# EFFECT OF SURFACE AND SUBSURFACE DRIP IRRIGATION METHODS AND IRRIGATION FREQUENCY ON COTTON YIELD AND WATER USE EFFICIENCY

# Effet de la surface et subsurface des méthodes d'irrigation au goutte à goutte et la fréquence d'irrigation sur le rendement et l'efficacité d'utilisation de l'eau dans du coton

**Jolaini[1], M. and Zarei[2], Gh.**

## ABSTRACT

This study was conducted to determine the impacts of irrigation frequency and drip irrigation method and their interactions on yield, water use efficiency and quality characteristic of cotton in Kashmar Agricultural Research Station in Razavi Khorasan Province. The study was done during 2006-2008 years. Experimental design was two factor completely randomized design with four replications. Design treatments included irrigation frequency (2, 4, and 6 day) and drip irrigation method (surface and subsurface drip irrigation). The combined analyze showed that irrigation method had significant effect on Yield and Water Use efficiency (P≤ 0.01). There was significant difference between yield in surface drip and subsurface drip irrigation (3074 and 3988 kg/ha, respectively). Water use efficiency in subsurface drip irrigation was 0.349 kg/m$^3$ that was greater than surface drip irrigation. Yields in different irrigation frequency had no significant difference and for 2, 4, and 6 days irrigation frequency were 3491, 3725 and 3364 kg/ha, respectively. The highest water use efficiency and yield were obtained in subsurface irrigation method with 4 days irrigation frequency (4315 kg/ha and 0.375 kg/m$^3$, respectively). However, the least water use efficiency and yield was obtained in surface irrigation method with 2 days frequency (3107 kg/ha and 0.265 kg/m$^3$, respectively). In general, subsurface dripirrigation whit 4 days irrigation frequency was selected and recommended as the best treatment.

Keywords: Cotton, Irrigation frequency, Drip irrigation, Subsurface irrigation, Water use efficiency

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1.Scientist. Khorasan Razavi Agriculture & Natural Resources Research Center
Email: mjolaini@yahoo.com Tel: 0915-5008834
2.Scientist. Agricultural Engineering Research Institute, Karaj, Iran.

# 1. Introduction

Water is the main limited resource for the Khorasan cotton production. Water aquifers are being depleted in many areas of the this province and farmers have adapted new agronomic practices to increase water use efficiency such as using narrower row spacing, reduce tillage practices, irrigate more frequently, use deficit irrigation, and use drip irrigation system. From the perspective of water stress view, the purpose of irrigation is to keep water status at a level that maximizes yield within the constraints of irrigation supply and growing season weather conditions.

Surface drip irrigation (DI) is an efficient system for delivering water to crops. However, a saturated or nearly saturated soil surface generally exists beneath each emitter. In arid and semi arid climates, evaporation from the soil surface beneath an emitter can be considerable, primarily due to the hot, dry air blowing across the wetted surface. In arid dry land farming, reduction in evaporation losses can significantly increase water use efficiency. So, subsurface drip irrigation (SDI) has been used to eliminate surface ponding by burying the irrigation lateral underground. The operational characteristics and advantages of SDI beyond those of surface drip irrigation are: (1) a substantial increase in water use efficiency (WUE), (2) a near total elimination of deep percolation and nitrate-nitrogen leaching and (3) long-term sustainability of the system. The major and unique characteristics of SDI which contribute to these advantages include (1) reduced soil evaporation, (2) larger wetted soil volume and surface area than with DI systems, and (3) deeper rooting pattern. Because of its unique characteristics, SDI offers the most promising and sustainable option to gravity irrigation. Use of surface and subsurface drip irrigation has progressed from being a novelty employed by researchers to an accepted method of irrigation of both perennial and annual crops. One of the annual crops is cotton which is one of the most row crops in Iran.

Recently, lot of emphasis is being given on improvement in irrigation practices to increase crop production and to sustain the productivity levels. Many researchers have reported higher yields and water use efficiency (WUE) of drip irrigation system over the conventional irrigation methods throughout the world. In drip irrigation the volume of wetted soil at a particular water application is controlled by the volume of water added, the discharge rate of dripper and the soil water content (Bresler, 1977). This method is most suited to semi-arid and arid areas where water is scarce and where low water consuming and high value crops can be grown. Cotton is one of the most important fiber-producing plants throughout the world. Drip irrigation method is being practiced for cultivation of cotton in many countries such as USA (Wanjura et al., 2002), Israel (Plaut et al., 1988), Spain (Mateos et al., 1991), and Turkey (Cetin and Bilgel, 2002). In India, drip irrigation in cotton is being practiced by some farmers in heavy textured soils (Bharambe et al., 1997; Kumar and Singh, 2002). But in Indo-Gangetic plains, where soils are light in texture and underground water is brackish, cotton drip irrigation is at experimental stage.

