Technical and economic evaluation of the deficit irrigation on yield of cotton

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Acknowledegment:

JEL Codes: C12, Y10

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Key words: drip irrigation, deficit irrigation, cotton, yield components, water use efficiency

1- Introduction

In arid and semi-arid areas, water can be a limiting factor for plant growth and agricultural yields. It is an important input to agricultural production and also an essential requirement for domestic, industrial and municipal activities. Increasing population and standards of living are contributing to a steep rise in demand for fresh water. The consequent wastage, over-exploitation, pollution and depletion of fresh water pose a serious threat the food security of the increasing population. Recent studies indicate that in developing countries, by 2025, one-third of the world population will be living in countries or region characterized by the absolute water scarcity, in the sense that they will not have sufficient water resources to meet their agricultural, domestic, industrial and environmental requirements (Ahmadian et al., 2011).

Cotton is the most important textile fiber crop and the worlds' second-most important oil-seed crop after soybean (Poehlman and Sleper, 1995) and plays an important role for employment in agriculture, industry and trade (Rahimian and Kakhki, 2007). Cotton oil-seeds have been consumed for more than a century and no harmful effects on human have been observed till now (Jenkins et al., 2008).

The crop productivity is based on assimilate formation and distribution between vegetative and reproductive sinks. However, this distribution is strongly affected by plant water status (Marani and Levi 1973; Constable and Gleeson 1977; Grimes et al. 1978) and it has been shown that a light water stress during the vegetative growth stage can depress vegetative development, allowing intensive flower and boll formation. Drought stress is the most common biotic stress in arid and semi-arid regions that has induced to an increasing number of studies on water and land use efficiency (Asadi et al., 2012).

Drip irrigation is considered one of the most efficient irrigation methods. One of the major advantages is its ability to apply water to the soil as often as desired and in smaller quantity than the other irrigation methods. Drip irrigation has been practiced for many years for its effectiveness in reducing soil surface evaporation and it has been widely used in horticultural crops in both greenhouse and open field. With this method, it is possible to reduce the input of fertilizers and pollutants, as well as to improve water use efficiency (Papastylianou and Argyrokastritis, 2015).

Deficit Irrigation is an optimum strategy for crop production under water shortages (Paygozar et al., 2009). This approach can contribute to eliminate losses during irrigation through the reduction of the volume of water provided in each watering, and allows increasing water use efficiency without any negative effect on net profit (Ghorbani and Hezar Jaribi, 2009). Several researches have considered the effects of deficit irrigation on water use efficiency and quantity and quality of different crops (Basal et al., 2009; Tavassoli et al., 2010; Babaeian et al., 2011). Some of them showed that, even reducing the amount of water applied with irrigation, other agricultural inputs can increase of crop yield at last income increase by about 42 percent than full irrigation (English, 1990).

The performance of surface and subsurface drip irrigation and the effects on crop yield of four different amounts of irrigation water (60, 80, 100 and 120 percent of the crop water requirement with the FAO-56 Penman-Monteith method) were investigated by Kalfountzos et al. (2007) on the basis of two years field experiments on cotton. The results evidenced that for 100 and 120 percent of the crop water requirement, crop yield did not result significantly different when considering surface and subsurface drip irrigation; on the other side, for 60 and 80 percent of the crop water requirement, the subsurface irrigation method produced significantly higher yield than the surface drip irrigation. According to the experimental results, subsurface drip method may improve water use efficiency, even more than 20% during dry years, if compared to traditional surface drip irrigation.

Basal et al. (2009) studied the effects of different irrigation regimes on yield, water use efficiency and quality of cotton fiber consequent to the application of four different levels of irrigation (0, 25%, 50% and 75% of soil moisture depletion) in East Turkey. Their results showed that cotton yield was similar under 0 and 25% of soil moisture depletion, even if to the latter associated the highest water use efficiency and also that the different irrigation levels did not affect significantly the cotton fiber quality. Whitaker et al. (2008) evidenced that, compared to sprinkler irrigation, subsurface drip could increase cotton yield and water use efficiency of about 8% and 15%, respectively, without affecting cotton fiber quality. Another two years experiment on cotton was carried out in north Xinjiang, China by Liu et al. (2013) in order to investigate the effects of different drip irrigation regimes on distribution and dynamics of water and solutes in the soil. The results revealed that irrigation frequency and water quality had significant effects on the spatial distribution and dynamic of soil water content, salt concentration and rate of crop water consumption, but has a limited impact on the seasonal cumulative water consumption and cotton yield.

