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TO CLARIFY THE EFFECTS OF TRADITIONAL AND DIRECT PLANTING ON SECONDARY PRODUCT CORN'S PRODUCTIVITY AND WATER CONSUMPTION

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Abstract

This study is carried on to clarify Traditional Planting and Direct Planting's effects on growth, water consumption and productivity in secondary corn product. On the trial that set up as random parcels, Pioneer 3394 corn variety is used. During the irrigation season, corn crops grown with TP and DP methods are watered 450 and 397 mm. Number of irrigation are 7 in both methods. With DP method 13.4% water saving is provided according to TP method. In Turkey on 9.87 million of deacres land where corn is produced choosing DP method instead of TP method, will save 522.9 million tons of water. Crop water consumption (ET) is calculated as 647 mm depending on soil samples. Plant height is measured as 207 cm on TP method, and 204 cm on DP method. Plant height and a year's day numbers consisting of growth period are used to obtain plant height growth model. Average leaf number is 16 in both TP and DP methods after the crop growth season. Average productivity is 1070 kg da^{-1} in TP method and 1048 kg da^{-1} in DP method. Depending on the study results, there are no differences in crop growth and productivity, between TP and DP methods ($P>0.005$). In DP method, under favour of mulch leftovers from primary product, soil surface preserves humidity better and doesn't need irrigation water for longer terms. Choosing DP method, will prolong the irrigation interval, provides less usage of water and reducing demand for cultivation, that means reduces main costs of agricultural jobs like irrigation water and labour costs.

Key words: *traditional and direct planting; water consumption; crop growth model.*

INTRODUCTION

In many parts of the world, increasingly declining water resources used for agricultural purposes constitutes a major challenge (Gencoglan, 1996; Rey et al., 2007; Tanrıverdi and Degirmenci, 2011) and thus importance of irrigation is increasing with day by day (Khairy et al; 2001; Tanriverdi, 2005). Water usage and industrial requirements of increasing world population also accelerate the decrease in water resources to a certain extent (Guitjens, 1982; Gençoğlan and Yazar, 1999; Tanrıverdi et al., 2011). Inadequacy of rainfall in terms of optimum plant growth and its irregular distribution in regions located in arid and semi-arid climatic zone pose a great risk in corn farming, and render irrigation as the most important factor of yield (Gençoğlan and Yazar, 1999). Turkey is located in arid and semi-arid climatic zone, which further increases the importance of irrigation. If for any reason the level of moisture in the soil is less than that required for optimum development, a reduction in production can be expected. In that case, the most appropriate approach is to make a decision by water and agricultural area, while making an irrigation program. Programs aiming to obtain the highest yield from unit water should be made in places where water is expensive, while those aiming to obtain the highest yield from unit area should be made in places with limited agricultural area (Korukçu and Kanber, 1981; Yıldırım and Kodal, 1998).

Agricultural irrigation and cultivation methods also have a significant impact on water resources. As in the world, the industry using the most water in Turkey is agriculture with a percentage of 73% (DSI State Hydraulic Works, 2014). If this percentage of water usage continues, it is estimated that there may be water shortages in almost the whole of Turkey and very serious shortages in about half of Turkey by 2030 (Lehner et al., 2001; EEA 2007; Konukcu et al., 2007). Although the amount of water used for irrigation in many regions of the world varies by climate, soil type, plant variety, water quality and irrigation techniques, many environmental and economic issues arise due to failure to utilize irrigation technologies (EEA, 2005). For this purpose, it is of great importance that technologies allowing use of less water, energy, and labor by appropriate methods and techniques are introduced into the use of limited fresh water resources for agricultural irrigation so that Turkey's sustainable crop production is more stable and sustainable (EU, 2014). Half of the water used in irrigated farming can be saved by irrigation techniques increasing irrigation efficiency and reducing the need for irrigation water (Seckler, 1996; Shiklomanov, 1998).

