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Effect of irrigation methods and nitrogen application on sugar beet yield and quality

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ABSTRACT

In order to study the effects of different irrigation system and different amounts of nitrogen fertilizer on yield and quality of sugar beet, an experiment was conducted at Ekbatan Research Station, Hamedan during 2005-2006 as split plot based on randomized complete block design with three replications. The main plots were irrigation systems (furrow, sprinkler and drip irrigation) and subplots were nitrogen fertilizer, (0, 120, 180 and 240 kgha^{-1}). The results showed that, interaction of irrigation system and nitrogen fertilizers was significant for all traits except sugar content, white sugar yield and mollases sugar. Results of means comparison showed that the highest root yield (101.61 ton.ha^{-1}) was obtained in sprinkler irrigation with application of 240 kgha^{-1} nitrogen fertilizer. The highest value of this trait in furrow irrigation was obtained with 180 to 240 and in drip irrigation with 180 kgha^{-1} nitrogen fertilizer. The amount of nitrogen required in sprinkler, furrow and drip irrigation was 240, 180 and 180 kgha^{-1}, respectively. In drip irrigation, rate of water use was 50 percent less than that of furrow irrigation, however the root yield was not significantly different in the two systems. Therefore, drip irrigation system in areas with limitation of water is recommended.

Keywords: drip, furrow, nitrogen, quality, irrigation, sprinkler, sugar beet, yield

INTRODUCTION

Sugar beet is considered as one of the important crops of Hamedan province, Iran. More than 85% of water resources of the province is obtained from underground natural supplies. With a glimpse to the province severe water limitations, the optimum utilization of water is the real priority to reserve natural resources as a goal. The fertigation management, resulting in increasing irrigation and water use efficiency, could be effective in this regard. Using the modern methods of irrigation is gradually expanding in the areas. Among these are sprinkler, drip (tape), and hydro-flume methods.

Nitrogen is the most substantial nutrition element in sugar beet growth. The quality and consumption of N, during the plant growth, is very important. Sugar beet is so sensitive to the Nitrogen shortage, and lack of the element could cause a severe decrease in yield. Since Nitrogen is a moving and conveyable element during irrigation, its unusual and irregular use could not only decrease the fertilizer use efficiency, but also to pollute the underground water resources as the most important factor. A great deal of Nitrogen in soil at the last period of sugar beet growth (after the full-growth of leaves) could increase the impurities and decrease the sugar yield (Koocheki et al. 1997). In a study on water and Nitrogen use efficiency in the normal and stress conditions in two sugar beet plant spacings in furrow irrigation, it was reported that the optimum water and Nitrogen utilization, in order to realize the maximum sugar yield in Karaj area, is approximately 13500 m^3/ha and 240 kg/ha, respectively. With the increase of water use, the sugar yield was en-

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hanced, but the water use efficiency was decreased. Nitrogen use up to 240 kg/ha increased sugar yield and water use efficiency (Taleghani 1998). In this research, it was reported that, in the case of high N fertilizer use, a great amount of it is wasted and causes not only economic losses, but also non-compensable damages to the environment. Karimzade (2006) studied the water use efficiency and sugar beet yield in the surface and sprinkler irrigation methods. The results showed that the sugar yield, extraction coefficient of sugar, molasses, root weight, sugar content, and white sugar content, under the effect of 3 irrigation methods, had no significant differences. Water use quantity and efficiency, at 5% probability level, showed a significant difference and the sprinkler irrigation was found to be superior to the two other methods. The sprinkler irrigation, in comparison to furrow irrigation, had 31% decrease in the water use and 55% increase in the water use efficiency, on the basis of root yield.

In an experiment, the effect of drip and furrow irrigation on sugar beet was evaluated (Hossain Abadi and Cohaemi 2004). The results showed that the water use, in drip irrigation, was 58% of surface irrigation. The maximum root yield was related to drip irrigation treatment, while among the treatments, there were no significant differences in white sugar yield.

