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Effect of Nitrogen Rates on Yield, Non-Sugar Impurities and NUE of Four Sugar Beet Varieties under Drip Irrigation Conditions

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ABSTRACT

To evaluate the effect of nitrogen (N) fertilization rate on quantitative and qualitative characteristics of drip-irrigated sugar beet, a two-year field experiment was carried out in two areas of Iran including Karaj and Moghan. Four different amounts of N fertilizer (no applied (N0), optimum rate (N100), 75% (N75) and 50% (N50) of optimum rate) and four varieties included two European varieties (Rosire and Flores) and two Iranian varieties (Pars and Ekbatan) were experimental treatments. The results in Moghan showed that the highest values of root and sugar yield were related to N75 by 74.09 and 9.13 t ha^{-1}, respectively. Flores and Rosier had greater sugar yield than Pars and Ekbatan varieties in both locations. Our findings in Karaj demonstrated that SC decreased with increasing N rate, however there was no significant difference among nitrogen levels in SC in Moghan. N application rate had no significant influence on content of the non-sugar impurities in both areas except K concentration. As data, European varieties contained lower non-sugar substances and higher root quality than Iranian varieties. In addition, greater nitrogen use efficiency (NUE) was gained in European varieties compared to Iranian varieties. Increasing N application rate also caused to decrease in NUE under two area conditions. The greatest NUE occurred by no application of N fertilizer as 46.13 and 45.35 kg sugar kg^{-1} N in Moghan and Karaj, respectively. In general, N fertilizer consumption can be reduced to 75% of the recommended N rate under the drip irrigation system that is developing in the country.

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1. Introduction

Sugar beet (*Beta vulgaris* L.) is one of the main crops in Iran that plays a key role in Iran's agricultural economy. The average cultivated area of sugar beet in Iran is almost112000 ha and produces about 0.86 million tons of sugar (Sadeghzadeh Hemayati, 2016). Sugar beet fertilization considerably influences sugar beet yield and root quality. N is the most limiting element in sugar beet because it directly affects yield formation and sugar beet root quality. Many researchers reported that N rates are applied in excessive amounts, resulting in more content of melas-forming substances (K, Na, α-amino N) (Tarkalson *et al.*, 2016), root maturity is slowed down, and the sucrose accumulation in the root is lower (Varga *et al.*, 2022). In addition, environmental pollution may be increased due to the increased N leaching. Variations of NUE, because of environmental impact (de Koeijer *et al.*, 2003), as well as environmental pollution problems and fertilizer cost (Herlihy and Hagarty, 1994), cause N fertilization guidance a challenging attempt in sugar beet cultivation. Hence, management of nitrogen fertilization in sugar beet should be considered as one of the main factors to improve sugar production. In this regard, the amount of applied N and NUE should be in the focus, particularly from the view of trying to decrease the N input and increase NUE in sugar production to produce high yield and

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technological quality but also to preserve environment (Varga *et al*., 2022).

The drip irrigation system is one of the main approaches to increase application efficiency of water and N. Many studies have also indicated that drip irrigation systems can improve the water and N-use efficiency of crop production (Fu *et al*., 2017; Sandhu *et al*., 2019; Wang *et al*., 2020). With drip irrigation system, it is possible to split N fertilizer applied at low rates during the growth season. Consequently, this irrigation method causes to increase in N use efficiency when compared to furrow irrigation as a result of coincident with the crop demand. Confirming this issue, Wei et al. (2024) mentioned that drip irrigation practices seemingly maintain a large amount of applied N in the root zone. In addition, drip irrigation has some advantages including reduced risk of leaching which results in decreased nitrate contamination of groundwater.

Yao et al. (2019) indicated that drip irrigation method could decline fertilization rates by 30% without yield reduction against flood irrigation. Therefore, the rate of N applied to the soil must be carried out according to not only the chemical and physical properties of the soil but also the irrigation method. It seems that N fertilizer recommendations for drip-irrigated sugar beet in Iran require modification because the current N application recommendation is related to furrow irrigation which was the most irrigation system in sugar beet fields. In other words, it is needed to determine the amount of N for drip irrigation which is extremely developing in the country. On the other hand, comparing new Iranian sugar beet varieties with European varieties is necessary to determine the production gap between these varieties and improve Iranian varieties via breeding and agronomical programs.