Tillage in agricultural production is performed in order to maintain soil fertility, reduce erosion, prepare a good seed bed, minimize loss of water in the soil, ensure good root growth, prevent soil compaction and ensure conservation of flora and diversity of the soil (Önal, 1995; Aykas and Onal, 1999). However, tillage is the biggest factor affecting the production costs (Gökçebay, 1983). At least 15% of the agricultural areas in the world has undergone serious erosion (Kececioğlu and Gulsoylu, 2002). A large part of this erosion has occurred due to inappropriate and unconscious tillage. 34.4% of Turkish territories are comprised of high slope (15-40%) lands fueling erosion so traditional tillage entails intensive and excessive tillage especially in Turkey, increasing soil compaction and erosion (Korucu et al., 1998). Conservation tillage requires covering minimum 30% of soil surface with pre-plant residues after planting to reduce erosion by water and wind (Köller, 2003). In conservation tillage, soil is exclusively cultivated to prepare seed bed, apply chemicals, remove weeds and sow seeds (SD, 2014). In areas where direct planting (DP) is performed, fall tillage is permissible to some extent. After decomposition of stubble residues in the fields, soil is tilled using non-inversion tillage tools. In that case, at least 50% of stubble residues should remain on the soil surface. Crop residues on the soil surface are of great importance for conservation of soil. The amount of soil loss would be 13 tons ha^{-1} if there is no crop residue in the soil, whereas there would be no soil loss if the amount of crop residues is 10 tons ha^{-1}. This demonstrates that the amount of soil loss decreases with increasing amount of crop residues in the medium (Korucu et al., 1998; Aykas et al., 2005). Today, not only the profitability but also environmental, social and agronomic dimensions of agricultural production should be taken into account (Berkman, 1996). In this conceptual framework, it is of utmost importance to conserve particularly nonrenewable natural resources or those which take a long time to be renewed, and reduce environmental pollution. Developments, including the spread of herbicide use, understanding the benefits of leaving organic matter on the field surface without burning the stubbles and before they decompose too much, development of modern stubble drills and their use in existing production systems, allowed reducing tillage or provided the opportunity of no-till farming practices (Zeren, 1985). Timely performance of DP method, which protects natural resources, protects the environment from degradation and pollution, by utilizing suitable machinery is recommended (GTHB, 2014).

When all these factors are examined, the advantages of DP method have been established as reducing soil loss caused by erosion, environmental factors, high input costs arising from energy and soil and environmental damage caused by stubble burning for the purpose of making the field ready for planting secondary crop. However, the impact of cultivation methods (TP and DP) on plant growth, yield and water consumption hasn't been discussed much. Therefore, the aim of this study was to establish the effects of planting method on irrigation water demand, plant growth and yield by comparing TP and recently developed DP methods in the case of secondary corn product.

MATERIALS AND METHODS

The study was conducted in a farmer's field in Kahramanmaras province, which is located at an altitude of 640 m and dominated by Mediterranean climate.

According to the data obtained from the meteorological station in the study site, the annual average temperature was 17.7 °C, whereas the average temperature for the period between June and November, the growth period for secondary corn product, was 24.2 °C. The temperature reached the highest value (30.1 °C) in August and the lowest value (13.2 °C) in November.

The average maximum and minimum temperatures for the growth period were 31.2 °C and 18.2 °C, respectively. In addition, the rainfall in this period was 96.2 mm.

The study site was a first-grade agricultural land with a slope in the range of 6 to 12% and a shallow soil depth of 20-50 cm, in which irrigated farming is performed. These lands have good drainage because of their slope and structure, and have no problems as salinity or alkalinity (KHGM, 1997).

Pioneer 3394 was used as secondary corn variety in the trial. Planting was set up according to the randomized block trial design. Parcel sizes in the trial site were taken as 8.4 x 50 m (420 m^2), considering existing field conditions and the work widths of planting machines, and gaps of 1 m and 4 m were allowed between parcels and blocks, respectively (Figure 1).

