Journal of Sugar Beet
http://jsb.areeo.ac.ir/
Journal of Sugar Beet 2015, 30(2)

Effects of different irrigation levels and salinity on qualitative and quantitative yield of sugar beet

H.A. Shahbazi[(1)*], A. Zolfagharan[(1)], A.R. Ghaemi[(2)], M. Ahmadi[(2)] and R. Mohammadian[(3)]

[(1)] *Instructor of Agricultural and Natural Resources Research Center Khorasan Razavi, Mashhad, Iran.*
[(2)] *Assistant professor of Agricultural and Natural Resources Research Center Khorasan Razavi, Mashhad, Iran.*
[(3)] *Associate professor of Sugar Beet Seed Institute (SBSI), Karaj, Iran.*

Shahbazi HA, Zolfagharan A, Ghaemi AR, Ahmadi M, Mohammadian R. Effects of different irrigation levels and salinity on qualitative and quantitative yield of sugar beet. J. Sugar Beet. 2015; 30(2): 103-108.

Received March 9, 2014; Accepted October 17, 2014

ABSTRACT

To determine the effects of different irrigation and salinity levels on qualitative and quantitative yield of sugar beet, an experiment was conducted for two years (2006-07)at Torogh Agricultural Research Center, Mashhad, Iran, using two sprinkler systems. Each of the two irrigation systems was connected to two water sources with 1 and 6 ds/m salinity. Irrigation was performed via two sprinkler pipes (line source) that were placed perpendicular to each other in a 28×28 m area. In each irrigation, sugar beet plants planted at the center of the square could receive full irrigation and less water was given to farther plants. Consequently, the salinity level was changed from 1 to 5.75 ds/m. At the end of each irrigation, water level and the salinity rate of the can samples located at the center of the square networks of 2 × 2 m^2 were measured. At the end of the growing season, beet samples were harvested from an area of 3 m^2 around each can and their yields were determined. Using the data obtained from each network, the quantity of water, average salinity level and quantitative and qualitative yield of sugar beet were measured. Results showed that root yield and sugar content were influenced by irrigation level and electrical conductivity (EC) of the water applied. With increase in irrigation level (with different ECs), root yield and sugar content were increased, and by increasing EC (in the same water levels), root yield and sugar content were decreased. The correlations of sugar content and impurities with irrigation level and EC were not statistically significant.

Keywords: Electrical conductivity, irrigation level, salinity, sugar beet

INTRODUCTION

In arid and semi-arid regions such as Khorasan Razavi, sugar beet irrigation has become a crisis and water deficit and salinity are of great importance. Irrigation is required to produce crops in arid and semi-arid regions. However, in such areas, water is generally salty, and it is therefore reasonable to consider salinity as a variable. Sugar beet is one of the major crops in Khorasan Razavi province. There are six sugar factories in the province. Nabipour and Alizadeh (1998) showed that sugar beet is sensitive to drought and salinity during germination and emergence, up to one month later; light and continuous irrigation is beneficial for reducing the risk of salinity and preventing soil clogging. Sadre Ghaen (2001) showed that under sprinkler irrigation, sugar beet produced more root and sugar yields compared with furrow irrigation and among the sprinkler irrigation treatments, supply of 90% sugar beet water requirement was found to be the best treatment with respect to root and sugar yields. No significant difference was observed among the furrow irrigation treatments in terms of root and sugar yield.

In an experiment conducted by Schafer et al. (1979), water use efficiency of sprinkler irrigation on different crops was evaluated and sugar beet had higher water use efficiency than the other crops. In a study by Kayimoglu et al. (1976), four different irrigation methods including sprinkler,

*Corresponding author's email: Shahbazy33@yahoo.com

tape, furrow and flood irrigation effect on sugar beet was evaluated. Sugar beet root yield in these methods was 65.4, 52.6, 50.1, 46.5 t ha^{-1}, respectively. The amount of sugar produced per unit area was not significantly different but the volume of water consumption under sprinkler irrigation was low. Howell et al. (1987) showed that water stress results in the variation of the qualitative and quantitative traits of sugar beet. Orchard et al., 1960) showed that restricting irrigation reduces sugar beet root yield and increases sugar content. Evapotranspiration (ET) should be completely compensated by irrigation to maximize the sugar yield. Hong and Miller (1984) reported that the reduction in irrigation to 40-50% would not affect the growth of leaf and root and also root yield. In sandy soil and in case of root irrigation much less than evapotranspiration rate, root function decreases sharply.