According to the above-mentioned explanations, a field experiment was conducted in two regions of Iran for two years to compare the response of two groups of sugar beet varieties (Iranian and European) to different amounts of N fertilizer under drip irrigation system. The specific aims of this investigation were to adjust the nitrogen fertilizer recommendations in drip-irrigated sugar beet and compare Iranian and European varieties in terms of both quantity and quality properties.

2. Materials and methods

A field experiment was established at two research stations in Iran (Agricultural research station of Oltan and Motahari) in 2015 and 2016. Oltan station (39° 22´ N, 47° 35´E; 60 m elevation) is located in Moghan region in northwest Iran with an annual average precipitation of 271.2 mm and mean temperature of 15.2° C. Annual mean precipitation and temperature are 243 mm and 11.4° C, respectively in Motahari station (35° 50´N, 50°52´E; 1244 m elevation) where is located in Karaj region in north central of Iran. The trial was performed as split plots based on randomized complete block design with four replications. The experimental treatments were different rates of nitrogen (N) as main plots and various varieties as sub-plots. N treatment at four levels included no application of N (N0), optimum rate of N by 25 mg N kg^{-1} soil (N100), 75% of optimum rate as 19 mg N kg^{-1} soil (N75) and 50% of optimum rate as 13 mg N kg^{-1} soil (N75). The optimum rate of N was considered the recommended rate of N based on soil testing. An important point to note is that the recommended N rate was previously arranged for surface irrigation system because Iran agriculture system is based on conventional approach and the most irrigation system in this approach is surface irrigation. Two European varieties (Rosire and Flores) along with two Iranian varieties (Pars and Ekbatan) were used as variety treatments at four levels. It tried to use two groups of varieties not only to compare them in terms of quantity and quality yield but also to evaluate their response to N levels under drip irrigation system. Rosire variety (by Florimond Desprez Company) is diploid monogerm hybrid and resistance to rhizomonia is the main property of this variety. Flores variety (by Maribo Seed Company) is also diploid monogerm hybrid that has double resistance to diseases included rhizomonia and Rhizoctonia. Ekbatan variety (by SBSI Institute) is diploid monogerm hybrid and the first resistant Iranian variety to Rhizoctonia that was released in 2013. Ekbatan has also relative tolerance to rhizomona disease. Pars variety (by SBSI Institute) is diploid monogerm hybrid and resistant to rhizomonia.

Plots were arranged as 8 m long and 2.7 m wide. Sugar beet seeds were planted in rows spaced 40 cm and 50 cm apart alternatively. Plant spacing was targeted as 20 cm for both sites and years. As soon as the sugar beet seeds were sown, soil water content in all plots was elevated up to field capacity in two first irrigations via a drip irrigation system. Considering Class A pan evaporation values and drip irrigation efficiency that is 90%, the rest irrigations were periodically arranged at three-day intervals and adjusted by water counter. Drip lines had emitters that the distance between them was 20 cm and were placed between sugar beet rows and the space between them was 40 cm. In other words, sugar beet rows were irrigated from one side. It causes to decrease in production costs such as irrigation water and drip lines. Water flow rate of drip lines was 1.2 L hr^{-1} under 0.6 bar operation pressure. Irrigation quantities in Moghan region were 6300 m^3 ha^{-1} and 8400 m^3 ha^{-1} in 2015 and 2016, respectively. In Karaj, the amounts were obtained as 9500 m^3 ha^{-1} and 9100 m^3 ha^{-1} in 2015 and 2016, respectively. That's while the amount of irrigation water is about 12000 to 15000 m^3 ha^{-1} under surface irrigation systems in these areas.

