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Effect of intermittent furrow irrigation, humic acid and deficit irrigation on water use efficiency of sugar beet

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ABSTRACT

Due to limited water resources, research on the optimizing irrigation water use an decrease in yield per unit of water used is very important. Thus, a field study was conducted in 2010 at Research Fields of University of Azad (Karaj) to evaluate the effect of IFI and humic acid under deficit irrigation and without drought stress on water use efficiency and some sugar beet traits. The treatment factors were irrigation methods at two levels (Conventional furrow irrigation (CFI) and intermittent furrow irrigation (IFI)), humic acid application at three levels (zero humic acid control, foliar application of humic acid, and humic acid application with irrigation), water stress at two levels of intensity (based on 40 and 70% depletion of available soil moisture). Irrigation methods and water stress treatments were as the main plot s and application of humic was as the subplot. water use efficiency (WUE), Total WUE, root yield (RY), WSY (white sugar yield), total dry matter (TDM), harvest index (HI) were estimated. Results indicated that statistically significant interactions between irrigation methods × humic acid on root yield and irrigation levels × humic acid on root yield (at $P \leq 0.01$ and $P \leq 0.05$, respectively). Results also showed that WUE and Total WUE were affected by irrigation methods, so that IFI method could enhance water saving by 35 %. For RY, WSY, the best results were obtained from humic acid with irrigation (76.94 and 7.94 ton ha $^{-1}$, respectively). Furthermore, WUE, RY and TDM (at $P \leq 0.01$) and WSY (at $P \leq 0.05$) were affected by stress levels.

Key words:intermittent furrow irrigation, humic acid, drought stress, sugarbeet, water use efficiency

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INTRODUCTION

Most regions of the world are subjected to drought Water shortage is one of the most important problems which human minds have focused. Water is one of the most important requirements for plant. Due to the shortage of water over the world, providing strategies such as proper irrigation methods, irrigation management, while offering ways to reduce and control the negative effects of water stress in plants and varieties more resistant to water etc., to save water in agriculture is critical and should be a priority research. To increase water use efficiency (WUE), according to its calculation method, it should be used ways that either to reduce water consumption or to increase crop yield [6]. Intermittent or alternate irrigation has been widely used in U.S.A. since 1962 and in the cultivation of potatoes, corn, sorghum, sugarbeet and cotton have had good results [8]. Samadi and sepaskhah [18] studied three irrigation methods (constant intermittent, variable intermittent, and normal furrow Irrigation method) on dry bean. Results showed that water consumption was lower under constant and variable intermittent furrow irrigation compared to conventional irrigation (a decrease by 20 % and 27 %, respectively).

Pandian et al. [16] observed that water use efficiency increased by 43-46 % under intermittent furrow irrigation than conventional furrow irrigation. An experiment conducted by Webber et al. [26] on peas and beans by variable intermittent furrow irrigation demonstrated that peas was more resistant to deficit irrigation and its yield increased by 0.13 kg m^{-3} with intermittent furrow irrigation. Aujla et al. [5] studied effect four irrigation method including unplanned furrow irrigation (conventional irrigation), planned furrow irrigation, intermittent furrow irrigation, and furrow irrigation with two rows on the stack, on cotton growth and yield. Results indicate that the water supply for the planned irrigation treatments was better compared with conventional irrigation, so that the maximum water supply was detected under intermittent furrow irrigation, followed by furrow irrigation with two rows on the stack.
Bauder and Ennen [6] reported that water consumption in soybean was decreased by 46 % with intermittent furrow irrigation in comparison to conventional irrigation. Result of this study confirmed that WUE for intermittent furrow irrigation and conventional irrigation was 6.1 and 5.5 kg ha^{-1} per ml H_20, respectively, and the rate of surface runoff by intermittent furrow irrigation was lower than that of conventional furrow irrigation.

Application of biofertilizers, i.e. humic acid, can be effective without environment destructive impact, particularly under variable environment conditions [9,19]. The positive effects of organic acids on yield and quality of agricultural products induced at low rates have been reported by Samavati and Malaliuti [19]. According to Aiken et al. [3], foliar application of humic acid at a rate of 54 mg/L could increase wheat root length and dry matter by50% and 22%, respectively, nitrogen uptake also increased significantly in the presence of humic acid. In the survey of the effects of humic acid on yield, dry and wet weight of oat Padem et al. [14] found that application of humic acid at a rate of 100 mg per pot increased remarkably dry and wet weight of oat.

