Selcuk J Agr Food Sci, (2017) 31 (2), 68-75

ISSN: 2458-8377 DOI: 10.15316/SJAFS.2017.21

Selcuk Journal of Agriculture and Food Sciences

Economical Analysis of Sprinkler and Drip Irrigated-Dry Bean Production

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ARTICLE INFO

Article history:

Received date: 23.05.2017
Accepted date: 06.06.2017

Keywords:

Dry bean crop
Sprinkler irrigation
Drip irrigation
Economical analysis

ABSRACT

The present study was conducted in 2016 to compare sprinkler irrigation (SI) and drip irrigation (DI) methods with regard to economic aspects. Fixed sprinkler irrigation and drip irrigation were applied in dry bean farming. Full irrigation was practiced. Methods were compared with regard to production costs and gross –net incomes. Current findings revealed that there were not significant differences between sprinkler and drip irrigation in dry bean farming with regard to irrigation costs, total production costs and incomes.

1. Introduction

Legumes including lentils, chickpeas, peas, broadbeans and black-eyed peas are the greatest protein source for more than two billions of people worldwide. About 22% of plant-originated proteins and 7% of carbohydrates used in human nutrition are supplied from edible legumes worldwide. With regard to sowing areas and production quantities, legumes are the second grain crops after cereals (Anonymous, 2016a). In Turkey, dry bean was cultivated over 93 000 ha land area and 235 000 tons production was performed in 2015. In the same year, dry bean was cultivated over 40 000 ha in Konya closed basin provinces (Konya, Karaman, Niğde and Aksaray) and 135 000 tons production was performed (Anonymous, 2016b). Considering these values of the year 2015, it was observed that Konya basin had 43.7% of dry bean cultivated lands and 57.5% of country production. Therefore, Konya basin was considered as the most significant place for dry bean cultivation of Turkey. In this basin, dry bean is produced under irrigated conditions. In present study, dry beans were irrigated with drip and sprinkler irrigation methods and economic comparisons were made for these irrigation methods. Irrigation and other production costs of both methods and net incomes were calculated. Considering the all the other costs fixed, irrigation costs per decare were determined in detail for drip and sprinkler irrigation for dry bean cultivation.

2. Materials and Methods

2.1. Field experiments

Field experiments were conducted in Kolukısa village of Kadınhanı town of Konya province in 2016. Soil samples were taken from 0-30 and 30-60 cm soil profiles and analyzed for irrigation parameters. Soil profile pits revealed that experimental soils were shallow and there was a hard barrier below 60 cm in soil profile. Soil physical characteristics are provided in Table 1.

Experimental soils have silty-clay-loam texture at 0-30 and 30-60 cm profiles. Bulk densities of soil were respectively measured as 1.34 and 1.32 g/cm^3. Available water capacity at 0-60 cm soil profile was calculated as 69.76 mm.

Experimental site has terrestrial climate and some meteorological parameters are provided in Table 2. Climate data were gathered from the records of the Directorate of Gözlü Agricultural Enterprise. Long-term (2000-2015) average annual precipitation was 308.5 mm, temperature was 11.5 ^{0}C and relative humidity was 61.2%.The precipitation values of the year 2016 were the same as long-term average, but annual total precipitation (291 mm) was lower than the long-term average. The amount of precipitation over the growing period (June-September) was 50 mm. Irrigation water was supplied from the nearby deep well of irrigation cooperative and the discharge rate was 140 m^{3}h^{-1}.

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Table 1

Soil physical characteristics

Soil layer (cm)	Texture Class	Texture			Bulk Density	Field Capacity	Permanent Wilting Point	Available Water Capacity	
		Sand (%)	Clay (%)	Silt (%)	(g cm $^{-3}$)	(%)	(%)	(%)	(mm)
0-30	SCL	51.75	32.00	16.25	1.34	17.08	9.12	7.96	31.99
30-60	SCL	48.50	31.00	20.50	1.32	19.18	9.64	9.54	37.77
Total (0-60 cm)									69.76

Table 2

Meteorological data for experimental site (Anonymous, 2016 c)

