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Effect of Higher Density Planting on Irrigation Water Use and Yield of Sugarcane

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ABSTRACT

Sugarcane is one of the important crops that needs plentiful water in tropical and semi-tropical regions. This crop is widely grown in Khuzestan province of Iran. In this study, triple-row planting of sugarcane was evaluated and compared to double-row planting as currently being practiced in the region. Results showed that in spite of the higher density planting in triple-row planting, there was no significant difference between triple-row planting and double-row planting in terms of leaf sheath moisture, leaf nitrogen, ridge EC, qualitative situations of cultivar, plant height and stem diameter. However, the number of shoots and stems per m^2 in the triple-row planting were found to be higher than in the double-row planting and the difference between them was significant at 5% level. In addition, water application efficiency, water use efficiency (WUE), mean yield of sugarcane and sugar content in triple-row planting were higher than double-row planting.

Keywords: Sugarcane, triple-row planting, double-row planting

INTRODUCTION

Sugarcane is one of the most important crops in Southwest Iran. Sugarcane is a C_4, a high biomass crop which requires large amount of water for maximum production. About 60 percent of the world's sugar content is supplied from sugarcane production and the rest is produced from sugar beet. The favourable temperature for growing is between 30-34°C and the favourable relative humidity is between 60-80%. These conditions are available in Khuzestan province that is located in southwest Iran. The current production of sugarcane in Iran is about 7 million t $year^{-1}$ and the average of sugarcane yield is about 70 t ha^{-1} and cultivated area is about 100000 ha (Anon, 2011). Van der Merwe et al. (2003) reported that the water use efficiency of sugarcane

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in alternate furrow irrigation method was better than other irrigation methods with sugar yield of 14.5 t ha^{-1} obtained from that method. Meanwhile, Sheini-Dashtgol (2007) reported that alternate furrow irrigation method consumed less water than current irrigation methods. Noori et al. (2008) reported that by decreasing furrow depth, water application efficiency of sugarcane increased. Bull and Bull (2000) reported that a method for increasing sugarcane production was higher density planting, in the form of double-row planting. Seeruttun and Ismael (2003) and Ismael et al. (2007) showed that sugarcane production increased with double-row planting. Songsri et al. (2009) reported that water application efficiency of sugarcane can be increased by having an extended root system in drought stress conditions. Smith et al. (2005) reported that sugarcane cultivars that have extended root systems, are more resistant to drought stress. There is a contradiction regarding the effect of row spacing and seeding densities on the quality parameters such as Brix, sucrose contents, juice extraction and commercial cane sugar, etc. (Sharar et al., 2000; Asokan et al., 2005; El-Geddawy et al., 2005; Pawar et al., 2005). Nevertheless, most of the studies agreed that sugarcane quality was not affected by row spacing and seeding densities (Asokan et al., 2005; El-Geddawy et al., 2005). In contrast, Pawar et al. (2005) reported that wider row spacing improved the sucrose contents and commercial cane sugar percentage. Similarly, according to Sharar et al. (2000), higher seeding density (100000 setts ha^{-1}) improved sucrose content and commercial cane sugar compared to seeding density of 75000 setts ha^{-1}. Patel et al. (2005) reported that higher seeding densities increased the commercial cane sugar. The current cultivation of sugarcane in Iran is in the form of double-row planting by hilling up activities. Thus, this research was conducted to investigate the effects of planting density on variation of water application efficiency, water use efficiency and crop yield. The purposes of this study were to introduce the triple-row planting of sugarcane and compare its advantages with those of the double-row planting in Iran.

MATERIALS AND METHODS

Geographical Location and Weather Characteristics

This study was conducted in farms located in the tropical climate of northwest Shush County in the Khuzestan province of Iran. Two different farms (labelled as A-01 farm and B-01 farm, respectively) were selected for the purpose of this experiment. Triple-row planting was done in A-01 farm and double-row planting was done in B-01 farm. The irrigation water of the farms is from Karkheh River. This research was carried out from October 2014 to October 2015. Some weather parameters and Karkheh River EC are shown in Table 1.