Nitrogen was supplied as ammonium nitrate with pure N of 34% that was used at five different times. N fertilizer application was initiated after thinning and subsequent applications were done at 20-day intervals until about three months before harvest. N fertilizer was applied via the drip irrigation system. N application time for all treatments was similar and 20% of N was used in each application time. Before sowing, soil samples were taken for layers of 0-30 and 30-60 cm and some physical and chemical soil properties were determined (Table 1). With respect to needed phosphorous at optimum level, a concentration of 20 mg P kg^{-1}soil is desired, and 20 kg of superphosphate triple was added to soil for increasing one mg P kg^{-1} soil. Required potassium was also conducted based on 250 mg K kg^{-1} soil and no amount of K fertilizer was applied due to higher concentration of K in soil (Table 1). In other words, there was no need for K fertilizer based on soil testing. Because the concentration of nitrate and ammonium in the field soil was greater than optimum level, therefore to depletion of soil N, maize was sowed before sugar beet planting in previous year, 2014. It should be noted that there are many fluctuations in soil nitrate concentration during growth season of sugar beet but what was considered as the basis of applying N fertilizer was the nitrate and ammonium concentration in the soil before sugar beet planting. N added to soil by irrigation water is also important source of N. In order to more accurately determine of required N, the amount of N in irrigation water added to the soil was measured and considered. Sampling for water nitrate determination was carried out at six different times. The results of water nitrate test in both sites are shown in Table 2.

Table 1. Physical and chemical soil properties in two studied sites

Parameter	Unit	Karaj	Moghan
pH	--	7.84	7.82
EC	ds m^{-1}	1.03	1.54
Na	meq l^{-1}	6.36	14.89
P	mg kg^{-1}	10.46	8.46
O.C	%	1.03	0.25
K	mg kg^{-1}	598.8	669.6
NH_4	mg kg^{-1}	5.95	6.3
No_3	mg kg^{-1}	14.63	15.82
Clay	%	30.45	51.40
Silt	%	49.85	36
Sand	%	19.70	12.6
Soil Texture	--	Loam-Clay	Clay

Table 2. The results of water nitrate tests in two studied areas

Karaj			Moghan		
Sampling date	Nitrate	Ammonium	Sampling date	Nitrate	Ammonium
June 15	0.87*	0.42	June 10	2.17	0.63
June 28	1.82	0.49	June 24	1.21	0.45
July 10	2.17	0.63	July 9	0.87	0.42
July 31	1.96	0.43	July 27	0.74	0.94
September 6	0.87	0.49	September 10	1.82	0.35
October 8	0.96	0.43	October 12	1.12	0.46

*: Units are based on mg kg^{-1} water.

At harvesting time, all plants in four centre rows of each plot (sampling area was about 3.6 m^{-2}) were harvested to determine root yield and prepare root pulp. Pulp samples were analyzed in the laboratory of the Sugar Beet Seed Institute and some properties such as sugar content (SC) as %, α-amino N, K and Na concentrations as meq 100 g^{-1} pulp were measured. Molasses sugar (MS, as %) and white sugar content (WSC, as %) were achieved by Equations 1 and 2.

$$MS\ (\%) = 0.343(K^+ + Na^+) + 0.094(\alpha\text{-amino N}) - 0.31 \quad (1)$$

$$WSC = SC - (MS + 0.6) \quad (2)$$

Sugar yield (SY, as t ha^{-1}) and white sugar yield (WSY, as t ha^{-1}) were clearly calculated by Equations 3 and 4.

$$SY\ (t\ ha^{-1}) = RY \times SC \quad (3)$$

$$WSY\ (t\ ha^{-1}) = WSC \times SC \quad (4)$$

Nitrogen use efficiency (NUE) indicating produced sugar per one Kg of input N was gained by Equations 5 and 6.

(5) $$\text{NUE} = \frac{SY}{N_{input}}$$

(6) $$N_{input} = N_{fertilizer} + N_{soil} + N_{water}$$

Where N_{input} is the available N in root zone (up to 60 cm) that was added to soil via fertilizer ($N_{fertilizer}$) and irrigation water (N_{water}) along with available N in soil before planting (N_{soil}). ANOVA was done to evaluate the significant effect of treatments on sugar beet properties. Statistically significant difference refers to 95% probability level.

Duncan’s multiple range test at the 0.05% level was arranged to separate and test the significant difference among treatment mean. The effect of the year on the most traits of sugar beet was statistically insignificant. Therefore, two years of data were pooled. Before pooling, the equality of variance by Bartlett's test was performed and its results illustrated variance homogeneity for all traits. Analysis of variance and mean comparison was performed by using SAS ver.9.2 software.