The effect of various humic acids on enzyme activity of phosphatase was studied by Vaughan and linehan [25], they found that humic acid inhibits phosphatase activity in wheat roots through combining and creating complex with the enzyme. Lee and Bartlett [12] showed that application 8 $mg.L^{-1}$ of Na Humic acid increased strongly the root volume of maize grown in a soil with low organic matter content. Kelting et al. [11] found that the humic acid extracted from leonardite increased root length of red maple. Similar results for sugarbeet [20] and maize [4] have also been reported.

The objectives of this study were to determine and compare the influence of intermittent furrow irrigation and conventional irrigation on WUE and some of sugarbeet traits, and evaluate the influence of humic acid and its application methods under normal irrigation and drought on WUE and some of sugarbeet traits.

MATERIALS AND METHODS

The field study was performed in 2010 at Karaj, Iran (35°45' N, 51°6'E, 1331 m), with soybean grown in a clay loam soil with pH of 7.6 and 5.55 $ds.m^{-1}$soil water conductivity at the depth of 0-30 cm. The experiment was a split plot factorial with a randomized complete block design using three replicates. The first treatment factor was irrigation methods at two levels (normal furrow Irrigation and constant intermittent furrow Irrigation). The second treatment factor was application of humic acid at three levels (zero humic acid control, foliar application of humic acid, and humic acid application with irrigation). The third treatment factor was two levels of water stress (based on 40 and 70% depletion of available soil moisture). Irrigation methods and water stress treatments were as the main plot s and application of humic was as the subplot. Soil water depletion and thus Irrigation time was determined using gypsum blocks previously calibrated using moisture depletion curves provided by Paknejad et al. [15] (Figure 1).

The sugarbeet"Rasoulmonogerm cultivar" was sown at desired density (100000 $plantha^{-1}$), seeds spaced 20 cm apart in rows spaced 50 cm apart on 10 May 2010. Each plot included six 5-m-long rows. To prepare the seedbed deep plowing (20-25 cm) was carried out with a moldboard plough each year in the fall followed by disking in the spring. Based on the soil test results, super phosphate triple and urea were applied before planting at a rate of 100 and 100 kg ha^{-1}, respectively. Moreover, 100 kg ha^{-1} N (as urea) was added at the 6leaf growing stage of sugarbeet.

Due to the early stages sensitive to environmental stress, plots were irrigated since germination stage to full deploy ment of crop and drought stress was applied at 8-leaf stage of sugarbeet growth. Under intermittent furrow irrigation, furrows up and down were closed intermittently in the full establishment of crop. Humic acid was used by spraying and along with irrigation at three stages (planting, 8-leaf, and 12-leaf stages) according to application method. The rate of Humic acid application was 8 kg ha^{-1}.

At the crop maturity, plants were harvested from two central rows in an area measuring 5 m^2. Plants were transferred to the laboratory for quantitative analysis after separating shoots of roots. The harvested roots were washed with gently running water and dough samples was prepared randomly from the total roots by automatic machine after weighting, the nit was placed in special trays and the samples were covered with nylon cover. The trays were transferred to a refrigerator with -20 ºc and then analyzed for sugar content and sugar yield was obtained.

