Selcuk J Agr Food Sci, (2018) 32 (1), 50-54

e-ISSN: 2458-8377 DOI: 10.15316/SJAFS.2018.63

Selcuk Journal of Agriculture and Food Sciences

Effect of different dripper discharge, spacing and lateral spacing on drip irrigated green bean yield and quality parameters

İnas Jameel Abdulwahhab ALBAYATİ, Ramazan TOPAK*
*Selçuk University, Faculty of Agriculture, Department of Farm Structures and Irrigation, Konya, Turkey

ARTICLE INFO

Article history:
Received date: 20.11.2017
Accepted date: 02.01.2018

Keywords:
Green bean
Drip irrigation
Emitter flow rate and spacing
Drip line spacing
Yield and quality

ABSRACT

Experiments were conducted to assess the effects of different dripper discharges, dripper spacings and lateral spacings on yield and physical quality attributes of drip-irrigated green beans. Three different drip irrigation systems were arranged as: DS1, in which dripper discharge is 2 L h^{-1}, dripper spacings is 33 cm and lateral spacings is 50 cm (a lateral line for each plant row); DS2, in which dripper discharge is 2 L h^{-1}, dripper spacings is 33 cm and lateral spacings is 100 cm (a lateral line for two plant rows); DS3, in which dripper discharge is 4 L h^{-1}, dripper spacings is 50 cm and lateral spacings is 100 cm (a lateral line for two plant rows). In irrigations, wetted area percentage was taken as 75%. Present findings revealed that different drip irrigation treatments did not have significant effects on yield and physical quality attributes of green beans. Therefore, it was concluded that lateral spacing in drip irrigation of greenbeans could be selected as 100 cm (a lateral line for two plant rows). This will bring at least 50% saving in lateral pipe costs of drip irrigation systems.

1. Introduction

Bean is leguminous crops and quite rich in vegetable-originated proteins. Therefore, they have a special place in human nutrition and they are the mostly cultivated legumes worldwide. Bean roots are able to fixate free atmospheric nitrogen into the soils through rhizobium bacteria. Thus, they enrich soil nitrogen contents and leave a nitrogen-rich soil to subsequent plants (Sprent, 2001). On the other hand, bean roots degraded within 1-2 weeks after the harvest, thus increases soil organic matter content, improves aggregate formation and stability and regulates soil texture (Akçin, 1974). Beans, consumed either dry or fresh, with their high protein contents, quite similar amino acid composition with meat proteins, rich carbohydrate, calcium, iron and especially phosphorus contents, have a superior place among similar foodstuff. Sulphur-containing amino acid content of beans is higher than the other edible legumes and that makes biological value of bean protein quite high (Çavuşoğlu and Akçin, 2007).

According to FAOSTAT statistics, annual production of 10 important greenbean producer countries is around 20.74 million tons and China is the leading country with an annual production of 16.2 million tons. Turkey with an annual production of 638 000 tons has the fourth place in World greenbean production (FAOSTAT, 2017). According to TUIK statistics for 2010-2016 period, green bean was cultivated annually over 50 000 ha land area and annual average production was around 630 000 tons. Within the same period, greenbean was cultivated over 1000 ha land area in Konya province and average annual production is around 12000–15000 tons (TÜİK, 2017).

In Turkey and Konya province, greenbeans are generally irrigated. Konya basin has quite deficit water resources. Therefore, water saving in irrigations is evident to irrigate larger fields with the available water resources and to improve the yield levels in agricultural practice. Water-saving irrigation systems should be widespread to have efficient irrigations and water savings in irrigations. Drip irrigation is thought to be the best method for greenbean and many crops cultivated except plants which demand special irrigation method. High initial investment cost is the only disadvantage of drip irrigation systems. Dripper lines constituting the

* Corresponding author email: *rtopak@selcuk.edu.tr*

basic component of drip irrigation system (lateral lines) have a significant share in system cost. System cost decreases with increasing lateral spacing. There are some previous studies on the irrigation of greenbeans. For instance, Yıldırım (1994) compared different irrigation methods for greenbean irrigation and reported higher performance for drip irrigation method than for sprinkler and furrow irrigation methods. Some other researchers (Sezen et al., 2005; Abdel-Mawgoud, 2006; Gençoğlan et al., 2006; Önder et al., 2006; Büyükcangaz et al., 2008) investigated the effects of deficit irrigation treatments and water stress on greenbean yields and quality attributes. This study was conducted to investigate the effects of three different drip irrigation systems with different dripper discharge, dripper spacing and lateral spacing, but with the same wetted area percentage on greenbean yield and quality.