3. Results and discussion

3.1. Root yield (RY)

ANOVA results indicated nitrogen and variety of treatments had a significant effect on root yield in Moghan (Table 3). In Karaj, nitrogen had no significant impact on RY, while RY was significantly affected by varieties (Table 4). The highest root yield in Moghan was found when sugar beet was supplied with 75% and 50% of the optimum N rate by 74.09 and 73.16 t ha^{-1}, respectively (Table 5). No application of N had the lowest RY with 65.63 t ha^{-1} (Table 5). Many of before researches revealed that application of N fertilizer caused high RY of sugar beet (Stevens *et al.*, 2011; Jahedi *et al.*, 2012; Hosseinpour *et al.*, 2013). One possible reason for low response of RY to N fertilizer resulted in the study may be associated with the type of irrigation system (drip) and N application (N splitting). Because optimum N rate has been suggested based on soil testing under furrow irrigation system and usually used on soil surface; whilst in the present study, drip irrigation system was used and N fertilizer was applied as fertigation and high split application by five times. Results also showed that Rosire and Flores cultivars, whose root yield was statistically similar in both cultivars, produced more root yield than Pars and Ekbatan cultivars so that data illustrated an average increase of 9% in root yield by cultivation Rosire and Flores varieties compared to Pars and Ekbatan varieties in Moghan location (Table 5). The results in Karaj location were in line with obtained data of Moghan (RY for Rosire and Flores were respectively 68.28 and 67.18 t ha^{-1}) and displayed higher RY compared to Pars and Ekbatan varieties (63.46 t ha^{-1} for Pars and 52.59 t ha^{-1} for Ekbatan).

However, there was no significant difference among Rosire, Flores and Pars varieties in Karaj (Table 6). Therefore, it is noticeable that Pars variety could produce appropriate SY in comparison with Rosire and Flores varieties in Karaj location although results found in Moghan are inconsistent. The field observations appeared that Rosier and Flores varieties produced lower shoots than Pars and Ekbatan did, nevertheless, higher RY was gained in European varieties, which indicates higher harvest index (HI) of European varieties in comparison with Iranian. In addition, Flores variety had more intense green leaves than other varieties. Since this characteristic is mainly inherited it can be suggested to consider it as an advantage in breeding programs of Iranian varieties. It is worth mentioning that in recent decades, it has poorly focused on sugar beet HI in breeding programs and breeding progress is particularly related to resistance against diseases in Iran. This study illustrated that some varieties, with low shoots, can produce high root yield due to more efficiency in terms of radiation use and HI.

Table 3. Analysis of variance (Mean Squares) for some measured traits of sugar beet in Moghan region

S.O.V.	df	RY	SY	SC	Sodium	Potassium	Nitrogen	MS	NUE
Replication (R)	3	70.6^{ns}	1.86^{ns}	0.72^{ns}	3.85^{ns}	2.21**	0.91^{ns}	1.30*	81.9^{ns}
Nitrogen (N)	3	652*	13.1*	0.38^{ns}	1.26^{ns}	0.45^{ns}	0.74^{ns}	0.38^{ns}	1176**
Error 1 (R×N)	9	91.49	1.89	1.66	2.78	0.17	0.71	0.28	63.3
Variety (V)	3	270*	90.1**	141**	73.2**	3.35^{ns}	4.15^{ns}	12.4**	1588**
N×V	9	171^{ns}	2.24^{ns}	0.34^{ns}	0.98^{ns}	0.21^{ns}	0.33^{ns}	0.20^{ns}	165^{ns}
Error 2	36	117	2.24	1.86	1.79	0.26	0.46	0.27	87.1
CV	-	15.5	17.7	11.3	17.1	9.34	16.2	11.2	23.9

*,**: Significant at the probability level of 5% and 1%, respectively. ns: Non-significant.