In a study on the effect of Nitrate of the soil before sowing, as sugar beet fertilization guide in the Mediterranean region, 33 experiments were carried out in 1989-2000 in different areas (Bilbao et al 2004). The treatments included 8 levels of N fertilizer from Zero (0) to 300 kg/ha, 1/3 of which before sowing and 2/3 of which after sowing were used (1/3 at the time of 3-leave stage and 2/3 at the time of 4-leave stage). In this research, the approximate total quantity of Nitrogen for the optimum production of sugar beet was obtained by using 268 kg Nitrogen per hectare.

In the field experiment, it was seen that the number of leaves per plant was enhanced with the increase of N use. The utmost quantity of active green leaves in the treatments were obtained by 120 kg/ha of N-fertilizer. Although, in this experiment, the water use in drip irrigation was 23-28% less than sprinkler irrigation, the sugar yield was the same in both of them (Caswell and Zilberman 1985).

In Utah, USA, an experiment on different irrigation methods in sugar beet cultivation showed that drip irrigation method is a good substitute for the furrow method and also for the development of sugar beet in the area. In the drip method, the root size and sugar yield were increased in comparison with the furrow method. In the furrow method, the costs of weed control and the total variable seasonal costs were enhanced in comparison with the sprinkler method. The returned income, in the furrow and drip methods, was 2080 $ and 2340$, respectively. Mean while the primary costs in the drip method could be compensated in a 40-hehtare farm within 7 years (Sharmasarkar et al. 2001).

A comparison between the furrow and under-pressure (linear and classic) irrigation methods with the different levels of N-fertilizer in USA showed that the irrigation systems had no significant differences for the sugar content, root yield, Na, K, and alpha-amino N in sugar beet. The molasses sugar percentage, in the classic irrigation, was less than that in furrow method. In the furrow method, compared with the classic method, in the same characteristics, more Nitrogen was consumed. Also, the leached Nitrogen through the runoff and soil drained water in the furrow irrigation was higher than the other treatments. The results showed that in the sprinkler method less Nitrogen is needed (Eckhotf et al. 2005).

Considering all above discussions, the research was conducted with the goal of evaluation of the impact of irrigation methods and different levels of N-fertilizer on sugar beet quality and quantity.

MATERIALS AND METHODS

The experiment was done as split plots on the basis of randomized complete block design in 3 replications and 12 treatments during 2005 and 2006 at Ekbatan Research Station, Hamedan. The various irrigation methods including traditional irrigation (furrow), sprinkler (classic) and drip (tape) were assigned to the main plots and the N fertilizer at 4 levels of zero, 120, 180, 240 kg/ha were tested in the sub-plots. The sowing was done in rows (two rows on each ridge and 4 ridges per plot) and the sowing pattern was 40×50 cm, in 8 rows with 30 m length. The distance between the replications was 10 m and between the plots was 2 m. In order to prevent the drift of sprinklers to other plots, one-sided sprinklers were used. On the basis of soil testing, the Nitrogen quantity of the soil samples was under 1%. So, the total N-fertilizer needed for the test was calculated on the basis of the so-called treatments and provided by the source of Urea (with pure Nitrogen of 40 %). Therefore, for the treatments of 120, 180, 240 kg

Table 1. Results of soil analysis in the experimental fields and determination of some of its physical and chemical characteristics

Sampling year	Sampling depth (cm)	Electrical conductivity	Saturated clay reaction	Neutralized Materials (%)	Organic Carbon (%)	Total Nitrogen (%)	Absorbable Phosphate (mg/kg)	Absorbable Potassium (mg/kg)	Soil texture
2005	0-30	0.46	8.2	15.77	0.72	0.072	13	355	Loam
2006	0-30	0.47	8.8	16.33	0.94	0.094	12.5	362	Loam

N-fertilizer, 260, 391, and 521 kg of Urea fertilizer were considered, respectively. 1/3 of Urea fertilizer was used at the time of sowing, and the rest was applied as top-dressing after thinning. The top-dressed fertilizer in the furrow method was used by spreading inside the plots, and in two methods of drip and sprinkler method was used by injection into the systems. The P-fertilizer, on the basis of soil testing, was provided by using super phosphate triple of 100 kg/ha. Based on the soil testing, there was no need for K-fertilizer (Table 1).