Soil Characteristics and Sugarcane Variety

Composite samples of 5 random points were taken from 0-30, 30-60, 60-100, 100-150 and 150-200 cm depths of the cultivated

Table 1
Some weather parameters and Karkheh River EC

Month (2014-2015)	Mean of min temperature (°C)	Mean of max temperature (°C)	Mean of temperature (°C)	Mean of min humidity (%)	Mean of max humidity (%)	Sum of rainfall (mm)	Sum of sunshine hours	EC of Karkheh River (dS m^{-1})
October	20.0	39.1	29.8	17.7	58.3	0	287.60	1.69
November	14.4	28.1	20.3	37.1	75.7	25.8	178.60	1.37
December	5.2	20.9	13.1	35.5	81.2	0	260.36	1.40
January	6.4	20.9	13.4	43.6	83.5	12.5	178.60	1.39
February	6.1	19.9	13.1	40.4	78.2	28.4	174.27	1.46
March	9.0	23.1	16.0	30.3	70.1	29	210.10	1.78
April	15.3	31.1	23.2	33.1	80.0	5.5	215.07	1.67
May	21.7	39.8	29.9	28.7	65.0	2.5	246.78	1.72
June	24.8	45.2	35.0	19.0	49.0	0	300.38	2.18
July	26.6	47.0	36.7	20.6	52.6	0	356.47	2.57
August	27.4	48.6	38.0	21.5	54.8	0	352.20	2.68
September	23.3	44.4	33.7	24.3	68.1	0	332.60	2.51
October	19.2	39.4	29.1	33.6	76.3	0	278.45	2.49

Table 2
Some physical and chemical properties of the soil before planting test

Depth (cm)	Texture	EC (dS m^{-1})	pH	Hco_3^- (meq l^{-1})	CL^- (meq l^{-1})	Mg^{2+} (meq l^{-1})	Ca^{2+} (meq l^{-1})	OM (%)
0-30	Silt Loam	2.00	8.27	0.10	1.4	13.6	13.5	0.51
30-60	Silt Loam	2.68	8.11	0.05	3.2	22.5	16.1	0.41
60-100	Silt Loam	2.74	8.10	0.06	7.5	21.1	17.3	0.25
100-150	Silt Loam	2.86	8.00	0.00	8.1	16.4	21.2	0.31
150-200	Silt Loam	3.03	8.04	0.05	7.6	17.1	21.2	0.31

land in the farms. The results are presented in Table 2. The sugarcane variety used in this study was CP69-1062. It is a middle-mature variety tolerant to drought stress and suitable for cultivation in subtropical regions. This variety is sensitive to cold weather with acceptable yield and sugar content.

Farming operations

A special furrow maker was used to create three small furrows for the sugarcane cuttings (Figure 1). Space between the rows in this step was 50 cm, whereas the depth of small furrows was 14 cm; the width of ridge in the triple-row planting was 130 cm, the width of ridge in the double-row planting was 90 cm and the length of the furrows was 50 m (Figures 3 and 4). After the furrower activities, cuttings of sugarcane were put in small furrows (Figure 2). Then, covering activities were done by using special covering apparatus. Meanwhile,

irrigation was done based on soil moisture measurement at FC, PWP and readily available moisture by sampling of root zone soil. Fertilisers were given according to the current fertilizer schedules of the sugarcane farms. A-01 farm (triple-row planting) and B-01 farm (double-row planting) were cultivated simultaneously and all the cultivation activities were equal for both of farms. Moreover, the measurements of ridge soil EC, leaf nitrogen and leaf sheath moisture content were simultaneously done for both the farms. The number of cuttings in the triple-row planting was about 23000 per ha and this was about 15000 per ha in the double-row planting.