A field experiments carried out by Wang et al. (2013) during three years allowed evaluating sustainable irrigation regimes for cotton, when low quality waters are available. The experiments involved mulched drip irrigation during the growing season and the subsequent flood irrigation. Numerical simulations, validated on the basis of the experiments and extended for 20 years, suggested that the alternative use of fresh and brackish water under mulched drip irrigation during the growing season and flood irrigation with freshwater after harvesting, can be considered a sustainable irrigation practice to avoid soil salinization.

Chuanjie et al. (2015) investigated effect of deficit irrigation (DI) regimes on cotton (Gossypium hirsutum L.) growth and yield in northern Xinjiang, China. The study showed that the growth, water use characteristics and yield of cotton varied with irrigation regime. They also suggested that proper DI schemes were necessary for sustainable cotton production in the region. While irrigation at 85% of ET was safe for high cotton yield, irrigation at 70% of ET was a viable alternative under limited irrigation water availability.

A few researches have been carried out to consider simultaneous effects of surface and subsurface drip irrigation as well as deficit irrigation on crop yield and water use efficiency, particularly for cotton production. The main objective of this work is to study the effects of surface and subsurface drip irrigation under different irrigation levels (i.e. full and deficit irrigation) on cotton yield and water use efficiency. Moreover, the net return associated to the different management strategies is presented and discussed, in order to identify the best irrigation practice applicable under limited water resources for cotton production.

2- Materials and Methods

2-1- Field Study

Kerman province, occupying about 11 percent of total area of the country (181,714 km^2), is one of the main province of Iran from agricultural viewpoint (Fig. 1). The region is characterized by a complex climate and severe long periods of drought that produces arid, such as deserts and grasslands and it is among the nation's poorest regions. Despite the diversity of climate, characterized by average annual precipitation and reference evapotranspiration ranging between 100 and 170 mm y^{-1} and 2100 and 3000 mm y^{-1}, respectively, and the limited water resources, this province represents one of the most important arable areas in Iran (Asadi et al., 2010). The diminution of available water resources in one hand and the rising the price of water in the other, has stimulate farmers in the region to a more efficient use of the available water resources. Field experiments were carried out, during two consecutive years (2014-2015), in the research farm of Natural Resources and Agriculture Research Center of Arzu'iyeh, located in the Kerman province. Experimental site (latitude 28°19'- 28°38' N , longitude 57°7'- 59°32' E, altitude 1067 m) is located about 250 km from west south of Kerman city (Fig. 1). The area is characterized by semi-arid and warm climate, with an average precipitation of 123 mm y^{-1} and reference evapotranspiration of about 1700 mm y^{-1}.

