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# Optimum lateral spacing for drip-irrigated corn in the Mediterranean Region of Turkey

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ABSTRACT

This study was carried out to determine the effects of different lateral spacings, and the full and deficit irrigation on yield and yield components of maize under the Mediterranean climatic conditions in Adana, Turkey. Experimental site was located at the Research Field of the Agricultural Structures and Irrigation Department (altitude 20 m above sea level, 36°59′N and 35°18′E) on a clay textured soil. Pioneer 3394 hybrid corn variety was used in this study.

Irrigation treatments consisted of three different lateral spacings ($A_1$: 0.70 m, $A_2$: 1.40 m, and $A_3$: 2.10 m) and two different water amounts ($I_{100}$, $I_{67}$). In the $I_{100}$ treatment, soil water deficit in the 90 cm soil profile depth was replenished to field capacity. For deficit irrigation treatment $I_{67}$, 33% less water was applied as compared to $I_{100}$ treatment plots. A 7-day irrigation interval was used in the study. The highest seasonal water use (ET) was determined in the $A_1I_{100}$ treatment as 758 mm; and the lowest ET was found in the plant row 1.05 m away from the drip lateral in the treatment $A_3I_{67}$ (569 mm). Lateral spacings and irrigation levels resulted in significantly different yields. The highest grain yield was obtained in $A_2I_{100}$ treatment with 9790 kg ha$^{-1}$, and the lowest yield was found in the plant row 1.05 m away from the drip lateral in $A_3I_{67}$ treatment with 6180 kg ha$^{-1}$. Yield from the 1.4 m spacing with full irrigation treatment ($A_2I_{100}$) was significantly higher than in the other two spacings. According to the research results, optimum lateral spacing for corn plant was found to be 1.4 m.

Significant second degree polinomial relationships between corn grain yield (Y) versus irrigation water (I) and water use (ET) were found as $Y = -0.0037I^2 + 5.835I - 1397.7$ ($R^2 = 0.62^{**}$) and $Y = -0.0039\mathrm{ET}^2 + 5.926\mathrm{ET} - 1365.1$ ($R^2 = 0.54^{*}$), respectively. The highest water use efficiency (WUE) was found in $A_2I_{100}$ (1.40 kg m$^{-3}$) and the lowest one was found in the plant row 1.05 m away from the drip lateral in $A_3I_{67}$ (1.09 kg m$^{-3}$). Thus a lateral spacing of 1.4 m (one drip lateral per two crop rows) was recommended for drip-irrigated corn in the Mediterranean Region under those specific conditions.



## 1. Introduction

The world's water resources are finite. Everyone benefits from their efficient use, both economically and environmentally. Irrigation is today the primary consumer of fresh water on earth (Shiklomanov, 1998) but the twin drivers of human population and development exert pressure on our water resources management regimes to be more productive with less water. To solve totally, or to reduce the severity of water scarcity, water management must improve. Thus, agriculture has the greatest potential for solving the problem of global water scarcity (Longo and Spears, 2003).

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Drip irrigation has been used for agricultural production for about the past 35 years. Drip irrigation has advantages over more traditional practices such as surface and sprinkler irrigation due to reduced labor requirements and its ability to conform to irregularly shaped fields. It is also much more efficient than sprinkler or surface irrigation (Camp, 1998). The reasons for the growing popularity of drip irrigation are several. Drip irrigation offers improved yields, requires less water, decreases the cost of tillage, and reduces the amount of fertilizer and other chemicals to be applied to the crop. Because drip irrigation makes it possible to place water precisely where it is needed and to apply it with a high degree of uniformity at very low flow rates, it lessens both surface runoff and deep percolation. These features make drip irrigation potentially much more efficient than other irrigation methods, which can translate to significant water savings (Hanson et al., 1994).

Since the initial installation costs for drip irrigation are high, it has not been considered a viable economic option for field row crops, such as corn. However, increasing the spacing of dripline laterals would be one of the most significant factors in reducing the high overall investment costs of drip irrigation (Lamm et al., 1997).

Lamm et al. (1997) carried out a 2-year study on a Keith silt-loam soil in northwest Kansas to determine the optimum dripline lateral spacing for irrigated corn using subsurface driplines installed at a depth of 40–45 cm in a direction parallel to the corn rows. Average corn yields were 13.6, 12.8, and 12.2 Mg ha$^{-1}$ for dripline spacings of 1.5, 2.3, and 3.0 m, respectively for a seasonal-irrigation amount of 462 mm. Yields decreased to 10.8 and 9.3 Mg ha$^{-1}$ when irrigation was reduced by 33 and 50% for the wider 2.3 and 3.0 m dripline spacings, respectively. The highest yield, highest water use efficiency, and lowest year-to-year variation was obtained by the 1.5 m dripline spacing.