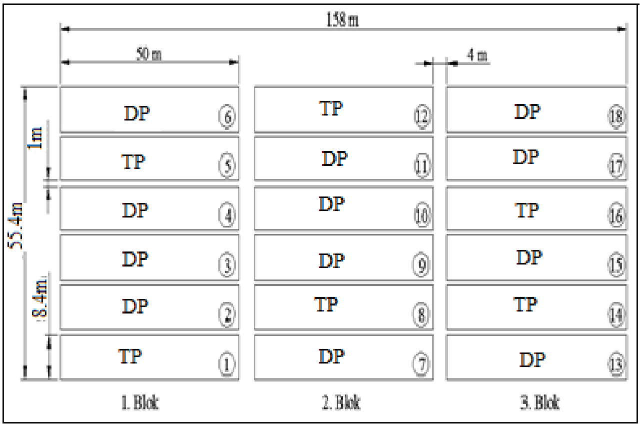

Figure 1. Trial area and parcel sizes

Accordingly, dimensions of the trial area were 158 x 55.4 m. In 6 of these parcels, planting was performed by traditional planting method (TP), while in 12, planting was performed by direct planting method (DP). Secondary corn product was planted on 25 June (175 DOY). There were 12 rows of plants in each parcel. Row spacing and seed spacing were 70 cm and 18 cm, respectively.

In traditional planting method (TP), 20 cm deep tillage was performed using chisel, and then disc harrow was used twice in order to break clods on the soil surface and smooth the soil surface. In order to enhance the success of the planting machine, the soil surface was harrowed, and then planting was performed using a four sequential pneumatic precision planting machine. In direct planting method (DP), planting was performed directly on primary product wheat stubble using the planting machine, without using any tillage tool to prepare the seed bed. While planting secondary corn product, row spacing, seed spacing and seeding depth were 70 cm, 16 cm, and 6 cm, respectively.

Following the planting procedure, the percentage of the residue cover was determined using the image processing method. It was determined that wheat residue cover was 18-22% in traditional planting method (TP) and 89-90% in direct planting method (DP).

Drip irrigation method was used in the study. In the irrigation system, laterals incorporating a 75 mm PE main pipe and a dripper with a diameter of 16 mm with a flow rate of 4 L h^{-1} with dripper spacing of 33 cm were used. Pressure and water required by the system were provided by a submersible pump system previously set up in the field. Lateral pipes were arranged so that there was one pipe in each row and their lateral lengths were taken as 50 m due to parcel length. The amount of irrigation water was measured by a water counter installed in the drip irrigation system.

Upon planting, 30 kg da^{-1} of NPK (15x15x15) base fertilizer was provided using a machine and mixed with the soil and when the plants reached a height of 15 to 20 cm, 40 kg da^{-1} of urea fertilizer was provided in the same way. First irrigation was performed immediately after planting and the next irrigation (6 further irrigation) were performed when 50% of the available water (Ry) allowed to be used in the soil was consumed, resulting in a total of 7 irrigation. To remove weeds, chemicals (22.5 g l^{-1} of a herbicide (Ekipp) with active agent Foramsulfuron) as well as mechanical control method using a hoeing machine at the time of earthing up were utilized.

Undisturbed soil samples were collected using 100 cm^3 standard cylinders from 4 different depths (0–30, 30–60, 60-90 and 90-120 cm) from the central point of each parcel in the study site, and after they were dried at 105 ^oC in a drying oven for 24 h until reaching a constant weight, their moisture contents and bulk density values were calculated by standard methods (Craig, 1984). Then, time of irrigation, the amount of irrigation and plant water consumption (ET) values were determined according to these values (Table 1).

Irrigation water was provided to the parcels when 50% of the available water (Ry) allowed to be used was consumed. For this purpose, field capacities, wilting points and bulk densities were determined under laboratory conditions using undisturbed soil samples collected from soil profiles of 0-30, 30-60, 60-90 and 90-120 cm.