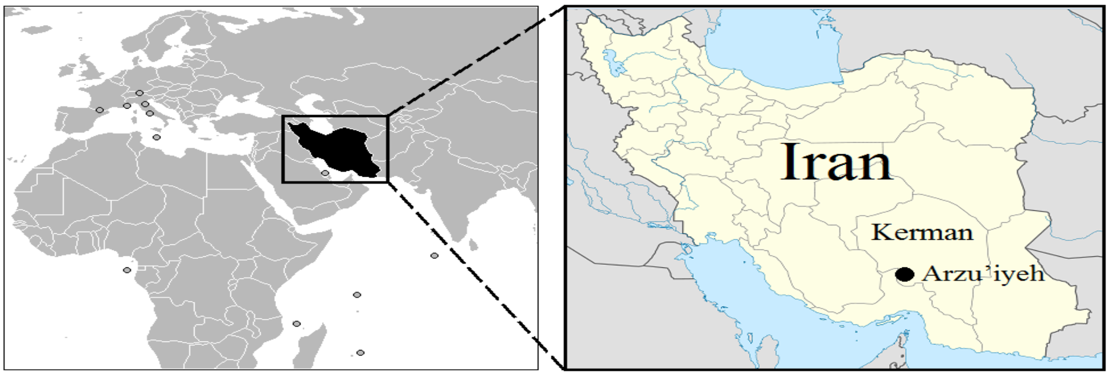


Fig. 1. Map of Kerman province and localization of the field study in Arzu'iyeh

2-2- Treatments and experimental design

In order to optimize water use on cotton through different drip irrigation methods, the experiments were implemented in form of split plots, on the basis of completely random blocks of split plots. Experiments were carried out on six treatments with three replications (three different irrigation regimes as main factor, i.e. L1=100, L2=80 and L3=60 percent of crop water demand at each irrigation event and two positions of the drip laterals used for irrigation as sub-factor, i.e. surface drip, S1, and subsurface drip, S2), for a total of 18 plots. Each plot, with dimensions of 3.5 m × 6.0 m meters, included 4 rows of 23 cotton bushes, with distances of 70 cm between the rows and of 25 cm between the plants. The distance between each group of three plots was 1.0 m, whereas between replications was 1.5 m. In surface drip irrigation, irrigation pipes were placed near the plants stem whereas in subsurface they were buried at the depth of 0.2m. Fig. 2 shows a schematic view of the experimental layout with indication of the different treatments.

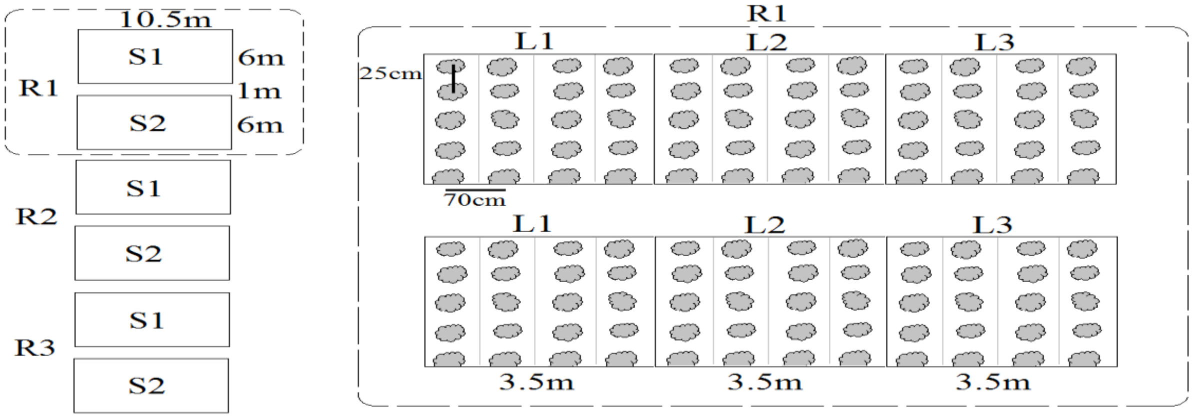


Fig. 2. Schematic view of the experimental layout with indication of the different treatments

Daily irrigation requirement of L1 treatment (I_{nL1}, mm) was calculated by Eq. (1):

$$I_{nL1} = \sum_{k=1}^{6}((\theta_{FCK} - \theta_{BIK}) \times D_K) \quad (1)$$

where I_{nL1} is the net irrigation depth (mm) for L_1 treatment, θ_{FCK}: is the volumetric soil water content at field capacity (FC, %), θ_{BIK}: is the volumetric soil water content before irrigation (%),D_K is the soil layer depth (mm) and *K* is the layer counter (i.e. six Decagon TDR sensors were installed in different soil layers for calculating irrigation requirement as will be described later). θ_{BIK} was measured daily one hour before each irrigation events during by Decagon TDRs. The L_2 and L_3 treatments were received 80% and 60% of calculated irrigation volume for L_1 treatment, respectively. In the present study, irrigation management for both surface and subsurface drip irrigation methods was scheduled every three days, starting shortly after plantation. The amount of water provided in each plot, was distributed by means of drip laterals with emitters of 2 L h^{-1} spaced 30 cm. A flow meter, installed in each plot, allowed controlling the amount of water distributed during each watering. In the period between planting and harvesting (10-May 2013/2014 to 7-Oct-2014/2015 for the 1st/2nd year) a number of 50 irrigation events were applied.