2. Materials and Methods

This study was conducted over the experimental fields of Soil Water and Desertification Control Research Institute in Konya (Turkey). Soil samples were taken from the experimental fields and irrigation-related soil characteristics were analyzed. Soil physical characteristics are provided in Table 1.

Soil texture of experimental plots was clay. Soil bulk density was 1.35 g cm^{-3} for 0-30 cm layer and 1.33 g cm^{-3} for 30-60 and 60-90 cm soil layers. Available water holding capacity at 0-90 cm soil profile was 122.7 mm. Infiltration tests were carried out and soil infiltration rate was measured as 13.5 mm h^{-1}.

Experimental site, Konya province, has a dominant terrestrial climate with hot and dry summers and cold winters. Climate data for the experimental year 2017 and long-term averages are provided in Table 2.

Table 1
Soil physical characteristics of the experimental site

Soil layer (cm)	Texture class	Texture			Bulk density	Field capacity	Permanent wilting point	Available water holding capacity	
		Sand (%)	Clay (%)	Silt (%)	(gr cm^{-3})	(%)	(%)	(%)	(mm)
0-30	C	22.04	54.25	23.70	1.35	24.12	13.4	10.72	40.14
30-60	C	17.79	56.38	25.83	1.33	25.64	15.0	10.64	42.45
60-90	C	14.59	58.51	26.89	1.33	25.53	15.47	10.06	40.14
Total									122.73

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

Year	Meteorological data	Months												Annual / average
		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
	Rel. 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 effects of different dripper discharges, spacings and lateral spacings on greenbean yield and quality attributes were investigated in this study. Three different treatments were experimented in randomized blocks design with three replications. Experimental treatments were arranged as: DS1, in which dripper discharge is 2 L h^{-1}, dripper spacings is 33 cm and lateral spacings is 50 cm (a lateral line for each plant row); DS2, in which dripper discharge is 2 L h^{-1}, dripper spacings is 33 cm and lateral spacings is 100 cm (a lateral line for two plant rows); DS3, in which dripper discharge is 4 L h^{-1}, dripper spacings is 50 cm and lateral spacings is 100 cm (a lateral line for two plant rows). Irrigations were performed once in a week. In irrigations, irrigated area percentage was considered as 75% in all treatments. Depleted moisture within the root zone was measured with a neutron probe before each irrigations. Access tubes were placed to a depth of 1.2 m just by the plant row and 15 cm away from lateral line in each plot. Crop water use was calculated with the water balance equation given by Garrity et al. (1982).

Coated"Nazende" greenbean seeds were used as the plant material of the study. This cultivar is an early and ground-type cultivar and resistant to mosaic virus. Seeds were sown over 1.8 da experimental field on 11

May 2017. About 25 kg da^{-1} DAP fertilizer was applied before sowing. Sowing was performed with 5-row sowing drill as to have a row spacing of 50 cm and on-row plant spacings of 8 cm. Following the sowing, two sprinkler irrigations (13 mm in each) were performed for homogeneous germination and emergence. Emergences were observed on 19 May. Whole experimental field was then divided into experimental plots when the plants had 4-5 leaves on 25 May 2017. Treatment plots were composed of 6 plant rows. Plots were 3 m wide and 25 m long. Two manual hoeing were performed for weed control. Following the establishment of the plots, drip irrigation systems were installed. Lateral length was selected as 25 m. Dripper discharge and spacing were determined according to principles specified in Güngör et al. (2003). For irrigation water quantities, wetted area percentage was taken as 75%. Irrigation water was passed through flow meters and then applied to experimental plots.

