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Lateral Spacing Affect On Yield And Quality Attributes Of Drip-Irrigated Sweet Corn

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ABSRACT

This study was conducted to determine optimum lateral spacing for drip-irrigated sweet corn. For this purpose, three different drip irrigation systems were planned. Irrigation treatments consisted of two different plant row spacings (standart 0.70 m and one narrow one wide row spacing, 45-95-45 cm) and two different lateral spacings, (0.70 m and 1.40 m). Effects of different lateral spacing on sweet corn yield and quality parameters were investigated. In the calculation of irrigation water, the percentage of wetted area is taken as 75%. Different lateral designs had significant effects on yields. The maximum fresh cob yield and single cob weight was obtained from a lateral line for each plant row. The differences in cob yields of the other two treatments (the ones with a lateral line for two plant rows) were not found to be significant.

1. Introduction

Sweet corn is commonly consumed as vegetable. It is quite delicious and nutritious, therefore it is important food supply in human nutrition. Sweet corn is rich of sugar and thus different from the other maize cultivars. According to FAO 2012 statistics, USA is the leading sweet corn producer of the world (about 22% of total maize cultivated lands and 42% of world total production). USA is respectively followed by Nigeria, Mexico, Indonesia, South Africa, Peru and Thailand (Arslan and Williams, 2015).

Sweet corn kernels harvested at milk-dough stage are quite rich in nutrients. Cobs are either boiled or grilled. Kernels are also used in food industry as canned food, boiled of frozen food stuff. In this way, consumption is not limited only by summer months and widespread over the entire year as a healthy nutrient source. Fresh consumption of sweet corn is rapidly increasing. Similarly it is widely used especially in large cities as canned and salad garnish (Albayrak, 2013). In sweet corn to be produced for fresh consumptions, larger cobs are always preferred in markets and bazaars. However, in industrial type sweet corn to be produced for canned or brine food, the cob kernel yield becomes the prominent parameter rather than the cob size. Besides the yield, quality parameters are also significant attributes in sweet corns. Sugar content is the most significant quality attribute of sweet corns (Boyette et al., 1990).

There is almost none available data about sweet corn production in Turkey. However, it is known that the production was increasing year by year. It is estimated that this type of corn is grown about 1-2% of total maize cultivated lands of Turkey (Arslan and Williams, 2015). Maize production is quite common in Konya province for grain or silage purposes. Maize production under rain-fed conditions is impossible in Konya region. According to 2016, grain corn was cultivated over 65 thousand ha land area and silage corn was cultivated over 23 thousand ha land area (With a total of 88 thousand ha in Konya region) (TÜİK, 2017). Sweet corn production is very limited in Konya region. In Konya province, growing period of sweet corn is about 90 days and harvest can be performed at the end of July. These characteristics result large amount of water saving in irrigations. Water shortage is very important problem in Konya basin. Therefore, efficient water use in irrigations is necessary to irrigate larger fields with the available water resources. Water-saving irrigation systems such as drip system should be used to maximize the irrigation efficiency under well management. Drip irrigation facilitates easy control of irrigation water. High initial investment cost is the only

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disadvantage of drip irrigation systems. Laterals in such system have a significant share in system cost. System cost decreases with increasing lateral spacing. Some researchers (Stone et al., 1997; Öktem et al., 2003; Hirich et al., 2012; Ertek and Kara, 2013) studied about the irrigation practices by drip irrigated sweet corn but almost none study was performed about effect of different plant row spacings and lateral spacings on sweet corn yield and quality parameters. In this study, different lateral spacings, therefore, was researched to determine effects of lateral spacings on sweet corn yield and quality.

2. Materials and Methods

Field experiments were conducted at experimental fields of Soil Water and Desertification Control Research Institute (Konya, Turkey) in 2017. Soil characteristics of the experimental fields are presented in Table 1.