Tables 1 and 2 show chemical properties of soil and irrigation water. The amount of fertilizers provided to the plants was established on the basis of recommendation of Soil Laboratory of Agriculture Research Center of Kerman. The amounts of fertilizers applied during the growing season were 110 kg ha^{-1} urea, 40 kg ha^{-1} triple superphosphate and 20 kg ha^{-1} potassium chloride. One-third of the nitrogen and all the phosphorus and potassium were applied before planting, whereas the remaining amount of nitrogen was distributed at five-leaf stage of the plants.

At the harvesting time, the following parameters were measured in both years: a) the cotton yield which was determined on the two central rows of each plot, omitting the border rows, and b) the yield components and in particular the number of bolls per plant, the weight of each boll and plant height. The total amount of irrigation water distributed during the entire growing seasons was also measured.

Table 1. Soil physical and chemical properties of the experimental field

SAR	pH	EC [ds/m]	Soluble anions and cations [meq/l]						Clay [%]	Silt [%]	Sand [%]	Soil depth [cm]
			Ca	Mg	Na	Cl	Hco_3	So_4				
1.65	8	0.85	4	6	4.21	4	2.8	7.63	18	60	22	0-30

Table 2 - Chemical characteristics of irrigation water

pH	EC [dS/m]	Anions [meq/l]				Cations [meq/l]					
		CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Mg^{2+}	Ca^{2+}	K^+	Na^+	Fe^{2+}	Mn^{2+}
7.1	4	-	5.2	57.2	41	21.4	13.4	-	69	0.078	0.014

Water Use Efficiency, *WUE* [kg m^{-3} ha^{-1}], was calculated as:

$$WUE = \frac{Y_T}{V_T} \tag{2}$$

where Y_T [kg ha^{-1}] is the crop yield and V_T [m^3] is the total volume of irrigation water applied during the growing season.

2-3- Economical assessment

In this research, after gathering field information in order to choose the most economic treatment, at first condition was investigated using partial budgeting method. Then, for economic analysis of the project, results were evaluated on the basis of the investment preference determination method.

Partial budgeting method is a planning and decision-making outline usually used to compare the costs and the benefits of different alternatives faced by a farm business. It helps the manager to evaluate the economic effects of minor adjustments in some portion of his business. It focuses only on the changes in income and expenses that would result from implementing a specific alternative. In other words, many aspects of business are fixed, in the short run. Hence, all aspects of farm profits that are unaffected by the decision can be safely discounted. Investment preference refers to the set of assumptions related to ordering some alternatives, based on the degree of profits/losses, provide a process which results in an economical choice. In investment preference determination method, after ordering treatments based on net profit reduction, amount of net profit and variable costs (including cost of worker for 1. pipe insulation, 2. distribution of fertilizer, 3. weeding, 4. harvesting and 5. irrigation), treatments were compared one by one. If there would be a treatment with higher amount of profit and lower variable cost, thereafter investment on that treatment was preferred in comparison to the other treatments. In that case, the analysis of the marginal rate on investment is required.

2-4- Data analysis

Data were statistically analyzed by a complete randomized model using SAS software. All treatments were compared in the same column or in the same row in order to evaluate any statistical difference, using the Duncan's multiple range tests at significant levels of 0.01 and 0.05.

3- Results and Discussion

The analysis of variance for yield, water use efficiency and yield components of cotton for the first and second years are given in Tables 3 and 4, respectively. The results showed that replication was significant for yield and plant height just for the second year. Irrigation levels and systems were significant for all the measured parameters with an exception for the water use efficiency related to irrigation level in the second year.

Table 3- Analysis of yield and yield components of cotton for the first year

SOV	df	Yield	Water use efficiency	Number of boll per plant	Weight of boll	Plant height
Rep	2	2486.8	0.00003	2.166	0.003	23.38
Irrigation	2	1455657.55**	0.007**	54.50**	1.95**	1903.72**
Error1	4	11421.63	0.00018	1.66	0.01	9.472
Systems	1	275776.8**	0.0039**	26.88**	0.42*	490.88**
Irrigation× Systems	2	2213.5^{ns}	0.0039**	2.055^{ns}	0.07^{ns}	42.38^{ns}
Error2	6	6567.83	0.0001	0.5	0.3	12.88
CV%	-	3.72	3.97	4.32	4.23	3.97