Table 1. Physical characteristics of soil belonging to trial area

Depth (cm)	Texture	Pw (TK) g/g (%)	Pw (MN) g/g (%)	A_s (g cm^{-3})
0–30 cm	SC	26.9	14.5	1.49
30–60 cm	SC	26.0	15.5	1.40
60–90 cm	SC	26.8	12.0	1.39
90–120 cm	SCL	29.6	12.9	1.34

The amount of irrigation water that will bring the existing moisture up to field capacity was calculated using equation 1 (Güngör et al., 2002).

$$d_n = \frac{\left(P_{w(TK)} - P_{w(MN)}\right)}{100} \times A_s \times D \times R_y \quad [1]$$

where dn is the amount of irrigation water provided (mm); Pw(TK), the field capacity by weight g/g (%); Pw (MN) , the wilting point by weight g/g (%); As, bulk density (g cm^{-3}); D, the soil depth (mm) and Ry, the amount of water allowed to be used (%).

Soil samples representing each parcel in the trial area were collected from 12 sites by Auger-hole method and soil structures were established (Table 1). As a result of structural analysis conducted on soil and water samples collected from the area, it was established that the soils have a clay structure and that water quality was C2S1 (Table 2). As can be seen in Table 2, irrigation water doesn't pose a threat to irrigation corn in terms of its cations and anions.

Table 2. Chemical analyse results of irrigation water

EC (µS m^{-1})	pH	SAR (me l^{-1})	Kation (ppm)			Anion (ppm)				Irrigation Quality
			Ca^{+2}+Mg^{+2}	Na^+	K^+	CO_3^{-2}	HCO_3^-	SO_4^{-2}	Cl^-	
402	7.55	0.12	213.59	8.20	7.20	-	0.63	16.88	0.53	C_2S_1

A total of 12 plants were randomly selected from rows 6 and 7 of each parcel in order to observe the growth of the corn plant. The height of selected plants was measured and their leaves were counted. These procedures were repeated once every 7 days throughout the growth period of the plant.

In order to identify the effects of various tillage methods on corn yield, corn crops within a distance of 5 m from each parcel were collected for 3 times. To eliminate the edge effect, plant samples were collected from middle row of the parcel. Plants within a distance of 5 m with 70 cm of inter-row distance were cut and harvested so each sample harvested area was

3.5 m^2. Total parcel weights, grain weights, corncob weights and moisture contents of the collected samples were measured. Parcel yield was calculated according to a humidity of 15% using the following equations and the measurement values (Cerit, 2001).

$$TKO = \frac{TPA - SA}{TPA} \times 100 \quad [2]$$

$$DA = \left[TPA \times \left(\frac{100 - Nem}{100} \right) \times \left(\frac{100}{85} \times \frac{TKO}{100} \right) \right] / 1000 \quad [3]$$

$$V = \frac{1000}{3.5} \text{ x } DA \quad [4]$$

Where TKO is the ratio of grain/cob (%); TPA, the weight of cobs harvested from the whole parcel (kg/3.5 m^2); SA, corncob weight (kg/3.5 m^2); DA, the corrected weight (kg/3.5 m^2); moisture, the moisture content of the product (%) and V, the yield (kg da^{-1}).

RESULTS AND DISCUSSIONS

The amount of irrigation water applied to cultivated secondary corn product by drip irrigation method was measured as 450 mm in traditional planting method (TP) and 397 mm in direct planting method (DP). According to the data obtained from regional meteorological station, the rainfall throughout the growth period of secondary corn product was 96.2 mm. When the rainfall was added to the amount of applied irrigation water, a total of 546.2 mm of water was applied to TP method and of 493.2 mm of water to DP method (Table 3).

Table 3. The irrigation water values that applied to planting methods

Planting method	Number of irrigation	Irrig. (mm)	Rainfall (mm)	Total water (mm)	ET (mm)
TP	7	450	96.2	546.2	647
DP	7	397	96.2	493.2	647

Thus, considering the amount of irrigation water applied to DP method through a total of 7 irrigation, a water saving of 13.4% was achieved. In that case, it emerges that if TP method is preferred, rather than DP, there will be additional costs due to excess water usage and loss of labor and time. Existing amount of moisture at the beginning of the trial, the rainfall throughout the trial and also soil water contents before and after each irrigation were established, and the calculated ET value was 647 mm (Figure 3).

