

THE EFFECT OF SOIL WATER AND ROOTING DEPTH MONITORING ON IRRIGATION WATER CONSERVATION

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ABSTRACT. Irrigation practices are influenced by the degree of root proliferation since water supply available to the plant is limited to the soil volume explored in the crop's root system. An investigation was undertaken to determine the effect of soil water and rooting depth monitoring of corn and sugar beet on irrigation water saving. Two independent experiments were conducted in a split plot design for corn and sugar beet for four irrigation methods with three replications in a semi-arid region in Southern Iran. The irrigation systems were furrow, surface drip, subsurface drip and conventional irrigation methods. A significant improvement in water saving was obtained with irrigation methods in which irrigation requirements were based on soil water and rooting depth monitoring comparing to conventional irrigation method that was based on a fixed irrigation interval. The experimental results indicated that a significant improvement in water saving also was observed when irrigation scheduling was based on monitoring comparing to the estimation using Penman Montith equation for water requirement.

Keywords: irrigation scheduling, water saving, soil moisture monitoring, root depth monitoring

Introduction

With increasing concern about declining water resources, there is a great intension to improve water management in farming systems to improve water saving (Buttar et al, 2007). Several possible approaches such as irrigation technologies and efficient irrigation scheduling (Kirda, 2000) may be adapted for more effective uses of limited water supplies. The great challenge of the agricultural sector is to produce more food from less water, which can be achieved by increasing crop water productivity. Irrigated agriculture is the largest water consuming sector and it faces competing demands from other sectors (Sander and Bastiaansen, 2004, Kijne et al., 2003). Hanson et al. (1997) evaluated improved furrow irrigation, surface drip and subsurface drip irrigation methods for reducing deep percolation, increasing yield and saving applied water. They reported that overall performance showed volumes of applied water from the drip methods ranged between 43 and 74% of that required from the furrow method. Also less variability in plant mass and yield occurred for the drip plots. Zwart and Bastiaansen (2004) reviewed 84 literature sources that had studied water use efficiency of wheat, rice, cotton and corn and concluded that water use efficiency can be increased significantly if irrigation water is reduced and crop water deficit is intentionally induced. Panda et al. (2004) evaluated the effect of different irrigation scheduling methods on root zone soil moisture, growth, yield parameters and water use efficiency of corn and concluded that under water scarcity conditions, irrigation should be scheduled at 45% of the maximum allowable depletion of available soil water of corn to obtain high yield parameters and high irrigation water use efficiency. Little information is available on the effect of soil water and plant rooting depth monitoring with different irrigation methods on water savings in corn and sugar beet production compared with conventional irrigation scheduling (based on a fixed irrigation interval) and irrigation required based on Penman-Montith equation.

The aim of this paper is to evaluate the effect of soil water and rooting depth monitoring on water saving comparing with conventional irrigation method and application of Penman-Monothoist equation in an arid region with water scarcity.

Materials and Methods

A field experiment was conducted at a municipal sewage secondary treatment site in Southern Iran. The average rainfall of site is 340 mm and the annual evaporation is 2585 mm. Some properties of the soil at the experimental site and some chemical properties of two types water (secondary municipal effluent and fresh water) used given in Tables 1 and 2. Soil texture was clay loam and the soil was classified as calcareous. The main treatments were four irrigation methods. Furrow irrigation, surface drip irrigation, subsurface drip irrigation all with soil moisture and rooting depth monitoring for irrigation scheduling and a conventional furrow irrigation method without any monitoring. The irrigation scheduling in conventional method was simulated as farmers do in the field but the length of furrows were same as the length of the former three irrigation methods. For this system irrigation interval was adjusted for 11 days (similar to the intervals applied by farmers). For Furrow, subsurface drip and surface drip methods irrigation scheduling was based on the soil moisture deficit in root zone at each irrigation event (difference between root zone soil water at field capacity and at irrigation time) with intervals of 4 days. To determine the soil moisture deficit, within the root zone, the depth of roots was measured weekly (pictures 1 and 2) and soil water was measured by gravimetric method at each irrigation event. In order to measure the root depth development, a number of trenches with depth and width of 1 m and 20 cm away from the plant rows were dug. At each measurement, three plants from each trench were selected and the depth of roots was measured manually by ruler.

Irrigation was scheduled based on soil moisture monitoring gravimetric method within the root zone and root depth development in each irrigation event. Soil moisture depletion within the root zone was calculated (based on the area of plots and depth of moisture depletion) and the required amount of water was applied. The volume of applied water was measured with flow meters installed in the delivering pipes at the beginning of plots.

Also the irrigation requirement in all four irrigation methods was estimated using Penman-Montith equation on the base of the long term mean meteorological data from the nearest climate station implementing the CROPWAT model.

Table 1. Physical properties of different soil layers at the experimental field

Soil depth (cm)	Soil texture	Bulk density (g cm ⁻³)	FC weight (%)	PWP weight (%)
0-20	Clay loam	1.29	21	17
20-40	Clay loam	1.30	23	17
40-60	Clay loam	1.36	22	19

FC and PWP: soil moisture at field capacity and permanent wilting point, respectively

Table 2. Some chemical properties of two types water used

Irrigation water	EC (dSm ⁻¹)	SAR (meqL ⁻¹) ^{1/2}	pH
Effluent	1.46	2.66	7.80
Fresh water	0.51	0.53	7.78



