Journal of Sugar Beet
http://jsb.sbsi.ir/
Journal of Sugar Beet 2013, 28(2)

Determination of suitable sowing pattern of sugar beet under tape-drip irrigation system

R. Mohammadian [(1)*], H. Sadrahghan [(2)]

[(1)] *Associate professor, Sugar Beet Seed Institute (SBSI), Karaj, Iran.*
[(2)] *Instructor, Agricultural Engineering Research Institute, Karaj, Iran.*

Mohammadian R, Sadrahghan H. Determination of suitable sowing pattern of sugar beet under tape-drip irrigation system. J. Sugar Beet. 2013; 28(2): 57-64.

Received March 19, 2011; Accepted April 9, 2012

ABSTRACT

For continues production if field crops in arid and semi arid regions of the world, such as Iran, beside of using of drought resistant varieties, water management must also be considered. In this context, the use of tape drip irrigation system could reduce the amount of irrigation water consumption. This study, was conducted to determine the best sowing pattern of sugar beet under type drip irrigation system, at Motahari station of Sugar beet seed institute(SBSI), Karaj, Iran during 2009 and 2010. Experiment was carried out in a randomized complete block design with three replications and seven treatments including sowing patterns with row distances of 45, 50, 60, 40-50 and 60- 40 cm and placing tapes every other rows and two sowing patterns with row distances of 50 and 60 cm and placing tapes on all seeding rows. The amounts of water applied in all of the treatments were almost same. Results showed that row distances of 60 cm with placing tapes every other row led to the lowest and highest number of roots and amount of root potassium, respectively, as compared with the other treatments. The highest sugar and white sugar yields and also water use efficiency for white sugar yield were achieved in sowing patterns with row distances of 60-40 cm and placing tapes every other rows and row distances of 50 cm and placing tapes on all seeding rows. High initial cost of tape drip irrigation is the most important factor preventing this system from spreading. Since the amount of applied tapes in the first sowing pattern, 40-60 cm, is less than the second sowing pattern, its costs are less. Therefore, sowing patterns with row seeding distances of 60-40 cm and placing tapes every other rows is recommend for cropping under tape irrigation system.

Keywords: Sowing pattern, Sugar beet, Tape-drip irrigation system

INTRODUCTION

Water is an invaluable, irreplaceable commodity in the economical and social development of the countries whose crucial role is undeniable in the planning of towns and countries, the development of infrastructures, and the protection of the stability and sustainability of the ecosystems and environments (Samani 2009). Nowadays, water deficiency which is gradually growing has posed as a major problem in Iran like other arid and semi-arid regions of the world. On the other hand, the recent droughts have fomented this crisis (Samani 2009). The current status of the water and predictions imply that the droughted agriculture should always be considered in these regions and that the identification of water-deficit tolerant crops, and the development of water management have to be prioritized in arid and semi-arid regions.

Sugar beet has shown to be a water-deficit tolerant crop (Scott and Jaggard 1993). Because of its long growth cycle, it is able to restore itself as soil moisture status improves. As well, in contrary to grain crops it lacks a critical reproductive stage and can use moisture reserves with its deep root system. However, it is believed that its response to drought is very complicated (Winter 1980).

In spite of the tolerance of sugar beet to water deficit during growing season, its net irrigation water demand required for realizing its potential yield is higher than that of other annual crops like tomato, potato, melon, watermelon, cotton, for-

*Corresponding author's email: r_mohammadian@hotmail.com

age corn and grain corn (Farshi 1997). Net irrigation water demand of sugar beet is approximately 8 000-10 000 $m^3 ha^{-1}$ in different sugar beet production areas of Iran (Farshi 1997). Since furrow irrigation system is currently used in most parts, approximately 28 000 $m^3 ha^{-1}$ water is, on average, required for realizing the maximum yield of sugar beet given 30-35% irrigation efficiency of this system. Thus, the application of pressurized irrigation system, which has higher irrigation efficiency, can be considered as a possible approach for water-saving. Considering the increased mechanization and continuous water deficiency, different pressurized irrigation systems have been already focused on including classic, center pivot and drip-tape irrigation systems whose application area is growing. These different methods aim at water consumption reduction, uniform irrigation, optimizing the water availability for crops, and preventing irrigation water loss.