Dressing fertilizers were applied through fertigation system. For this purpose, 10 kg da^{-1} urea (46% N) and 10 kg da^{-1} ammonium sulphate (21% N) fertilizers were applied. Also, 5 kg da^{-1} potassium sulphate (in powder form) and 5 kg da^{-1} mono amonyum fosfat (MAP) (powder) fertilizers were applied. Greenbean plants were treated with "Antracol WP 70" fungicide against anthracnose twice in July. Harvest was performed from the central two rows and 7.5 m sections from both ends were omitted as to consider the side effects (1.0 x 10 = 10 m^2). Four harvests were performed and resultant plot yields were converted into unit area (da) yields. Field experiments were terminated after the forth harvest. Pod weight, length, width and number of beans were also analyzed as quality attributes. Resultant data were subjected to variance analysis to see the differences between experimental treatments.

3. Results and Discussion

3.1. *Irrigation and water use*

Considering the lateral lines and plant rows, neutron probe access tubes were placed at the same location of each plot just by a plant row. The distance between Access tube and lateral line was 15 cm. Therefore, there were not significant differences in weekly soil moisture depletion levels of the experimental plots and thus the same amount irrigation water was applied to each plot. Irrigation dates, irrigation water quantities and irrigation durations are provided in Table 3. Following the sowing, two sprinkler irrigations were performed to have homogeneous emergence and a total of 26 mm water was applied. Treatments were irrigated 9 times throughout the growing season. The first irrigation was performed on 22 June and the last irrigation was performed on 17 August. Field experiments were terminated with the forth harvest made on 22 August. Weekly applied irrigation water quantities varied between 35.6 – 46.2 mm. The total amount of applied irrigation water was 412.5 mm. During the field experiments (11 May – 22 August) 38.4 mm precipitation was received. About 30 mm of this amount was considered as effective precipitation. There was a total of 5 mm deep percolation in two irrigations. Under present field conditions, seasonal water consumption of Nazende greenbeans was calculated as 488.6 mm. Seasonal water consumption of drip-irrigated greenbeans were reported as 338 mm by Sezen et al (2005) under Mersin conditions, as 470 mm by Gençoğlan et al. (2006) under Kahramanmaraş conditions, as 552 mm by Önder et al.(2006) under Hatay conditions, as 582 mm by Büyükcangaz et al. (2008) under Bursa conditions and finally as 700 mm by Köksal et al.(2010) under Ankara conditions.

The irrigation durations of different drip irrigation systems for the same irrigation water quantities were different. The shortest irrigation duration was observed in DS1 treatment and the irrigation duration of DS2 treatment was twice as much of DS1. The irrigation duration of DS3 treatment was 1.5 times as much of DS1 treatment. Considering the system cost and irrigation duration together, the DS3 treatment was considered to be superior over the other systems

Table 3
Irrigation applications

Irrigation Dates	Irrigation Water Quantity (mm)	Irrigation Durations (hour)		
		DS1	DS2	DS3
Germination-Emergence	26.0			
22.06.2017	45.8	3.78	7.56	5.72
29.06.2017	35.6	2.94	5.88	4.45
06.07.2017	42.4	3.50	7.00	5.30
13.07.2017	45.1	3.72	7.44	5.64
20.07.2017	44.8	3.69	7.39	5.60
27.07.2017	46.2	3.81	7.62	5.77
03.08.2017	43.7	3.60	7.20	5.46
10.08.2017	42.3	3.49	6.98	5.29
17.08.2017	40.6	3.35	6.70	5.07
Total	412.5	31.88	63.76	48.31
Water consumption (mm)			488.6	

3.2. Fresh bean yield

Four harvests were performed throughout the experiments. The first harvest was performed 74 days after the sowing on 24 July, the second harvest was performed on 2 August, the third and the fourth harvests were performed respectively on 13 and 22 August.Unit area yields of the experimental treatments varied with harvest dates. The lowest yield was obtained from the first harvest and the greatest yield was obtained from the third harvest. Average greenbean yields of the treatments varied between 113- 182 kg da^{-1} in the first harvest, between 419 – 483 kg da^{-1} in the second harvest, between 1151 – 1351 kg da^{-1} in the third harvest and finally between 540 - 609 kg da^{-1} in the fourth harvest.

Variance analysis was performed to detect the differences in greenbean yields and number of pods per plant of the treatments. The results on yields and number of pods per plant are provided in Table 4. Variance analysis revealed that treatments did not have significant effects on greenbean yields and number of pods per plant.