Ns, ** not significant, significant at the 1 percent levels of probability

Table 4- Analysis of yield and yield components of cotton for the second year

SOV	df	Yield	Water use efficiency	Number of boll per plant	Weight of boll	Plant height
Rep	2	86155.5**	0.00003	5.05	0.1156	359.72**
Irrigation	2	1264686.72**	0.00041^{ns}	51.05**	1.526**	1505.38**
Error1	4	50858.31	0.000192	3.13	0.09	7.88
Systems	1	278755.5**	0.0056**	18.00*	0.40*	612.50**
Irrigation× Systems	2	2154.38^{ns}	0.00023^{ns}	0.16^{ns}	0.029^{ns}	6.50^{ns}
Error2	6	6884.28	0.00018	1.44	0.038	8.83
CV%	-	3.81	4.45	4.45	4.87	3.11

Ns, ** not significant, significant at the 5 percent and 1 percent levels of probability

The analysis of variance presented in Table 5 shows that the effect of first and second mutual effect was significant only for the plant height and has no effect on the yield. Effect of irrigation levels (L) was significant on all measured parameters. Effect of irrigation system was significant on all of the factors measured in this experiment. Significant interaction effects of main and sub treatments were noted only on water use efficiency. Considering the year parameter (Y) in Y*L, Y*S and Y*L*S rows in Table 5 indicates that operation of first or second year has no significant effect on yield, water use efficiency, number of boll per plant and weight of boll.

Table 5- Combined analysis of yield and yield components of cotton

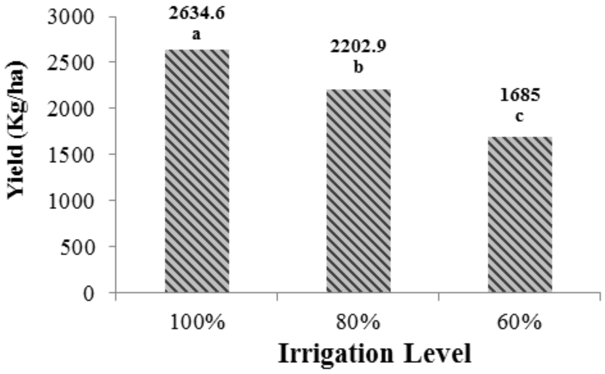
SOV	df	Yield	Water use efficiency	Number of boll per plant	Weight of boll	Plant height
Year	1	18.77	0.0000114	0.44	0.000023	240.25**
Error1	4	44321.22	0.00081	3.61	0.059	191.55
Irrigation	2	2712564**	0.00121*	105.36**	3.47**	3366.86**
Y*L	2	7779	0.00021	0.19	0.02	42.25*
Error2	8	31139	0.00061	2.4	0.05	8.68
Systems	1	554528**	0.01143**	44.44**	0.8**	1100.02**
S*L	2	4096	0.00053	1.36	0.07	38.86
Y*S	1	4	0.000001	0.44	0.001	3.36
Y*L*S	2	271.58	0.000005	0.86	0.03	10.02
Error3	11	6726	0.0002	0.97	0.034	10.86
CV%	-	3.7	4.51	6.07	4.59	3.55

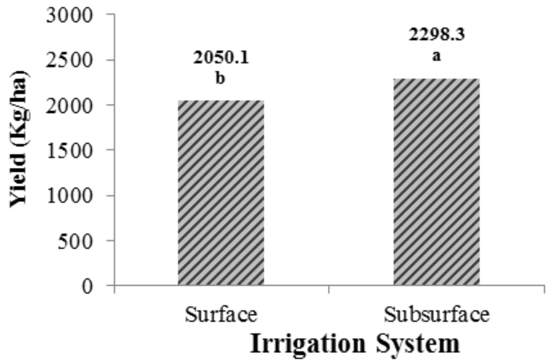
Ns, *, ** not significant, significant at the 5 percent and 1 percent levels of probability

3-1- Amount of water consumption and crop yield

Amount of irrigation water applied in the two main treatments was the same but the total amount consumed in sub-treatments was 9200, 7360 and 5520 m^3 ha^{-1} for 100, 80 and 60 percent of crop water demand during total growing season, respectively. In treatment of 100 percent of water requirement, maximum yield of 2634.6 kg ha^{-1} was obtained which was about 16.4 and 36 percent higher than treatments of 80 and 60 percent of crop water demand at each irrigation event for the average of two years, respectively (Fig. 3a). The small adverse effect of treatment of L2could be due to the relatively slight stress observed during the growing season on cotton yield components (White and Raine, 2004). This study suggests that severe drought stress can led to decrease of ball size and/or decrease of plant photosynthesis level thereby reduced plant yield. (Payero et al., 2006). Even Dagdelen et al. (2009) evidenced similar results to those obtained within this research.