Spurgeon and Manges (1990) reported no significant differences in corn yields among spacing treatments ranging from 0.75 to 3.0 m in a wet season (1989) at Garden City, Kansas. However, there was a 1.3–3.8 Mg ha$^{-1}$ range in yields 1990 and 1991, respectively (Spurgeon and Makens, 1991). The driplines in this study were perpendicular to the corn rows. As a result, a corn plant could be as much as 1.5 m from a drip line for the 3.0 m dripline spacing.

Kruse and Israeli (1987) examined subsurface drip irrigation using a 1.5 m dripline spacing for corn production in Colorado. They found considerable yield variation with distance from the dripline, and they concluded that it was important to center driplines between corn rows to assure good production.

Howell et al. (1997) compared the effect of irrigation frequencies of 1 and 7-day for corn on Pullman silt-loam soil in Bushland, TX, and concluded that there were no significant differences in corn grain yields between the irrigation frequencies under the full irrigation.

Corn is one of the most important crops in the Mediterranean Region in Turkey. Common irrigation methods used for corn production in this region are wild flooding, furrow and sprinkler irrigation. In general, the farmers overirrigate, resulting in high water losses and low irrigation efficiencies, thus creating drainage and salinity problems (Yazar et al., 2002).

The objectives of this study were to determine the effects of different lateral spacings, and the full and deficit irrigation on yield and yield components of maize under the Mediterranean climatic conditions of Turkey.

## 2. Materials and methods

The experiment was conducted in the experimental field of the Irrigation and Agricultural Structures Department of the Cukurova University in Adana, Turkey during 2003 corn-growing season. The station has the latitude of 36°59′N, the longitude of 35°18′E, and is at 20 m above mean sea level. The soil of the experimental site is clay textured throughout the profile. The water holding capacity of the soil is 156 mm in the 90 cm profile. Some physical and chemical properties of the soil are given in Tables 1 and 2. Soil pH values ranged from 7.62 to 7.78, electrical conductivitiy of the saturation paste (ECe) varied between 0.11 and 1.13 dS m$^{-1}$, volumetric soil water contents at the field capacity (0.1 bar) and permanent wilting point (15 bar) of the root zone are 40–41 and 19–24%, respectively. Mean bulk density varies from 1.15 to 1.25 g cm$^{-3}$.

The drip irrigation system consisted of a control unit and distribution lines. The control unit of the system contained a diskfilter, control valves, pressure gauges and a water flow meter. Distribution lines consisted of polyethelene pipe manifolds (supply and discharge) for each plot. Drip laterals of 16 mm in diameter had in-line emitters spaced 0.35 m apart, each delivering 4 l h$^{-1}$ at the pressure of 100 kPa. Each manifold had removable end caps for flushing.

Commercial farm equipment was used for agronomic practices. The experimental field was planted with a four-row planting machine at 70 cm row spacing. Pioneer-3394 hybrid corn variety was planted on 24 June 2003 following the harvest of wheat.

**Table 1 – Physical properties of different soil layers of the experimental field**

| Soil depth | Particle size distribution (%) | | | Texture class | FC* (cm$^3$ cm$^{-3}$) | WP* (cm$^3$ cm$^{-3}$) | SP* (cm$^3$ cm$^{-3}$) | BD* (g cm$^{-3}$) |
|---|---|---|---|---|---|---|---|---|
| | Sand | Silt | Clay | | | | | |
| 0–30 | 28 | 21 | 51 | C | 40 | 24 | 51 | 1.19 |
| 30–60 | 28 | 19 | 53 | C | 40 | 23 | 54 | 1.16 |
| 60–90 | 28 | 18 | 54 | C | 41 | 22 | 55 | 1.15 |
| 90–120 | 27 | 19 | 54 | C | 41 | 19 | 50 | 1.25 |

FC, field capacity; WP, permanent wilting point; SP, saturation point; BD, bulk density.

**Table 2 – Chemical properties of different soil layers of the experimental field**

| Soil depth (cm) | ECe* (dS $m^{-1}$) | pH | $CaCO_3$ (%) | OM* (%) | Cations (me $l^{-1}$) | | | | Anions (me $l^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $Ca^{++}$ | $Mg^{++}$ | $Na^{+}$ | $K^{+}$ | $HCO_3^{-}$ | $SO_4^{-2}$ | $Cl^{-}$ |
| 0–30 | 1.13 | 7.68 | 5.99 | 1.23 | 1.62 | 0.53 | 0.63 | 0.10 | 1.79 | 0.40 | 0.62 |
| 30–60 | 0.17 | 7.62 | 6.38 | 0.98 | 1.79 | 0.74 | 0.70 | 0.07 | 1.50 | 1.17 | 0.59 |
| 60–90 | 0.12 | 7.75 | 6.65 | – | 2.71 | 0.85 | 0.74 | 0.05 | 1.53 | 1.93 | 0.69 |
| 90–120 | 0.11 | 7.78 | 7.40 | – | 2.78 | 0.84 | 0.76 | 0.04 | 1.50 | 2.17 | 0.71 |

OM, organic matter; ECe, electrical conductivity of the saturation paste.