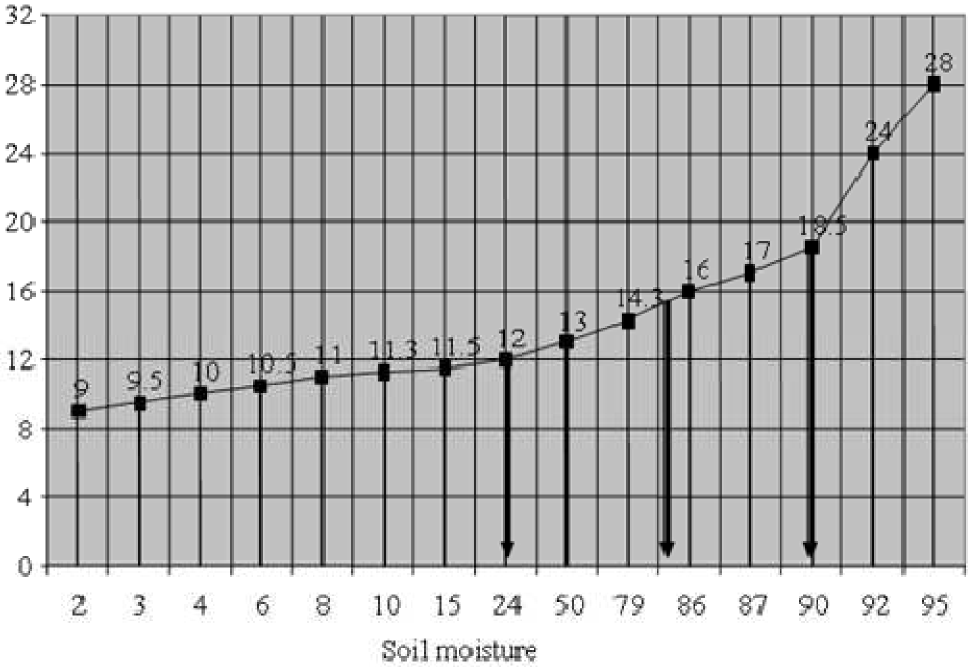

Fig.1. Calibration and changes of electrical conductivity of gypsum blocks[15]

Amount of water received by each plot and during the growing season were determined with Washington state college flumes. Several methods were applied to measure water use efficiency (WUE). However, the conventional method is by dividing the Obtained dry weight/the water loss through evaporation and transpiration. In sugarbeet is generally based on sugar yield/used water. By calculating rate of consumed water, sugar yield content was calculated for each treatment. WUE and Total WUE were also calculated according to the following equations:

WUE= sugar yield (kg ha^{-1})/ consumed water (m^{-3} ha^{-1})

Total WUE=biomass ((kg ha^{-1})/ consumed water (m^{-3} ha^{-1})

All data were subjected to ANOVA using the GLM procedure of SAS (SAS Institute, 2002). Treatment means were compared using Duncan's Multiple Range Test at $P < 0.05$. The graphs were fitted using excel 2007 statistical software.

RESULTS AND DISCUSSION

Wateruse efficiency (WUE)

WUE affected by environment and genetic factors, calculated based on kg m^{-3} per unit area. The result of ANOVA showed significant effects of irrigation methods on WUE (at $P \leq 0.01$), so that intermittent furrow Irrigation had a higher efficiency than conventional furrow irrigation (0.58 kg m^{-3} vs. 0.38 kg m^{-3}, respectively) (Table 2), indicating saving and reduced water consumed by IFI compared to CFI. According to results, although there were no statistically significant differences between two irrigation methods on root yield, sugar, white sugar, and other traits, IFI method with a lower water consumption produced the same yield. Water consumption in IFI and CFI was 18424 $m^{-3}ha^{-1}$ and 11986 $m^{-3}ha^{-1}$respectively, while yield rate was similar. Indeed, about 35% water saving under IFI.

The result of ANOVA demonstrated significant effects of humic acid on WUE (at $P \leq 0.01$), so that the highest WUE (0.54 kg m^{-3}) occurred by application of humic acid along with water irrigation. No significant difference was observed between foliar application of humic acid and untreated control (0.47 kg m^{-3} and 0.42 kg m^{-3}, respectively)

(Table 2). This result represents that with the same water consumption sugar yield was higher by humic acid application through irrigation.

Result also indicated that WUE affected by irrigation levels (at $P \leq 0.01$). Drought stress showed a higher WUE than normal irrigation (0.53 kg m^{-3} vs.0.42 kg m^{-3}, respectively). Although stress level resulted in a lower yield compared to normal level,its WUE was greater because of lower water consumption.

Total WUE

The result of ANOVA showed significant effects of irrigation methods, humic acid, irrigation levels on total WUE (at $P \leq 0.01$). Mean comparison indicated that total WUE under IFI was higher than that of CFI (1.10 kg m^{-3} and 0.71 kg m^{-3}, respectively) (Table 2). The rate of sugarbeet Yield (root yield, white sugar yield, …) under IFI and CFI methods was similar, although IFI had a less water consumption than CFI (11986 kg m^{-3} vs. 18424 kg m^{-3}, respectively).

Application of humic acid with irrigation could increase total WUE (0.99 kg m^{-3}) and produced a greater total dry matter. Also, mean comparison of irrigation levels showed that drought stress with 0.99 kg m^{-3} of total WUE hadBetter performance compared to normal irrigation with 0.88 kg m^{-3} of total WUE. While deficit irrigation produced a less dry matter compared to normal irrigation, total WUE of stress conditions was too less.

