Financial analysis of chickpea production using different supplemental irrigation strategies

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Abstract

Cost-benefit analysis was performed to determine the profitability of producing chickpea under different supplemental irrigation (SI) regimes in a semiarid environment with scarce water resources. No irrigation after sowing (Rainfed, RF) as a control, and three supplemental irrigation treatments as follows: one time irrigation at flowering stage (SI_F), one time irrigation at pod filling stage (SI_G) and two times irrigation at flowering and pod filling stages (SI_{F+G}). Results of study showed that all of treatments examined are economically viable. Net income of irrigation treatments was higher than that of rain–fed production. The most profitable economic treatment for the chickpea grower is SI_{F+G} treatment.

Keywords: Chickpea, Supplemental irrigation, Net income, economic productivity, Benefit–cost rate, Economic water productivity.

Introduction

Chickpea is mainly cultivated for human consumption, providing an important source of protein, especially in developing countries. Chickpea is the third most important pulse crop in the world, with a total production of 12.1 million tons and a cultivated area of almost 12.65 million hectares in 2016 (FAOSTAT, 2018). About 90% of chickpea in the world is grown under rainfed conditions where drought is one the major constraints, limiting its production.

Generally, chickpea is cultivated on a wide range of environments, from the subtropics to arid and semi-arid environments of Mediterranean climatic regions (Pacucci *et al*. 2006). In Mediterranean regions, chickpea is conventionally grown as a rain–fed crop, planted in spring (López-Bellido *et al.* 2008), and it is considered one of the most drought tolerant edible legumes (Silva *et al*. 20014). In Mediterranean basin, Turkey is the important a producer of chickpea, and according to TÜİK statistics for 2017 and 2018 years, chickpea was cultivated over 395 000 and 510 000 ha area and average production was around 470 000 and 630 000 tons, respectively (TÜİK, 2018). Chick pea production is based on the rain fed conditions in Konya basin, and that basin accounts about 15% of production of Turkey. Although this basin has approximately 3 million hectares of cultivated land, it faces a lot of water scarcity due to limited water resources (3% potential available water of Turkey) and low precipitation (320 mm/year) (Topak *et al*. 2010). Irrigation is vital important in basin and most of evapotranspiration, about 80-90%, is met by irrigation (Yavuz *et al*., 2015; Topak *et al.*, 2016; Yavuz *et al*., 2018; Yavuz *et al*., 2019). In basin, about 800 000 ha farmland is under irrigation (Anonymous, 2019). The crop pattern should be designated in favor of less water consuming crops in Konya basin. In that regard, chick pea is one of the alternative crops having low water use in region.

Some researchers (Oweis *et al*. 2004; Toğay *et al*. 2005; Kayan, 2012; Doğan *et al*. 2013) reported that supplemental irrigation plays an important role in increasing chickpea grain yield and quality. Supplemental irrigation, generally applied between flowering and the beginning of seed growth, can improve significantly spring-sown chickpea yield (Biçer *et al*. 2004; Nielsen, 2001; Pacucci *et al.* 2006; Soltani *et al*. 2001). Shamsi *et al*. (2010) reported that supplemental irrigated chickpea average yields ranged from 900 to 1200 kg ha^{-1}, while average rainfed chickpea yield was 550 kg ha^{-1}. Nielsen (2001) reported an increase in chickpea yield from 600 to 3500 kg ha^{-1} with the increase in water use (220–420 mm) in April sown chickpea. Consequently supplemental irrigation has the potential of stabilizing chickpea yield, reducing the risk of drought (Oweis *et al*. 2004; Soltani *et al*. 2001).

The financial aspects of supplemental irrigated-chickpea in semiarid areas have not yet been compared to those of rainfed production system. Financial analysis is needed to identify the conditions in which these irrigation practices can be justified. In this study, we compare several financial indices using benefit cost analysis, for supplemental irrigated and rainfed chickpea production in a semiarid environment.