Albayrak et al. (2010) reported that drip irrigation system resulted in higher water saving than sprinkler and furrow systems in sugar beet fields in addition to higher efficiency and profit-making. The development of drip irrigation system in sugar beet production allows economical and efficient water consumption through reducing the consumed water and the costs. Comparing furrow, sprinkler and drip irrigation systems in sugar beet production, Karimzadeh (2006) found that drip irrigation system had the highest water use efficiency whereas furrow system had the lowest one. He found no significant difference in white sugar yield between drip and furrow systems in spite of the fact that drip irrigation used one-third of the amount of water used in furrow system. Baghani and Khosbazm (2007) reported that as the irrigation system was changed from furrow to drip system in Khorasan province, Iran, mean water uses of sugar beet, forage corn, tomato and potato were decreased by 33.9-44.1%, their yield was increased by 9.2-21.1%, and their irrigation water use efficiency was increased by 83.2-116.3%.

In addition to reducing irrigation water use owing to its high efficiency, drip irrigation system allows the use of low-irrigation. For example, Mirzaee and Ghademi-Firoozabadi (2006) studied the quantity and quality of sugar beet harvest under two furrow irrigation systems with furrow spacing of 90 cm and the planting of two rows on each hill (40-50) irrigated with tape system with water amount of 100, 75 and 50% of crop water demand in spring planting in Hamedan and Karaj, Iran and in autumn planting in Dezful, Iran. They reported that the effect of the studied treatments was not significant on K, Na, alkalinity coefficient, extractable sugar percentage, molasses percentage and water use efficiency in spring planting. Furthermore, root yield and white sugar yield did not show statistically significant differences at 5% probability level between furrow and tape irrigation systems with 100 and 75% of crop water demand. Mean water use under furrow and tape irrigation systems with 100, 75 and 50% of crop water demand was 14 858, 10 156, 8 326 and 6 520 $m^3 ha^{-1}$, respectively. The effect of the studied treatments was not significant on sugar content, K, α-amino N, white sugar percentage, coefficient of extractable sugar percentage and molasses percentage in autumn planting too. Additionally, root yield and white sugar yield did not exhibit any differences between furrow and tape irrigations with 100 and 75% of crop water demand. But, water use efficiency significantly decreased in autumn planting from furrow irrigation to tape irrigation with 100, 75 and 50% of crop water demand. Mean water use of these treatments was 13 536, 5 904, 4 773 and 3 812 $m^3 ha^{-1}$, respectively. Accordingly, they recommended using tape irrigation with 75% of crop water demand in sugar beet fields instead of furrow irrigation system. In a study on the effects of different low irrigation treatments on sugar beet yield in drip-tape irrigation system, Farzamnia et al. (2011) recommended two-day irrigation interval at establishment and four- and five-day intervals at technological development and maturiity stages, respectively. Also, Topak et al. (2010) reported that irrigating sugar beet by drip method with 75% of crop water demand resulted in economical saving of water and higher water use efficiency. It proves the decisive usefulness of low irrigation under water deficit conditions. Economically speaking, 25% saving of water corresponds 6.2% increase of net income. Also, Badbezanche and Boromandnasab (1997) recommended that under water deficit conditions with drip-tape irrigation method in sugar beet fields, irrigation can be scheduled with three-day interval for supplying 50% of evaporation from the class-A pan. Under these conditions, although sugar yield decreases by 49% as compared to supplying irrigation water on the basis of 100% of evaporation from the class-A pan, 8.3 $t ha^{-1}$ white sugar yield is produced with the application of 6 100 $m^3 ha^{-1}$ water. On the other hand, Mirzaee et al. (2011) reported that drip-tape irrigation method is more appropriate than furrow system for selecting drought-

