SHORT, NON-REFEREED PAPER

EVALUATION OF DIFFERENT METHODS FOR IMPROVING WATER APPLICATION AND WATER USE EFFICIENCY IN SUGARCANE FIELDS

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Abstract

Sugarcane is an important crop in Khuzestan province in Iran, where the crop is irrigated through gated pipes. Water resource limitation is a big challenge which farmers face in Iran. In this paper the authors studied different practical methods for improving water application efficiency and water use efficiency in sugarcane. These methods consisted of alternate furrow irrigation at different stages of sugarcane growth in heavy soils, changing the furrow shape and establishing furrows with low wetted perimeters for decreasing the infiltration rate and optimisation of water application efficiency in sandy or loamy sand soils. Selection of the best time of cut-off inflow through the gated pipes and reuse of drainage water for irrigation were also investigated. Overall, the results indicated that the use of alternate furrow irrigation at all stages of growth, resulted in 36.5% of water saving compared to the conventional method. A change of furrow shape, from the conventional U shape to a V shape, improved water application efficiency. The results showed that water saving improved with V shaped furrows compared to the shallow U and deep U shaped furrows, with a saving of 28 and 9.5% respectively. Another study applied the best time of cut-off inflow with two discharge inflow rates - medium and high - with water savings of 35 and 38% respectively. Reusing sugarcane drainage water mixed with irrigation water, at three stations (A,C,D) by pumping drainage water at 50, 66 and 60% respectively, and mixing with the irrigation water, 90% of the sugarcane yield was achieved. Station B had the best conditions in comparison to the other stations for recycling; by pumping 70% from drainage water and mixing with 30% irrigation water a 100% sugarcane yield was achieved. The authors conclude that all of these methods are recommended to enhance irrigation water productivity and water application efficiency on Iranian sugarcane farms.

Keywords: sugarcane, alternate furrow irrigation, furrow shape, reuse of drainage, cut-off

Introduction

Alternate furrow irrigation, regular furrow irrigation and conventional irrigation (every row) were all tested in sugarcane. Alternate furrow irrigation consumed the least amount of water and had the highest cane production and water use efficiency (WUE), with a production of 1.39 M/t of white sugar (Sheyni Dashtegol *et a*l., 2006).

Raine and Bakker (1995) showed that water application efficiency on soils with high infiltration rates in the Australian Burdekin Delta sugar industry is generally low, with an average of 30%. However, in soils with low infiltration rates, it is more than 80%. Changing the shape of the furrow and introducing surface compaction could reduce water consumption by 47% with no reduction in crop yield. In a later report, Kashkoli *et al.* (2000) measured application efficiencies of 52-69% on two sugarcane farms of the Haft Tapeh Company in Iran with clay loam soil.

Abbasi and Sheyni (2014), showed that irrigation interval on the sugarcane farms studied was short, irrigation time was long, and water consumption on most of the evaluated farms was more than required. Irrigation application efficiencies on the farms varied, with an average efficiency of 42.5%.

The most important method is reuse of water; this method can enhance water use efficiency by up to 15% in the high infiltration rate soils (Raine and Bakker, 1996). Egypt has for many years applied drainage water, and have performed many research projects which showed that this method can enhance WUE in furrow and drip irrigation (Sayed and Abdel Gawad, 2003).

The authors aimed to verify and to study the effects of alternate furrow irrigation, a change in furrow shape, and the application of irrigation management on irrigation cut-off times on sugarcane productivity, and reuse of drainage water to optimise WUE.