		Months												
		1	2	3	4	5	6	7	8	9	10	11	12	Avr./Annual
Long-term	Temperature(^{0}C)	-1	1.2	5.8	10.8	15.6	19.7	24.1	23.3	18.3	12.3	6.3	2.1	11.5
	R. Humidity (%)	82.1	76.7	66	61.3	56.2	49.3	40.7	40.9	47.3	61.3	71.9	80.7	61.2
	Precipt. (mm)	31.2	23.4	28.1	34.1	33.1	28.5	5.3	4.8	22.4	30.5	28.2	39.0	308.5
2016	Precipt. (mm)	37.1	12.0	28.6	15.7	65.1	32.2	17.3	1.6	21.8	1.6	12.4	45.6	291

DI and SI methods were applied in dry bean cultivation in this study and irrigation methods were compared with regard to economic aspects. Two separate experimental plots were formed for drip and sprinkler irrigation. Full irrigation program was applied in both methods. Irrigations were performed weekly.

Dripper line tests were carried out over the field to determine dripper discharge and spacing. Tests were carried out in accordance with the principles specified by Yıldırım (2008). The wetted line width was determined as about 40 cm for drippers with 1.6 L h^{-1} discharge and 33 cm spacing. Therefore in drip irrigation system, laterals with drippers of 1.6 L h^{-1} discharge and 33 cm spacing, 16mm in diameter were used. Percentage of wetted area was calculated by diving wetted line width (40 cm) to lateral spacing (45 cm) as about 1. The lateral line length was taken as 50 m and a lateral line was placed for each plant row. Experimental plots had 22 rows and drip irrigation plot was 500 m^2 in size. Irrigation water was applied through a water flow meter.

Sprinkler irrigation system installed over 14 decare experimental field plot. Sprinklers were installed as solid set system at 10x10 m system design. Sprinklers had 2.5 / 3.5 mm nozzle diameter, 1.05 m^{3}h^{-1} discharge rate and operated at 1.5 atm. The pipes 125 mm and 90 mm in diameter were used as main pipe line and lateral lines respectively. One decare of sprinkle irrigation system, where average sprinkler pressure is 1.5 atm, was considered in economic assessments. Sprinkler pressure was measured with a pitot-tube monometer. Amount of irrigation water to be applied was divided by sprinkling rate of the system to calculate irrigation duration. Sprinkling rate was determined with water collection containers placed over the experimental plot.

Experimental field (15 decare, 60×250 m) was plowed with 4-rows plough in autumn, tilled with a cultivator in December and no other tillage was performed until spring. Base fertilizers (20 kgda^{-1} composed fertilizer 15%N-%15P_2O_5-%15K_2O) were applied in April in spring. Before sowing, seed bed was prepared by rotary hoe and field was made ready for sowing. “Alberta” dry bean seeds were used as the plant material. The dry bean seeds were planted with a five-row pneumatic seed drill with a spacing of 45 cm between and 8 cm within rows. Machine hoeing was performed at the beginning of July and during hoeing, 15 kgda^{-1} urea (46%N) was applied to the field. Manual hoeing was performed in the middle of July for weed control. At the beginning of August, machine hoeing was performed again and 10 kg da^{-1} nitrate fertilizer (33%N) was applied.Again 10 kgda^{-1} nitrate (33%N) was applied through fertigation at pod-set period.For disease and pest control, two treatments were performed for fungal diseases and two treatments were performed for insects.

The first irrigation was performed on 5 July and the last one was performed on 30 August (a total of 9 irrigations were performed in both methods). Soil moisture content was measured before each irrigation. Soil samples were taken from 0-30 and 30-60 cm soil depths with a soil auger and moisture content at plant root region was determined with gravimetric method. Soil moisture was also measured at sowing and harvest again with gravimetric method.Experimental soils were shallow soils and there was a hard barrier layer at 60 cm. Therefore, effective root depth was taken as 60 cm.

Harvest was performed manually on 14 September 2016. Harvested beans were threshed with a thresher on 30 September 2016 and plot yields were determined.

2.2. Production inputs

Production costs apart from irrigations, irrigation costs, total production costs and unit area (decare) production values were calculated. Agricultural practices were taken into consideration to determine production costs for 15 decare dry bean sown fields and input costs were then converted into unit area (da) costs.