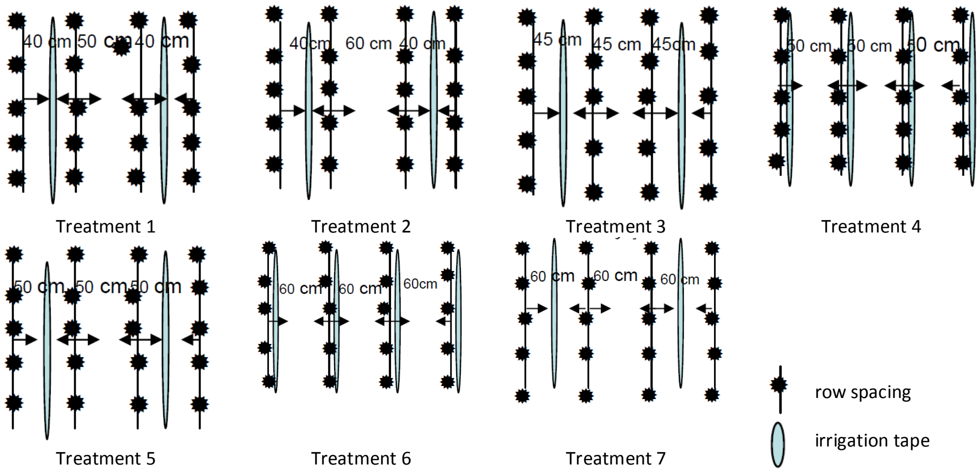

Fig. 1. Schematic view of different sowing patterns in terms of row spacing and the position of irrigation tapes

resistant genotypes owing to the fact that the effects of drought stress on yield can be observed more clearly. Rezvani et al. (2009) compared different methods of irrigation including sprinkler, furrow and drip-tape methods in Isfahan, Iran. They found that drip-tape method had the highest water use efficiency, but sprinkler method had the highest economical return. Also, they studied and evaluated different methods of irrigation in terms of the quantity and quality of sugar beet and reported that root yield was more than twice as great under sprinkler method as the drip and furrow methods, but gross and white sugar yield, gross and white sugar percentage, K, Na and α-amino N contents, alkalinity, extraction percentage, and molasses percentage did not show any significant differences under different irrigation methods. Whereas the amount of water consumed under these three methods was 14 096, 10 972 and 7 635 m^3 ha^{-1}, respectively, the water use efficiency for root and white sugar yield was more than twice as great under drip irrigation method as under the other two methods. But this higher yield was not economical given the highest costs of drip irrigation methods.

Salemi et al. (2005) conducted an evaluation and technical and economical comparison on tape and furrow irrigation methods in sugar beet fields in Isfahan and Chaharmahal and Bakhtiari Provinces, Iran and revealed that in spite of the saving of water consumption in drip-tape irrigation method as compared to furrow method, the return:cost ratio is <1 in the former and >1 in the latter. They related it mainly to the farmers' ignorance about correct implementation of the system. Also, given the fact that the main part of the annual uniform costs of tape method (31%) was associated with the costs of tapes, they recommended the cut of the costs of tapes as an alternative solution for enhancing return:cost ratio of drip-tape irrigation method.

Since the quantity of the tapes can be changed by changing the sowing pattern of sugar beet, the present study was carried out to determine the most appropriate sowing pattern of sugar beet under drip-tape irrigation method.

Materials and Methods

The present study was conducted at Motahari Research Station of Sugar Beet Seed Institute in Karaj, Iran in 2009-2010 aiming at determining the most appropriate sugar beet sowing pattern and how to deploy tapes in drip-tape irrigation method. It was based on a Randomized Complete Block Design with seven treatments as presented in Fig. 1 and Table 2 with three replications (Fig. 1). The sowing date was mid-May in the both years. Each treatment was conducted in an experimental plot including six 3-m-long sowing rows. The replications were 5 m apart to allow commuting of machineries. On-row, inter-plant spacing was selected as to be about 20 cm after thinning. Before sowing, the soil was sampled for chemical analysis and meeting the nutritional needs in accordance with standard criteria. Some physical and chemical properties of soil of the study farm are given in Table 1. Whole potash and phosphorus fertilizers and one-third of N fertilizer were applied concurrently with sowing date and the remaining two-third of N was applied as topdressing by irrigation-fertilization system. The genetic monogerm variety Zaragan was used in the study.