Methods

In order to study the impact of alternate furrow irrigation, a field with a silty clay soil was selected and prepared for planting using conventional methods. Sugarcane variety CP69-1062 was planted in furrows 35 cm deep at a row spacing of 1.53 m. The land slope was about 0.0007 m/m and the rows were 240 m long. After applying the first round of irrigation, subsequent irrigations were:

1. Control: Conventional irrigation from the end of March to end of September (all furrow irrigation - AFI).
2. Alternate furrow: From the end of March to end of September (all stages of growth - AFAI).
3. Alternate furrow: From the end of March to end of May (development stage of growth - DFAI).
4. Alternate Furrow: From the end of May to end of July (mid-stage of growth - MFAI).
5. Alternate Furrow: From the end of July to end of September (late stage of growth - LFAI).

The five irrigation treatments were each replicated three times in a randomised complete block design with six furrows per plot. Type 2 WSC flumes were used to measure water flow into each furrow. Flow was set at 2 L/s.

In another experiment to study the effect of furrow shape on water use efficiency and water application efficiency, an experimental block that had a clay loam to loam soil was chosen. After the first land preparation operation three furrow types were constructed:

- A type with a depth of 30 cm.
- B type with a depth of 22 cm.
- C type with a depth of 16 cm.

Each treatment was replicated three times in six furrows over 250 m row length in a randomised complete block design. Irrigation efficiencies were measured during May, June and July. Irrigation was by the gated pipe system. WSC flume types 2 and 3 were used in the middle and at the beginning of the furrows. An infiltration equation was used and the advance time was measured for each experimental furrow. Cross-section measured the shape of the furrow; the Kastiakov-Louis equation $Z=At^m+f_0t$ was used to define the infiltration parameters by the two-point method. To determine the efficiency of irrigation the following equations were applied (Alizadeh, 2005):

$$Ea = \frac{(Zreq)(L)}{Q0 \times tco}$$

$$DPR = \frac{Vz - (Zreq)L}{Q0 \times tco}$$

$$TWR = 100 - Ea - DPR$$

$$Er = 100\%$$

where E_a= application efficiency, DPR= deep percolation ratio, TWR= tail water ratio (at the end of furrow when blocked this was 0) and E_r = water requirement efficiency= 100% Z_{req}= deep water requirement, L= length of furrow, Q_0= inflow discharge, t_{co}= Time of cut-off and V_Z = total volume of deep percolation.

To determine the effect of irrigation management on application efficiency at the different discharge rates studied, the maximum and minimum discharge in two treatments was as follows:

- Conventional management time of cut-off (Control).
- Best management time of cut-off at the maximum discharge.
- Best management time of cut-off at the medium discharge.

Reuse depends on the water quality and plant tolerance. There are two methods of application: the first method is to use drainage water directly, and the second method is to mix the drainage water with the irrigation water to dilute and decrease the damage caused by hazardous ions. The probability of being able to reuse drainage water can be evaluated by these equations:

$$LR = \frac{ECw}{5(ECe) - ECw}$$

$$ECw(mix) = ECw1 \times R1 + ECw2 \times R2$$

where: LR= leaching requirement, ECw=electrical conductivity for irrigation water, ECe=electrical conductivity for saturation soil, ECw (mix) =electrical conductivity of irrigation and drainage water, ECw1=electrical conductivity of irrigation water, ECw2=electrical conductivity of drainage water, R1= percentage of irrigation water that should be mixed on drainage water; R2= percentage of drainage water that should be mixed on irrigation water.

Results and Discussion

Alternate furrow irrigation

The treatments MFAI, LFAI and DFAI gave the highest percentage refined sugar yields. AFAI consumed the least amount of water and had the highest WUE (Table1). The lowest yielding treatment was AFI. However, comparison of the treatments with the control gives a clear indication that with more aeration of soil an increase in the percentage of refined sugar can be achieved. Even under conditions where no water shortage exists, a method such as MFAI (i.e. alternate furrow irrigation at mid-stage growing season) is advisable, as irrigation water can be used more efficiently.

Table1. Yield of refined sugars, and Water Use Efficiency for the different treatments.

