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Irrigation Water Productivity and Water use Efficiency of Sugarcane Plants under Drought Conditions (Case Study in Farabi Agro-Industry Lands)

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Abstract: This study was aimed to evaluate the productivity and performance indexes of sugarcane biomass` irrigation water use, at its growth different ages in 2009-2010 cropping year, in Farabi agro-industry farms. During this study, based on the age, four farms were selected for each plant. These farms had the highest performance among different ones. Performance rate, plant evapotranspiration, and total quantity of irrigation water were determined during the plant growth period and, based on their amounts, irrigation water productivity index and the average water use efficiency were 2/64 to 3/399 kg/m^3 and 25/43 to 38/35 kg/ha.mm, respectively.

Key words: Irrigation water productivity, sugarcane field, water use efficiency

INTRODUCTION

Drought is a natural phenomenon occurred to many regions around the world every year. Drought has brought many problems in various social, economical, and environmental fields which the most important problem, in agricultural sector, is the crop yield reduction. Our country (Iran), like many other countries with rainfall annual average of about 250 mm, is considered among the world's arid and semi arid zones. Crisis is caused by population growth followed by the increased demand for water and limited water resources. Water is essential for both the human society and the ecological systems that humans rely on. But this essential resource is finite. With the population growth and economic development, water has become increasingly scarce in a growing number of countries and regions in the world. As the largest water user, the agricultural sector is facing a challenge to produce more food with less water. This requires an increase in Water Productivity (WP) and Water Use Efficiency (WUE), (Kijne *et al*., 2003; Sepaskhah *et al*., 2006). One of indexes used in plant yield and water use discussions, economically based is WP which is defined as crop yield to water use ratio. Water use consists of rainfall, irrigation or irrigation plus rainfall. WP indicates production level per input.

In addition to WP index, Water Use Efficiency (WUE) is applied in optimization (Jensen *et al*., 1990), achieving from seed yield to real plant evapotranspiration ratio. In some references evapotranspiration productivity is referred to WUE and would be indicated as WP_{ET} (Deju and Jingwen, 1993; Turner, 1997; Tuong, 1999). Sugarcane is a perennial plant growing in 30º North latitude to 30º South. Duration form plant growth to harvest time is 12 to 18 months in tropical and subtropical areas but, in the higher elevations such as New South Wales, is one time in a two years period. Dry harvest is more than 65 tons/ha (Monteith, 1978). A 2 years study in alluvial soils (silt loam heavy clay) of northern India showed that the average water use efficiency for sugarcane in Plant and Ratoon ages is 71 and 63 kg/ha of mm, respectively (Singh *et al*., 2007). Heidari *et al*. (2007) measured the indexes of water use efficiency of wheat, sugar beet (sugar), potatoes, corn, forage, cotton, alfalfa (biomass), barley, and sugar cane (sugar) as 0/75, 0/64, 2/06, 5/58 0/71, 1/46, 0/56 and 0/29 kg/m^3, respectively. Shainy *et al*. (2009) concluded that the variable and fixed alternate furrow irrigation treatments had a respectively 41 and 29% increasing process compared to the control (normal irrigation) so that a variable alternate furrow irrigation treatment had the minimum quantity of water consumption, maximum water use efficiency, and the highest sugarcane and sugar production. to complete an economical assess of the variable alternate irrigation systems for sugarcane, Quresh *et al*. (2001) reported the increasing water use efficiency and indicated that the conventional irrigation needs higher investment. One of the major factors in the determination of water use efficiency for agricultural production is the index of water use efficiency. This index shows the rate of per unit production (performance) of water consumed per area unit (hectare). Usually, water use efficiency is referred to the amount of dry material produced per consumption water unit; but water and soil researchers define water use efficiency as produced material rate (not dry material) per the area unit to the quantity of consumption water (Alizadeh, 2005).