Table 4. Analysis of variance (Mean Squares) for some measured traits of sugar beet in Karaj region

S.O.V.	df	RY	SY	SC	Sodium	Potassium	Nitrogen	MS	NUE
Replication (R)	3	96.0^{ns}	2.28^{ns}	0.38^{ns}	0.40^{ns}	0.17^{ns}	0.17^{ns}	0.13^{ns}	16.9^{ns}
Nitrogen (N)	3	24.3^{ns}	1.76^{ns}	3.05*	1.27^{ns}	0.69*	0.05^{ns}	0.09^{ns}	1283**
Error 1 (R×N)	9	171	5.46	1.13	0.73	0.12	0.15	0.12	157
Variety (V)	3	1641*	91.1**	50.4**	20.3**	2.83^{ns}	9.63**	4.57*	1293**
N×V	9	63.7^{ns}	1.57^{ns}	1.21^{ns}	0.62^{ns}	0.07^{ns}	0.09^{ns}	0.10^{ns}	53.8^{ns}
Error 2	36	103	2.65	1.77	0.63	0.17	0.28	0.12	85.1
CV	-	16.2	16.8	7.06	20.1	12.5	22.7	14.9	25.3

*,**: Significant at the probability level of 5% and 1%, respectively. ns: Non-significant.

Table 5. Mean comparison of some measured traits of sugar beet in Moghan region

Treatment		RY (t ha^{-1})	SY (t ha^{-1})	SC (%)	Sodium (meq 100 g^{-1} pulp)	Potassium (meq 100 g^{-1} pulp)	Nitrogen (meq 100 g^{-1} pulp)	MS (%)
Nitrogen	N0	65.63^{b}	7.91^{b}	12.07^{a}	7.72^{a}	5.50^{a}	4.25^{a}	4.62^{a}
	N100	66.05^{b}	7.91^{b}	12.02^{a}	7.66^{a}	5.41^{a}	3.97^{a}	4.54^{a}
	N75	74.09^{a}	9.13^{a}	12.27^{a}	7.78^{a}	5.65^{a}	4.32^{a}	4.70^{a}
	N50	73.16^{a}	8.88^{ab}	12.13^{a}	8.10^{a}	5.66^{a}	4.18^{a}	4.80^{a}
Variety	Pars	65.79^{b}	6.62^{b}	10.15^{b}	9.16^{a}	5.79^{a}	3.94^{a}	5.19^{a}
	Ekbatan	66.50^{b}	7.04^{b}	10.48^{b}	9.00^{a}	5.82^{a}	4.70^{a}	5.21^{a}
	Rosire	72.55^{a}	9.88^{a}	13.66^{ab}	6.06^{b}	5.46^{a}	4.15^{a}	4.03^{b}
	Flores	71.09^{a}	9.88^{a}	14.21^{a}	7.05^{b}	5.14^{a}	3.94^{a}	4.04^{b}

In each column, means followed by similar letters are not significantly different at the 5% probability level.

Table 6. Mean comparison of some measured traits of sugar beet in Karaj region

Treatment		RY (t/ha)	SY (t/ha)	SC (%)	Sodium (meq 100 g^{-1} pulp)	Potassium (meq 100 g^{-1} pulp)	Nitrogen (meq 100 g^{-1} pulp)	MS (%)
Nitrogen	N0	63.58^{a}	10.01^{a}	15.70^{a}	3.73^{a}	3.50^{a}	1.58^{a}	2.32^{a}
	N100	63.23^{a}	9.54^{a}	15.02^{b}	4.12^{a}	3.15^{b}	1.64^{a}	2.34^{a}
	N75	63.08^{a}	9.55^{a}	15.19^{b}	4.13^{a}	3.39^{ab}	1.67^{a}	2.42^{a}
	N50	61.60^{a}	9.54^{a}	15.51^{ab}	3.84^{a}	3.34^{ab}	1.66^{a}	2.31^{a}
Variety	Pars	63.46^{a}	8.84^{b}	13.92^{c}	4.85^{a}	3.62^{a}	1.96^{ab}	2.78^{a}
	Ekbatan	52.59^{b}	7.70^{b}	14.82^{bc}	4.40^{a}	3.24^{a}	2.19^{a}	2.52^{ab}
	Rosire	68.28^{a}	10.85^{a}	15.86^{ab}	3.28^{b}	2.97^{a}	0.96^{b}	1.92^{b}
	Flores	67.18^{a}	11.27^{a}	16.41^{a}	3.29^{b}	3.54^{a}	1.45^{ab}	2.17^{ab}

In each column, means followed by similar letters are not significantly different at the 5% probability level.