According to TUIK data for 2012, corn is grown in 9,866,976 da of land in Turkey. If it is assumed that in this entire area, corn is produced by traditional method utilizing drip irrigation method and a further irrigation water of 450 mm is provided, total annual water consumption is estimad to be 4.4 billion tons. If direct planting is performed in the same area and if this area is irrigated by drip irrigation method by providing 397 mm of water, total annual water consumption would be 3.9 billion tons, and water saving of 522.9 million tons would be achieved.

Compared to TP method, in DP method, the soil was covered by mulch and tillage was performed to a lesser extent so loss of moisture from the soil surface was less. Accordingly, although irrigation time varies by season and plant growth period, it was delayed by one day on average in the parcels in which DP method was applied.

The following growth model was developed by utilizing plant growth (Equation 5) and the parameters of the model are given in Table 4.

$$PL = a / \left(1 + \exp^{b - cDOY}\right) \quad [5]$$

Where b and c represent constant coefficients, PL, the plant height (cm), a estimated plant height; DOY, a specific day of the year.

Table 4. Parameters acquired on corn plant growth model

Treatment	Parameter	Estimate	Std error	95%	Confidance bound
TP	a	205.30	2.97	197.00	213.60
	b	31.83	1.39	27.97	35.69
	c	0.15	0.01	0.13	0.17
DP	a	199.60	2.50	192.60	206.40
	b	36.80	1.56	32.48	41.13
	c	0.17	0.01	0.15	0.19

Graphical illustrations of plant growth model obtained using plant heights measured throughout the growth period of corn plant for TP and DP applications are given in Figure 2 and Figure 3. The dashed line in Figure 2 represents measured values, while the solid line represents expected values in plant growth model. Hence, when the value for a specific day of the year (DOY) is entered in the formula as the desired day value, the plant height expected on that particular day can be calculated.

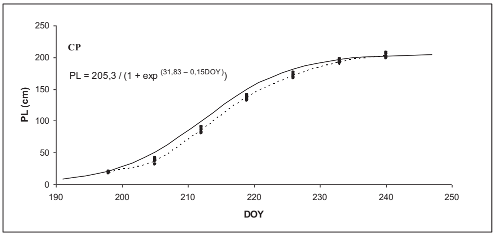

Figure 2. Height growth and model in secondary corn product for TP

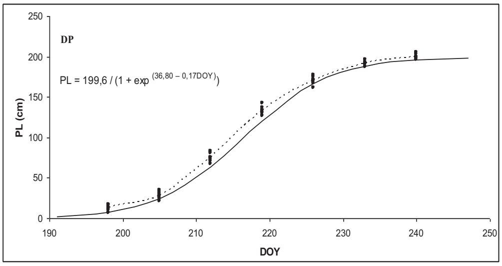

Figure 3. Height growth and model in secondary corn product for DP

It is clear from Figure 3 (DP) that there are height differences between the measured values. In the measurements made on plants grown by TP method, the average difference between plant heights (PL) was 8.84 cm, whereas in DP method, average difference between plant heights (PL) was 12.58 cm (Table 5).

Table 5. Differences in plant length (PL) on growth period

DOY	Vegetation of the day	TP	DP
198	23	3.33	10.00
205	30	10.17	13.20
212	37	10.92	16.03
219	44	10.90	16.08
226	51	9.58	15.50
233	58	8.58	8.72
240	65	8.39	8.51
	Mean PL Difference	8.84	12.58

In Table 5, small difference between plant heights in TP method shows regular growth, while high difference until 226 DOY in DP method irregular growth. After 226 DOY (day 51 of vegetation), in the measurements made in DP parcels, differences between minimum and maximum plant heights (PL) were significantly reduced. As a result, despite the irregular growth in the parcels in which DP was applied, during periods when plant height increased, plant heights became similar over time. This is a result of the fact that although the growth of corn plants whose plant height reached maximum values stopped, other short plants continued to grow.