Table 4
Greenbean yields and number of pods per plant

Treatments	Green bean yields (kg da^{-1})	Number of pods per plant (pods $plant^{-1}$)
DS1	2462	36.5
DS2	2349	33.6
DS3	2478	35.9

The drip irrigation system with 2 L h^{-1} dripper discharge, 33 cm dripper spacings and 50 cm lateral spacings (DS1) had greenbean yield of 2462 kg da^{-1} and number of pods per plant of 36.5 pods. The drip irrigation systems with the same drippers, but 100 cm lateral spacing (DS2) had green bean yield of 2349 kg da^{-1} and number of pods per plant of 33.6 pods. The drip irrigation system with 4 L h^{-1} dripper discharge, 50 cm dripper spacings and 100 cm lateral spacing (DS3) had green bean yield of 2478 kg da^{-1} and number of pods per plant of 35.9 pods. These findings revealed under the same irrigation water quantities that there were not significant differences in yields and number of pods per plant of all three irrigation treatments. Therefore, lateral spacing should be taken as 100 cm and dripper discharge and spacing should be selected either as 2 L h^{-1} and 33 cm or 4 L h^{-1} and 50 cm in drip irrigation of greenbeans with 75% wetted area percentage. Considering the system costs of drip irrigation systems, a lateral line for two plant rows can be used to reduce lateral line costs at least 50%.

Sezen et al. (2005) investigated the effects of different irrigation intervals and different irrigation levels applied with a lateral line for each plant row on greenbean yields and reported the yields of Gina greenbeans as between 1224 - 2055 kg da^{-1} with the greatest yield from frequent and full irrigation. Similarly, Gençoğlan et al. (2006) in a study with different irrigation levels through traditional and relative root dry irrigation techniques, reported greenbean yields as between 686 - 1087 kg da^{-1}.

3.3. *Quality attributes*

Pod length, width, weight and number of beans were measured to assess the effects of experimental treatments on physical quality attributes. For this purpose, measurements were made on randomly selected 10 pods from the third harvest and resultant data were subjected to variance analysis. Quality attributes of the experimental treatments are provided in Table 5. Variance analysis revealed that different drip irrigation treatments did not have significant effects on physical quality attributes.

Table 5
Physical quality attributes

Treatments	Pod Length (mm)	Pod Width (mm)	Number of Bean Per Pod	Pod Weight (g)
S1	130.13	15.43	5.7	9.57
S2	129.27	15.46	5.4	9.94
S3	127.73	15.56	5.7	9.78

Pod weights of the experimental treatments varied between 128-130 mm, pod weights varied between 15.4-15.6 mm, number of beans per pod varied between 5.4 - 5.7 pods and single pod weights varied between 9.6 - 9.9 g. Sezen et al. (2005) reported pod lengths of drip irrigated Gina green beans as between 108-126 mm, pod widths as between 13.2-15.2 mm and number of beans per pod as between 4.7-5.3. Önder et al. (2006) reported pod lengths of Alman Ayşe pole green beans as between 197-203 mm, pod widths as between 10.5-11.2 mm and pod weights as between

5.1-6.5 g. Büyükcangaz et al. (2008) reported pod lengths, widths and weights of Hanzade greenbeans irrigated at different irrigation levels respectively as between 121-170 mm, between 14-17 mm and between 4.8 - 8.8 g.

4. Conclusions

Present findings revealed that lateral spacing could be taken as 100 cm in drip irrigation of greenbeans. This means at least 50% reduction in lateral costs of drip irrigation system. Present findings also revealed for clay soils, 75% wetted area percentage and a lateral line for two plant rows that dripper discharge of 2 L h^{-1} and dripper spacing of 33 cm and dripper discharge of 4 L h^{-1} and dripper spacing of 50 cm treatments did not result in significant differences in greenbean yields. As to conclude, considering the system cost and saving in irrigation durations, 4 L h^{-1} dripper discharge and 50 cm dripper spacing (DS3) had better performance outcomes than the other two treatments.

5. Acknowledgements

This manuscript was derived from Master's Thesis of İnas Jameel Abdulwahhab ALBAYATİ. Authors wish to thank Selçuk University Scientific Research Projects Department for the financial support provided for thesis (Project No:17201051).

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