Table 1. Some physical and chemical properties of the soil of the study farm in Karaj, Iran (2009 and 2010)

Study year	Soil sampling depth (cm)	Nitrate N (mg kg^{-1})	Available P (mg kg^{-1})	Available K (mg kg^{-1})	Soil reaction	EC	Organic C %	Na (mg kg^{-1})	Texture
2009	0-30	18.585	22.29	596.75	7.715	1.25	1.42	3.817	Loam-clay
2010	0-30	15.68	13.86	484.69	8.26	0.97	1.76	4.27	Clay

Table 2. Amount of water consumed during growth cycle at different sowing patters of sugar beet under tape irrigation method in Karaj, Iran (2009 and 2010)

Treatment No.	Sowing spacing (cm)	Irrigation tape disposition (tape)	Consumed irrigation water (m^3 ha^{-1})	
			2009	2010
1	40-50	Tape in 40-cm rows	8947.53	10765.43
2	40-60	Tape in 40-cm rows	9399.44	10477.78
3	45	Alternate tape disposition	8906.79	10691.36
4	50	Tape disposition in all rows	8923.89	10572.22
5	50	Alternate tape disposition	8781.67	10611.11
6	60	Tape disposition in all rows	8308.52	10481.48
7	60	Alternate tape disposition	8253.70	10472.22
Mean			8788.79	10581.66

The volume of irrigation water was determined on the basis of water demand calculated by modified Penman-Monteith equation (Smith 1988) taking into account the efficiency of 90%. Then, the water was equally applied to all plots. The water consumed at each irrigation phase was calculated by a calibrated contour. The irrigation interval was 3 days. The volume of the consumed water varied with the water demand over the time. The mean amount of the consumed water in all treatments is presented in Table 2. Disc filter was used to prevent the blockage of droppers. The spacing between droppers on drip tapes was 20 cm and the outflow of the droppers was 1.2 l ha^{-1} under the pressure of 0.6 bars. All agronomical operations including thinning, weeding, herbicide application, etc. were uniformly applied in all treatments during the growing season. In the both years, the plots were harvested during late-October. At the end of the growing season, the marginal effect was eliminated and then, two middle rows with the length of 10 m were harvested and weighed. Then, the number of roots was counted, the roots were washed and weighed, and their pulp was prepared and sent to Sugar Technology Laboratory of SBSI for chemical analysis. The collected data were statistically analyzed by SAS software. In addition, water use efficiency of all treatments was calculated and evaluated on the basis of the produced sugar. The means of the studied traits were compared by Duncan Test at 5% probability level.

RESULTS AND DISCUSSION

The results of analysis of variance of the studied quantitative and qualitative traits under different sowing patterns with tape irrigation are presented in Table 3. As can be seen, the effect of year was significant on the all studied traits except coefficient of alkalinity of the roots. The influence of the treatments of different sowing patterns was also significant on the number of roots, root K content, white sugar yield, and water use efficiency on the basis of white sugar yield ($P < 0.05$). F test showed that the effect of different sowing patterns was not significant on the other studied traits.

As can be seen in Table 4, the desirable traits including root yield, sugar percentage, white sugar yield and coefficient of sugar extraction were significantly higher in 2010 than in 2009 which might have been caused by the effects of year and/or the properties of the soil of the study farm.

Plant density at harvest time varied from 60 000 to 92 000 plants ha^{-1} under various sowing patterns. As expected, the number of plants at harvest time was lower under 60-cm sowing spacing than under the sowing spacing of 40-50, 40-60, and 45 and 50 cm (Table 5). On the other hand, alternate mounting of tapes in 60-cm sowing spacing resulted in the lowest number of roots among the studied sowing patterns. Also in this treatment, plant density at harvest time was 28% lower than the expected density (83 333 plants ha^{-1}). In other words, in this treatment the number of

Table 3. Means squares of combined variance analysis of quantitative and qualitative traits of different sowing patterns of sugar beet under tape irrigation in Karaj, Iran (2009 and 2010)