The variety Rasoul was sown by pneumatic sowing machine and the preliminary irrigation was done; meanwhile, during the growth period all the cultural practices were conducted regularly. The harvesting was carried out on two rows of 5 m long. At first the shoots were sampled and weighed and some were used to determine the dry mater percent, then the roots were taken, counted, washed and weighed.

The irrigation, in the different methods, was done based on evaporation from the class A evaporation pan. In the sprinkler and furrow methods, the time was determined for 80 mm, whereas in drip method the time was determined for 20 mm cumulative evaporation for the exact determination of water volume in each irrigation turn. Before irrigation, the moisture percentage of soil was measured at the root depth of 30-60cm by using TDR device (Time Domain Reflectometry) and then the depleted moisture to be reached to the level of Field Capacity (FC) was met by irrigation according to the equation (1). Irrigation efficiency for furrow, sprinkler, and tape systems are 50 %, 70% and 90%, respectively.

$$D = (\Theta_{FC}-\Theta_{FI}) \times \rho_b \times Z (1)$$

In this equation, Θ_{FC} is moisture weight percentage per Field Capacity and Θ_{FI} is the soil moisture at the time of measurement, P_b is soil bulk specific weight (g/cm^3), Z is root development depth, D is Water-Irrigated Required Depth (cm^3) (Ghasemzade 1990).

The quantity of input water in all sprinkler, drip and furrow systems was measured by using volume counter. In furrow method, the water volume drained from plots was measured by WSC flume (type 4) through equation 2, subtracted from input water volume and then the net utilized water volume, in each irrigation period, was calculated:

$$Q_4=0.0294 \times H^{2/102} \quad (2)$$

In this equation, H is water height in flume (cm) and Q Debby quantity (lit/s) (Ashrafi et al. 1996). Total utilized water volume, in the various irrigation systems, was shown in Table 2. After gathering data and ensuring that variances are rational (well calculated) through the Bartlet Test, the combined variance analysis was done and for comparing the means the Duncan's Multiple Range Test was used.

Table 2. Volume of water used during the growth period in different irrigation systems (m^3/ha)

Cropping year	Sprinkler	Furrow	Tape (Drip)
2005	11388	14045	7559
2006	12929	14961	8953
Two-year average	12158	14503	8256
Ratio(%)	84	100	57

Results and Discussion

As seen in variance analysis Table (Table 3), the irrigation systems had no significant influence on root yield, sugar content, extractable sugar content, sugar yield, white sugar yield and alpha-amino N and molasses sugar. But the effect of irrigation systems on shoot weight and dry weight was significant at 5% probability level.

The effect of N fertilizer levels on root yield, sugar yield, white sugar yield, α-amino N, shoot weight and shoot dry matter was significant at 5% probability e level. The molasses percentage, sugar content and also the extractable sugar content were not affected by fertilizer levels. Since the N fertilizer has a direct influence on the plant growth, the observed effects on shoots weight and yield was predictable. On the other hand, when the root yield was affected by a treatment, the sugar yield would also follow it. The interac-

Table 3. Mean of squares of combined variance analysis for some quality and quantity characteristics measured (2005-2006)