Rafei (1995) studied the seasonal dry matter accumulation pattern in shoot, root and the whole plant of different sugar beet cultivars and reported the reduction of dry matter accumulation and the growth indices in all cultivars by salinity treatment. It was also shown that salinity treatments had significant effect ($P<0.01$) on total yield, white sugar yield and qualitative traits of sugar beet including sugar content, white sugar content, losses of molasses sugar, extraction coefficient of sugar, potassium, α-amino nitrogen, alkalinity and root crude substances with no impact of salinity on shoot yield, sodium and content.

Mohammadian et al. (1997) reported that the germination percentage and average seedling length of strong seed lots under normal (EC = 0) and different salt treatments (EC = 12 and 22 dS/m) was significantly higher than weak seed lots. Yazdani (2001) showed that in both susceptible and resistant sugar beet cultivars to salinity, salinity stress increased proline content in leaf tissue. The amount of proline accumulation in salinity-resistant cultivar was more than susceptible cultivar. Also, root chemical analysis showed no significant difference between the two forms of nitrogen in terms of sugar content, extraction coefficient of sugar, sugar yield and molasses sugar content. Other researchers (Mass et al. 1977; Shannon et al., 1997) studied the susceptibility of different plants to salinity, and reported that although sugar beet is resistant to water and soil salinity stresses, it is susceptible at early growth stages. Katerji et al. (2001) used models, that estimate the water-yield relation under normal conditions, for different plants such as corn, sunflower, sugar beet and potato under salinity conditions. The obtained result led to the fact that the yield of these plants is consistent with the results of the above relationship.

Linear source sprinkler (Hanks et al., 1976) has been widely used as a useful tool in studies of the effect of irrigation on the yield of crops. In this system, uniform application of water along the irrigation line creates a gradient in the direction of perpendicular to the irrigation line. In spite of this desirability, a weakness of the linear system is that there is no statistical test to show the effect of irrigation levels on a crop as the irrigation volume is always applied systematically (non-random) (Hanks et al., 1980). Frenkle et al. (1990) used a dual linear system to determine the reaction functions concurrently to both salinity and water and their interaction with forage corn. Zolfegharan (2005) created a variable gradient of water and salinity using two line source irrigation pipes. In their study, the effects of irrigation volume on wheat yield under different salinity levels was investigated and a general equation was presented for yield calculation as a function of irrigation and salinity levels.

In order to investigate the effects of different irrigation volume and salinity levels on root and sugar yield and their interaction on sugar content and impurities, this study was conducted in Mashhad city.

MATERIALS AND METHODS

This experiment was conducted to study the effects of irrigation water on sugar beet yield and quality at different levels of water salinity at Torogh Research Station, Mashhad, Iran during 2006 and 2007. After a relatively deep plow, one turn was made of a light disc and a hard disc. Then, leveler and fertilizer spraying were performed. Seeds of Dorothea cultivar were planted using planter. Plants were thinned at 2-4 leaf stage. The row and plant spacings of 50 and 20 cm were applied, respectively.

Primary irrigation was performed as furrow to hasten seed germination. In accordance with Figure 1, irrigation was carried out using two single-line sprinkler irrigation pipes (perpendicular line) in a 28 × 28 m^2 area (the intersection of two tubes). Each of the pipes was connected to a water source with salinities of about 1 and 5.75 ds m^{-1}. At each turn of irrigation, the water was given to sugar beet plants at the center of plot based on Pennman-Mantheis method, which resulted in the