Fertilizer applications were based on soil analysis results and all the plots received the same amount of total fertilizer. A compound fertilizer (15-15-15) was applied at the rate of 445 kg $ha^{-1}$ at planting. On July 22, all plots received 154 kg N $ha^{-1}$ in the form of urea, which was applied in banding along the rows and then incorporated into the soil.

The experimental design was a factorial randomized block with three replications. Irrigation management treatments consist of three different lateral spacings ($A_1$: 0.70 m, $A_2$: 1.40 m, $A_3$: 2.10 m) and two different water amounts ($I_{100}$, $I_{67}$). In $A_1$, one drip lateral was laid out at the center of two adjacent crop rows; in $A_2$, one lateral at the center of alternative rows; and in $A_3$, one drip lateral served three crop rows (Fig. 1). The amount of irrigation water applied to treatment of $I_{100}$ was estimated as the quantity equal to replenishing the soil moisture deficit to field capacity in the 90 cm soil profile depth. For deficit irrigation treatment $I_{67}$, 33% less water was applied as compared to $I_{100}$ treatment plots. A 7-day irrigation interval was used in the study. Three uniform rate applications varying from 42 to 79 mm were carried out during the plant establishment period. Differentiated irrigations were started on 15 July, and ended on 9 September 2003. A total of nine applications were made and treatments received irrigation water depths varying from 51 to 72 mm in full irrigation plots; and 35 to 60 mm in deficit irrigation treatment plots. Irrigation set times were estimated using the following equation:

$$T = A\frac{d}{q}$$

where $T$ is irrigation duration (h); $A$ the area served by a single emitter ($m^2$); $d$ the irrigation depth (mm); and $q$ is the emitter flow rate (l $h^{-1}$). Irrigation set times varied from 3.1 to 4.4 h in $A_1$, 6.2 to 8.8 h in $A_2$, and 9.3 to 13.2 h in $A_3$ plots.

The soil water content measurements were made 1 day before irrigations until harvest for all treatments by soil sampling in 0–30 cm, and using a neutron probe (Campbell Pacific model 503 DR Hydroprobe) at 30 cm depth increments over 120 cm depth with 15-s counts. The neutron access tubes were placed in the plant rows at two distances from the drip laterals (0.35 and 1.05 m). The probe was field calibrated for the experimental soil. In addition, tensiometers were installed at two different depths (0.30 and 0.60 m) and two distances from the drip laterals (0.35 and 1.05 m) in $A_3$ treatment for monitoring the soil matric potential. The plot dimensions were 8 m by 5.6 m (eight plant rows). A layout of the experimental plots, tensiometers and access tube locations is shown in Fig. 1.

Plant and soil water measurements and observations were started 21 days after planting, and were terminated on the harvest date. In order to determine total dry matter above the ground level, all plants within 0.5 m of a row section in each plot were cut at the ground level at 14-day intervals until harvest. All plant samples were dried at 65 °C until constant weight was achieved.

Grain yield was determined by hand harvesting the 8 m sections of three adjacent center rows in each plot on 8 October 2003 and was adjusted to 15.5% water content. In $A_3$ treatment plots, the grain yields of individual rows were determined in order to evaluate the yield uniformity among the rows. In addition, 1000-seed weight, grain yield per cob, grain number per cob, and harvest index values were also evaluated.

Crop water use (ET) was estimated based on a one-dimensional water balance equation using soil water mea-