3.2. Sugar content (SC)

The final product of sugar beet depends on two factors root yield and sugar content. There was no significant difference among nitrogen levels in SC, while a significant difference was observed among varieties in Moghan (Table 3). According to data of Karaj, SC response to N application rate was significant. In addition, SC response to a variety of treatments in Karaj resembled the found results in Moghan (Table 4). Our findings in Karaj illustrated that SC generally decreased with increasing N rate. Thus, no applied N had the greatest SC value at 15.7% and the lowest value was obtained by applying N rate at maximum level as 15.02% (Table 6). Similar results have been reported in the literature when evaluating SC response to N rates (Hosseinpour *et al.*, 2013; Stevens *et al.*, 2007: Jahedi *et al.*, 2012; Salami and Saadat 2013). Application of N fertilizer may enhance root yield but on the other hand, it can reduce SC, especially when applying more than optimum rate of N fertilizer (Hoffmann, 2010). Marlander et al. (2003) also mentioned that excessive application of N fertilizer results in a higher RY but consequently in lower SC. An important point to note is that no extensive difference in SC was observed among different rates of N so SC as affected by N levels ranged from 15.02% to 15.7%, which indicated that the difference between the highest and lowest SC was 0.68%.

Flores variety had considerably more SC than others especially Iranian varieties in both areas, so the sugar content in Flores was 14.21% in Moghan and 16.41% in Karaj, whereas it was recorded for Rosier, Pars and Ekbatan varieties as 13.66%, 10.15% and 10.48% in Moghan and 15.86%, 13.92% and 14.82% in Karaj, respectively (Tables 5 and 6). One possible reason for high SC in Flores variety may be because it has more green leaves than other varieties. In addition, field observations illustrated that yellowing and falling of leaves in Flores occurred later than others. Since young leaves emerge after the falling of old leaves and it results in loss of some sugar (Fathollah Taleghani *et al.*, 2001), therefore it seems that varieties with high leaf area duration such as Flores have more sugar content.

3.3. Sugar yield (SY)

Different levels of nitrogen fertilization could significantly influence sugar yield in Moghan. A similar trend was noticed with variety of treatment in both locations (Tables 3 and 4). Statistical analysis for Karaj data showed that N application rate was not significant in SY. Decreasing N application rate to 75% of N100 had a strong effect on sugar yield, so the greatest sugar yield was obtained under N75 by 9.13 t ha^{-1}in Moghan area (Table 5). This result is in line with report by Braziene (2009), who suggested that with moderate N fertilizer rate, N fertilizer has the positive effect on SY. Applying N0 and N100 treatments had the lowest sugar yield (7.91 t ha^{-1}) among nitrogen levels (Table 5).

Stevens et al. (2011) reported that SY response to N application was similar within the range of N rates. They concluded that decrease in sugar content was offset by an increase in root yield as N application rate increased, which caused no response of sugar yield was observed as affected by N treatment. A related point to consider is that using drip irrigation system can provide conditions to split N fertilizer and increase sugar production due to coincident of N with the crop demand, and furthermore, it causes decreased production costs and environmental pollution. As data, Flores and Rosier had greater sugar yield than Pars and Ekbatan varieties in both locations. In Moghan, sugar yield was 9.88 t ha^{-1} for both Rosire and Flores cultivars, which yielded 3.26 and 2.84 t ha^{-1} more SY than Pars and Ekbatan cultivars, respectively (Table 5). Similarly, SY tended to increase more sharply in Flores and Rosier when compared to Pars and Ekbatan varieties in Karaj, so Rosire produced 2.01 t ha^{-1} more SY than Pars and 3.15 t ha^{-1} more than Ekbatan. These values for Flores variety were 2.43t ha^{-1} and 3.57 t ha^{-1}, respectively (Table 6). It seems that remarkable difference in SC between European varieties and Pars variety led to the production of higher SY by European varieties in spite of non-significant difference between Pars and European varieties in terms of RY. These observations confirm that more focusing on improvement of SC than RY in breeding programs can be an effective way to increase SY in Iranian varieties.