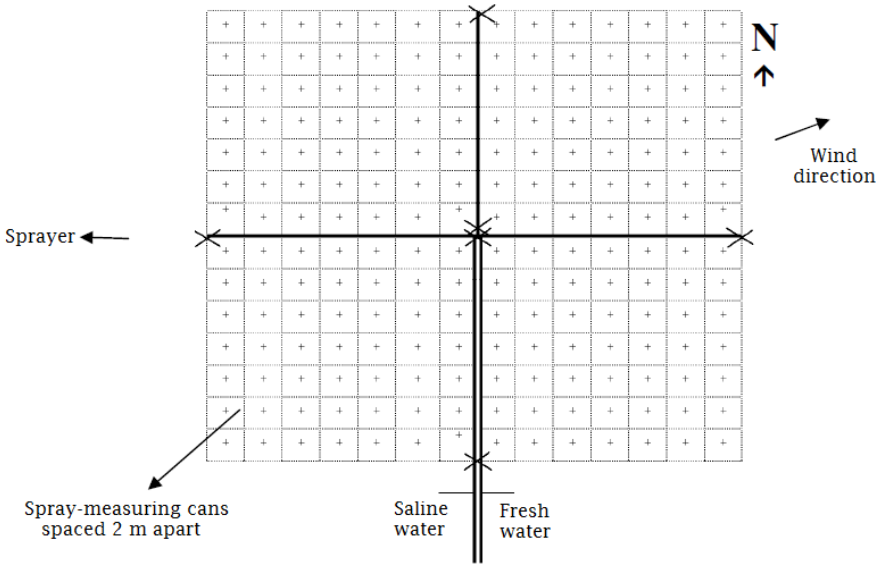

Figure 1. Position of spray-measuring cans and location of sprayers on saline and sweet water pipes (irrigation was performed during quiet times without wind)

water shortage in the parts farther to the center. The average of the salinity reached to any point of the land ranged between 1 to 5.75 ds m^{-1}.

Considering that the pattern of water spraying from the line-source technique in an ideal condition is a single share, the spray pattern in this design in which two single-strand lines of saline and sweet water are perpendicular are formed as a cone. On the other hand, since the volume of water reaching the plants varied from each of the saline and sweet water lines, therefore, salinity reached to them varied and was equal to their average weight. At each irrigation time, the irrigation volume and salinity (EC) was measured at 196 points.

The average of the chemical analysis of irrigation water is presented in Table 1. Saline water from the Abbas Abad station, the eastern livestock breeding center located at 20 km east of Mashhad, was transported to the experimental site by a 10,000-liter tanker and was used for irrigation.

To determine some physical and chemical properties of the soil, composite samples were taken from 0-30 and 60-30 cm soil depth. The results of soil test of the experimental site are presented in Table 2.

The rate of fertilizer needed was determined on the basis of soil test so that 300 and 250 kg ha^{-1} urea and ammonium phosphate fertilizers were applied, respectively. After each irrigation, the volume and salinity of the collected water inside the cans at the center of 2 × 2 m^{-2} squared networks were measured. Irrigation was carried out at the time of no wind blowing. The volume of water inside the cans (196 points) and salinity were measured by Graduated cylinder and portable EC meter, respectively.

On November 15th, samples of 3 m^2 (2 × 1.5 m^2) were harvested around each can and sent to the laboratory. For each plot of the experiment, root weights, root number and leaf weight were measured. Pulp was prepared and different traits such as sugar content, Na, K, and amino-N were measured using Beta-Lyser. The sugar yield was

Table 1. Chemical analysis of the irrigation water

Water resource	pH	EC (ds m^{-1})	Anion (meq l^{-1})				Cation (meq l^{-1})		
			Carbonate	Bicarbonate	Chlorine	Sulfate	Ca	Mg	Na
Abas abad Station (salt water)	7.35	5.75	-	4.7	43.5	5.61	6.3	10.1	40.1
Torogh Research Station (fresh water)	7.8	0.8	1.8	-	3.2	2.35	2.4	2.4	3

Table 2. Results of soil analysis of the experimental site

Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)	Soil texture	Bulk density (g cm^{-3})	Volume of moisture content at F.C	Volume of moisture content at P.W.P	Acidity	EC (ds m^{-1})
0-30	28	49	23	Silty-loam	1.33	27.6	12.9	8.0	1.74
30-60	36	41	23	Silty-loam	1.33	27.6	12.9	8.0	1.78