Materials and methods

This study was conducted to assessment of economic consequences of irrigated and rain-fed chickpea production in Konya (Turkey). In this region, the climate varies from arid to semi-arid. Experimental site has a dominant terrestrial climate with hot and dry summers and cold winters According to the long-term data, the annual average temperature, relative humidity and precipitation are 11.5 ^{0}C, 61.2% and 308.5 mm, respectively. In crop growing period (from April to September), rainfall is 128 mm which is about 41.5% of the annual precipitation. Some properties of the experimental field soils are given in Table 1.

Table 1. Some physical properties of the soils taken from the experiment field

Soil Layers (cm)	Soil Texture				Bulk Density (g cm^{-3})	Field Capacity (%W)	Wilting Point (%W)	Available Water Capacity (%W)
	Sand (%)	Silt (%)	Clay (%)	Tex.class				
0-30	24.05	32.50	43.45	C	1.26	28.29	17.15	11.14
30-60	20.92	26.25	52.82	C	1.23	28.56	18.29	10.27
60-90	18.90	26.25	54.70	C	1.23	29.19	19.0	10.19

The field experiment was arranged in a randomized block design with four treatments and three replications. Crop developmental stages were considered in supplemental irrigations (SI). The control treatment (rainfed, RF) had no irrigation after sowing, and there were three supplemental irrigation treatments. These were one - time irrigation at flowering stage (SI_F), one time irrigation at pod filling stage (SI_G) and two times irrigation at flowering and pod filling stages (SI_{F+G}). Depleted moisture within the crop root zone was determined by gravimetric sampling. The plots were irrigated by drip irrigation system. In the drip system, the diameters of the laterals were 16 mm, emitter spacing and discharge rate were chosen 0.25 m and 2 L s^{-1}, respectively to be based on soil characteristics. The amounts of water applied to treatments (Table 2) were measured with water meters.

Table 2.Suplemental irrigation strategies and amounts of irrigation water applied

Treatment	At flowering stage (mm)	At pod filling stage (mm)	Total irrigation water applied (mm)	Crop water use (mm)
RF	-	-	-	180.5
SI_F	78.6	-	78.6	254.1
SI_G	-	116.7	116.7	285.1
SI_{F+G}	78.6	100.2	178.8	355.4

“Azkan” chickpea seeds were used as the plant material of the study. All plots received 250 kg ha^{-1} compose fertilizer (20:20:00). All fertilizer was applied just before seed sowing. Seeds were sown experimental field on 23 April 2016. Sowing was performed on rows with 45–cm spacing and 10-cm on-row spacing. Each plot was 10 m in length and 2.7 min width, and the total area was 27 m^2. Plots were separated by a 1 m wide zone without any irrigation to minimize the interference of adjacent plots. Harvest was performed on 26 July 2016. The central two rows of each plot were harvested to determine the grain yield. Except for Combine harvester, the input data were obtained from field experiment records. Information associated with Combine harvester was taken from farmers.

There are numerous ways to assess sustainability of a production system. Economists use productivity or total factor productivity (Herdt and Steiner, 1995). In this study, we conducted a cost-benefit analysis to calculate economical indices for irrigated and rainfed chickpea production. In this regards, we evaluated three parameters such as net income (NI), economic productivity (EP) and benefit-cost ratio (BCR). Total income value was calculated by multiplying crop yield by average price per kg taken from KTB (2019) records for 2018 year. Total costs were calculated based on area of unit (ha) and included costs of fertilizer, electricity for irrigation, drip irrigation system, machinery, diesel fuel and seed (Table 3). Costs related to drip irrigation system investment and operation were excluded for the rainfed treatment. NI was taken as the difference between gross income and total costs. The EP shows amount (kg) of chickpea produced per one $ cost. Benefit–cost ratio was calculated by dividing the gross value of production by the total cost of production per hectare.

On the other hand, we calculated those two parameters: The economic water productivity (EWP) (Pereira *et al*. 2012; Çetin and Kara, 2019) and break-even point (García-García *et al*. 2004). The EWP ($ m^{-3}) shows the net income generated per m^3 of water used by crop. The break-even point is a profitability threshold that indicates on the one hand the minimum chickpea price ($ kg^{-1}) or production cost and on the other the minimum quantity that has to be produced (kg ha^{-1}) to generate positive results (García-García *et al*. 2012).