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Table 1: plant`s performance rate, the total quantity of irrigation water, evapotranspiration, plant growth season, and each farms` size

Farm no.	Plant age	Area (ha)	The total quantity of irrigation water (ha/m^3)	Biomass (kg/ha)	Evapotranspiration (mm)
S_{12-13}	Plant	20.580	22800	83870	2130
S_{12-09}	Plant	22.470	24000	82340	2130
S_{12-15}	Plant	19.880	22800	80880	2130
S_{12-11}	Plant	24.000	22800	79690	2130
S_{09-32}	Ratoon1	21.868	21000	84990	2130
S_{03-21}	Ratoon1	23.496	21600	80910	2130
S_{10-27}	Ratoon1	23.908	20400	77660	2130
S_{02-21}	Ratoon1	17.974	22800	76450	2130
N_{01-27}	Ratoon2	17.206	21600	69260	2130
N_{01-21}	Ratoon2	21.759	21600	67650	2130
S_{09-20}	Ratoon2	24.083	22500	59580	2130
S_{09-25}	Ratoon2	24.780	22500	58230	2130
N_{01-29}	Ratoon3	13.130	20400	65120	2130
S_{02-31}	Ratoon3	22.120	21600	59410	2130
N_{01-23}	Ratoon3	23.230	22800	56040	2130
S_{05-31}	Ratoon3	22.594	21600	53920	2130
N_{01-31}	Ratoon4	8.770	21600	59200	2130
N_{02-32}	Ratoon4	14.285	25200	53600	2130
S_{07-23}	Ratoon4	24.987	18000	52570	2130
N_{02-28}	Ratoon4	16.2159	25200	51270	2130

Fig. 1: Iran map

According to Sepaskhah *et al*. (2006), Zhang (2003), Oweis and Hachum (2003), Oweis *et al*. (2004a, b) and Tavakkoli and Oweis (2004), water productivity indexes are considered by researchers from different aspects (productivity of irrigation water added to production in dry conditions or any other treatment, irrigation water productivity in the whole performance, rain productivity ,and irrigation productivity plus rainfall in the total performance). According to the recent years` rainfall reduction and that the sugarcane is a tropical and subtropical plants that require plenty of water and sensitive to dehydration and, also, is not compatible with the long-term root flooding, this study is aimed to evaluate the effect of plant`s real evaporation and the quantity of irrigation water on the productivity index of water and performance of lively biomass.

Water productivity indexes for biomass yield are defined as the following:

$$WP = biomass/irrigation$$

WP : Irrigation water productivity for biomass yield (Kg/ha.mm)
Biomass : Kg/ha
Irrigation : m^3

Water use efficiency indexes for seed and biomass yields estimated by following equations:

$$WUE = Yield/ ETa$$

WUE : water use efficiency for biomass yield (Kg/ha.mm)

Yield : (Kg/ha)
Eta : (mm)

MATERIALS AND METHODS

Farabi agro-industry located in the south of Ahvaz and East of Karun River (Fig. 1 and 2); its average height than the open sea level is about 6/5 m and the plan lands have a gentle slope of about 0/1 to 0/2 per thousand. Most days of the year are dry and precipitation is mostly in winter. In most years, there is lack of winter ice in this area which, if there is, ice is mostly less than six days. this land`s Irrigation is done by furrow irrigation and porthole hydrophlome tubes instead of 4º channel. In this study, the total irrigation water productivity for the biomass of sugarcane plant with CP69-1062 variety for different ages of plant (Plant, Ratoon1, Ratoon2, Ratoon3, Ratoon4) during 2009-2010 cropping years is evaluated. Four farms, for each plant age with maximum performance, were selected from Farabi agro-industry`s lands; plant`s performance rate, the total quantity of irrigation water, evapotranspiration, plant growth season, and each farms` size are shown in Table 1. Using the data of this table, the average of the irrigation water productivity and water use efficiency listed for farms were calculated.

RESULTS AND DISCUSSION

Irrigation water productivity and water use efficiency for the biomass of plant, Ratoon 1, Ratoon 2, Ratoon 3, and Ratoon 4 farms were calculated and the results are illustrated in Table 2.

Comparison of different plant ages shows that Ratoon1 has the maximum Irrigation water productivity (3/73 kg/m^3) and Ratoon 4 (2/46 kg/m^3) has the minimum; sugarcane, at the Plant age, has the maximum irrigation water use efficiency and Ratoon 4 has the minimum. Results of this comparison are shown in Table 3.