Sources of variation	df	Root No.	Root yield	Sugar %	Na	K	α-amino N	Alkalinity coefficient	White sugar %	Extraction coefficient	Molasses %	Gross sugar yield	White sugar yield	Water use Efficiency for white sugar yield
Year	1	8875668722**	753.11**	49.57**	123.19**	42.30**	8.94*	9.73	178.44**	2377.97**	39.91**	71.16**	119.75**	475095.23**
Year (replication)	4	302697604	5.91	0.17	0.36	0.27	0.82	2.34	0.16	5.09	0.17	0.10	0.18	1952.93
Sowing pattern	6	797857118*	61.82	0.70	0.88	0.35*	0.45	1.50	1.53	21.10	0.29	1.76	1.78*	13878.08*
Year × sowing pattern	6	114471708	51.18	0.83	0.91	0.08	0.32	1.35	1.48	16.85	0.20	0.74	0.29	2146.03
Error	24	270446490	37.27	0.62	0.51	0.08	0.14	0.59	0.97	10.33	0.10	1.18	0.88	10634.49
Coefficient of variation (%)		20.43	9.52	4.76	24.11	4.86	19.15	16.01	7.59	4.13	10.47	11.82	12.92	13.91

* and ** show significance at the one and five percent statistical probability level.

Table 4. Means squares of some quantitative and qualitative traits in different years of experiment under tape irrigation method in Karaj, Iran (2009-2010)

Year	Root No.	Root yield	Sugar %	Na	K	N	Alkalinity coefficient	White sugar %	Extraction coefficient	Molasses %	Gross sugar yield	White sugar yield	Water use efficiency for white sugar yield
				(m eq per 100 g sugar beet pulp)									
2009	65.942B	51.06B	15.47B	4.70A	7.02A	2.42A	5.28A	10.94B	70.29B	3.94A	7.90B	5.59B	634.91B
2010	95016A	59.53A	17.64A	1.26B	5.02B	1.50B	4.32A	15.06A	85.34A	1.99B	10.50A	8.97A	847.63A

Table 5. Means squares of some quantitative and qualitative traits under tape irrigation method in Karaj, Iran (2009-2010)

Treatment	Root No.	Root yield	Sugar %	Na	K	N	Alkalinity coefficient	White sugar %	Extraction coefficient	Molasses %	Gross sugar yield	White Sugar yield	Water use efficiency for white sugar yield
				(m eq per 100 g sugar beet pulp)									
40-50 with alternate irrigation	91481 A	55.48 A	16.24 A	3.41 A	6.06 B	2.08 A	4.66 A	12.51 A	75.96 A	3.13 A	9.02 AB	6.95 CD	697.73 CD
40-60 with alternate irrigation	90000 A	58.35 A	16.99 A	2.44 A	5.68 B	1.74 A	4.74 A	13.75 A	80.73 A	2.64 A	9.94 A	8.09 A	808.33 A
45 with alternate irrigation	80065 AB	57.56 A	16.11 A	3.15 A	6.03 B	2.25 A	4.20 A	12.46 A	76.73 A	5.05 A	9.33 AB	7.26 BC	730.80 BCD
50 with irrigation of all rows	90333 A	56.47 A	16.90 A	2.47 A	5.84 B	1.55 A	5.66 A	13.61 A	80.17 A	2.69 A	9.62 A	7.83 AB	791.23 AB
50 with alternate irrigation	79667 AB	55.14 A	16.40 A	3.18 A	6.03 B	1.75 A	5.28 A	12.79 A	76.98 A	3.01 A	9.08 AB	7.10 BCD	723.96 BCD
60 with irrigation of all rows	71528 BC	55.52 A	16.46 A	2.95 A	6.02 B	2.10 A	4.53 A	12.90 A	77.63 A	2.96 A	9.20 AB	7.26 BC	760.48 ABC
60 with alternate irrigation	60278 A	48.52 A	16.80 A	3.25 A	6.47 A	2.23 A	4.53 A	12.97 A	76.51 A	3.23 A	8.22 B	6.45 D	676.38 D

Means with similar letter(s) in each column did not show significant differences at the five percent probability level.

plants was lower at the end of the season because of the distance between soil wetting patterns and the sown seeds and consequently, the reduced number of the emerged seeds. In the treatments of 45 and 50-cm row spacing with alternate irrigation too, the number of plants at harvest time was, for the same reason, about 28 and 20% lower than the expected population (111 000 and 100 000 plants ha^{-1}), respectively. In two sowing patterns of 40-50 and 40-60 cm, despite the fact that the irrigation tapes were similarly mounted at the middle of 40-cm rows, the percentage of plant loss at harvest time compared to the expected population was unexpectedly higher in the first sowing pattern than in the second one (by about 8%) which needs further study. Ashraf Mansoori (1990) studied the effect of plant density on root and sugar yield of sugar beets in Darab, Iran and found that root and white sugar yields were significantly higher under 120 000 plants ha^{-1} than under 72 000 plants ha^{-1}. Basati et al. (1996), too, showed that impurities increased in roots and as a result, their quality decreased with the increase in the root size and the decrease in plant density.