Besides, in A-01 farm (triple-row planting), three furrows with three replications were evaluated, and generally, nine furrows including three groups of triplex furrows were therefore evaluated. These conditions were repeated exactly for B-01 farm (double-row planting). The comparison between two cultivations was according to the average data of nine furrows in every farm. The means comparison was done according to Duncan's multiple range test ($P < 0.05$).

RESULTS AND DISCUSSION

Evaluation of Leaf Sheath Moisture and Leaf Nitrogen

Leaf sheath moisture content for both farms was found to tbe equal and there was no significant difference between them (Table 3). In spite of the higher density planting in the triple-row planting, the leaf sheath moisture content was equal to that of the double-row planting.

Table 3
Percent of leaf sheath moisture of Sugarcane in triple-row planting and double-row planting

Date	Leaf sheath moisture	
	Double-row planting	Triple- row planting
2015/27/03	81.01	80.21
2015/10/04	80.31	80.34
2015/24/04	81.02	79.85
2015/06/05	79.75	79.52
2015/20/05	80.42	79.01
2015/11/06	78.15	78.46
2015/24/06	78.84	78.03

Figure 1. Triple-row furrower

Figure 2. The sugarcane cuttings in triple-row planting

Figure 3. The width of ridge in triple-row planting

Figure 4. The width of ridge in double-row planting

Leaf nitrogen in both farms was found to be equal and there was no significant difference between them (Table 4). In spite of the higher density planting in triple-row planting, the leaf nitrogen was nearly equivalent to that of the double-row planting. Thus, it was not necessary to apply more nitrogen fertiliser for the triple-row planting (higher density planting) compared with the double-row planting.

Table 4
Percent of leaf nitrogen in triple-row planting and double-row planting

Date	Leaf nitrogen (%)	
	Double-row planting	Triple-row planting
2015/27/03	2.05	2.19
2015/10/04	2.22	2.00
2015/24/04	2.03	1.94
2015/06/05	2.02	1.75
2015/20/05	2.08	1.78
2015/11/06	1.61	1.56
2015/24/06	1.52	1.50

Evaluation of the Ridge Soil EC

The soil EC of the ridge for both the farms was nearly equal and there was no significant difference between them. The soil EC of the ridge for the double-row planting was 4.1 dS m^{-1} and this was 4.03 dS m^{-1} for the triple-row planting. Thus, despite the wider ridge which allows more salt to enter in the triple-row planting compared to that of the double-row planting, the soil EC of the ridge for the triple-row planting was nearly equal with that of the double-row planting. This might be due to the less height of ridge in the triple-row planting (14 cm) in comparison with the height of ridge in the double-row planting (25 cm). In other words, the lesser height of ridge in the triple-row planting caused better entrance of water in the ridge and reduced ridge soil EC.

Evaluation of Qualitative Parameters of CP69-1062 Cultivar

As shown in Table 5, there was no significant difference between the qualitative parameters of CP69-1062 cultivar in both farms (Table 5). Therefore, sugarcane can be cultivated in the farm with higher density although its quality parameters can be stable.

Evaluation of Plant Height and Stem Diameter

The height of plant for both farms was observed to be nearly equal and there was no significant difference between them, whereas the tallest plant was relevant to the double-row planting (313 cm) and the shortest was relevant to the triple-row planting (303.8 cm) numerically. Hence, in the triple-row planting with higher density planting, the height of plant was not significantly shorter than that of the double-row planting (see Figure 5).

Similarly, the diameter of sugarcane stem for both the farms was nearly equal, and there was no significant difference between them. The largest diameter (2.28 cm) was associated with the double-row planting and the smallest diameter (2.07 cm) was noted for the triple-row planting numerically. Thus, in higher density planting, the stem diameter was not significantly smaller than that of the double-row planting.