Table 1
Soil physical characteristics of the experimental site

Soil Depth (cm)	Texture Class	Texture			Bulk Density	Field Capacity	Permanent Wilting Point	Available Water Holding Capacity	
		Sand (%)	Clay (%)	Silt (%)	(g cm^{-3})	(%)	(%)	(%)	(mm 90^{-1} cm)
0-30	C	34.39	42.95	22.66	1.32	23.19	12.51	10.68	42.29
30-60	C	28.11	49.21	22.68	1.30	24.63	13.72	10.91	42.55
60-90	C	26.23	51.15	22.62	1.32	22.55	13.23	9.32	36.9
0-90									121.74

Soil texture of experimental site was clay. Bulk densities varied between 1.30-1.32 g cm^{-3} and available water holding capacity at 90 cm soil profile was 121.7 mm. Infiltration rate was found as 13.2 mm h^{-1}.

Experimental site has semi-arid climate conditions. Climate data for the experimental year of 2017 and long-term averages are provided in Table 2. Long-term average precipitation of Konya is about 322 mm.

Table 2
2017 year and long-term climate data for the experimental site

Year		Months												Annual / Average
	Meteorological Data	1	2	3	4	5	6	7	8	9	10	11	12	
2017*	Temperature (°C)	-5.0	-1.3	6.9	10.7	15.2	20.2	24.6	23.6	20.7	11.6	5.8		
	Precipitation (mm)	81.2	1.2	76.4	21.8	33.7	15.2	0.0	7.2	0.0	12	57.8		
	Wind Speed (m s^{-1})	0.9	0.8	1.3	1.3	1.2	1.1	1.1	1.1	0.5	0.7	0.4		
(1929-2016)**	Temperature (°C)	0.2	1.4	5.5	11.0	15.8	20.1	23.5	23.1	18.5	12.5	6.3	1.7	11.6
	Relative Humidity (%)	77	72,2	64,1	58,2	55,9	48,2	41,8	42,3	47,7	59,9	70,4	77,6	59.6
	Precipitation (mm)	37.5	29.0	28.4	32.1	43.5	24.7	6.4	4.7	12.5	29.9	31.7	42.0	322.4
	Wind Speed (m s^{-1})	1.0	1.2	1.3	1.2	1.0	1.1	1.2	0.9	0.7	0.6	0.8	0.9	1.0

*: TSÇMAE, 2017; **MGM, 2017.

The study was conducted to determine optimum lateral spacing for drip-irrigated sweet corn. Drip tubes (laterals) with 2 L h^{-1} drippers spaced at 33 cm distance were experimented at different lateral spacings (70 and 140 cm) at different plant row spacings (row spacing of 70 cm: 70-70-70; a narrow and a wide row spacing: 45-95-45) under field conditions. Field experiments were conducted in randomized blocks design with three replications. Experimental treatments are below and plot details are in Figure 1.

DS-1: Plant row spacing is 70 cm and lateral spacing is 70 cm (one lateral for each plant row).

DS-2: Plant row spacing is 70 cm and lateral spacing is 140 cm (one lateral for two plant rows).

DS-3: A narrow and a wide row spacing (45-95-45 cm) and lateral spacing is 140 cm (one lateral for two plant rows).