Picture 1. Corn root depth monitoring



picture 2. Sugar beet root depth monitoring

Results and Discussion

The amounts of irrigation water applied for corn in the furrow (FI), surface drip (SD) and subsurface drip (SSD) irrigation methods were 6822, 6591 and 5907 m³ ha⁻¹, respectively, while in the simulated conventional method (C I) was 13200 m³ ha⁻¹, which was 93.5%, 100% and 123% more than that applied for the FI, SD and SSD methods, respectively that the irrigation scheduling was based on monitoring. The amount of water applied for the conventional method for sugar beet was 16042 m³ ha⁻¹, which was 40.7%, 92.5% and 10.1.5% more than that applied for the FI, SD and SSD methods with monitoring, respectively. Irrigation requirements for sugar beet in four investigated irrigation methods including the conventional method and also the furrow irrigation based on Penman–Montith equation are shown in Fig.1. The applied water on the base of monitoring and irrigation requirement estimated by Penman-Montith equation (CROPWAT) for corn and sugar beet was calculated on the base of the mean long term climatic data and the saved water for both crops are listed in Table 3. The measurements showed that when irrigation scheduling for corn was based on monitoring, the SSD, SD and FI methods led to 36.5%, 35% and 38.5% water savings (less water used), respectively compared with the CROPWAT estimation. Irrigation based on monitoring the soil moisture and rooting depth for sugar beet also led to a saving of 14.6%, 32.4% and 31.8% for FI, SD and SSD irrigation methods compared to the irrigation water based on the CROPWAT estimation.

As shown in Fig.1 water saving in sugar beet cultivation for FI, SD and SSD irrigation methods with monitoring comparing to conventional irrigation method was 43.8%, 98.8% and 92.5% respectively. Based on this logic if local farmers simply supply their irrigation water in furrow irrigation systems using Penman-Montith equation and the mean long term weather data instead using a constant irrigation interval they would save 16% water while using monitoring they would save much more water (43.8% for furrow method). These figures would mainly represent the effect of irrigation scheduling using soil water and rooting depth monitoring rather than using the empirical equations such as Penman-Montith although it is the most recommended model for the study region. The reasons for less applied water using soil water and rooting depth monitoring instead of using Penman-Montith (CROPWAT model) could be probably due to the use of mean long term weather data instead of using the actual weather data for the experimental year, the distance of weather station (10 Km) from the experimental site, and the depth of the water table though it was kept below 180 cm during the experiment time.

Conclusion

Although the modern irrigation systems such as surface drip and subsurface drip have had contribution in lowering the water used for both corn and sugar beet comparing to the traditional method used in the region, the soil water and rooting depth monitoring for irrigation scheduling led to a considerable reduction in irrigation water compared to the irrigation based on empirical Penman-Montith equation. However, increasing the salinity build up within the root zone in long term would be a great concern when considerable water saving is achieved. One alternative to this short come would be leaching during the precipitation time by flooding the soil with an efficient management program, otherwise the salinity build up would be a severing problem.

Table 1. Applied water and irrigation requirement estimated by Penman-Montith in different irrigation methods

Irrigation methods	Applied water Based on monitoring		Irrigation requirement Based on Penman-Montith		Saved water			
	corn	sugar beet	corn	sugar beet	corn	%	sugar beet	%
	(m ³ ha ⁻¹)		(m ³ ha ⁻¹)		m ³ ha ⁻¹		m ³ ha ⁻¹	
Furrow	6822	11400	10743	13349	3921,	36.5	1949,	14.6
Surface drip	6591	8520	10146	12608	3555,	35	4088,	32.4
Subsurface Drip	5907	8140	9612	11944	3705,	38.5	3804,	31.8
Conventional *	13200	16042	15219	18911				

* no monitoring

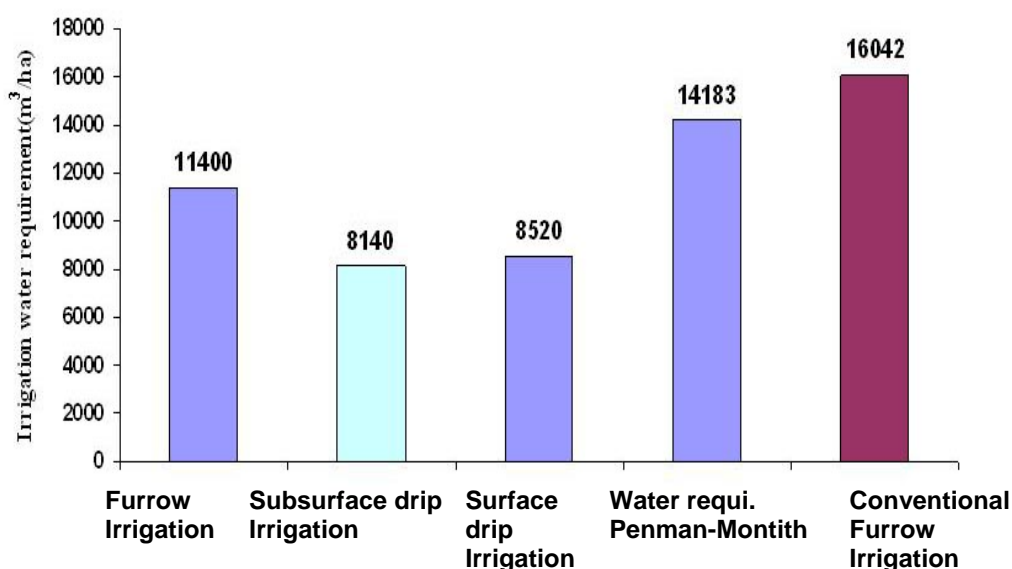


Fig. 1 Irrigation requirement of sugar beet with different irrigation methods and irrigation scheduling

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