In spite of the difference of different sowing patterns in root number, the differences had no significant effects on root yield ($P > 0.05$, Tables 3 and 5). Also, Ashraf Mansoori (1990) reported that root and white sugar yield in density range of 72 400-90 500 plants ha^{-1} had no significant effect on root and white sugar yields. However, the highest (58.35 t ha^{-1}) and lowest (48.52 t ha^{-1}) root yield in the present study was obtained from the sowing pattern of 40-60 and row spacing of 60 cm with alternate irrigation by tape method (Table 5) whereas it has been reported that the highest root yield in furrow irrigation method is obtained from the sowing pattern of 50 cm with the irrigation of all furrows (Ashrafmansouri and Jokar, 1990; Gohari and Moayeri, 2005; Rahnamaeeian, 2009). The inconsistent results of the present study with those reports can be related to the different characteristics of the two furrow and tape irrigation methods.

Although root K content was significantly ($P < 0.05$) higher in 60-cm row spacing with alternate irrigation (Tables 3 and 5), root Na and α-amino N content as well as alkalinity coefficient showed no significant differences among the studied treatments ($P > 0.05$; Tables 3 and 5). There are various reports about the effect of sowing pattern on these elements. Ashraf Mansoori and Jokar (1990) reported that in furrow irrigation method, the effect of sowing pattern was significant on root α-amino N and K content and insignificant on root Na content. They observed the highest K content in sowing pattern of 60 and 50 cm and the highest α-amino N content in sowing pattern of 40-60 cm. Rahnamaeeian (2009) reported that in furrow irrigation method, the lowest amounts of K, Na and α-amino N contents were observed in 50-cm row spacing as compared to 60-cm row spacing. In addition, the lowest amounts of K and Na in 50-cm row spacing were obtained under inter-plant spacing of 20 and 25 cm, whereas the lowest amounts of these three traits in 60-cm row spacing were observed in inter-plant spacing of 15 and 20 cm. But, the amounts of α-amino content N among different levels of plant density in 50-cm as well as 60-cm row spacings showed no significant differences.

Gross and white sugar percentage did not show significant differences among different sowing patterns, too ($P>0.05$; Table 3). Mean white and gross sugar percentages was 16.55 and 13%, respectively (Table 5). Since two impurities of the root, i.e. Na and α-amino N, which are effective on the extraction of white sugar, had no difference among the studied treatments, then sugar extraction coefficient as well as the molasses sugar had no significant differences, too ($P>0.05$; Tables 3 and 5). There are different reports about the effect of sowing pattern on these traits in furrow irrigation method. Javaheri (2006) reported that in autumn planting conditions in Orzuiyeh plain of Kerman, Iran, no significant difference was observed in qualitative traits between 50 and 60-cm row spacing, whereas Rahnamaeeian (2009) stated that the highest gross and white sugar percentage and molasses sugar percentage was obtained from 50-cm row spacing as compared to 60-cm row spacing. Furthermore, he added that the highest gross and white sugar percentage in 50 and 60-cm row spacing was obtained from inter-plant spacing of 20 cm (100 000 plants h^{-1}) and 15 cm (110 000 plants ha^{-1}). The lowest amount of K and Na and molasses sugar percentage in row spacing of 50 cm was obtained from inter-plant spacing of 20 and 25 cm, whereas the lowest amount of these traits in 60-cm row spacing was obtained from the inter-plant spacing of 15 and 20 cm. But α-amino N content showed no significant differences among different plant densities under 50-cm row spacing and also under 60-cm row spacing. The inconsistent findings of the studies may show that these factors do not uniformly and permanently affect these traits.

