pan corresponding to 2-, 4-, 6- and 8-day irrigation frequencies, respectively. The amount of irrigation water required was calculated by Class A Pan evaporation everyday. Crop water consumption in the treatments was calculated by Equation 1.

\[
ET = P - R_f - D_p - \Delta S
\]  
where ET is crop water consumption (mm), P is rainfall (mm), I is irrigation water (mm), R is surface runoff (mm), \(D_p\) is deep percolation (mm), \(\Delta S\) is soil water content variation in crop root depth (mm).

The amount of irrigation water (I) was calculated using Equation 2 as:

\[
I = A \cdot E_p \cdot K_{cp} \cdot CAI
\]  
where I is amount of irrigation water (mm), A is plot area (m²), \(E_p\) is cumulative water depth from Class A Pan based on irrigation frequencies (mm), \(K_{cp}\) is crop pan coefficient and CAI is canopy area index which was assumed to be 1.0.

During the experiment the variation of soil water content at 0-30, 30-60 and 60-90 cm soil depth in each treatment plot was continuously determined by a gravimetric method. To determine water use-yield relationship, dimensionless parameters in relative yield reduction and relative water consumption were used.

\[
\left( \frac{Y_a}{Y_m} \right) = k_y \left( \frac{ET_a}{ET_m} \right)
\]  
where \(Y_a\) is actual yield tonnes/ha, \(Y_m\) is maximum yield tonnes/ha, \(1-(Y_a/Y_m)\) is relative yield, \(1-(Y_a/Y_m)\) is decrease in relative yield, \(ET_a\) is actual crop water consumption (mm), \(ET_m\) is maximum crop water consumption (mm), \(ET_a/ET_m\) is relative crop water consumption, \(1-(ET_a/ET_m)\) is decrease in relative crop water use, \(K_y\) is yield response factor defined as decrease in yield with respect to per unit decrease in ET.

**RESULTS AND DISCUSSION**

**Water-use relationships**

The maximum amount of water applied to the crop was 1,292 and 1,306 mm in IF2 treatment, while the minimum amount was 909 and 923 mm in IF8 treatment in 1998 and 1999 respectively (Table 1). Seasonal water consumption (\(ET_a\)) was found maximum 1,409 and 1,367 mm) in 2-day irrigation frequency (IF 2) in 1998 and 1999 respectively. Minimum \(ET_a\) was 1,103 and 1,017 mm in IF8 treatment in 1998 and 1999 respectively. Similar seasonal water use values were also reported by Gecoglan (1996) and Oktem et al. (2003).

Plants transpire less under high humidity conditions and more when the vapour pressure deficit of the air high since relative humidity is very low in the Harran Plain especially during summer time, the plants transpire more water for the one unit of dry-matter accumulation.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>(Y_a) (tonnes/ha)</th>
<th>(Y_d) (tonnes/ha)</th>
<th>(ET_a) (mm)</th>
<th>(ET_a/ET_m)</th>
<th>(1-Y_d/Y_m)</th>
<th>(1-ET_a/ET_m)</th>
<th>Irrigation water (l, mm)</th>
<th>Water saving (%)</th>
<th>(k_y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IF2</td>
<td>12.60</td>
<td>13.37</td>
<td>1,409</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1,292</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>IF4</td>
<td>13.80</td>
<td>12.64</td>
<td>1,301</td>
<td>0.92</td>
<td>0.92</td>
<td>0.08</td>
<td>1,171</td>
<td>9.4</td>
<td></td>
</tr>
<tr>
<td>IF6</td>
<td>12.32</td>
<td>12.27</td>
<td>1,247</td>
<td>0.89</td>
<td>0.82</td>
<td>0.11</td>
<td>1,027</td>
<td>20.5</td>
<td>0.73</td>
</tr>
<tr>
<td>IF8</td>
<td>10.83</td>
<td>11.30</td>
<td>1,103</td>
<td>0.78</td>
<td>0.85</td>
<td>0.22</td>
<td>909</td>
<td>29.6</td>
<td>0.68</td>
</tr>
<tr>
<td>1999</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IF2</td>
<td>11.11</td>
<td>11.66</td>
<td>1,367</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1,306</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>IF4</td>
<td>11.73</td>
<td>11.15</td>
<td>1,309</td>
<td>0.96</td>
<td>0.82</td>
<td>0.18</td>
<td>1,160</td>
<td>11.2</td>
<td></td>
</tr>
<tr>
<td>IF6</td>
<td>9.78</td>
<td>9.53</td>
<td>1,125</td>
<td>0.82</td>
<td>0.82</td>
<td>0.18</td>
<td>1,041</td>
<td>20.3</td>
<td>1.00</td>
</tr>
<tr>
<td>IF8</td>
<td>8.32</td>
<td>8.58</td>
<td>1,017</td>
<td>0.74</td>
<td>0.74</td>
<td>0.26</td>
<td>923</td>
<td>29.3</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Details of characters are given in Materials and Methods
Table 2. Grain yield values, LDS groups, total water-use efficiency (TWUE) and irrigation water-use efficiency (IWUE) values for corn irrigated by furrow irrigation system