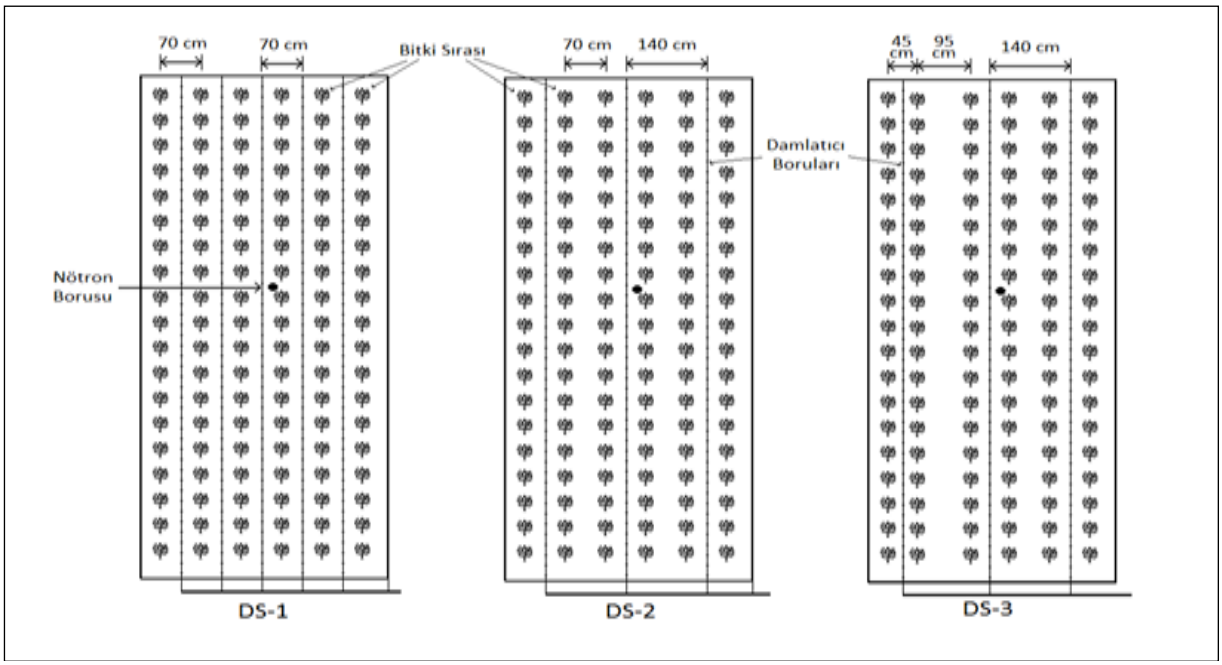

Figure 1
Plot details of experimental treatments

Irrigation interval was 7 days. Wetted area percentage was considered as 75% in all treatments. Soil moisture was measured with a neutron probe before each irrigation event. Aluminum Access tubes was placed to a depth of 1.2 m just by the plant row and 20 cm away from lateral line in each plot. Crop water use was the total of seasonal water depletion (planting to harvest) plus rainfall and irrigations during the same period.

Hazar-F1 sweet corn seeds were used as the plant material of the study. Seeds were sown over 21 x 100 m plots (2.1da) on 11th of May, 2017. About 25 kg da^{-1} DAP fertilizer was applied at sowing. Seeds were sown with 4-row sowing drill as to have 70 cm row spacing and 18 cm on-row plant spacing. In the same day, experimental treatment plots were placed with poles, and then new plant rows were formed with manual sowing as to have one narrow-one wide row spacing. Sprinkler irrigation was performed twice to have homogeneous emergence. About 10 days after sowing, a homogeneous emergence was observed. When the plant height reached to 8-10 cm, the areas beyond the plots created with poles at corners were plowed on 25 May 2017 to clearly form the experimental plots. Treatment plots had 6 plant rows. Plots were 4.2 m width and 25 m length. In plots with one narrow and one wide row spacing, the unnecessary rows sown with the drill were removed manually. Two manual hoeing were performed for weed control. Following the establishment of treatments plots, drip irrigation systems were installed. Dripper discharge and spacing were determined according to principles specified in Güngör et al. (2003). Irrigation water was measured by flow meters, and then applied to experimental plots.