Quantities of materials to be used in per unit area of dry bean farming (seed, fertilizer, chemicals, fuel and etc.) and duration of utilization (tractor and equipment) were determined. Material use quantities and durations were multiplied by unit prices. Seed, fertilizer and chemical unit prices were taken from invoices of these materials. Unit time (hour) costs of tractor and other equipment were determined through dividing purchasing prices (A) by efficient use life (L – hour) (A/L). To determine duration of use for tractor and other equipment, the durations of each activity over 15 da bean field (soil preparation, sowing, fertilization, hoeing, chemical treatments) were determined and total duration was divided by 15 to convert the values into unit area (hour decare^{-1}). Efficient use life of tractor and other equipment are provided in Table 3.

Table 3

Efficient use life of tractor and other equipment (Diepenbrocket al., 1995)

Machinery-Equipment	Efficient Life (hours)
Tractor	5000
Plough	2300
Cultivator	2300
Liquid fertilizer spreader	1000
Pulverizator	750
Hoeing machine	1200

To determine fuel consumption in agricultural practices for bean farming, fuel consumption in each practice (seed, fertilizer, chemicals, fuel and etc.) was calculated for 15 da experimental plot and resultant values were divided by 15 to get unit area fuel consumptions for each practice. Then, total fuel consumption per unit area was multiplied by fuel price of that period to get total energy cost.

Human labor was used in hoeing, harvest and threshing. The labor cost per unit area was also calculated through dividing total labor cost by 15.

Irrigation system costs, irrigation labor costs and water+electricity costs were taken into consideration to calculate unit area costs for irrigation methods. For irrigation system costs, purchasing prices of sprinkler and drip irrigation systems for 1 decare and their economic lifewere taken into consideration. Then, annual system cost was determined. Irrigation water was supplied from the hydrant of Groundwater irrigation cooperative. Irrigation water price was paid over unit-time pricing of the cooperative. Irrigation water price of the well with 140 m^3/hour discharge rate was 36 TL h^1 in 2016. These data indicated that the price of 1 m^3 irrigation water was 0.257 TL. Unit area irrigation water costs of irrigation methods were calculated based on this price. Economic lifes of irrigation system components are provided in Table 4. Production value per decare (TL da^{-1}) was calculated through multiplying grain yields of irrigation methods (kg da^{-1}) by dry bean prices of 2016 (TL kg^{-1}).

Table 4

Economic lives of irrigation system components

System components	Economic Life (Years)
PVC pipes	15*
Sprinklers	8*
Dripper lines	6**

*: Rodrigues et al., 2013; **: Farmer declared 6 years of use.

2.3 Economic analysis

Increase in net income is the greatest factor effecting producer adoption of a new growing technique. “Benefit/Cost Analysis Method” and “Partial Budgeting Method” were used in economic analysis of field experiments (Sezen et al., 2012). Since dry bean is an annual crop, “Partial Budgeting” was used in economic analysis. The method is also simple and effective. Partial Budgeting depends on comparison of additional benefits with additional costs of a new production technique or any decisions.

Since the effects of sprinkler and drip irrigation methods on dry bean yields under Konya basin conditions were investigated in this study, financial equivalents of yield differences caused by irrigation methods (increase in gross production value) were compared with additional costs caused by the irrigation methods. Since all production cost apart from irrigation were kept constant, additional costs covered only the irrigation-related ones. The yield obtained from unit area was multiplied by product unit price to get gross production value. Product unit prices were the prices offered by merchants for product samples.

3. Results and Discussion

3.1. Amount of irrigation water and yield of irrigation methods

Irrigation dates, amount of irrigation water applied and seasonal plant water consumption values for sprinkler and drip irrigation methods are provided in Table 5.

Since seeds were sown to seed beds, germination and emergence irrigations were not performed. The first irrigation was performed when 65% of available water was depleted. A total of 9 irrigations were performed in both methods and the last irrigation was performed on 30 August 2016. Of these irrigations, 4 were performed in July and 5 in August (Table 5).