<table>
<thead>
<tr>
<th>Irrigation treatment</th>
<th>Grain yield (tonnes/ha)</th>
<th>TWUE (kg/m³)</th>
<th>IWUE (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF2</td>
<td>12.60ab†</td>
<td>11.11 ab</td>
<td>11.85 b</td>
</tr>
<tr>
<td>IF4</td>
<td>13.80a</td>
<td>11.73 a</td>
<td>12.77 a</td>
</tr>
<tr>
<td>IF6</td>
<td>12.32b</td>
<td>9.78 bc</td>
<td>11.05 c</td>
</tr>
<tr>
<td>IF8</td>
<td>10.83~</td>
<td>8.32 c</td>
<td>9.59 d</td>
</tr>
<tr>
<td>LSD</td>
<td>1.252</td>
<td>1.555</td>
<td>0.6522</td>
</tr>
</tbody>
</table>

*** P<0.05; **P<0.01
Grain yield values calculated at 15% grain moisture†There is no statistical difference among same letter at 0.5 level according LSD test

Moreover, some other factors such as ground cover percentage and low leaf-area index in early growing stages accelerate water loss from soil via evaporation.

Grain yield was affected significantly (P<0.01) by the irrigation treatments in both the years. Maximum yield was found to be 13.80 and 11.73 tonnes/ha in IF4 treatment group, in which the water saving rate was 9.4 and 11.2% in 1998 and 1999 respectively. The lowest grain yield was found under IF8 treatment in both years since low humidity and high air temperature cause plant to close, resulting in less assimilation due to a decrease CO₂ uptake for photosynthesis.

Decrease ratio in relative yield was 8.7% and 5.3% in IF2 treatment group compared to IF4 treatment in 1998 and 1999 respectively. The rate of decrease in yield was not accordingly with the decrease in water applied per unit. Our results confirm those of Oktem et al. (2003). Increased water deficits resulted in a decrease in crop yield. The rates of water saving were increased at IF6 and IF8 treatment groups in both years (Table 1).

Tassel and ear flowering and milky stage are critical periods for yield in corn. Hot and dry climate and also drought during this period resulted in a yield reduction. In this study, plants were exposed to water stress during these periods at the 6- and 8-day irrigation frequency.

Second order polynomial relationship was found between the amount of water applied (I) and grain yield (Yₐ) in both years from the regression analysis as seen in Fig. 1. In this study, intensive root length, the longest root length, main root number and root weight were investigated but irrigations treatments did not affect these root traits significantly. The highest root diameter (0.45mm), the longest root length (49.0 cm) and the highest root weight value (25.48 g) were determined at IF4 treatment (Fig. 2.). Intensive root length increased with increasing water deficit. The water deficit increased the root length and root weight (Eghball and Maranville, 1993).

Crop roots take up nutrients and the water from upper parts of the soil under the conditions of low water stress or non-stress. When the water stress is experienced by the crops, their roots penetrate deep in the soil to withdraw water and crop nutrients (Rhoads and Bennett, 1990). The
Irrigation treatments

Fig. 2. Effect of irrigation treatments on average intensive root length (cm) (IRL); longest root length (cm) (LRL); main root number, (MRN) root weigh (g) (RW) and grain yield (tonnes/ha\(^{-1}\)) (GY).

rate of having benefit from the nutrients for the crops is high if the roots penetrate in the soil. Therefore, better aeration in the root zone, better utilization of nutrients and efficient use of soil water by the crops might cause increased yield in IF4 treatment compared to IF2 treatment.

**Crop response factor (k\(_y\))**

Crop response factor was determined 0.73 (IF6 treatment) and 0.68 (IF8 treatment) in 1998 and the values were 1.00 (IF6 and IF8 treatment) in 1999 (Table 1). Less ET\(_a\) resulted in maximum yield under IF4 treatment in both years (13.80 and 11.73 tonnes/ha). In the previous studies, k\(_y\) value of 0.97 (Yildirim et al. 1996) and 0.76 (Oktem et al., 2003) have been reported.