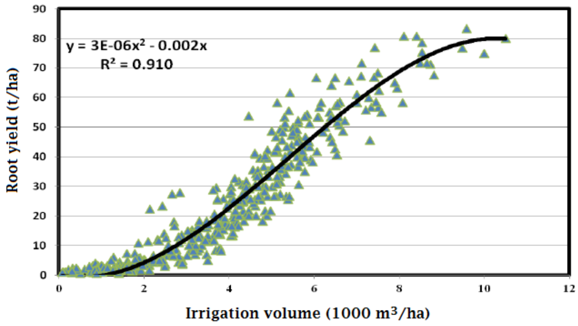

Figure 2. Correlation of root yield with irrigation volume increase (with different EC)

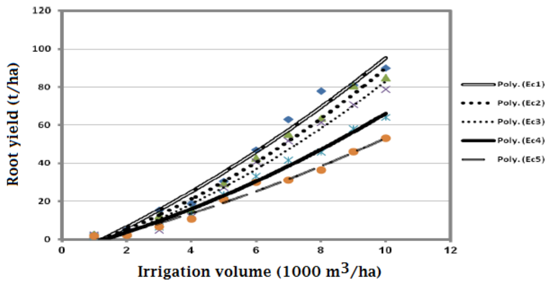

Figure 3. Correlation of root yield with irrigation volume increase (with similar EC)

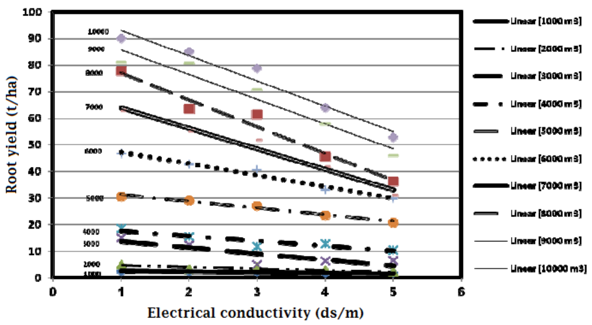

Figure 4. Correlation of root yield with EC increase (EC changes in static irrigation volume)

volume and different EC values was determined and the curve with the highest fitness was determined.

Results

Root yield

Relationship between root yield and irrigation water volume. As the volume of irrigation water (with different EC values) increased from 1000 m^3 to 12000 m^3, root yield increased. At the early stages of the growth, root yield increased slowly and continued to increase sharply, and again, at irrigation volumes higher than 10,000 m^3, the root yield growth became slow. Equations fitted to these numbers are of second degree polynomial type and have a correlation coefficient of r = 0.95 (Figure 2).

If the irrigation volume is classified according to the EC and its relation with irrigation increase is drawn, it will be determined that with increasing irrigation, the root yield in all EC treatments would increase. In a static EC, the root yield is strongly affected by irrigation volume. With increase in irrigation volume, regardless of its quality, the root yield is greatly increased. The greater the volume of irrigation, the greater the difference in root yield between different EC treatments (Figure 3). The reason is that in sugar beet, root yield has a very strong relationship with irrigation volume and with an increase in irrigation volume, root yield would increase in all treatments.

Relationship between root yield and EC. By increasing the electrical conductivity of irrigation water from one to five, there was no significant linear correlation between increasing electrical conductivity and root yield, although the root yield decreased. The correlation coefficient in the above linear equation was r = 0.57. If irrigation treatments with different EC are classified according to the irrigation volume, the relationship between EC changes and sugar yield becomes significant (Figure 4). As mentioned above, there was no significant correlation between root yield and irrigation with different EC levels. However, if irrigation treatments with different EC values are classified based on irrigation volume, the effects of electrical conductivity changes on root and sugar yield are completely determined. Results showed that in all irrigation treatments, with increase in EC, the root yield decreased. In higher irrigation volumes with increase in EC, the yield reduction was higher but in lower irrigation volumes, the root yield decreased with a lower slope. In other words, in low electrical conductivity, the difference in root yield among different irrigation treatments is high and the with an increase in EC, the difference between treatments is lower. For example, in treatment of 10000 m^3 irrigation, with an increase in EC from one to five, root yield decreased to 42%.