In this study, the average plant height at the end of plant growth period was measured as 207 cm for TP and 204 cm for DP. Similar plant height values were also obtained by various researchers in studies conducted under various conditions (Dervis, 1986; Ul, 1990; Altuntaş and Dede, 2007; Çıkman et al., 2008; Yalçın et al., 2009). In that case, the average plant heights measured in the study were similar to plant heights measured by previous studies conducted in various regions under different conditions.

Plant growth was also monitored using the number of leaves, in addition to the heights of the corn plant (Figure 4). The number of leaves was calculated by taking the average of the values measured using the same method as the plant height measurements. As illustrated in Figure 4, the number of leaves was higher in TP method by a narrow margin (1 on average). Average number of leaves at the end of the growth period of the plant was 16 in both methods in this study.

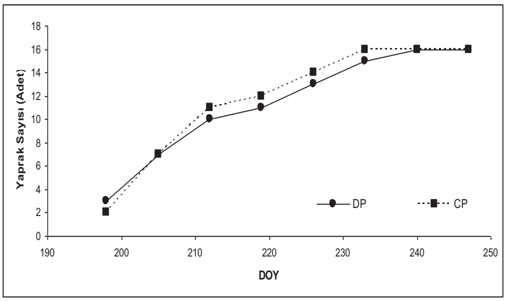

Figure 4. Leaf number on secondary corn product

According to t tests, it was revealed that the effects of TP and DP methods on plant growth were insignificant in terms of plant height (P=0.84) and the number of leaves (P=0.87) (P>0.05).

CONCLUSIONS

Throughout the irrigation season, corn crops grown using TP and DP methods were watered by 450 and 397 mm. DP method provided a water saving of 13.4%, as compared to TP method. Given that corn is produced in 9.87 million decare of land in Turkey, choosing DP method instead of TP method would save 522.9 million tons of water per annum.

Corn yield values were measured for each parcel in the study site. Yield values varied in the range of 628.7 to 1254.7 kg da^{-1} in TP method and of 636 to 1398.1 kg da^{-1} in DP method. In calculations made over mean yields per parcel, a yield of 1070.27 kg da^{-1} (sp ± 205.24) was obtained in TP method and a yield very similar to this, i.e. 1048.24 kg da^{-1} (sp ± 226.82) was obtained in DP method. According to independent two samples t test, the difference (P=0.85) between the yields by method of planting was found to be insignificant (P>0.05).

In this study, it was revealed that the total amount of water was 493.2 mm and average yield was 1048 kg da^{-1} in DP method. Yields reported by previous studies conducted in the same region for secondary corn product were 885.4 kg da^{-1} (Önder, 1994); 677 kg da-1 (MAR, 1995, 2012); 1001.5 kg da^{-1} (Gencoglan, 1996) and 994 kg da^{-1} (Idikut et al., 2005). In studies on secondary corn product conducted using drip irrigation method, yields obtained by applying 581 mm, 644 mm, and 571 mm of water were 1192 kg da^{-1} (Gençel, 2002), 1040.3 kg da^{-1} (Gökçel, 2008) and 641.6 kg da^{-1} (Vural and Dağdelen, 2008), respectively. It emerged that DP method didn't cause any adverse effect on yield, on the contrary, it allowed a water saving of 13.4%.

In view of soil density values (Table 1), as values in upper layers were higher than those in lower layers, which may be ascribed to compaction caused by tillage tools in TP method. Therefore, in DP method, in which tillage is used to a lesser extent by about 60%, it is estimated that soil density values for various soil profiles would be much similar over time.

At the end of this study, it was revealed that when TP and DP are compared, there is no difference in terms of plant growth and yield, however, DP method was identified to be superior in terms of several parameters, including the amount of irrigation, labor, costs and time saving. Therefore, it was concluded that DP method should be preferred.

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