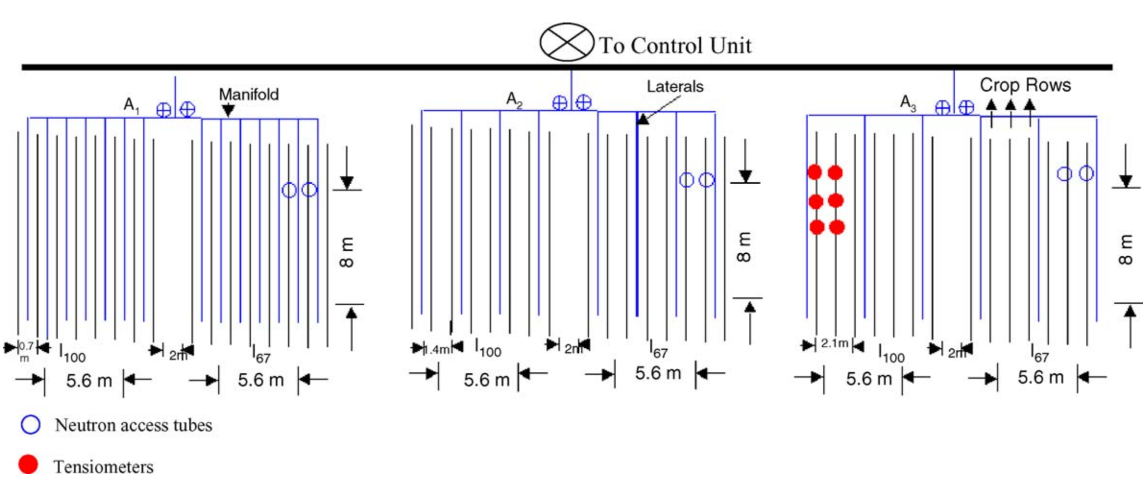


**Fig. 1 – Layout of the experimental plots, and location of tensiometers and neutron access tubes (one replication).**

sured by the neutron and gravimetric sampling methods. Water use was the total of seasonal water depletion (planting to harvest) plus rainfall and irrigations during the same period. The water balance equation is as follows:

$$ET = I + P \pm \Delta S - D \quad (1)$$

where ET is evapotranspiration (mm), $I$ the irrigation (mm), $P$ the precipitation (mm), $D$ the deep percolation (i.e., drainage, mm) and $\Delta S$ is change of soil water storage in a given time period $\Delta t$ (days) within plant rooting zone. Deep percolation losses below the root zone were assumed to be negligible in the study. However, percolation losses might occur in the $A_3I_{100}$ plots, where plants evidently suffered water stress in spite of the correct water amounts applied.

Water use efficiency (WUE) was computed as the ratio of corn grain yield to seasonal water use. Irrigation water use efficiency (IWUE) was determined as the ratio of corn grain yield for a particular treatment to the applied water for that treatment (Howell et al., 1995).

MSTATC program (Michigan State University) was used to carry out statistical analysis. Treatment means were compared using Duncan's Multiple Range Test (Steel and Torrie, 1980).

## 3. Results and discussion

The 2003 corn-growing season climatic conditions were typical of those that prevail in the Eastern Mediterranean Region of Turkey. Table 3 summarizes the monthly climate data compared with the long term mean climatic data, where the experiment was carried out. During the experimental season, rainfalls received (17 mm) were less than the long term mean rainfall (51 mm).

The seasonal amount of irrigation water applied, water use, biomass and grain yield, 1000-grain weight, water use efficiency and irrigation water use efficiency, and harvest index data are given in Table 4. Variance analysis of ET and grain yield are given in Tables 5 and 6, respectively.

**Table 3 – Historical mean monthly and growing season climatic data of the experimental area**

| Years | Climatic parameters | June | July | August | September | October |
|---|---|---|---|---|---|---|
| Long-term means 1929-99 | Average tempature (°C) | 25.9 | 28.3 | 28.8 | 26.2 | 21.9 |
| | Relative humidity (%) | 66.6 | 71.9 | 71.2 | 65.2 | 61.3 |
| | Wind speed (m $s^{-1}$) | 2.4 | 2.6 | 2.4 | 2 | 1.6 |
| | Rainfall (mm) | 16.7 | 9.4 | 7.5 | 17.2 | 38.2 |
| | Evaporation (mm) | 210.1 | 243.4 | 224.6 | 181.0 | 120.8 |
| Growing season 2003 | Average tempature (°C) | 26.5 | 28.7 | 29.3 | 25.8 | 22.4 |
| | Relative humidity (%) | 70.8 | 74.7 | 75.9 | 65.8 | 66.9 |
| | Wind speed (m $s^{-1}$) | 1.2 | 1.0 | 0.3 | 0.8 | 0.8 |
| | Rainfall (mm) | 6.7 | 1.0 | 0.0 | 9.3 | 17 |
| | Evaporation (mm) | 214.3 | 239.9 | 222.4 | 160 | 109.3 |

**Table 4 – Corn grain yield, seasonal irrigation, water use and water use efficiency and harvest index data**

| Treatments | Dry matter yield (kg $ha^{-1}$) | Corn grain yield (kg $ha^{-1}$) | Seasonal irrigation (mm) | Water use (mm) | Water use efficiency (kg $m^{-3}$) | Irrigation water use efficiency (kg $m^{-3}$) | Harvest index |
|---|---|---|---|---|---|---|---|
| $A_1I_{100}$ | 31435 | 8566 | 756 | 758 | 1.13 | 1.13 | 0.27 |
| $A_1I_{67}$ | 27156 | 7553 | 600 | 615 | 1.23 | 1.26 | 0.28 |
| $A_2I_{100}$ | 26502 | 9790 | 713 | 701 | 1.40 | 1.37 | 0.37 |
| $A_2I_{67}$ | 27139 | 7974 | 567 | 573 | 1.39 | 1.41 | 0.29 |
| $A_3I_{100L}$ | 30233 | 8986 | 716 | 720 | 1.25 | 1.26 | 0.30 |
| $A_3I_{100}$ | 24419 | 8850 | 716 | 705 | 1.26 | 1.24 | 0.36 |
| $A_3I_{67L}$ | 27214 | 7250 | 550 | 592 | 1.22 | 1.32 | 0.27 |
| $A_3I_{67}$ | 22169 | 6180 | 550 | 569 | 1.09 | 1.12 | 0.28 |