The major drawback of the drip irrigation system is its high initial investment; however, cost can be recovered in a short span if proper nutrient, water management and design principals are followed. Among the various components of drip irrigation system, the cost of lateral is the major factor, which influence the total system cost. Any effort made to reduce the length of lateral required per unit area of the field will result in reduction of the system cost. Studies in the southeastern U.S. and elsewhere have shown that drip and sprinkler irrigation increased seed cotton yield compared to dry land cotton yield (Camp et al., 1994; Camp et al., 1997; Bronson et al., 2001; Pringle and Martin 2003; Sorensen et al., 2004; Kalfountzos et al., 2007). However, a four-year study conducted on loamy sand in the southeastern coastal plain found that cotton did not respond to drip irrigation in two seasons likely due to the small amounts of irrigation applied (Camp et al., 1997; Bauer et al., 1997). Similarly, Camp et al. (1999) reported that subsurface drip irrigation (SDI) in North Carolina did not increase cotton yield and attributed the absence of response to soil compaction that restricted

root growth above the SDI lines. The profitability of drip irrigation is impacted by the design life of the system, the spacing and placement of laterals, and the method by which irrigation and fertilization is scheduled and applied.
The objective of this paper are to evaluate the impacts of drip irrigation methods, irrigation frequency and their interactions on yield, water use efficiency and quality characteristic in cotton cultivation.

## 2. Material and methods

This study was conducted to determine the impacts of irrigation frequency and drip irrigation method and their interactions on yield, water use efficiency and quality characteristic of cotton in Kashmar Agricultural Research Station in Razavi Khorasan Province. The study was done during 2006-2008 years. Experimental design was two factor completely randomized design with four replications. Design treatments were includes irrigation frequency (2, 4, and 6 day) and drip irrigation methods (surface and subsurface drip irrigation). Varamin cultivar was studied in this research. Water quality was tested and its results are shown in Table 1. Soil physical characteristics of the experimental site were determined by creating a profile in the soil up to 60 cm depth. The soil conditions in tow layers from 0-30 to 30-60 cm were determined. Soil texture, moisture at field capacity and wilting point, pH, Electrical conductivity (EC) and soil chemical elements, including nitrogen, phosphorus, potassium, calcium and magnesium were mentioned physical characteristics.
These results are given in Table 2.

**Table 1.** Test results of irrigation water quality
Les résultats des tests de qualité de l'eau d'irrigation

| EC (dS/m) | PH | Soluble captions (meq/lit) | | | | Soluble anions (meq/lit) | | | SAR |
|---|---|---|---|---|---|---|---|---|---|
| | | $Na^{+}$ | $Mg^{++}$ | $Ca^{++}$ | $K^{+}$ | $CL^{-}$ | $So_4^{--}$ | $Co_3^{--}$ | |
| 1.0 | 7.9 | 7.5 | 1.2 | 1.3 | - | 5.0 | 3.4 | 2.0 | 6.7 |

**Table 2.** Soil physical properties of the test site
Propriétés physiques du sol du site d'essai

| Soil depth (cm) | Particle size Distribution (%) | | | Texture | Bulk density ($g/cm^3$) | Soil Moisture (%) | | |
|---|---|---|---|---|---|---|---|---|
| | Sand | Silt | Clay | | | FC | PWP | AW |
| 0-30 | 23 | 22 | 55 | SL | 1.41 | 31.5 | 18.0 | 13.5 |
| 30-60 | 23 | 23 | 54 | SL | 1.48 | 35.7 | 19.1 | 16.6 |

Four cultivated lines were considered for each treatment. Lines had 15 meters long. Distance between treatments and replications were 1.5 m. Also, distances between rows were 0.75 m and between plants on rows were 20 cm. The planting was done manually and varieties of Varamin were used. Potassium, phosphorus and one-third of nitrogen fertilizers requirements was given based on soil test results before planting. Residual nitrogen fertilizer was used as fertigation during the growing season. All practices during the growing season included pest, diseases and weeds control were alike for all treatments.
Drip tape irrigation method was used for irrigation of cotton. In this method, the distance between emitters was 30 cm and the discharge of tapes was 4 liters per

hour per meter and the thickness of tape tubes were 300 microns. In the surface drip irrigation, one pipeline (tape) was considered for each row which was to widen the distance of rows was 10 cm. However, In subsurface drip irrigation for each row in each plot a lateral line was considered and pipes were installed at depth of 15 cm from soil surface.

In each treatment which were consisted of 4 lines with 15 meters long, one meter from beginning and edge of the planting cotton was removed and the remain planted cotton (length 13 m) were harvested. The yield of cotton, water consumption and water use efficiency of each treatment were determined. Data were analyzed statistically using the MSTAT-C software. However, Mean Comparison was performed using Duncan's Multiple Range tests.

## 3. Results and discussion

### 3.1 Combined analysis

Results of combined variances analysis of tow year's experiment are shown in table 3. According to this table, the effect of year on all the traits is significant the 1% level (P≤ 0.01). The effect of irrigation frequency has not significant more of the attribute investigated. The effect of irrigation methods had not significant effect on the height of cotton, while on the early ripeness; yield and water use efficiency was significant at the 1% level (P≤ 0.01). The reaction effect of irrigation frequency and irrigation method had not significant over any of the attributes.