Although root yield and gross and white sugar percentage showed no significant differences among the studied treatments, they had significant differences in terms of two important traits of gross and white sugar yields ($P<0.05$; Tables 3 and 5). The highest gross sugar yield was obtained under the sowing pattern of 40-60 cm with alternate irrigation and the sowing pattern of 50 cm (9.94 and 9.62 t ha^{-1}, respectively) whereas the lowest one was obtained under the sowing pattern of 60 cm with alternate irrigation (8.22 t ha^{-1}). Other treatments were in middle in terms of this trait. The highest white sugar yield, too, was observed in the sowing pattern of 40-60 cm with alternate irrigation and the sowing pattern of 50 cm (8.90 and 7.83 t ha^{-1}, respectively) whereas the lowest one was observed in the sowing pattern of 60 cm with alternate irrigation (6.45 t ha^{-1}). In the present study, white sugar yield was unexpectedly lower in 40-50 cm sowing pattern than in 40-60 cm one, both with alternate irrigation. The main reason was higher impurities and the resulting lower white sugar percentage in the former sowing pattern than the latter one. This observation needs further study. There are different reports about the effect of sowing pattern on white sugar yield. Noroozi (2008) reported that under sprinkle irrigation system, although white sugar yield was higher under 45-cm row spacing than under 50-cm one, white sugar yield did not have significant difference under these treatments, while it was significantly decreased under 60-cm row spacing. In a study under autumn sowing conditions using furrow irrigation method, Javaheri (2006), too, showed that white sugar yield was slightly but insignificantly higher under 50-cm row spacing than under 60-cm spacing. Also, Rahnamaeeian (2009) reported that the highest gross and white sugar yields were obtained under 50-cm row spacing. Gohari and Moayeri (2005) studied furrow irrigation system under spring and autumn sowing conditions and found the highest mean sugar yield under 50-cm sowing pattern with alternate irrigation. The reason for the different results of the studies can be related to such factors as the difference in irrigation method, soil texture and organic matter and the climatic conditions of the study farm.

As can be seen in Table 5, the highest irrigation water use efficiency for white sugar yield was obtained from the sowing pattern of 40-60 cm and 50 cm (808.33 and 791.23 g m^{-3} water used, respectively). The lowest water use efficiency (676.38 g sugar per m^{-3} water used) was observed in the sowing pattern of 60 cm. The variation of white sugar yield among the studied treatments was the reason for these differences in water use efficiency. In a study on furrow irrigation method, Gohari and Moayeri (2005) found the highest water use efficiency in the sowing pattern with row spacing of 60 cm with alternate irrigation.

According to the results of the present study, it can be concluded that two sowing arrangements of 40-60 and 50 cm produced the highest white sugar yield and had the highest irrigation water use efficiency under the conditions of the study field with tape irrigation system. Therefore, these two treatments can be proposed as the superior treatments as compared to the other treatments. Since the main limitation of developing tape-drip irrigation system is its high initial costs and given the fact that 31% of its annual costs is associated with the costs of tape (Salemi et al. 2005), in sowing pattern of 40-60 cm the amount of consumed tape is half as great as 50-cm sowing pattern with the irrigation of all sowing rows, and therefore, it is recommended to use this sowing pattern in tape-drip irrigation method.

REFERENCES

Albayrak M. Gunes E, Gulcubuk B. The effects of irrigation methods on input use and productivities of sugar beet in Central Anatolia, Turkey, African Journal of Agricultural Research. 2010; 5:188-195.

Ashraf Mansoori GH. Final report of effect of planting date and plant density on root and sugar yield in two sugar beet varieties in Darab region. Agriculture Research Center of Fars Province Publication, 1990; pp. 40. (in Persian)

Ashraf-Mansoori GH, Jokar L. Effect of planting pattern on quantitative and qualitative characteristics of sugar beet in temperate regions of Fars province. Journal of Sugar Beet. 2009; 25:141-152. (in Persian, abstract in English)

Badbezanche M. Boromand-nasab S. Assessment of different levels of irrigation on yield and yield components of sugar beet in irrigation tape method. The first conference of adaptability to dehydration. 1997. http://www.civilica.com/Paper-CCWS01-CCWS01_033.html (in Persian)