The source of variation	df	Root Yield	Sugar content	White sugar content	Sugar yield	White Sugar Yield	α-amino Nitrogen	Molasses sugar	Arial plant Part weight	Dry matter of arial plant part
Year	1	455.11	39.24	32.07	0.03	0.06	65.57	0.36	68.11	2.20
Replication	2	72.29	4.10	4.52	5.20	5.12	0.82	0.24	67.84	1.01
Irrigation	2	1047.72$^{n.s}$	8.72$^{n.s}$	5.05$^{n.s}$	55.73$^{n.s}$	32.46$^{n.s}$	5.81$^{n.s}$	1.05$^{n.s}$	1089.28$^{n.s}$	25.32*
Year × Irrigation	2	26.33	2.20	3.41	0.80	1.98	3.18	0.68	71.17	1.58
Error	4	51.26	1.56	2.40	1.41	1.21	0.47	0.18	27.43	0.80
Nitrogen	3	8939.28*	1.07$^{n.s}$	2.54$^{n.s}$	266.57*	175.70*	4.08*	0.35$^{n.s}$	1171.02*	22.87*
Nitrogen ×Year	3	94.95	0.60	0.95	2.73	2.21	0.30	0.06	33.38	0.60
Irrigation × Nitrogen	6	159.91*	1.40$^{n.s}$	1.62$^{n.s}$	4.79*	2.86*	0.44*	0.08$^{n.s}$	82.98*	1.57*
Irrigation × Nitrogen × Year	6	35.57	1.04	1.52	1.67	1.76	0.31	0.06	9.20	0.18
Experimental error	36	45.59	0.42	0.48	1.52	1.20	0.18	0.04	18.42	0.45
CV	-	9.80	3.66	4.71	10.08	10.83	17.62	8.59	13.87	15.37

^{ns}, * and ** are insignificant and significant at levels of 5% and 1 %, respectively.

tions of irrigation treatments and N- fertilizers on all the measured characteristics, except for sugar content, extractable sugar and molasses, were significant. This is likely because of the differences in the distribution of N fertilizers in the different irrigation systems (Table 3). On the other hand, there is a strong relation between the water distribution in the field and the quantity of soluble N fertilizer in water. And this is because of the movable state of N fertilizer in the soil water.

The mean comparisons (Table 4) of the measured characteristics showed that among the 3 tested irrigation systems, the highest root yield was obtained in sprinkler method with 76.57 t/ha. In comparison, the tape and furrow irrigations, without a significant difference, were in the lower groups. Considering the increase of the shoot weight and dry matter in the sprinkler system compared with the other ones, it is probable that the sprinkler irrigation could cause the increase of plant canopy and, consequently, the root yield would be enhanced. With increasing the root yield, it is expected that sugar yield is also increased, which on the basis of Table 4, the sugar yield in sprinkler irrigation was 13.97 t/ha, being more than the other two systems. For white sugar yield, the result was the same. As a whole, considering the fact that there is no effectiveness of the irrigation systems on sugar content and extractable sugar, one could conclude that the irrigation systems are not significant for the sugar content, but influencing root yield could affect sugar yield (Table 4). The shoots and dry matter weights, in the tape irrigation system, were significantly less than that of in two other ones. A lower quantity of shoots fresh weight in tape system is likely the due to the water distribution quality around the roots, while in this system 30-40% of water use has been saved (Table 2) (Eckhoff et al. 2005). Also, they concluded that, comparing the furrow and sprinkler with the different levels of N fertilizers, there is no significant difference between the two systems in sugar content, root yield, Na, K, and alpha-amino N.

In Table 5, the comparison of the different levels of N fertilizers on quality and yield of sugar beet has been shown. As can be observed, the increase in the consumption of N fertilizer would enhance the root yield, sugar yield, white sugar yield, alpha-amino N, molasses, shoots and dry matter weights. The trend of root yield and N fertilizer enhancement was not linear and the lowest yield (36.62 t/ha) was obtained at the 0 level of the N-fertilizer, but with utilization of 120 kg Urea fertilizer per hectare, the yield grew to 100% reaching to 71.85 t/ha. With the increase of Urea fertilizer quantity to 181 kg/ha, the yield enhanced to 81.56 t/ha. For 240 kg/ha of N fertilizer, in comparison to 180 kg/ha, there was no yield increase statistically and it reached to 85.56 t/ha.