Despite consumption of similar amount of water in treatments of irrigation systems, yield in treatment of subsurface drip irrigation system was 10.8 percent higher than in surface drip irrigation system for average of the first and second years (Fig. 3b). According to the results of Dastourani et al., 2007, under subsurface irrigation system, lower are evaporation losses, better is the control of weeds; moreover, delivery water directly to root zone increases yield compared to surface drip irrigation. Even Onder et al. (2009) observed similar results when compared yield obtained with SDI and traditional DI systems.



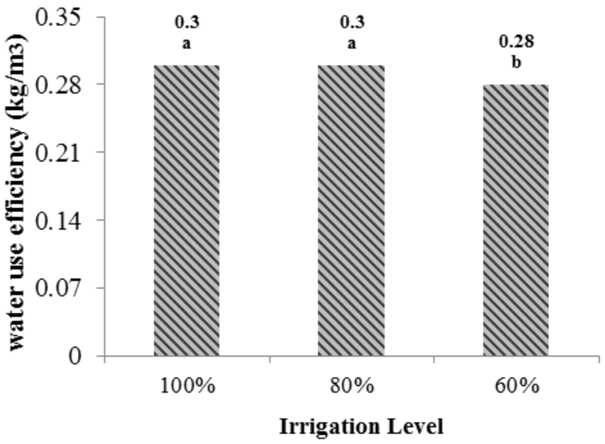


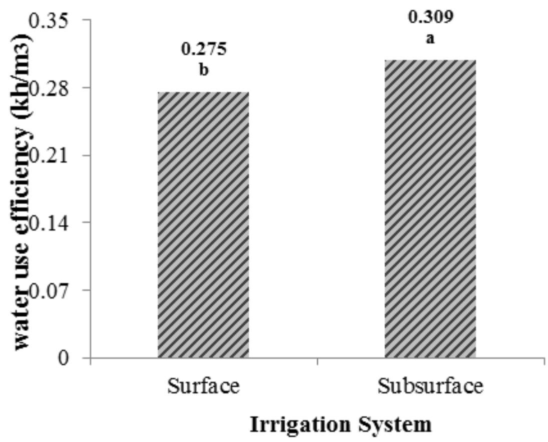
a) b)

Fig. 3. Main effect of irrigation a) irrigation levels, b) irrigation systems on cotton yield

3-2- Water use efficiency

Environmental and genetic factors can influence water use efficiency of cotton. Reducing soil moisture may increase water use efficiency through the closure of stomata (Zwart and Bastiaanssen, 2004). Experimental data evidenced that there was a significant effect on water use efficiency due to irrigation level (Fig. 4a) and irrigation system (Fig. 4b) for the average of two years. Despite differences of amount yield (432 kg h^{-1}) and 1840 m^3 ha^{-1} in treatments of 100 and 80 percent of crop water demand at each irrigation event, but in terms of water use efficiency were no difference and they stayed on same group a. However, treatment of 60 percent of crop water demand at each irrigation event had a 6.7 percent difference with these two treatments and was placed in group b (Fig. 4a). Also water use efficiency in treatment of subsurface drip irrigation system was 11 percent higher than in surface drip irrigation system for average of the first and second years (Fig. 4b). Unlu et al. (2010) from a study in Turkey and Jared et al. (2008) from a study in drought regions of California and Arizona reported the similar results to present experiment.





a) b)

Fig.4. Main effect of irrigation a) irrigation levels, b) irrigation systems on water use efficiency

3-3- Morphological characteristics

Number of boll in 100 percent of crop water demand at each irrigation event has increased 14 and 31 percent compared to 80 and 60 percent of crop water demand at each irrigation event respectively for average of the first and second years (Table 6). This was due to the effect of increased intensity of water stress on number of bolls per plant. Similar results were presented by Ayars et al. (1999) and White and Raine (2004). Also Number of boll in treatment of subsurface drip irrigation system was 12.8 percent higher than in surface drip irrigation system for average of the first and second years (Table 7).