Baghani J, Khoshbazm R. Effects of irrigation systems of surface and drip on row crops. Ninth seminar of irrigation and reduce evaporation. 2007; http://www.civilica.com/Paper-ABYARI09-ABYARI09_128.html (in Persian)

Basati G, Koolivand M, Gholizade R, Fazli H. Final report of determination of relation between root weight and sugar beet quality. Research Center of Kermanshah Province Publication, 1996; pp. 34. (in (in Persian)

Ebrahimi H. Analysis and Evaluation of simplified irrigation systems in Khorasan. Journal of Agricultural Sincec. 2006, 12, 577- 589. (in Persian, abstract in English)

Farshi AA, Shariati MR, Jaralhy R, Ghaemi MR, Shahabi-Far M, Tavalaee M. Water requirements estimation of main crops and gardening plants of country, Agricultural Education Publishers, 1997; Vol. 1, pp. 900. (in Persian)

Farzamnia M, Zareie GH, Fatolah-Taleghani D, Darvishi D. Role of controlled deficit irrigation on sugar beet quantity and quality. Journal of Sugar Beet. 2011; 26:169-183. (in Persian, abstract in English)

Gohari J, Moayeri M. Effect of planting pattern on water use efficiency, quantity and quality of sugar beet yield. S.B.S.I. Publication, 2005; PP. 39. (in Persian)

Javaheri M. Final report of effects of row width and variety on quantity and quality characteristics of sugar beet in Orzyuieh area (autumn cultivation). S.B.S.I. Publication, 2006; pp. 36. (in Persian)

Karim zadeh-Moghaddam M. Effect of sprinkler and furrow irrigation systems on water use efficiency and yield of sugar beet quality and quantity. National conference of managing irrigation and drainage networks. Chamran University, Faculty of Water Science. 2006. http://www.civilica.com/Paper-IDNC01-IDNC01_099.html (in Persian)

Mirzaee MR, Ghadami-Firoozabadi A, Fatola-Taleghane D, Sadreghan SH. Final report of methodology of drought stress imposition on sugar beet. S.B.S.I. Publication, 2011; pp. 49. (in Persian)

Mirzaee MR, Ghadami-Firoozabadi A. Final report of investigation of quantity and quality characters of sugar beet crop under furrow and micro irrigation systems. S.B.S.I. Publication, 2006; pp. 32. (in Persian)

Noroozi A. Final report of determination of the best plant density of sugar beet (Beta vulgaris) under sprinkler irrigation. S.B.S.I. Publication, 2008; pp. 25. (in Persian)

Rahnamaeeian M. Final report of the effect of plant density and arrangement on quality and quantity of sugar beet. Agriculture Research Center of Lorestan Province Publication, 2009; pp. 38. (in Persian)

Rezvani S, Noroozi A, Azari K. Final report of impact of different irrigation systems on nitrogen and water use efficiency and the quality and quantity of sugar beet. S.B.S.I. Publication, 2009; pp. 79. (in Persian)

Salemi HR, Nikooyi AR, Jahad-Akbar MR. Final report of evaluation and technical-economical comparison of tape and furrow irrigation methods in sugar beet. Agricultural Engineering Research Institute Publication, 2005; pp. 61. (in Persian)

Samani JMV. Report of performance of the water section and its position in the fifth Program. Office of Infrastructure Studies. 2009. http://www.majlis.ir/pdf/Reports/9750.pdf (in Persian)

Scott RK, Jaggard KW. Crop physiology and agronomy. In: The Sugar Beet Crop: Science into Practice (Eds D.A. Cooke & R. K. Scott), 1993, pp. 179-237. London: Chapman and Hall.

Smith M. Calculation procedures of modified Penman equation for computers and calculators. FAO, Rome, Italy. Water Resources, Development Services. 1988; 32 P.

Topak R, Süheri S, Acar B. Effect of soil drip irrigation regimes on sugar beet (*Beta vulgaris* L.) yield, quality and water use efficiency in Middle Anatolian, Turkey. Irrigation Science. 2010; 29:79-89.

Winter SR. Suitability of sugar beets for limited irrigation in semi-arid climate. Agronomy Journal, 1980, 72, 118-123.