Root yield (RY)

The result of ANOVA showed no significant effects of irrigation methods on RY (at $P \leq 0.01$) (Table 1), indicating that CIFI method had a higher efficiency on RY than CFI. This result is consistent with previousstudiesAujla et al. [5] on grain corn. Samadi and Sepaskhah[18] from total water entering into the furrow under IFI method, about 47 % and 53 % was saved in non-irrigated and irrigated furrows, respectively. According to the statements of these researchers, under IFI method plantwas not affected by water stress during the growing season which this is may be a reason for no sugarbeet yield loss.

Result showed that RY of sugar beet was strongly affected by humic acid (at $P \leq 0.01$) (Table 1). The maximum and minimum root yield of sugarbeet occurred in plots with and without humic acid application (76.94 and 61.13 ton ha^{-1}, respectively).It is not worthy that RY of sugarbeet in foliar application of humic acid was lower than that of humic acid application by irrigation (Table 2). The present study indicated a 25 % increase in sugarbeet RY under humic acid application with irrigation. These findings are in agreement with previous studies on sugarbeet[24]. Padem et al. [14] found that eggplant and peppers yields increased by 20-40 %. According to Tana and Nopamorn bodi [23], humic acid could enhance available elements as well as increasedfresh and dry weigh to froots in different plants [17,10,21,13,2].

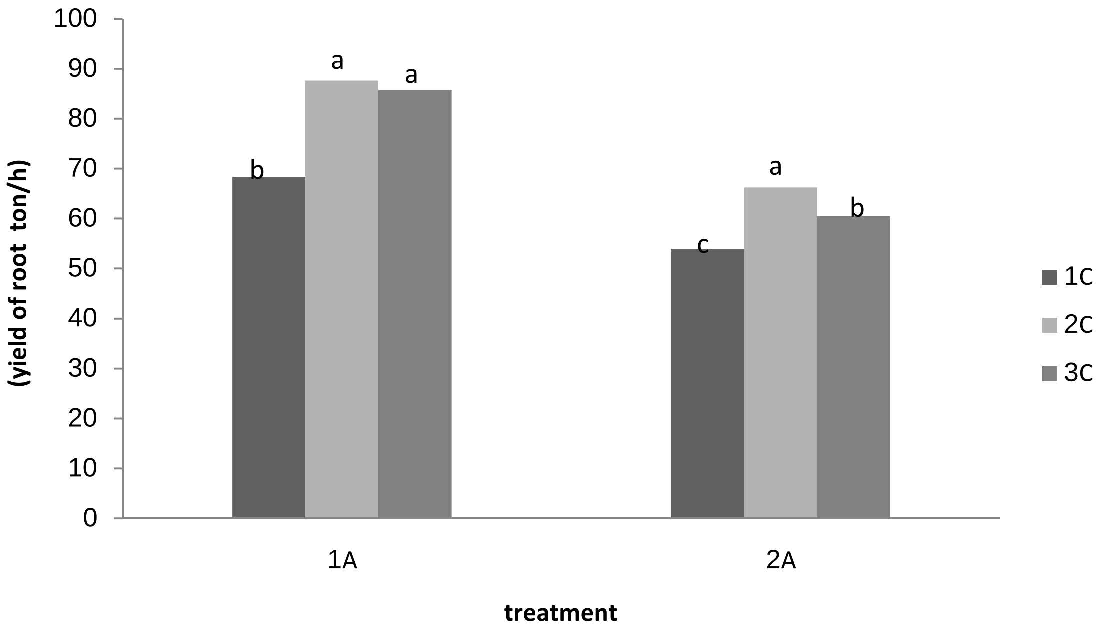

Fig 2.Intraction effect of irrigation levels(A)× Humic acid(C) on root yield

The result of ANOVA showed significant effects of irrigation levels on RY (at $P \leq 0.01$) (Table 1). The RY of sugarbeet in normal conditions was improved remarkably compared with drought stress (80.59 ton ha^{-1} vs. 60.22 ton ha^{-1}, respectively) (Table 2). Sugarbeet yield and growth reduction under drought stress has been reported by Abdollahian-Noghabi and Williams [1]Cooke and Scott [7] reported that drought stress reduced the growth of sugar beet especially reduced the cell inflammation and increased the soil potential.