**Water-use efficiencies**

The TWUE and IWUE were different, based on the treatments and years (Table 2). The TWUE were 0.89, 1.06, 0.99 and 0.98 kg/m\(^3\) for the treatments IF2, IF4, IF6 and IF8, respectively, in 1998 and 0.81, 0.90, 0.87 and 0.82 kg/m\(^3\), respectively, in 1999. Similar values were reported by Oktem et al. (2003).

The TWUE increased with the increase in the amount of irrigation water except IF8 treatment in both years. The IWUE values were 0.98 to 1.20 kg/m\(^3\) in 1998 and 0.85 to 1.01 kg/m\(^3\) in 1999. Gencoglan (1996) reported TWUE values between 1.02 and 2.43 kg/m\(^3\) and TWUE values 0.22 and 1.25 kg/m\(^3\).

**Yield characteristics**

The effects of irrigation treatments on plant height, kernels/ear and kernel weight/ear were significant (P<0.05). Irrigation treatments were significantly affected the ear length in 1998 (P<0.01) and significant in 1999 (P<0.05).

The highest plant height was under at IF2 treatment in both years (198.0 and 196.9 cm), whereas the lowest values under IF8 treatment (179.6 and 178.3 cm). Increased water deficit and longer irrigation frequencies shortened the plant height. Sammis et al., (1988) reported that plant height can be changed at different levels of water deficit and plant height was a good indicator for determining the water stress.

Ear length was 19.80–23.23 cm in 1998 and 19.87–22.67 cm in 1999 (Table 3.) The shortest ears were recorded under IF8 treatment, while the longest ears under IF4 treatment.

Ear length decreased with increased water deficit. This result confirm the findings of Gencoglan (1996). Kernels/ear varied from 658.2 (IF2) to 585.6 in 1998, from 670.3 (IF4) to 593.9 (IF8) in 1999. Kernels/ear decreased with increasing water deficit and getting longer irrigation frequency. Gencoglan (1996) also reported similar findings. Kernel weight/ear changed from 232.7 g (IF4) to 173.0 g (IF8) in 1998, from 217.8 g (IF4) to 182.0 g (IF8) in 1999. Eck (1986) stated that water deficit at vegetative period affects negatively kernels/ear and water deficit at grain-filling period results in less kernel weight/ear.

Thus grain yield was the highest at IF4 treatment (water was applied as 90% of evaporation of Class A Pan in 4-day irrigation frequency) with furrow irrigation in semiarid region. Water saving was 9.4% and 11.2% in IF4 treatment compared to IF2 treatment in both the years. The rate of the decrease in relative yield was 21.30% and 29.07% at IF8 treatment in 1998 and 1999 respectively. Yield characteristics were affected negatively by increased water deficit and longer irrigation frequencies.

**REFERENCES**

Eck, H.V. 1986. Effects of water deficits on yield. Yields components and water use efficiency of irrigated corn. *Agronomy*
Table 3. Effect of irrigation treatments of plant height, ear length, ear diameter, kernels/ear, 1,000-kernel weight and kernel weight/ear in corn

<table>
<thead>
<tr>
<th>Irrigation</th>
<th>Plant height (cm)</th>
<th>Ear length (cm)</th>
<th>Kernels/ear</th>
<th>kernel weight/ear (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF2</td>
<td>198.0 a</td>
<td>196.9 a</td>
<td>196.4 a</td>
<td>22.57 a</td>
</tr>
<tr>
<td>IF4</td>
<td>195.2 a</td>
<td>195.9 ab</td>
<td>195.5 a</td>
<td>23.23 a</td>
</tr>
<tr>
<td>IF6</td>
<td>185.7 b</td>
<td>189.1 b</td>
<td>187.4 b</td>
<td>21.50 b</td>
</tr>
<tr>
<td>IF8</td>
<td>179.6 b</td>
<td>178.3 c</td>
<td>179.0 c</td>
<td>19.80 e</td>
</tr>
<tr>
<td>LSD</td>
<td>7.014</td>
<td>7.183</td>
<td>2.829</td>
<td>0.902</td>
</tr>
</tbody>
</table>

*P=0.05; **P=0.01

There is no statistical differences among same letter at 0.05 level according LSD test.

Journal 78: 1,035–1,040.