Table 5

Amount of irrigation water applied in each method (mm)

Irrigation date	Sprinkler Irrigation (SI)		Drip Irrigation (DI)	
	Irrig. duration (hours)	Applied water (mm)	Irrig. Duration (hours)	Applied water (mm)
5.7.2016	4.7	49.3	4.1	45.9
12.7.2016	4.4	46.2	3.8	42.6
19.7.2016	4.8	50.4	4.1	45.9
26.7.2016	5.1	53.5	4.3	48.2
02.8.2016	5.3	55.6	4.5	50.4
09.8.2016	5.2	54.6	4.4	49.3
16.8.2016	5.0	52.4	4.3	48.2
23.8.2016	4.6	48.3	3.9	43.7
30.8.2016	4.1	43.0	3.4	38.1
Total	43.2	453.4	36.8	412.3
Seasonal water consumption (mm)		520.4		515.7

There were 56 days between the first and the last irrigation. Crop water need gradually increased until mid-August and relatively decreased after mid-August. A total of 453.4 mm irrigation water was applied in sprinkler irrigation and 412.3 mm was applied in drip irrigation. Seasonal crop water consumption at full irrigation was 520.4 mm in sprinkler and 515.7 mm in drip irrigation.

Average dry bean yields obtained from sprinkler and drip irrigation methods are provided in Table 6.

The yield per decare was 265.3 kg in sprinkler irrigation and 284.5 kg in drip irrigation. However, the differences in yields of irrigation methods were not found to be significant.

Table 6

Yields of irrigation methods

Irrigation method	Yield (kg da^{-1})
SI	265.30
DI	284.54

3.2. Economic analysis of irrigation methods

3.2.1.Production costs

To determine the costs other than irrigation, tractor, machinery-equipment, fuel, seed, fertilizer, chemicals and labor costs were taken into consideration. General characteristics of tractor, machinery-equipment is provided in Table 7. Farmer owned the machinery-equipment used in experiments. Tractor was bought as second-hand and 68 000 TL was paid for 3700 hours effective life. The effective life of tractors was assumed to be 5000 hours.

The other production costs of dry bean farming are provided in Table 8. All incurred costs in this study were calculated from the actual values. Soil tillage, seed and sowing, fertilizer, hoeing, chemicals, harvest and threshing costs were calculated. Since different fertilizers were used and they have different prices, total fertilizer cost calculations are provided in Table 9.

Table 7

Technical specifications for tractor and other equipment

	Purchasing price (TL)	Effective life (hours)*	Working width (m)	Weight (kg)	Unit price (TLh^{-1})
78.2 kW Tractor	68000	3700	-	3500	18.38
Plough	7600	2300	1.2	800	3.3
Cultivator	9000	2300	2.75	520	3.91
Fertilizer spreader	2200	1000	10	210	2.2
Pulverizator	1600	750	10	140	2.133
Hoeing machine	10000	1200	2.70	630	8.33

*: Diepenbrock et al. (1995)

Table 8
Basic production inputs and costs in dry bean farming (TL da^{-1})

	Material	Material Use			Unit Price (TL)	Unit Value (TL da^{-1})
		Duration (h da^{-1})	Amount (kg da^{-1})	Quantity (L da^{-1})		
Soil tillage	Tractor	0.288			18.38	5.30
	Plough	0.225			3.3	0.75
	Cultivator	0.062			3.91	0.25
	Fuel			3.5	4.0	14
	Total					**20.30**
Seed+ Sowing	Seed		10		4.5	45
	Sowing					25
	Total					**70**
Fertilizer+ Fertilization	Fertilizer					77.25
	Tractor	0.14			18.38	2.57
	Fertilizer spreader	0.14			2.2	0.31
	Fuel			0.25	4	1.0
	Total					**81.13**
Hoeing	Tractor	0.075			18.38	1.38
	Hoeing machine	0.075			8.33	0.62
	Fuel			0.75	4	3
	Labor					55
	Total					**60.0**
Chemicals-treatments	Chemicals					10
	Tractor	0.03			18.38	0.55
	Pulverizator	0.03			2.133	0.064
	Fuel			0.15	4	0.60
	Total					**11.21**
Harvest	Labor					37
	Total					**37**
Threshing	Tractor	0.5			18.38	9.39
	Thresher	-				-
	Labor					6.6
	Fuel			1.5	4	6
	Total					**22.05**
General Total (TL da^{-1})						**301.69**