Also, results demonstrated that significant differences exists (p>0.05) between interaction effects irrigation levels and humic acid on RY (Table 1). Accordingly, under CFI the greatest RY (87.63 ton ha^{-1}), occurred when humic acid applied with water irrigation, followed by foliar application of humic acid (87.63 ton ha^{-1}). However, no significant different between different levels of water stress (irrigation levels) on RY was found (p >0.05).While, lowest RY(68.34 ton ha^{-1}) was detected in plots without humicacid. Moreover, under drought stress the maximum and minimum RY was related to plots with humic acid application in water irrigation andwithout humic acid, 66.24 ton $ha^{-1}$and 53.92 ton ha^{-1}, respectively, indicating large effects of humic acid along with irrigation compare with its foliar application in drought stress conditions (Figure 2).

The result of ANOVA showed that significant differences exists (p>0.05) between interaction effects irrigation methods and humic acid on RY (Table 1). As observed in Figure 2, under CFI system application of humic acid with irrigation showed the highest RY (77.06 ton ha^{-1}) and plots without humic acid produced the lowest (62.36 ton ha^{-1}), while in IFI method the most RY were detected in plots which humic acid applied along with irrigation and plots with foliar application of humic acid, 76.84 ton ha^{-1} and 74.65 ton ha^{-1}, respectively. Furthere more, the least RY in IFI occurred in plots with no humic acid application (59.91 ton ha^{-1}) (Figure 3).

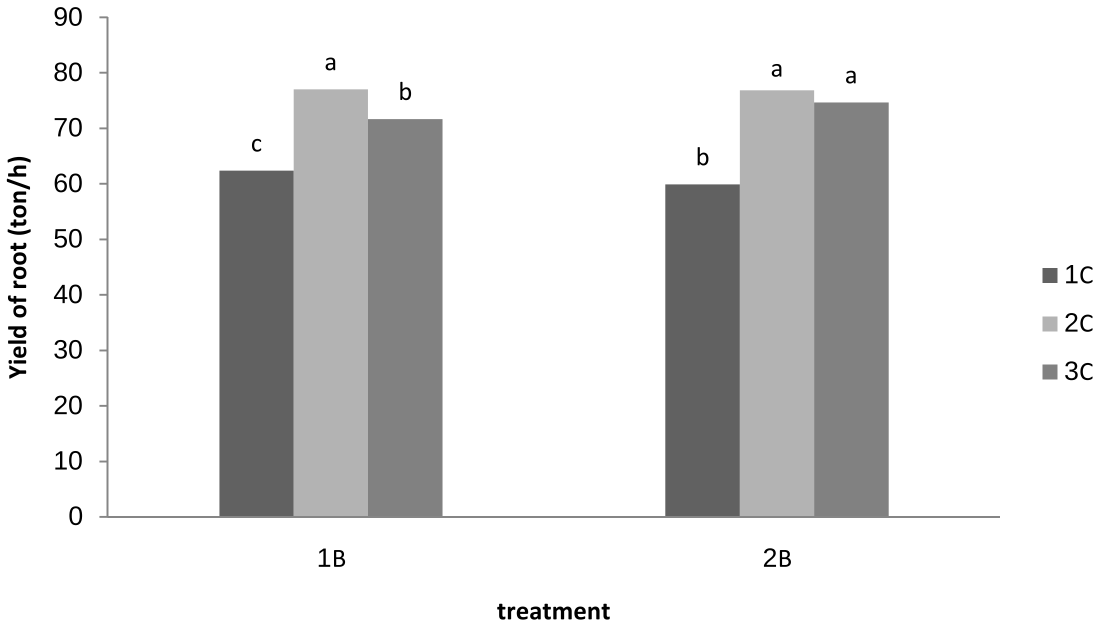

Fig 3.Intraction effect of irrigation method(B)× Humic acid(C) on root yield

White sugar yield (WSY)

The result of ANOVA demonstrated no significant effects of irrigation methods on WSY (at $P \leq 0.01$) (Table 1). Also, results indicated significant effects of humic acid application on WSY (at $P \leq 0.01$) (Table 1), so that humic acid could increase WSY by 27 % compared with untreated control which correspond with results of Sanchez et al. [20] and Sladky [22]. However, according to Table 1, there was no significant difference between application and non- application of humic acid in foliar application method, this can be attributed to sugar content reduction in humic acid levels through spraying method compared to untreated control.

WSY was not affected by the different levels of irrigation (at $P \leq 0.05$).Herenormal irrigation with average 7.34 ton ha^{-1} was in a higher level in relation to drought stress with 6.52 ton ha^{-1} (Table 2).