Table 4. Mean comparison for some of the characteristics of sugar beet measured in the irrigation system

Irrigation treatments	Root yield (t/ha)	Sugar content (%)	White sugar Content (%)	Sugar yield (t/ha)	White sugar yield (t/ha)	α-amino Nitrogen (meq/100gr)	Molasses sugar (%)	Arial plant part weight	Dry matter of arial plant part
Classic	76.51^{a}	18.32^{a}	15.04^{a}	13.97^{a}	11.43^{a}	2.98^{a}	2.68^{a}	36.66^{a}	5.37^{a}
Furrow	65.65^{b}	17.14^{b}	14.22^{a}	11.16^{b}	9.24^{b}	2.03^{b}	2.31^{b}	32.66^{b}	4.37^{b}
Tape	64.56^{b}	17.923^{ab}	15.00^{a}	11.55^{b}	9.66^{b}	2.27^{b}	2.33^{b}	23.52^{b}	3.32^{c}

*Means with the same letter in each column, on the basis of Duncan test, have no significant differences at 5% level.

Table 5. Mean comparison for some of the characteristics of sugar beet measured at different levels of Nitrogen used

Treatments of Nitrogen fertilizer (t/ha)	Root yield (t/ha)	Sugar content (%)	White sugar content (%)	Sugar yield (t/ha)	White sugar yield (t/ha)	α amino Nitrogen (meq/100gr)	Molasses sugar (%)	Arial plant part weight	Dry matter of arial plant part
0 kg	36.62^{c}	18.00^{a}	15.02^{a}	6.6^{c}	5.51^{c}	1.97^{c}	2.38^{bc}	14.49^{c}	2.73^{c}
120 Kg	17.85^{b}	18.01^{a}	15.13^{a}	12.94^{b}	10.87^{b}	2.12^{c}	2.28^{c}	31.16^{b}	4.42^{b}
180 kg	81.56^{a}	17.59^{a}	14.50^{b}	14.34^{a}	11.81^{a}	2.58^{b}	2.49^{ab}	36.09^{a}	5.16^{a}
240 kg	85.59^{a}	17.57^{a}	14.36^{b}	15.02^{a}	12.26^{a}	3.03^{a}	2.61^{a}	37.06^{a}	5.09^{a}

*Means with the same letter in each column, on the basis of Duncan test, statistically have no significant differences at 5% level.

This trend was predictable, considering the role of N fertilizer in the plant canopy development and its relation to root yield. As seen in Table 1, the shoots weight was significantly increased with the increased levels of N- fertilizer, and the same as yield, with increasing of N-fertilizer levels from 0 to 180 kg, the shoots and dry matter weights were doubled. White sugar and sugar yields were increased with the enhancement of Urea-fertilizer quantities, so that these two characteristics, with an increase in the level of N-fertilizer from 0 to 120 kg, showed more than 100% increase.

In the comparison of two irrigation systems of furrow and sprinkler, with the N-fertilizers levels (studied by Eckhoff et al. 2005), it was mentioned that in furrow irrigation, more nitrogen was utilized, compared with the classic irrigation. Also, the nitrogen in runoff and soil drained water was more in furrow irrigation. According to Table 6, the increase of N- fertilizer in sprinkler irrigation system caused the acceptable enhancement of yield, in such a way that, at the level of 24 kg N-fertilizer, the utmost yield of 101.61 t/ha was resulted. In the furrow irrigation system, the highest yield was obtained at the level of 180 and 240 kg N-fertilizers per hectare, whereas in the tape irrigation system, the utmost yield was obtained at the level 180 kg N-fertilizer and the increase of N-fertilizer to 240 caused the decrease of root yield to some extent. So, it could be concluded that the utmost use of N-fertilizers in classic, furrow and tape systems are 240, 180 and 180 kg/ha, respectively, above which do not cause increase in root yield. The decreased yield in tape system at the level of 240 kg N- fertilizer could be related to the characteristic of this system in the water and fertilizer use efficiency increase and the runoff decrease and finally the increase of alpha-amino N. The results of sugar yields were the same as root yields in both systems of tape and sprinkler. In furrow system, though, sugar yield not being significant at levels of 180 and 240 kg N- Fertilizer, the highest amount of N- fertilizer used for the sugar yield was 240 kg. For shoots and dry matter weights, it is observed that in sprinkler and furrow irrigation systems, at the level of 180 and 240 kg N- fertilizer, there are the utmost levels in the characteristics, whereas at the level of 0 kg N-fertilizer, there are the least levels. In tape system, for shoots dry weights, using 120- 240 kg N- fertilizer, no significant differences could be observed. From all the results, it could be concluded that in tape system, because of the decreasing canopy, in comparison with sprinkler system, the need for N- fertilizer is less; meanwhile, leaching N-fertilizer is also less, whereas in furrow system,