Combined effect of irrigation and salinity on root yield. The irrigation volume, EC, and obtained root yields at harvest points were plotted in a three-dimensional space (Figure 5). This plot shows the variations in root yield in relation to the irrigation depth and salinity using field data in two years of the experiment. As shown in this figure, in an equal irrigation volume, lower salinity levels had higher root yields. In all salinity treatments, with increase in irrigation volume, root yield would

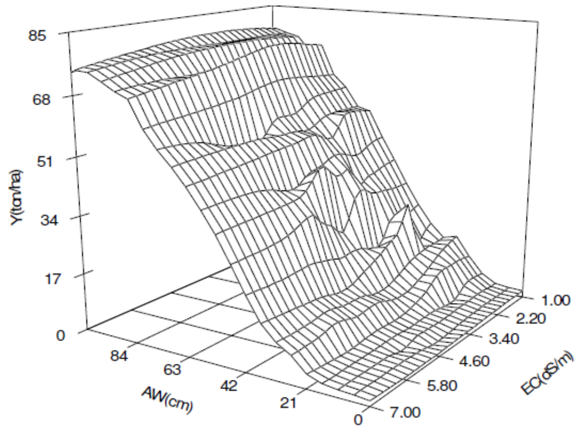

Figure 5. Root yields in relation to applied irrigation water (AW) and salinity (EC)

increase. This indicates the importance of irrigation in root yield increase.

Sugar content and impurities

RELATIONSHIP OF SUGAR CONTENT AND IMPURITIES WITH IRRIGATION WATER VOLUME. The relationship between sugar content and increase in irrigation volume (with different EC levels) was not significant (r = 0.012). With increase in irrigation volume (with different EC levels), no correlation was found between water consumption and impurities including Na, K and N.

RELATIONSHIP OF SUGAR CONTENT AND IMPURITIES WITH EC. With increase in EC, regardless of irrigation volume, no significant relationship was found between EC and sugar content. There was also no significant relationship between EC increase and impurities such as Na, K and N. The classification of EC based on equal irrigation volume did not show any linear correlation between EC increase and sugar content and impurities.

Sugar yield

RELATIONSHIP BETWEEN SUGAR YIELD AND IRRIGATION WATER VOLUME. With increase in irrigation water volume (with different EC values), the sugar yield increased. Increasing the irrigation volume to about 10000 m^3 resulted in sharp increase in sugar yield and from 10000 m^3 onward, the trend was slowed down and then remained almost constant. The relationship is 2nd degree polynomial with r = 0.93 (Figure 6). If the treatments are classified based on different EC values with equal irrigation volume, the relationship between sugar yield and irrigation volume has an increasing trend with high correlation (Figure 6).

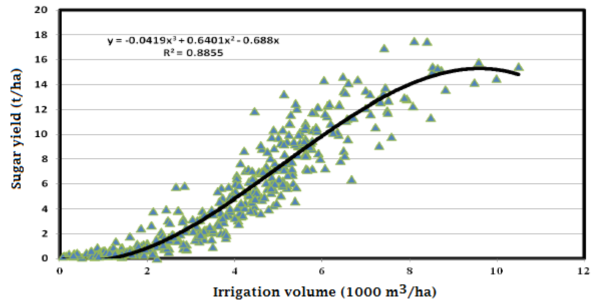

Figure 6. Correlation of sugar yield with irrigation water volume (with different ECs)

RELATIONSHIP BETWEEN SUGAR YIELD AND EC. The correlation between sugar yield and increased EC was 0.33. With increase in EC (in equal irrigation water volume), the sugar yield decreased but the reduction was not significant. If irrigation treatments with different EC levels are classified according to the equal irrigation level, and under this condition, the relationship between sugar yield and irrigation water volume be drawn, with an increase in EC, the sugar yield would decrease sharply.