Total dry matter (TDM)

The result of ANOVA exhibited no significant differences of irrigation methods on TDM, while TDM affected by the level of humic acid (at $P \leq 0.01$) (Table 1). The maximum TDM (14.45 ton ha^{-1}) was obtained from humic application through irrigation and the lowest TDM (11.54 ton ha^{-1}) was observed when humic was not applied

(Table 2), indicating optimal photosynthesis activity as a result of irrigation with humic due to due to increases oil nutrients and growth-stimulating effect of the humic acid. Padem et al. [14] found that eggplant and peppers yields increased by 20-40 %.

No significant differences between the irrigation levels on TDM were also reported (Table 1). Mean comparison indicated that normal irrigation with 15.19 ton ha^{-1}TDM had a higher performance than that of drought stress with 11.30 ton ha^{-1}. This may be because of less photosynthesis activity and lower absorption ability of crop under stress [7].

Harvest index (HI)

Sugarbeet HI was not affected by irrigation methods (Table 1). Based on the results, HI was affected by humic levels (at $P \leq 0.05$).The greatest HI (55.16 %) occurred with humic application through irrigation, followed by irrigation without humic application (53.83 %). Furthermore, the lowest HI (49.58 %) was obtained under foliar application of humic. This is probably due to growth shoot due to humic spraying and plants tend to allocate more assimilates to shoot[21,2].

Table 1.Results of analysis of variance for qualitative and quantitative traits in sugar beet

S.O.V.	df	Water use efficiency(WUE)	Total water use efficiency(TWUE)	Root yield(RY)	White sugar yield(WSY)	Total dry weight	Harvest index(HI)
Replication	2	0.009^{ns}	0.10^{**}	131.4076	1.6238	2.98	39.36^{**}
Irrigation levels(A)	1	0.11^{**}	0.23^{**}	3733.2100^{**}	7.4802^{**}	135.87**	667.36^{**}
Irrigation method(B)	1	0.35**	1.33^{**}	0.1344^{ns}	0.2550^{ns}	0.003^{ns}	8.02^{ns}
A×B	1	0.009^{ns}	0.004^{ns}	0.1600^{ns}	0.5550^{ns}	0.016^{ns}	26.69^{ns}
Error (A×B)	6	0.002	0.006	30.6021	0.4022	1.03	27.47
Humic acid(C)	2	0.043^{**}	0.13^{**}	1633.4869^{**}	9.2861^{**}	55.30^{**}	102.02^{*}
A×C	2	0.003^{ns}	0.007^{ns}	182.0175^{**}	0.1785^{ns}	7.30^{**}	3.69^{ns}
B×C	2	0.006^{ns}	0.015^{ns}	45.5548^{*}	1.3878^{ns}	1.76^{ns}	34.19^{ns}
A×B×C	2	0.004^{ns}	0.006^{ns}	8.1490^{ns}	0.0564	0.21^{ns}	1.19^{ns}
Error	16	0.002	0.01	6.2693	0.5136	0.24	26.40
C.V.(%)	-	10.33	4.33	3.55	24.72	3.77	9.72

*In each column, ns, * and ** means non-significant and significant at 0.05 and 0.01 probability level, respectively*

Table 2.Comparisons of means for traits in sugar beet

Treatment	Water use efficiency (WUE) (kg/m^3)	Total water use efficiency (TWUE) (kg/m^3)	Root yield (RY) (ton/h)	White sugar yield (WSY) (ton/h)	Total dry weight (ton/h)	Harvest index (HI) (%)
Irrigation method						
normal	0.38b	0.71b	70.46a	7.06a	13.25a	53.33a
intermittent furrow irrigation	0.58a	1.10a	70.34a	6.89a	13.23a	52.38a
Humic acid						
zero humic acid	0.42b	0.79c	61.13c	6.22b	11.54c	53.83ab
With irrigation	0.54a	0.99a	76.94a	7.94a	14.45a	55.16a
Foliar application	0.47b	0.94b	73.14b	6.75b	13.75b	49.58b
Irrigation levels						
normal	0.42b	0.88b	80.59a	7.34a	15.195a	48.55b
stress	0.53a	0.93a	60.22b	6.52b	11.30b	57.16a

Mean with the same letters in each column have not significant differences at 0.05 and 0.01 probability level.

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