Dressing fertilizers were applied through fertigation system. For this purpose, 20 kg da^{-1} urea (46% N) was applied in two equal portions. Also, 5 kg da^{-1} potassium sulphate (powder form) and 5 kg da^{-1} mono amonyum fosfat (MAP) (powder) fertilizers were applied through fertigation system. Harvest was performed from the central two rows; 2.5 m from each end were not harvested as to consider the side effects (1.4 x 20 = 28 m². Plot yields were converted into unit area (da) yields. Cob weight, cob length, cob diameter, number of rows in cob and number of kernels per row were also determined. For this purpose, measurements were performed over the cobs of randomly selected 5 plants and average of measurements was taken. Experimental data were subjected to variance analysis.

3. Results and Discussion

3.1. Irrigation and water use

There were not significant differences in soil moisture depletion levels of experimental treatments. Therefore, average of three treatments was taken and equal amount of irrigation water was applied to each treatment. Irrigation dates, irrigation water quantities and irrigation durations are provided in Table 3. Irrigation treatments were initiated on 22 June and ended on 10 August. A total of 8 irrigations were performed. A total of 433.5 mm irrigation water was applied to sweet corn. The total precipitation during the field experiments (between 11 May and 16 August – 97 days) was measured as 38.4 mm. About 30 mm of this amount

was considered as effective precipitation. Deep percolation was measured as 32 mm for DS-2 and DS-3 treatments and there was not any deep percolation in DS-1 treatment. The seasonal water use of sweet corn was determined as 525.6 mm for DS-1, 491.4 mm for DS-2 and DS-3 treatments, respectively. Öktem et al. (2003) reported seasonal water consumption of sweet corn under Şanlıurfa conditions as between 700- 1000 mm while being predicted as 348-504 mm by Ertek and Kara (2013) under Isparta conditions. Hirich et al. (2012) found as 492 mm in Morocco whereas Stone et al. (1997) calculated as 311 mm in New Zeland.

The irrigation durations of different drip irrigation systems for the same irrigation water quantities were different. The shortest irrigation duration was observed in DS-1 treatment and the irrigation durations of the other two treatments were twice as much of the DS-1. However, unit area lateral cost of DS-2 and DS-3 treatments was 50% less.

Table 3
Irrigation schedules

Irrigation Date	Irrigation Water (mm)	Irrigation Durations (hour)		
		DS-1	DS-2	DS-3
Germination-Emergence	26.0	-	-	-
22.06.2017	52.7	6.08	12.16	12.16
29.06.2017	43.8	5.06	10.12	10.12
06.07.2017	48.5	5.60	11.20	11.20
13.07.2017	52.3	6.04	12.08	12.08
20.07.2017	52.5	6.06	12.12	12.12
27.07.2017	53.4	6.16	12.32	12.32
03.08.2017	52.6	6.08	12.16	12.16
10.08.2017	51.7	5.97	11.94	11.94
Total	433.5	47.06	94.12	94.12
Crop water consumption (mm)		525.6	491.4	491.4

3.2. Fresh Cob Yield

Total vegetation period of sweet corn was as 97 days. Fresh cobs were harvested on 16 August. Number of plants and number of harvested cobs were different in each treatment. Number of plants and cobs for DS-1, DS-2 and DS-3 treatments were respectively identified as 165-157, 159-146 and 151-144. These results indicated that some plants had no cobs. Variance analysis was performed to identify the differences in fresh cob yields of the treatments. Fresh cob yields of the treatments are provided in Table 4.

Table 4
Fresh cob yields of the treatments

Treatments	Fresh Cob Yield (kg da^{-1})*	Relative Cob Yield (%)
DS-1	1963.7a	100.0
DS-2	1748.2b	89.03
DS-3	1726.5b	87.92