Table 9
Fertilizer costs

Irrigation Method	Applied Fertilizers		Fertilizer Unit Price (TL 50 kg^{-1})*	Unit Area Fertilizer Cost (TL da^{-1})
	Type	Quantity (kg da^{-1})		
SI	Composed (15-15-15)	20	77.5	31
DI	Urea (46%)	15	67.5	20.25
	Nitrate (33%)	20	65	26
Total				77.25

*: Unit prices for relevant year.

The total of other costs was calculated as 301.7 TL da^{-1} (Table 8). Fertilizer and fertilization, seed and sowing and hoeing practices which were calculated as 81. 70, and 60 TL da,$^{-1}$ respectively, accounted for the majority of the costs in dry bean farming. Chemicals + treatments constituted the least portion of that total sum (11.2 TL da^{-1}).

3.2.2. Irrigation costs

Irrigation costs are composed of irrigation system, water+energy and labor. The cost calculation for irrigation systems are provided in Table 10 and 11. Irrigation water + energy cost calculations are provided in Table 12.

The annual total irrigation system cost for drip irrigation with one lateral line for each plant row was calculated as 56.7 TL da^{-1} (Table 10) and about 82% of this sum was constituted by dripper lines.

For sprinkler irrigation method, annual system cost per unit area was calculated as 28.1 TL. About 13 TL of system cost was constituted by lateral pipe lines and 12 TL by sprinklers.

As can be seen from Table 12, cost of irrigation from deep well was higher in sprinkler irrigation (116 TLda^{-1}) than drip irrigation (106 TL da^{-1})

Total irrigation costs of the methods are provided in Table 13. Total irrigation cost was higher in drip irrigation than sprinkler irrigation.

Table 10
System cost for drip irrigation method (TL da^{-1})

Pipe costs									Annual total pipe cost per unit area (TL da^{-1})
Lateral pipes (Ø 16 mm)			Manifold (Ø 90 mm)			Main line (Ø 125 mm)			
Need for pipe (m da^{-1})	Pipe unit price (TLm^{-1})*	Annual Cost (TL da^{-1} 6 years^{-1})	Need for pipe (m da^{-1})	Pipe unit price (TL m^{-1})*	Annual Cost (TL da^{-1} 15years)	Need for pipe (m da^{-1})	Pipe unit price (TL m^{-1})*	Annual cost (TL da^{-1} 15 years)	
2222	0.125	46.29	8.0	6	3.2	8.3	13	7.2	56.70

*:Market prices of the relevant year.

Table 11
System cost for sprinkler irrigation method (TL da^{-1})

Pipe costs							Sprinkler set costs			Annual total cost per unit area (TL da^{-1})
Lateral pipe (Ø 90 mm)				Main line (Ø 125 mm)						
Length (m)	Need for pipe (m da^{-1})	Unit price (TLm^{-1})*	Annual cost (TL da^{-1} 15 years^{-1})	Need for unit area (m da^{-1})	Unit priceTL m^{-1})*	Annual cost (TL da^{-1} 15years^{-1})	Need for unit area (triple group da^{-1})	Unit price (TL triplegroup-^{1})*	Annual cost (TL da $^{-1}$ 8 years^{-1})	
500	33.33	6	13.33	3.0	13	2.6	3.3	29.5	12.2	28.1

*: Market prices of the relevant year.