Plant height in 100 percent of crop water demand at each irrigation event has increased 15.1 and 30.6 percent compared to 80 and 60 percent of crop water demand at each irrigation event respectively for average of the first and second years (Table 6). Also plant height in treatment of subsurface drip irrigation system was 11.5 percent higher than in surface drip irrigation system for average of the first and second years (Table 7).

Boll weight in 100 percent of crop water demand at each irrigation event has increased 22.8 and 9.3 percent compared to 80 and 60 percent of crop water demand at each irrigation event respectively for average of the first and second years (Table 6). Also boll weight in treatment of subsurface drip irrigation system was 7.7 percent higher than in surface drip irrigation system for average of the first and second years (Table 7).

Table 6. Main comparison of irrigation level effect of yield components

Year	treatments	Number of boll per plant	Weight of boll (g)	Plant height (cm)
1st year	100 %	19.16a	4.51a	108.83a
	80 %	16.66b	4.11b	88.50b
	60 %	13.16c	3.38c	73.33c
2nd year	100 %	19.00a	4.48a	110.16a
	80 %	16.16a	4.05a	97.33b
	60 %	13.16b	3.47b	78.66c
Average	100 %	19.08a	4.50a	109.50a
	80 %	16.41b	4.08a	92.92b
	60 %	13.16b	3.43b	76.00c

Table 7. Main comparison of systems effect of yield components

Year	treatments	Number of boll per plant	Weight of boll (g)	Plant height (cm)
1st year	Surface	15.11b	3.84b	85.00b
	Subsurface	17.55a	4.16a	95.44a
2nd year	Surface	15.11b	3.85a	89.55b
	Subsurface	17.11a	4.15a	101.22a
Average	Surface	15.11b	3.85b	87.28b
	Subsurface	17.33a	4.16a	98.33a

3-6- Economical analysis

In Table 8, the amount of gross income of each treatment according to different aspects of treatments in terms of revenue is tabulated.

Table 8. Gross income of experimental treatments per hectare

Treatment		L3S2	L3S1	L2S2	L2S1	L1S2	L1S1
Water usage (m3)		5520		7360		9200	
Yield (kg)		1825	1545	2307	2099	2763	2506
Gross income	Thousand Rials	22812	19312	28837	26237	34537	31325
	USD $ equivalent	919.4	778.3	1162.2	1057.4	1391.9	1262.5

Note: Price for 1 kilogram of cotton was considered 12500 Rials (0.50 $).

From Table 8 it can be seen that the gross income of L1S2 (100 percent of crop water requirement in subsurface system) treatment is more than the other treatments, followed by L1S1 (100 percent of crop water demand at each irrigation event in surface system).

Different aspects of treatments in terms of costs

The calculation of different aspects of treatments in terms of costs is shown in Table 9. Each row in Table 8 is defined as below:

Row 1 (Installation): In order to install the irrigation pipes, there are 4 workers are needed per hectare in the surface drip irrigation system, and 7 workers in the subsurface irrigation system per each hectare (the wage is 180 thousand Rials/7.25$). Row 2 (harvesting): for harvesting 1 ton of cotton, 3.5 workers are needed (the wage is 180 thousand Rials/7.25$). Row 3 (Opportunity cost of water):

Opportunity cost is a key concept in economics (Buchanan, 1987; Crowards, 1998). The opportunity cost is the net benefit forgone, because the resource providing the service can no longer be used in its next-most-beneficial use. The opportunity cost approach is a very useful technique when benefits of certain uses, such as preservation, protection of habitats, cultural or historical sites, cannot be directly evaluated.

As the L3S1 and L3S2 treatments consume the lowest amount of irrigation water, the thrift difference of irrigation water cost was virtually used to increasing the cultivation of other treatments and the final cost has been calculated.