Table 5
Qualitative parameters of CP69-1062 cultivar in triple-row planting and double-row planting

Farm	Pol (%)	Brix (%)	Purity (%)	Purity Coefficient	Quality Ratio	Refined Sugar (%)
Triple-row planting	16.50	18.96	90.25	130.45	7.66	10.36
Double-row planting	16.55	18.68	90.26	130.46	7.64	10.39

Pol: The juice sucrose percent or Pol percent is the actual cane sugar present in the juice.
Brix: Juice Brix refers to the total solids content present in the juice expressed in percentage.
Purity coefficient: It refers to the percentage of sucrose present in the total solids content in the juice.
Purity Percentage = (Pol Brix^{-1}) 100

Number of Shoots and Stems

The difference between the number of shoots per m^2 in the triple-row planting in comparison with double-row planting was significant at 5% level. The number of shoots in the triple-row planting was 385.83, while the number of shoots in the double-row planting was 334.15. Hence, the number of shoots in the triple-row planting was higher than the number of shoots in the double-row planting because of higher number of cuttings.

Meanwhile, the difference in the number of stems per m^2 in the triple-row planting in comparison with the double-row planting was significant at 5% level. The number of stems per m^2 in the triple-row planting was 265.42, while the number of stems per m^2 in the double-row planting was 208.25. Hence, the number of stems per m^2 in the triple-row planting was higher than the number of stems per m^2 in double-row planting because of bigger number of cuttings and also the higher number of shoots in the unit area. Moreover, only strong stems were included in the counts. Therefore, the number of stems was less than the number of shoots.

Evaluation of Water Application Efficiency and Water use Efficiency (WUE)

The mean of water application efficiency in the triple-row planting was about 49.6%, which was higher than the water application efficiency of 45% in the double-row planting. The lower down-slope of A-01 farm (triple-row planting) in comparison with B-01 farm (double-row planting) had probably caused more water application efficiency in the triple-row planting. Figure 6 shows the variation of water application efficiency in the period of 4 months.

Water use efficiency in the triple-row planting was more than WUE in double-row planting (Table 6). This is because less water was consumed and more sugarcane and sugar yield were produced in the triple-row planting compared to that of the double-row planting.

Table 6
Water use efficiency (WUE) in triple-row planting and double-row planting

Farm	The volume of consumed water (m^3 ha^{-1})	The mean of produced Sugarcane (t ha^{-1})	The mean of produced cane sugar (t ha^{-1})	WUE of produced Sugarcane (kg m^{-3})	WUE of produced cane sugar (kg m^{-3})
Triple- row planting	26623.53	138.45	14.05	5.20	0.528
Double-row planting	29673.46	119	12.55	4.01	0.423