**Table 5 – Variance analysis of water use data**

| Variation source | Degrees of freedom | Mean square | F-value | Probability |
|---|---|---|---|---|
| $A$ (Lateral spacings) | 2 | 4764.667 | 5.204 | 0.028* |
| $I$ (Irrigation levels) | 1 | 90312.500 | 98.634 | 0.000** |
| Replications | 2 | 231.167 | 0.252 | 0.782 |
| $AI$ | 2 | 494.000 | 0.540 | 0.599 |
| Error | 10 | 915.633 | | |
| Total | 18 | | | |

* Significant at 5% level.
** Significant at 1% level.

**Table 6 – Variance analysis of corn grain yield data**

| Variation source | Degrees of freedom | Mean square | F-value | Probability |
|---|---|---|---|---|
| A (Lateral spacings) | 2 | 14172.134 | 4.354 | 0.044* |
| I (Irrigation levels) | 1 | 108888.889 | 33.453 | 0.000** |
| Replications | 2 | 318.037 | 0.098 | 0.908 |
| AI | 2 | 3305.361 | 1.015 | 0.397 |
| Error | 10 | 3254.964 | | |
| Total | 18 | | | |

* Significant at 5% level.
** Significant at 1% level.

Treatments received irrigation water varying from a low of 550 mm in deficit irrigation plots ($A_3I_{67}$) to a high of 756 mm in non-stress plots ($A_1I_{100}$) during the season.

The highest water use was observed in treatment $A_1I_{100}$ (758 mm), and the lowest was found in the plant row 105 cm away from the drip lateral in the treatment $A_3I_{67}$ (569 mm). Water use in corn rows close to lateral (35 cm) in $A_3I_{67}$ was estimated to be 592 mm. Seasonal water use values in treatmets $A_2I_{100}$ and $A_2I_{67}$ were found to be 701 and 573 mm, respectively. There were slight differences in water use among the deficit irrigation treatments. The differences can be attributed to soil water measurement errors under the spatially variable soil water conditions under the drip irrigation. Since the rainfall received during the corn-growing season was not significant, the crop water consumption practically depended only on the amount of the irrigation water supplied to the plots. Variation of cumulative water use of the corn crop during the growing season with respect to the treatments is shown in Fig. 2. As indicated on Fig. 2, water use values in the treatments $A_3$, in which one drip lateral served three crop rows, were evaluated according to the row distance from the lateral because of the spatial variability of soil water content with drip irrigation. Crop water use in the rows next to the lateral was higher for full irigation level ($A_3I_{100}$) than deficit irrigation plots ($A_3I_{67}$). In addition, water use in the rows next to the lateral in the treatment $A_3I_{67L}$ was higher than the water use at distant rows (1.05 m from the lateral). This result indicated that one lateral per three rows is not suitable for corn production under the study conditions since insufficient irrigation water is supplied to crops 1.05 m away from the drip lateral. Variance analysis of the seasonal water use data