Biomass change rate in Farabi agro-industry is between 51/270 (Tons per hectare) and 84/990 (Tons per hectare) having not much different with the average biomass of this product that is 65 tons per hectare (Monteith, 1978). Average water use efficiency for different ages in this agro-industry is between 25/43 (Ratoon) and 38/35 (Plant) which is much less compared with the average water use efficiency of sugarcane in north India for Plant and Ratoon ages, which are 71 and 63 kg/ha.mm, respectively (Singh *et al*., 2007) The reason is real evapotranspiration rising that reduces water use efficiency in the agro-industry. Except Plant age compared with Ratoon1, Comparing the average irrigation

Fig. 2: Map, Farabi agro-industry located

Table 2: Irrigation water productivity and water use efficiency for the biomass of plant for different field

Farm no.	Plant age	Water productivity (Kg/M^3)	Water use efficiency (Kg/Mm)	Field no.	Plant age	Water productivity (Kg/M^3)	Water use efficiency Kg/(Ha.Mm)
S_{12-13}	Plant	3.68	39.38	S_{09-25}	Ratoon2	2.6	27.34
S_{12-09}	Plant	3.43	38.66	Average Ratoon2		2.9	29.90
S_{12-15}	Plant	3.55	37.97	N_{01-29}	Ratoon3	3.19	30.57
S_{12-11}	Plant	3.50	37.41	S_{02-31}	Ratoon3	2.75	27.89
Average Plants		3.54	38.35	N_{01-23}	Ratoon3	2.46	26.31
S_{09-32}	Ratoon1	4.04	39.90	S_{05-31}	Ratoon3	2.5	25.31
S_{03-21}	Ratoon1	3.75	37.98	Average Ratoon3		2.72	27.52
S_{10-27}	Ratoon1	3.81	36.46	N_{01-31}	Ratoon4	2.74	27.79
S_{02-21}	Ratoon1	3.35	35.89	N_{02-32}	Ratoon4	2.13	25.16
Average Ratoon1		3.73	37.56	S_{07-23}	Ratoon4	2.92	24.68
N_{01-27}	Ratoon2	3.21	32.52	N_{02-28}	Ratoon4	2.04	24.07
N_{01-21}	Ratoon2	3.13	31.76	Average Ratoon4		2.46	25.43
S_{09-20}	Ratoon2	2.65	27.97				

Table 3: The average irrigation water productivity and water use efficiency for the biomass of plant for different field

Plant age	Water productivity (kg/m^3)	Plant age	Water use efficiency kg/(mm.ha)
Raton1	3.73	Plant	38.35
Plant	3.54	Raton1	37.56
Raton2	2.9	Ratoon2	29.9
Raton3	2.72	Ratoon3	27.53
Raton4	2.46	Ratoon4	25.43

water productivity at different ages shows that as the age of plant is increased, irrigation water productivity levels would be reduced. The reason is as follows:

The average performance of Plant (81695 kg/ ha) is more than Ratoon1 (80002/5 kg/ha) Because it was under cultivation after a period of appropriate fallow and tillage operations and increased the biomass performance at the Plant age; also, irrigation water of Ratoon1 (20400 cubic meters per ha) is less than the Plant (23100 cubic meters per ha) because, at the Plant stage, more irrigation water is required due to the furrow unsteadiness.

CONCLUSION

If both the irrigation water and irrigation itself are reduced, irrigation water productivity index would be increased. One of the major constraints in sugarcane cultivation in the south areas of Khuzestan is the irrigation water unlimited consumption in the warm seasons that cause under earth water levels ascend up in the farms and, coupled with the salinity and alkalinity, damages the plants. Thus, optimum use of irrigation water and avoid the uncontrolled irrigation has became one of the basic requirements for this plant cultivation in the south areas of Khuzestan. If the land preparation stage and tillage are completed more carefully and Furrows are constructed repeatedly, water productivity in the plant stage would be more than Ratoon1.

Important reasons for low water use efficiency can be the following factors:

- High water losses in agricultural fields
- Inappropriate shape and size of farms in relation with irrigation water quantity and irrigation method
- Some lands` inappropriate quality

Considering that Shainy Dashtgol, in the first year of harvesting, obtained the water use efficiency in the control treatments, alternate variable and fixed as 0/8, 0/72 and 0/62 kg sugar per cubic meter of consumption water, respectively and showed that water use efficiency in the alternate variable and fixed irrigation treatments have increased about 33/5 % and 22/6 % more than the control, and also the alternate variable furrow irrigation had a 14/5 percent enhance more than the constant and 16/6 percent than the normal irrigation in sugar production, it can be said that to achieve a better perspective of land utilization, especially during drought, the method of irrigation can be useful and effective in improving the water management and increasing the Irrigation water use efficiency ,turnover, and agricultural crop production.

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