Table 6. Mean comparison for the interaction of irrigation ×nitrogen treatments during the two years of the experiment

Method of irrigation	Quantity of Nitrogen	Root yield (t/ha)	Sugar content (%)	White sugar content (%)	Sugar yield (t/ha)	White sugar yield (t/ha)	α-amino Nitrogen (meq/100gr)	Molasses sugar (%)	Arial plant part weight	Dry matter of arial plant part
Classic	0	42.22^{e}	18.20^{ab}	15.09^{abc}	7.67^{f}	6.36^{f}	2.23^{cdef}	2.51^{b}	21.26^{e}	3.09^{f}
	120	76.35^{cd}	18.92^{a}	15.90^{a}	14.41^{bc}	12.11^{bc}	2.45^{cd}	2.41^{bc}	39.24^{ab}	5.83^{ab}
	180	85.85^{b}	18.28^{ab}	14.86^{bc}	15.68^{b}	12.74^{b}	3.32^{b}	2.83^{a}	43.37^{a}	6.47^{a}
	240	101.61^{a}	17.88^{bc}	14.30^{c}	18.12^{a}	14.52^{a}	3.90^{a}	2.98^{a}	42.78^{a}	6.09^{ab}
Furrow	0	32.61^{f}	17.82^{bc}	14.94^{bc}	5.83^{g}	4.89^{g}	1.82^{f}	2.27^{bc}	21.46^{bc}	2.92^{fg}
	120	69.44^{d}	17.23^{c}	14.39^{bc}	11.97^{e}	10.01^{e}	1.87^{ef}	2.24^{bc}	29.85^{c}	4.11^{de}
	180	80.22^{bc}	16.29^{d}	13.36^{d}	13.01^{cde}	10.66^{de}	2.03^{def}	2.33^{bc}	36.43^{b}	4.88^{cd}
	240	80.31^{bc}	17.21^{c}	14.20^{c}	13.82^{cd}	11.41^{bcde}	2.41^{cde}	2.40^{bc}	42.91^{a}	5.57^{bc}
Tape	0	35.02^{ef}	17.98^{bc}	15.01^{abc}	6.30^{fg}	5.27^{fg}	1.87^{ef}	2.36^{bc}	15.74^{f}	2.19^{g}
	120	69.76^{d}	17.89^{bc}	15.10^{abc}	12.45^{de}	10.50^{e}	2.05^{def}	2.19^{c}	24.37^{de}	3.34^{ef}
	180	78.61^{bc}	18.21^{ab}	15.29^{ab}	14.32^{bc}	12.04^{bcd}	2.39^{cde}	2.32^{bc}	28.48^{cd}	4.13^{de}
	240	74.85^{cd}	17.63^{bc}	14.59^{bc}	13.13^{cde}	10.84^{cde}	2.77^{c}	2.44^{bc}	25.48^{cde}	3.60^{ef}

*Means with the same letter in each column, on the basis of Duncan test, have no significant differences at 5% level.

because of increasing volume of water used, leaching N-fertilizer is more than that of the two other systems. Therefore, the exact and proper use of N-Fertilizer in the irrigation systems, from the quantitative and qualitative standpoints, and even environmental issues are highly important. And it is necessary to fulfill the standards for using Urea-fertilizers in irrigation systems. Noticing the used water volume in tape system, which is nearly 50% less than that in furrow irrigation (Table 2), and the yield in tape system, which is statistically in the same group with that in furrow system, it is recommended to use the tape irrigation system in the areas encountered with water limitations and to use the sprinkler system in the areas with less limitations (or better water conditions).

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