*: P<0.05

There were significant differences in fresh cob yields of the treatments ($p<0.05$). The greatest fresh cob yield (1963.7 kg da^{-1}) was obtained from DS-1 treatment. There were not significant differences in fresh cob yields of DS-2 and DS-3 treatments. Fresh cob yield was measured as 1748 kg da^{-1} in DS-2 treatment and as 1726 kg da^{-1} in DS-3 treatment, respectively. These results revealed that DS-1 treatment (a lateral for each plant row) had about 200 kg higher fresh cob yield than that of the DS-2 and DS-3 treatments (a lateral for two plant rows). The unit area lateral cost in DS-2 and DS-3 treatments was 50% less than the unit area lateral cost in DS-1 treatment, but irrigation durations were twice as much of DS-1 treatment. According to these findings, it was seen in drip-irrigated sweet corn culture that lateral spacing of 70 cm (a lateral line for each plant row) was beneficial for fresh cob yield and irrigation duration, but 140 cm lateral spacing (a lateral line for two plant rows) had 50% unit area lateral cost, thus brought a cost advantage over 70 cm lateral spacing.

Ertek and Kara (2013) reported that fresh cob yield for Lumina F1 sweet corn irrigated at different irrigation levels with a lateral per plant row was between 1123.4 and 1473.7 kg da^{-1} and, the maximum yield was achived at full irrigation condition. Similarly, Öktem et al. (2003) reported fresh cob yields as between 792 - 1343 kg da^{-1} with the maximum yield from frequent and full irrigation for Merit sweet corn. Basava (2012) investigated 120 cm lateral spacing (one lateral for two plant rows) and different irrigation levels at sweet corn, and reported that fresh cob yield of sweet corn as between 871 - 1283 kg da^{-1} with the maximum yield from the highest irrigation water. In our study, present fresh cob yields of all three-drip irrigation systems were quite higher than the yields reported in those previous

studies for full irrigation treatments. For instance, fresh cob yields of DS-2 and DS-3 treatments were respectively 18 and 35% higher than the cob yields of previous studies.

3.3. Fresh cob quality

Physical quality attributes of fresh cobs (cob weight, cob length, cob diameter, number of rows in cob, number of kernels per row) were measured and resultant data were subjected to variance analysis. Fresh cob quality attributes are provided in Table 5. Variance analysis revealed that irrigation treatments had significant effects on husked cob diameter ($p<0.05$). The effects of different irrigation treatments on the other quality attributes were not found to be significant.

Table 5
Sweet corn quality attributes

Treatment	Fresh Cob Weight (g)	Husked Cob Weight (g)	Husked Cob Length (mm)	Husked Cob Diameter (mm)*	Number of Rows per Cob	Number of grain per Row
DS-1	372.62	282.17	183.67	48.61a	15.60	41.20
DS-2	342.57	257.46	181.51	44.85b	15.13	39.53
DS-3	346.46	263.41	182.58	43.69b	15.47	38.03

*: P<0.05

As can be seen in Table 5, fresh cob weights of the treatments varied between 342.6-372.6 g, husked cob weights varied between 257.5-282.2 g, cob lengths varied between 181.5- 183.7 mm, cob diameters varied between 43.7-48.6 mm, number of rows per cob varied between 15.1-15.6 rows and number of kernels per row varied between 38-41 grains. Ertek and Kara (2013) reported cob lengths of Lumina F1 sweet corn irrigated at different irrigation levels with a lateral per plant row as between 128-188 mm, cob diameters as between 32.5- 46.4 mm and cob weights as between 178.2-224.4 g. Öktem (2008) in a deficit irrigation study, used a lateral for each plant row and reported cob lengths as between 158.4-195 mm and fresh cob weights as between 161.2-249.5 g and reported the greatest value for full irrigation treatment.

4. Conclusion

It was concluded that the drip irrigation systems with a lateral line for each plant row (70 cm lateral spacing) (DS-1) had better performance in drip-irrigated sweet corn. The other drip irrigation systems with 70 cm row spacing an done narrow-one wide row spacing (45-95-45) at sowing and 1.4 m lateral spacing (a lateral line for two plant rows) (DS-2 and DS-3) had no significant differences in yield and quality attributes. DS-1 provided about 10% yield increase, but DS-2 and DS-3 treatments had 50% less unit-area lateral line cost.

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