Table 9. Annual calculation of different aspects of treatments based on costs

	Treatment					
Row	L3S2	L3S1	L2S2	L2S1	L1S2	L1S1
1	328TR/ 13.2$	187TR /5.5$	328TR/ 13.2$	187TR /5.5$	328TR/ 13.2$	187TR /5.5$
2	1149TR/46.3$	973TR/39.2$	1453TR/58.6$	1322TR/53.3$	1741TR/70.2$	1578TR/63.6$
3	-	-	2830TR/114.1$	2907TR/117.1$	5137TR/207.0$	5298TR/213.5$
Total	1478TR/59.6$	1161TR/46.8$	4612TR/185.9$	4416TR/178.0$	7206TR/290.4$	7064TR/284.7$

Note: TR stands for thousand Rials

From Table 9, it can be concluded that the L3S1 (60 percent of crop water demand at each irrigation event in surface system) has the lowest amount of costs whereas the L1S2 (100 percent of crop water demand at each irrigation event in subsurface system) has the most.

Economic analysis of project by investment Preference Determination method

In Preference determination method, the treatments are ordered on the basis of net return and thereafter the investment preference is determined (Table 10).

Table 10. Economic analysis of project by investment Preference Determination method

	Treatment					
	L1S2	**L1S1**	**L2S2**	**L2S1**	**L3S2**	**L3S1**
Rank	**1**	**2**	**3**	**4**	**5**	**6**
Cost	7206TR/290.4$	7064TR/284.7$	4612TR/185.9$	4416TR/178.0$	1478TR/59.6$	1161TR/46.8$
Gross income	34537TR/1391.9$	31325TR/1262.5$	28837TR/1162.2$	26237TR/1057.4$	22812TR/919.4$	19312TR/778.3$
Net return	27331TR/1101.5$	24261TR/977.8$	24225TR/976.3$	21821TR/879.4$	21334TR/859.8$	18151TR/731.5$
dominate or undominate	UD	UD	UD	UD	UD	UD

Table 11. MRR between treatments

	Treatment					
	L3S1	**L3S2**	**L2S1**	**L2S2**	**L1S1**	**L1S2**
Net income	18151TR/731.5$	21334TR/859.8$	21821TR/879.4$	24225TR/976.3$	24261TR/977.8$	27331TR/1101.5$
Cost	1161TR/46.8$	1478TR/59.6$	4416TR/178.0$	4612TR/185.9$	7064TR/284.7$	7206TR/290.4$
MRR%	-	1004	16	1226	1	2161

Because of MARR=100 percent, L3S2 treatment is economically better than L3S1 and L2S1 treatments, L2S2 is better than L2S1 and L1S2 is better than L1S1.

Table 12. MRR between L3S2 and L2S2

	Treatment	
	L3S2	**L2S2**
Net income	21334TR/859.8$	24225TR/976.3$
Cost	1478TR/59.6$	4612TR/185.9$
MRR%	-	92

Because of MARR=100 percent, L3S2 treatment is economically better than L2S2 treatment.

Table 13. MRR between L3S2 and L1S1

	Treatment	
	L3S2	**L1S2**
Net income	21334TR/859.8$	27331TR/1101.5$
Cost	1478TR/59.6$	7206TR/290.4$
MRR%	-	104

L1S2 treatment is economically better than L3S2 treatment.

Net return is gross return minus costs. According to the results of Tables 8-13, it can be seen that the most economic treatment is L1S2 (100 percent of crop water demand at each irrigation event in subsurface system).

4- Conclusions

Results of two years of technical and economic analysis of drip irrigation systems and irrigation levels on yield and water use efficiency of Cotton showed that yield, water used efficiency, boll weight, number of boll and plant height in subsurface drip irrigation system (S2) have increased 10.8, 11, 7.45, 12.8 and 11.2 percent compared to surface drip irrigation system (S1). Also yield, number of boll, boll weight and plant height in 100 percent of crop water requirement (L1) have increased 16.4, 14, 9.3 and 15.1 percent compared to 80 percent of crop water requirement, but water use efficiency has been equal in the two treatment and

1840 cubic meters of water per hectare was saved which can be seen as a strength of 80 percent of crop water requirement (L2). Economic analysis showed that applying 100 percent of crop water requirement in subsurface drip (L1S2) was superior to the other treatments. Therefore, to increase farmers' income, achieve higher water use efficiency and less water consumption for cotton production in the study region, it is suggested that full crop water requirements be applied in a subsurface drip irrigation system in cotton cultivation in Arzu'iyeh in Kerman.

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