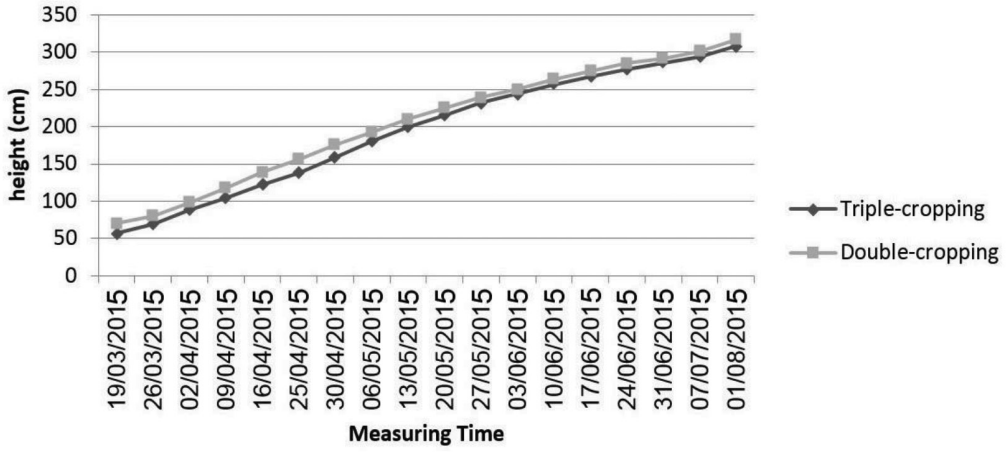

Figure 5. The height of sugarcane in both farms

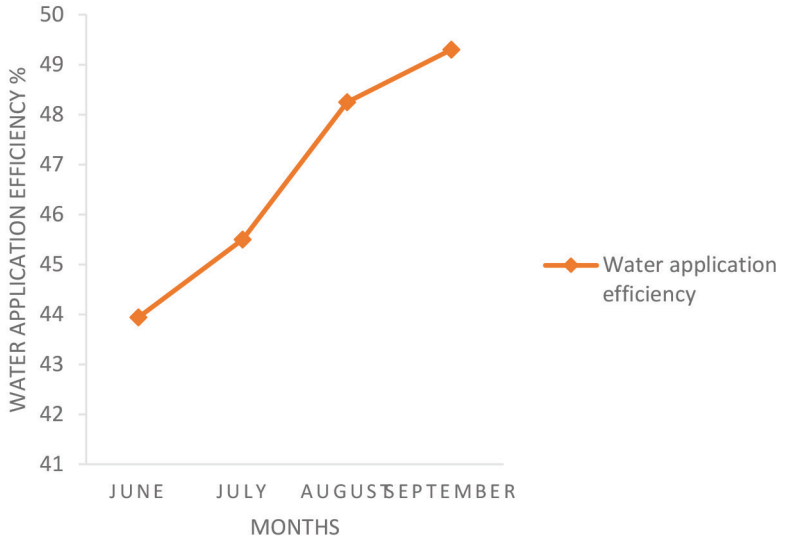

Figure 6. Water application efficiency in triple-row planting

EVALUATION OF THE MEAN YIELD OF SUGARCANE AND SUGAR CONTENT

The mean yields of sugarcane and sugar content in triple-row planting were 138.45 t ha^{-1} and 14.05 t ha^{-1}, respectively. These were numerically higher than the mean yields of sugarcane and sugar content in the double-row planting of 119 t ha^{-1} and 12.55 t ha^{-1}, respectively, although the difference between them was not significant. The reason was that the higher number of shoots due to the increase in the number of cuttings in the triple-row planting compared to that of the double-row planting. It is important to explain that in the end of growing season of sugarcane, all the nine furrows in every farm were harvested and the mean weight of stems was considered as the sugarcane yield. Then, the harvested stems were sent to laboratory to determine the qualitative and quantitative characteristics of sugarcane. After extracting stems by using press apparatus, the qualitative characteristics of sugarcane were identified by Saccharimeter and Polarimeter, followed by determining the other characteristics.

CONCLUSION

The research work of the current study showed that in spite of higher density planting, there was no significant difference between the triple-row planting and double-row planting on the ridge in terms of leaf sheath moisture, leaf nitrogen, ridge soil EC, quality parameters of the sugarcane cultivar, plant height and stem diameter. However, the difference in the number of shoots and number of stems per m^2 in the triple-row planting than the double-row planting was significant at 5% level. The numbers of shoots and stems per m^2 in the triple-row planting were higher because of the increased numbers of cuttings and in the unit area that were higher than the numbers of shoots and stems per m^2 in the double-row planting. Besides, water application efficiency, water use efficiency (WUE) and the mean yield of sugarcane and sugar in the triple-row planting were also higher than those of the double-row planting, although the difference between them was not significant. Actually, we can use yield data from the triple-row planting to increase the mean yield of sugarcane and sugar in spite of higher density planting in comparison to the double-row planting and also increase water application efficiency and water use efficiency of sugarcane and cultivate more lands in arid and semi-arid regions with lower water storage requirement.

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