Table 12
Unit area irrigation water + energy costs

Irrigation methods	Irrigation water + energy costs				
	Well discharge (m^{3}h^{-1})	Well operating price per hour (TL h^{-1})	Unit price of water (TL m^{-3})	Applied total amount of irrigation water (m^{3}da^{-1})	Irrigation costs from the well (water+electricity) (TL da^{-1})
SI	140	36	0.257	453.4	116.52
DI	140	36	0.257	412.3	105.96

Table 13
Total irrigation cost of the methods (TLda^{-1})

Irrigation methods	Cost			
	System cost (TLda^{-1})	Water + energy cost (TLda^{-1})	Irrigation labor (TLda^{-1})*	Total irrigation costs (TLda^{-1})
SI	28.10	116.52	24	168.62
DI	56.70	105.96	24	186.66

*: Irrigation labor of 150 da including experimental field (system installation + irrigations + system removal and etc.) was performed by a single worker and 1200 TL was paid monthly. Bean farming was carried out for 3 months, thus the labor cost per unit area was calculated as 24 TL (1200 TL x 3 months / 150 da =24TLda^{-1}).

The total irrigation cost per decare was calculated as 186.66 TL for drip irrigation and as 168.62 TL for sprinkler irrigation. For drip irrigation, about 30.4% of total cost was composed of system, 56.7% by water + energy and 12.9% by labor. For sprinkler irrigation, 16.7% was composed of system, 69.1% by water + energy and 14.2% by labor cost.

3.2.3. Total production costs

Annual total production costs of dry bean farming under drip and sprinkler irrigation methods are provided in Table 14. The total production cost was calculated as 488 TL da^{-1} for drip irrigation with 45 cm lateral spacing and 470 TL da^{-1} for sprinkler irrigation. Such numbers indicated that there were not significant differences in total costs of both methods. Similarly, Narayanamoorthy (2008) indicated that there were not significant differences in production costs of sprinkler and drip irrigation for cotton farming. Irrigation costs constituted 35.9% of total production costs in sprinkler irrigation and 38.2% in drip irrigation. Sezen et al (2012) reported that irrigation costs constituted about 25.8% of total production costs in pepper production. Çetin and Uygan (2008) indicated that irrigation costs constituted about 16% of total production costs in tomato farming. Topak et al (2014) reported that irrigation costs constituted about 55% of total production costs in sugar beet farming with drip irrigation.

Table 14
Total production costs of dry bean farming

Irrigation methods	Costs					Annual total production cost (TLda^{-1})
	Irrigation costs			Total irrigation costs (TLda^{-1})	Dry bean production costs (TLda^{-1})	
	System cost (TLda^{-1})	Water + energy cost (TLda^{-1})	Irrigation labor (TLda^{-1})*			
SI	28.10	116.52	24	168.62	301.69	470.31
DI	56.70	105.96	24	186.66	301.69	488.35

3.2.4. Gross production value

Production value per decare of dry bean under different irrigation methods was calculated and provided in Table 15. As can be seen from the table, dry bean unit prices were different. These prices were quoted by the merchants to the samples according to their quality in October 2016. The gross income per decare was calculated as 928 TL for sprinkler and 910 TL for drip irrigation. There were not significant differences in gross incomes of irrigation methods.

Table 15
Gross income values of drip and sprinkler irrigation

Irrigation method	Grain yield (kg da^{-1})	Unit price (TL kg^{-1})	Gross income (TL da^{-1})
SI	265.30	3.50	928.55
DI	284.54	3.20	910.53

3.2.5. Assessment of irrigation methods with regard to net incomes

Net incomes of irrigation methods are provided in Table 16. With regard to net income, sprinker irrigation exhibited relatively better performance than drip irrigation. Net income was calculated as 458TLda^{-1} for sprinkler and 422TLda^{-1} for drip irrigation. These numbers indicated that sprinkler irrigation provided 9% more income than drip irrigation.

Table 16
Net incomes of sprinkler and drip irrigation (TLda^{-1})

Irrig. method	Annual total production costs (TL da^{-1})	Gross income per unit area (TL da^{-1})	Net income per unit area (TL da^{-1})
SI	470.31	928.55	458.24
DI	488.35	910.53	422.18

4. Conclusion

Present findings revealed that there were not significant differences between sprinkler and drip irrigation in dry bean farming with regard to total irrigation costs and net incomes. In brief, both sprinkler irrigation and drip irrigation provided quite close net incomes in dry bean farming.

5. Acknowledgements

The present study was derived from Master's Thesis of Esat YURTERİ. Authors wish to thank Selçuk University Scientific Research Projects Department for the financial support provided for thesis (Project No:16201059).

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