Description of treatment	Sugarcane yield (t/ha)	Sugar yield (t/ha)	Percent refined sugar (%)	Volume of water consumption	Water use efficiency (kg white sugar/m^3)	Amount of saved water in comparison with control (%)
AFI	137.84	14.05	10.2c	22870	0.61	-
AFAI	132.04	13.73	10.4bc	14525	0.94	36.5
DFAI	145.86	16.03	11.06abc	22050	0.73	3.6
MFAI	137.45	15.53	11.3a	19750	0.79	13.6
LFAI	140.54	15.74	11.2ab	20610	0.76	9.9

Furrow shape

The average water path profile in the A furrow was 1 370 cm^2, 1 195 cm^2 in B furrow, and 562 cm^2 in C furrow, with wetted perimeters of 127, 141 and 78 cm, respectively. Average water application efficiencies over all the irrigation rounds were higher in C furrows than in A and B furrows (Table 2). Overall, the results for the A furrows are similar to those of Kashkoli *et al.* (2000).

Table2. Irrigation efficiencies in treatments with different furrow shapes.

Furrow type	Deep percolation (m^3)	Applied water (m^3)	Water requirement (m^3)	Deep percolation ratio (%)	Application efficiency (%)
A	10.73	37.23	26.50	28.8	71.2
B	15.51	42.67	27.16	36.3	63.7
C	6.53	33.38	26.85	19.5	80.5

Management of time of cut-off

The amount of water consumption in the treatments for best management of time of cut-off with respect to the maximum and medium discharge were 38.5 and 35% respectively, lower than the control treatment. The major issue in surface irrigation methods is low irrigation efficiency, mainly due to the lack of irrigation management (Abbasi and Sheyni, 2014). Irrigation application efficiency in the present study varied at different locations on the farm, with the average being 42.5%. By applying the best management on time of cut-off, the irrigation application efficiency increases up to 79%.

Reuse of drainage water

The salinity of the drainage water measured was semi-limiting, and no limit was seen in the sodium absorption ratio (SAR). The sodium and chloride ions were seen to be semi-limiting at the stations. A regular program is necessary for reuse of the sugarcane drainage water, which is partly irrigation water (EC_{w1}), mixed with drainage water (EC_{w2}). The threshold level of water salinity for sugarcane is 1.2 ds/m.

A Station**:** the salinity of the irrigation water and drainage water were 1.2 and 3.4 ds/m, respectively. At this station, the use of irrigation water alone achieved 100% sugarcane yield. By applying 50% of irrigation water mixed with 50% of drainage water a 90% sugarcane yield was achieved.

B Station**:** the salinity of the irrigation water and drainage water were 0.44 and 1.39 ds/m, respectively. At this station 30% of irrigation water mixed with 70% of drainage water achieved a 100% sugarcane yield. There is no limited use to direct application of drainage water for achieving a 90% sugarcane yield.

C Station**:** the salinity of the irrigation water and drainage water were 1.2 and 2.86 ds/m, respectively. At this station irrigation water alone achieved a 100% sugarcane yield. Applying 34% irrigation water mixed with 66% drainage water will achieve a 90% sugarcane yield.

D Station**:** the salinity of the irrigation water and drainage water were 1.2 and 3.05 ds/m, respectively. At this station only irrigation water should be applied for a 100% sugarcane yield. However, applying 40% of irrigation water mixed with 60% of drainage water will achieve a 90% sugarcane yield.

Conclusions

Based on above results, in order to achieve the maximum yield in the heavy soils and for management of the water table level, alternate furrow irrigation can be applied at different stages of plant growth. However, lateral movement from the wetted furrow is needed to reach the stool, so this method will be effective only on certain soils. Change of furrow shape in the loamy sand soils was very effective to improve water application efficiency, with a change from the U shape to the V shape. Managing the time of cut-off during irrigation events can also help in better management of irrigation water. Water reuse provides reliable local water supply that reduces vulnerability to drought and other water supply constraints. It can also be economic and have other environmental benefits.

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