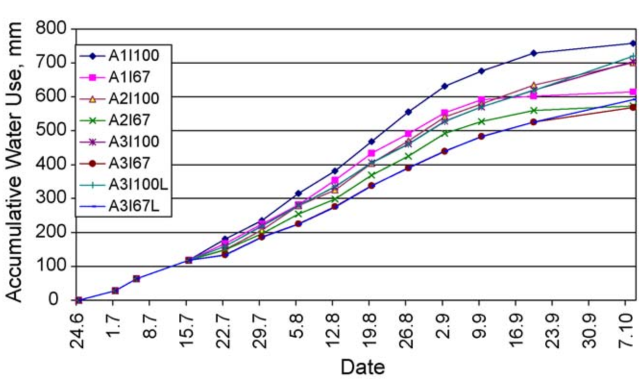


**Fig. 2 – Evolution of accumulative water use (ET) in time in the different treatments.**

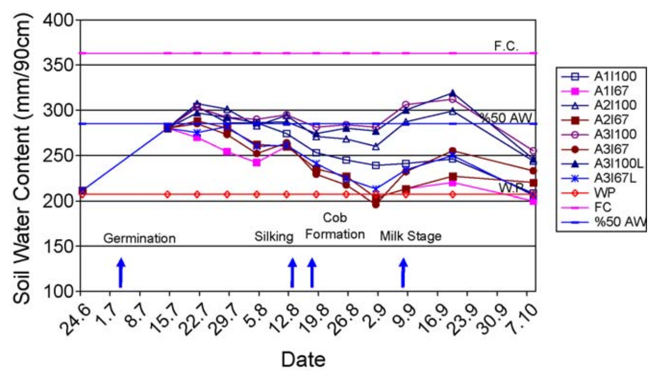


**Fig. 3 – Variation of soil water content in the 90 cm profile prior to irrigation under the different treatments.**

revealed that lateral spacings and irrigation levels resulted in significantly different water use. In the deficit irrigation treatment plots ($I_{67}$), degree of the water stress gradually increased towards the end of the growing season and resulted in reduced crop yields.

Soil water content measurements in the treatment plots were carried out throughout the growing season at weekly intervals. Variation of soil water contents in the 90 cm profile depth prior to irrigations in the different treatments are shown in Fig. 3. As shown in the Fig. 3, water contents in all the plots remained between field capacity and wilting point. Profile soil water contents in the treatments $A_3I_{100}$ and $A_2I_{100}$ remained higher than in the other treatments. In deficit irrigation treatments, water contents gradually decreased but still remained above the wilting point throughout the study period. In the treatment $A_1I_{100}$, soil water contents resulted in between the other full irrigation treatments ($A_3I_{100}$ and $A_2I_{100}$) and deficit irrigation plots. Corn is most susceptible to water stress during the period covering tasseling through the milk stage. As shown in Fig. 3, soil water contents in the $I_{67}$ treatment plots during the abovementioned period were below the 30% of the available water in the crop root zone depth. Thus, water stress in deficit irrigation treatments resulted in lower yields as compared to the full irrigation treatment.

Soil water potential at different depths (30, 45 and 60 cm) and at two distances from the drip lateral (0.35 and 1.05 m) in the $A_3I_{100}$ and $A_3I_{67}$ treatment plots were measured with tensiometers throughout the growing season. Variation of soil water potentials in the $A_3I_{67L}$, $A_3I_{100L}$, $A_3I_{100}$ plots are shown in

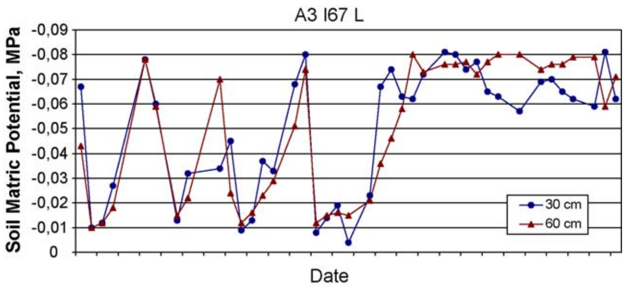


**Fig. 4 – Variations in time of soil matric potential in different depths prior to irrigation ($A_3I_{67L}$).**

Figs. 4–6, respectively. *L* symbol denotes the distance close to drip lateral (0.35 m). A clear response to irrigation also occurred at the 60 cm with values decreasing to less than 0.01 MPa. Soil water content measurements at 120 cm depth with neutron meter indicated increase in water contents between two consecutive readings in the $A_3I_{100L}$. Thus, indicating some deep percolation occurred below the root zone depth in the treatment $A_3I_{100L}$. In the $A_3I_{100L}$ and $A_3I_{67L}$ treatment plots, soil matric potentials in the crop rows next to laterals for the 45 and 60 cm depths followed very similar trend throughout the growing season. Tensiometer readings were much higher (more negative), even close to the limit of the tensiometer, in the late season than the early and mid-season.