Table 3. Production inputs and its technical informations

Inputs	Characteristics	Quantity per unit area (ha)			
		RF	SI_F	SI_G	SI_{F+G}
Diesel (L)		60	60	60	60
Electricity (kWh)		-	495	735	1126
Nitrogen (kg)		50	50	50	50
Phosphorus (kg)		50	50	50	50
Tractor (h)	78.2 kW, 5000 h $life^{-1}$	5	5	5	5
Plow (h)	2500 h $life^{-1}$	2	2	2	2
Cultivator (h)	2300 h $life^{-1}$	1	1	1	1
Sowing machine (h)	1200 h $life^{-1}$	2	2	2	2
Combine harvester ($)		70	70	70	70
Drip system					
PE Φ90 mm (m)	life 15 years	-	100	100	100
PE Φ16 mm (m)	life 6 years	-	22220	22220	22220
Output					
Grain Yield (kg)		2076	2721	2581	3511

Results and discussion

Table 4 shows the costs and economic indices of irrigated and rain–fed chickpea production. As the table shows, grain yields ranged from 2076–3511 kg ha^{-1}, representing significant differences in yield-values between treatments. Yield values were consistent with irrigation levels. Highest yield was obtained from the SI_{F+G} treatment (3511 kg ha^{-1}). This was followed by SI_F treatment with 2721 kg ha^{-1}. The annual grain yields of SI_F, SI_G and SI_{F+G} irrigation strategies are 31.07% (645 kg ha^{-1}), 24.33% (505 kg ha^{-1}) and 69.12% (1435 kg ha^{-1}) higher than that of rain–fed chickpea production (2076 kg ha^{-1}). The results of our study support the findings by other researchers who reported that irrigation plays an important role in increasing chickpea grain yield (Silva *et al*. 2014; Oweis *et al*. 2004; Kayan, 2012;Doğan *et al*. 2023; Bicer *et al*. 2004; Shamsi *et al*. 2010).

Table 4. Economic analysis of irrigated and rainfed chickpea production

Cost items	Cost accounting for treatments ($ ha^{-1})			
	RF	SI_F	SI_G	SI_{F+G}
Tractor +Machinery	122.1	122.1	122.1	122.1
Fertilizers	77.8	77.8	77.8	77.8
Diesel	76	76	76	76
Drip system	-	250.4	250.4	250.4
Seed	111.2	111.2	111.2	111.2
Electricity for irrigation	0	42.9	63.7	97.6
Total Costs	387.1	680.4	701.2	735.1

Indexes of economic assessment for treatments

Treatment	Total Cost ($ ha^{-1})	Gross Income ($ ha^{-1})	NI ($ ha^{-1})	EP (kg $\$^{-1}$)	BCR	EWP ($ m^{-3})	Break- even point (kg ha^{-1})
RF	387.1	1702.3	1315.2	5.36	4.4	0.73	472.0
SI_F	680.4	2231.2	1550.8	4.00	3.28	0.61	829.7
SI_G	701.2	2116.4	1415.2	3.68	3.02	0.50	855.1
SI_{F+G}	735.1	2879.0	2143.9	4.78	3.92	0.60	896.4

Chickpea seed price 1.0 $ kg^{-1} (Anonymous, 2018); Chickpea sales price 0.82 $ kg^{-1} (KTB, 2019)

Economic analysis clearly showed that all of treatments examined are economically viable. Compared to net the economic profit of the rain–fed system (1315.2 $ ha^{-1}), the net incomes of SI_F, SI_G and SI_{F+G} treatments are 18 % (235.6 $ ha^{-1}), 7.6% (100 $ ha^{-1}) and 63% (828.7 $ ha^{-1}) higher, respectively. Highest net income was calculated for SI_{F+G} treatment with 2143.9 $ ha^{-1}. These data show that SI_{F+G} treatment increases significantly the economic profit in chickpea farming. Rain–fed chickpea system shows the lowest profit, as it has the smallest grain yield. Net income was also significantly higher for SI_{F+G} in comparison to other irrigation treatments. This difference can be explained by the fact that while production costs were nearly equal for the SI_F, SI_G and SI_{F+G} treatments, with only a small difference stemming from the reductions in water costs due to the application of less irrigation water on SI_F and SI_G treatments, grain yield differed significantly between the treatments. As result, the chickpea net income and grain yield varied under different irrigation treatments (Fig. 1). When the yield by irrigation was increased, the net income increased. Table 4 shows the input structure of irrigated and rain–fed chickpea production systems. As shown in Table 4, the input costs of irrigation treatments are higher than that of rain–fed production. This is because that the RF treatment incurred none of the costs associated with drip irrigation system and operation.