Root and sugar yields were influenced by irrigation water volume and EC. Increasing the irrigation volume, regardless of its EC, increased root yield. However, increasing EC level alone, regardless of irrigation volume, would not decrease root and sugar yields. However, under equal irrigation volume, with increase in EC, root and sugar yield decreased. By increasing irrigation volume, in water with high EC, the yield reduction due to water shortage can be compensated. With increase in electrical conductivity (under equal irrigation level), root yield had a decreasing trend. The white sugar yield and sugar yield were not influenced by the increase in EC. As a result, with increase in EC (under equal irrigation volume), the sugar yield also decreased. With increase in irrigation volume, the slope of the yield reduction increased with increase in EC.

In this paper, the relationships of EC and irrigation water volume with root and sugar yields, sugar content and impurities were investigated. In total, it can be deduced that sugar beet is a plant with high susceptibility to water stress than salt stress. A decrease in irrigation water volume, irrespective of its quality, would greatly reduce root yield. In other words, if in a given irrigation water volume, the salt stress implemented, the root yield would not be affected sharply, and even the sugar content will increase to a certain extent. Therefore, in order to increase the yield in saline areas, increasing the irrigation water volume can increase the root and sugar yields and reduce the damage caused by salinity.

REFERENCES

Frenkel H, Mantell A, Vinten A, Meiri A. Double line–source sprinkler system for determining the separate and interactive effects of water and salinity on forage corn.1990. Ir. Sci. 11: 227-231.

Hanks RJ, Keller J, Rasmussen VP, Wilson GD. Line source sprinkler for continuous variable irrigation- crop production studies. 1976. Soil Sci. Soc. Am. J. 40: 426-429.

Hanks RJ, Sisson DV, Hurst RL, Hubbard KG. Statistical analysis of results from irrigation experiments using the line – source system. Soil Sci. Soc. Am. J. 1980. 44: 886-888.

Hang AN, Meller DE. Responses of sugar beet to deficit high frequency sprinkler irrigation II, Sugar beet development and partitioning to root Growth. 1984. Agro. J. 78:15-18.

Howell T, Ziska ALH, Mccormick RL, Burtch Fisher LM. Response of sugar beets to irrigation frequency and cut off on a clay loam soil. 1987. Ir. Sci. 8:1-11.

Katerji N, Van Hoorn JW, Hamdy A, Mastrorilli M. Salt tolerance. 2001. Agric. Water manage. 47:1-8.

Kayimoglu S, Vanlio N. Determination of sugar beet yield quality and economic utility of drop rent Irrigation methods. G. Seter. Turkey. 1976. 14:100, 10-29.

Mass EV, Hoffman GJ. Crop salt tolerance. J. Ir. Drain. Div. ASCE, 1977. 103 (2): 115- 134.

Mohammadian R, Ghasemi Golezani K, Moghadam M. Fatigue effects on seed germination and seedling growth under salt stress on seven bulk of sugar beet.1997. Journal of Gorgan University. Year 3, No. 4 Pages 49-39. (in Persian, abstract in English)

Nabipour M, Alizadeh A. Effect of water and irrigation on yield and quality of sugar beet. MA thesis. 1998. Ferdowsi University of Mashhad. (in Persian)

Orchard B. Effect of soil water deficit on plant growth. 1995. Rep. Rothamsted Exp. Sth. Rafei M. Evaluation of salt tolerance in sugar beet varieties. 1960. MA thesis. University of Technology of Eesfehan. (in Persian)

Sadre Ghen H. Technical Comparison and analysis of water use efficiency and yield of sprinkler irrigation and leakage on sugar beet. 2001. Project supported by the National Scientific Research Council.

Schafer W. Result of intermittent. Sprinkler Irrigation.1979. Archivfur Acker und pflanzehbau und Bodenkunde. 23 (2):121-128

Shannon MC. Adoption of plants to salinity. 1997. Advances in Agronomy. 60:75-120.

Yazdani M. Effect of nitrogen form and some physiological characteristics of salt tolerance in sugar beet. 2001. MA thesis, Tarbiat Modarres University, Faculty of Science.

Zolfegharian A. Effects of water stress on wheat yield in different salinity in irrigation water. 2005. Final Report Institute of Agricultural Engineering. Reg: 84.1.