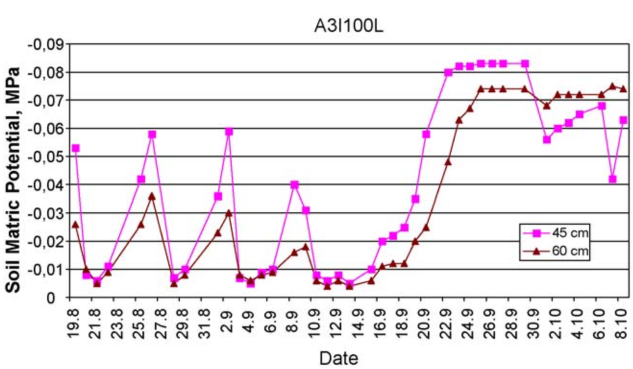


**Fig. 5 – Variations in time of soil matric potential in different depths prior to irrigation ($A_3I_{100L}$).**

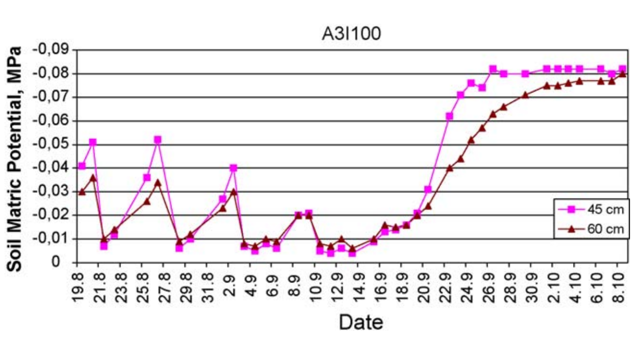


**Fig. 6 – Variations in time of soil matric potential in different depths prior to irrigation ($A_3I_{100}$).**

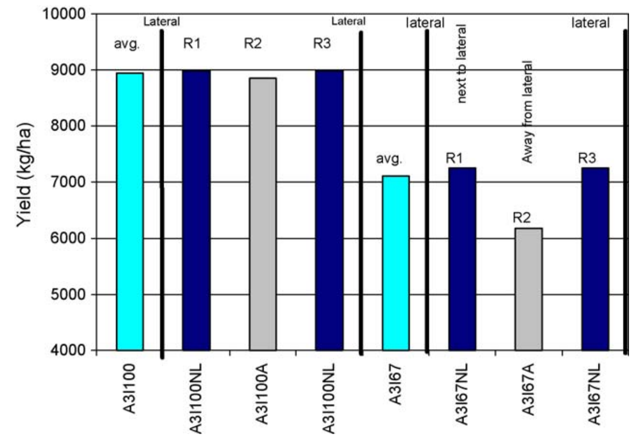


**Fig. 7 – Yield variation with the distance from the lateral in $A_3I_{100}$ and $A_3I_{67}$ treatments (individual rows: *R*1, *R*2, *R*3).**

Grain yields varied from 6180 to 9790 kg ha$^{-1}$ among the treatments. The highest average grain yield was observed in $A_2I_{100}$ treatment as 9790 kg ha$^{-1}$, and the lowest yields was found in the plant row 1.05 m away from the drip lateral in $A_3I_{67}$ treatment as 6180 kg ha$^{-1}$. According to research results, optimum lateral spacing for corn plant was found to be 1.4 m. Yield from the wider ($A_3$ = 2.1 m) dripline spacing with full irrigation ($A_3I_{100L}$ and $A_3I_{100}$) was 8.2 and 9.6% lower, respectively, than the yield from the suggested dripline spacing (1.4 m), while closer dripline spacing (0.7 m) with full irrigation ($A_1I_{100}$) reduced the yield by 12.5% as compared to yield from the optimal spacing. At the high overall yield levels, these reductions imply economically significant losses. These yield reductions increased to 25.9 and 36.9% for treatment $A_3I_{67L}$ and $A_3I_{67}$, respectively, with the 2.1 m spacing at the reduced irrigation levels.

Grain yields in the $A_3$ treatments (dripline spacing of 2.10 m) were evaluated separately for each crop row in order to quantify the non-uniformity of yield with the distance from the lateral. Grain yields from the corn rows adjacent to the drip lateral in the $I_{100}$ treatment plots were significantly higher than the deficit irrigation plots for the same locations (Fig. 7). Grain yields away from the dripline (1.05 m) were significanly lower than the yields from corn rows adjacent to the lateral in the deficit irrigation plots. Non-uniformity of grain yield increased with deficit irrigation in the wider lateral spacing. The research results revealed that a lateral spacing of 2.10 m (one lateral per three corn rows) are not suitable for the drip-irrigated corn production under the Mediterranean Region of Turkey under those specific conditions.

Variance analysis of the grain yield data indicated that both lateral spacings and irrigation levels significantly affected the yields (Table 6). The lateral spacing of 1.40 m resulted in significantly higher grain yields than the other two spacings (0.70 and 2.10 m). As for the Duncan classification made with respect of irrigation levels, the plots receiving the full irrigation ($I_{100}$) in all three lateral spacings, resulted in significantly higher grain yields than deficit irrigation treatments ($I_{67}$). Gençoğlan and Yazar (1999), found that average corn grain yields were 1050 kg ha$^{-1}$ for non-irrigated treat-

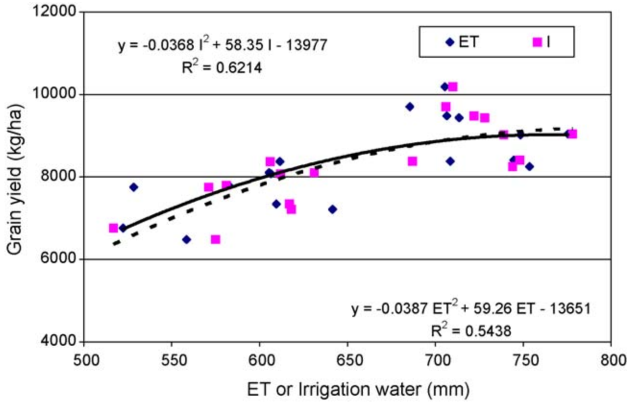


**Fig. 8 – The relationship between corn grain yield and seasonal-irrigation water and evapotranspiration (ET).**

ment and 10,015 kg $ha^{-1}$ for full irrigated treatment; for comparison Yazar et al. (2002), reported that the highest average corn grain yield obtained in the same plain from the full irrigation treatment with 6-day irrigation intervals using trickle irrigation method was 11,920 kg $ha^{-1}$.