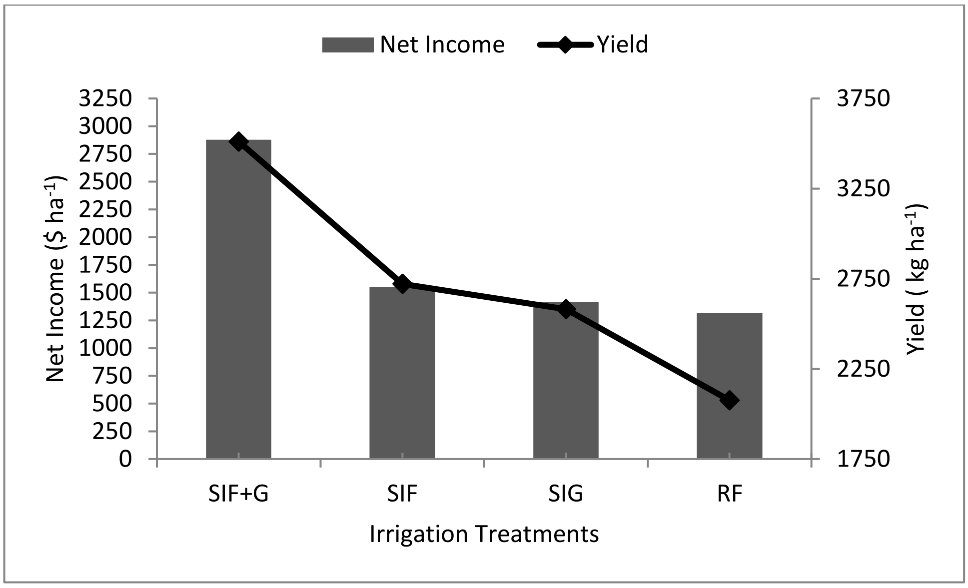

Figure 1. Effects of supplemental irrigation treatments on grain yield and net income

Compared to the economic productivity of RF system, SI_F, SI_G and SI_{F+G} treatments showed lower EP values. The economic productivity was higher in the SI_{F+G} production (4.78 kg $\$^{-1}$) than SI_F and SI_G treatments. Similarly the SI_{F+G} treatment has highest the net income. The benefit-cost ratio (BCR) can be used to describe the sustainability of the system in terms of economic; the higher the BCR, the better the system's sustainability. The BCR values of treatments are 4.4, 3.28, 3.02 and 3.92 for RF, SI_F, SI_G and SI_{F+G}, respectively. These data show that highest BCR value was RF treatment.

The economic water productivity (EWP) analysis indicated the most profitable irrigation strategy for chickpea cultivation to be one time irrigation at flowering stage (SI_F), which had an EWP value of 0.61 \$ m^{-3}. This was followed by SI_{F+G} treatment with 0.60 \$ m^{-3}. Among irrigation treatments, SI_G treatment had lowest EWP value (0.50 \$ m^{-3}). Break-even point was highest in the SI_{F+G} treatment and lowest in RF. In general, irrigated chickpea systems had a higher break-even point than rain–fed production.

Conclusion

This study evaluated the economic viability of irrigated and rainfed chickpea production based on benefit-cost analysis. Economic analysis clearly showed that all of treatments examined are economically viable. But, the results show that irrigated chickpea systems (SI_F, SI_G and SI_{F+G}), having a relatively higher yield, are promising systems and the most profitable economic strategy for the chickpea grower is two times irrigation at flowering and pod filling stages (SI_{F+G}) treatment. Economic water productivity (EWP) values, calculated based on net income and crop water use, indicated one - time irrigation at flowering stage (SI_F) to be the best water management strategy and the one time irrigation at pod filling stage (SI_G) to be the weakest.

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