### 3.2 Cotton yield

Results of Mean comparison of cotton yield in different treatments showed that irrigation frequency had not significant effect on yield, while the method of irrigation has significant difference in the level of 5% (P≤ 0.01) for cotton yield (Table 4). The amount of yield in subsurface drip irrigation has been equal to 3987 kg/ha and compare to the surface drip irrigation (3074 kg/ha) was in a higher rank. The most yields was obtained from subsurface drip irrigation method with four days irrigation frequency (4315 kg/ha). However, the least yield was belonged to surface drip irrigation method with tow days irrigation frequency (3107 kg/ha).

**Table 3.** Combined variance analysis of yield and water use efficiency of cotton
Analyse de la variance combinée de rendement et l'efficacité d'utilisation de l'eau de coton

| Variation source | Degrees of freedom | Mean square (MS) | |
|---|---|---|---|
| | | Yield (kg/ha) | WUE (kg/m$^3$) |
| Year (A) | 1 | 3452976** | 0.615** |
| Irrigation frequency (I) | 2 | 536458 $^{ns}$ | 0.003 $^{ns}$ |
| AI | 2 | 86163 $^{ns}$ | 0.001 $^{ns}$ |
| Irrigation method (R) | 1 | 9812799** | 0.079** |
| AR | 1 | 602675 $^{ns}$ | 0.006 $^{ns}$ |
| IR | 2 | 227671 $^{ns}$ | 0.002 $^{ns}$ |
| AIR | 2 | 112668 $^{ns}$ | 0.001 $^{ns}$ |
| Error | 30 | 267523 | 0.002 |
| Coefficient of variation (%) | - | 14.44 | 14.96 |

Explanation: **, * and $^{ns}$ are Significant difference at 1% and 5% level and no significant, respectively.

**Table 4.** Mean comparison of yield of cotton in different treatments
Comparaison de la moyenne des rendements du coton dans les différents traitements

| Treatment | | Yield of cotton (kg/ha) |
|---|---|---|
| Irrigation frequency (I) | 2 day | 3491 a |
| | 4 day | 3725 a |
| | 6 day | 33634 a |
| Irrigation method (R) | Surface drip irrigation | 3074 b |
| | Subsurface drip irrigation | 3988 a |
| Reaction effects | $I_1R_1$ | 3108 |
| | $I_1R_2$ | 3874 |
| | $I_2R_1$ | 3135 |
| | $I_2R_2$ | 4315 |
| | $I_3R_1$ | 2981 |
| | $I_3R_2$ | 3747 |

### 3.3. Water use efficiency

Results of Mean comparison of cotton water use efficiency in different treatments (Table 5), showed that the irrigation frequency had not significant effect on water use efficiency (WUE), while the effect of the irrigation method treatment on WUE was significant at the 1% level (P≤ 0.01). Similar to yield indices, the amount of water use efficiency in subsurface drip irrigation was been more than surface drip irrigation. Water use efficiency in subsurface drip irrigation from 0.349 kg/$m^3$ decrease to 0.268 kg/$m^3$ in surface drip irrigation. The maximum water use efficiency was 0.375 kg/$m^3$ in subsurface drip irrigation with four days irrigation frequency treatment. However, the least WUE was 0.265 kg/$m^3$ in the surface drip irrigation with tow days irrigation frequency.

**Table 5**. Mean comparison of water use efficiency of cotton in different treatments
Comparaison de la moyenne d'efficacité de l'utilisation de l'eau de coton dans les différents traitements

| Treatment | | WUE of cotton (kg/$m^3$) |
|---|---|---|
| Irrigation frequency (I) | 2 day | 0.298 a |
| | 4 day | 0.323 a |
| | 6 day | 0.304 a |
| Irrigation method (R) | Surface drip irrigation | 0.268 b |
| | Subsurface drip irrigation | 0.349 a |
| Reaction effects | $I_1R_1$ | 0.256 |
| | $I_1R_2$ | 0.331 |
| | $I_2R_1$ | 0.272 |
| | $I_2R_2$ | 0.375 |
| | $I_3R_1$ | 0.267 |
| | $I_3R_2$ | 0.341 |

## 4. Conclusion and Recommendations

According to the results of combined variances analysis of this project, in both years, the most yield was obtained from subsurface drip irrigation with four days irrigation frequency (4315 kg/ha). Also, the least yield was obtained from surface drip irrigation with tow days irrigation frequency (3107 kg/ha). Because of the cotton plant is a plant with unlimited growth and during parts of its growth, the process of breeding and growing are correlated, therefore the management of growth sources such as water

and fertilizer are very much important. The highest water use efficiency (0.375 kg/$m^3$) was obtained from subsurface drip irrigation and four days irrigation frequency. However, the lowest water use efficiency (0.265 kg/$m^3$) was obtained from surface drip irrigation methods with tow days irrigation frequency. Irrigation turns each day, most of the production increasing may lead to further loss of water to evaporation, especially in the shallow water. The overall result of this project is that in cotton plantations, subsurface drip irrigation methods and irrigation every four days is the best treatment.

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