Significant second degree polinomial relationships between grain yield (Y) versus irrigation water (I) and grain yield (Y) versus water use (ET) were found as $Y = -0.0037I^2 + 5.835I - 1397.7$ ($R^2 = 0.6214^{**}$) and $Y = -0.0039ET^2 + 5.926ET - 1365.1$ ($R^2 = 0.5438^{*}$), respectively (Fig. 8).

The highest water use efficiency (WUE), averaging 1.40 kg $m^{-3}$, was obtained in treatment $A_2I_{100}$ while the lowest one was found in treatment $A_3I_{67}$ (1.09 kg $m^{-3}$). In general, WUE values decreased with increasing water use. Irrigation water use efficiencies (IWUE) varied from 1.12 to 1.41 kg $m^{-3}$. The highest irrigation water use efficiency averaging 1.41 kg $m^{-3}$ was obtained in treatment $A_2I_{67}$ and the lowest was found in treatment $A_3I_{67}$ (1.12 kg $m^{-3}$). In the cases where the lateral spaces were every two rows (1.40 m), WUE, IWUE were at their highest. Generally, in fully irrigated treatments the IWUE is higher than in the deficit irrigation treatments. The evident reason for the fact that IWUE and WUE values were quite similar is that the entire water supply to the plants was provided by irrigation due to the negligible precipitation during the growing period.

Water shortage led to smaller seeds compared to those gained from the full irrigation cases. There was no significant difference on 1000-seed weights considering different lateral spacings.

Total dry matter varied from 22,169 to 31,435 kg $ha^{-1}$ with the highest dry matter was observed in $A_1I_{100}$ (31,435 kg $ha^{-1}$) and the lowest in $A_3I_{67}$ (22,169 kg $ha^{-1}$). The dry matter production under the full irrigation was significantly higher than that under the deficit irrigation treatment. The highest dry matter production was observed in the treatment of one lateral per corn row, this can be attributed to the wetter soil water conditions, which enhanced the vegetative development.

Harvest Index (HI), known as, the proportion of the grain yield to the dry matter, is presented in Table 4. The highest harvest index was observed in $A_2I_{100}$ (0.37), and the lowest in $A_1I_{100}$ and $A_3I_{67L}$ (0.27). According to the variance analysis, it appears that the lateral spacings and irrigation levels do not have any significant effect on harvest index.

Grain yield per cob varied from 153.3 to 194.9 g among the treatments. The highest grain yield per cob was observed in $A_2I_{100}$ at 194.9 g, and the lowest was found in $A_3I_{67}$ at 153.3 g. According to the variance analysis, the effect of the lateral spacings on grain number per cob was found to be statistically significant while irrigation levels were not significant.

The highest grain number per cob was observed in $A_2I_{100}$ (593), and the lowest was found in $A_3I_{67}$ (496). According to the variance analysis, it appears that the lateral spacings and irrigation levels did not have any significant effect on grain number per cob.

Although the effects of the irrigation levels or lateral spacings were statistically insignificant, cob length, grain yield per cob and grain number per cob was found to be relatively higher in full irrigation treatments as compared to the deficit irrigation cases.

## 4. Conclusions

This study was carried out to evaluate the effects of full and deficit irrigation and different lateral spacing on yield and yield components of maize under specific pedo-climatic conditions. According to results, optimum lateral spacing for corn plant was found to be 1.4 m, which produced the maximum yield of 9790 kg $ha^{-1}$. In other words, one drip lateral laid out at the center of two crop rows is recommeded for the corn producers in the region. Grain yields away from the dripline (105 cm) were significanly lower than the yields from corn rows adjacent to the lateral both in the full and deficit irrigation plots. Non-uniformity of grain yield increased with deficit irrigation in the wider lateral spacing.

Considering that the cost of the pipes (all tubing and laterals included) is about 45% of the total cost, one drip lateral per two crop rows would result in considerable saving in total installation cost of a drip system. The research results also revealed that a lateral spacing of 2.10 m (one lateral per three corn rows) is not suitable for the drip-irrigated corn production under the Mediterranean Region of Turkey due to long irrigation set times, and probable deep percolation losses.

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