3.4. Root quality

Sugar content is negatively associated with α-amino N, Na and K content (Hoffmann, 2010). The non-sugar substances such as K, α-amino N and Na have an adverse impact on efficiency of sugar processing in the factory. In other words, the efficiency of sugar processing depends extensively upon the relative rate of sugar that can be crystallized and the rate that is left in molasses. Root impurities increase the sugar in molasses because they raise the solubility of sucrose and thereby reduce crystallization. Therefore, low values of non-sugar substances and molasses sugar imply high root quality. Statistical analysis confirmed that N application rate, which was evaluated in this study, had no significant impact on concentration of the root impurities and molasses sugar in both areas except for K concentration in Karaj (Tables 3 and 4). The results of other studies are inconsistent with the data achieved in the study. Increasing impurities as affected by increasing N application rate is supported by those reported by Stevens et al. (2008); Stevens et al. (2011). As discussed above, one possible explanation for no response of non-sugar substances to N application in the present study could be attributed to high split application of N that results in coinciding with the plant demand and absorbing elements in the adequate amounts in spite of applying N fertilizer under recommended rate. K concentration of 3.5 meq 100 g^{-1} pulp was recorded as the highest value in no applied N treatment in Karaj. It seems that sugar beet supplied with N fertilizer caused to decline in K concentration in root, probably as a result of higher Na uptake under applying N fertilizer conditions; although there was no significant effect of N treatment on Na concentration. ANOVA results of Moghan area indicated that different sugar beet varieties significantly affected Na concentration and molasses sugar, while no differences among varieties were obtained for α-amino N and K percentages (Table 3). In Karaj, molasses sugar and all root impurities except K concentration were statistically affected by variety (Table 4).

Na concentration ranged from 6.06 meq 100 g^{-1} pulp to 9.16 meq 100 g^{-1} pulp in Moghan and 3.28 meq 100 g^{-1} pulp to 4.85 in Karaj as affected by various varieties, so the high Na values were found in Iranian varieties, which had the lowest SC (Tables 5 and 6). Previous studies also showed that root impurities were high in Moghan location (Moharamzadeh *et al.*, 2013;

Farahmand *et al.*, 2014). As a result, the lowest Na content was gained in Rosire variety by 6.06 meq 100 g^{-1} pulp and 3.28 meq 100 g^{-1} pulp for Moghan and Karaj, respectively, although there is no statistical difference in Na content between Rosire and Flores varieties (Tables 5 and 6). High molasses sugar was recorded under cultivation of Iranian varieties, so it was 5.21% for Ekbatan and 5.19%for Pars varieties in Moghan and 2.52% and 2.78%, respectively in Karaj. Whilst using Rosire and Flores resulted in low molasses sugar by 4.03% and 4.04% (in Moghan); 1.92% and 2.17% (in Karaj), respectively (Tables 5 and 6). According to the negative effect of root impurities on extraction coefficient of sugar, lower values of WSC in Iranian varieties were expected. Therefore, it can be suggested that we should consider decreasing root impurities, especially Na concentration in our breeding programs to improve quality of Iranian varieties. Because the high values of non-sugar substances in Iranian varieties indicate that these varieties have potential to enhance their sugar concentration by a further reduction of the root impurities concentration. Hoffmann (2010) explained that the sugar content can only be increased by reducing non-sugar substances, although he believed that the concentration of these substances is already low in advanced varieties and further reduction of them causes to negative influence on plant growth.

3.5. Nitrogen use efficiency (NUE)

NUE was highly influenced by N rate and variety in both studied areas (Tables 3 and 4). In Moghan, NUE in response to nitrogen rate ranged from 31.61 kg sugar kg^{-1} N under the greatest N rate (N100) to 46.13 kg sugar kg^{-1} N in the lowest rate (N0). Karaj data were identical to those found on Moghan and application of N100 had the lowest NUE (30.61 kg sugar kg^{-1} N), while N0 treatment had the highest (45.35 kg sugar kg^{-1} N) (Fig. 1). The results generally indicated a decrease in NUE by increasing N application rate. Similar results have been reported in the literature (Noshad *et al.*, 2012; Laufer *et al.*, 2016). Our results reflect that application of N fertilizer not only decreased SC but also elevated root impurities, which interfere with the extraction of sugar, in spite of increasing RY. This issue can be the main explanation for lower NUE under applying N fertilizer conditions when compared to no application.

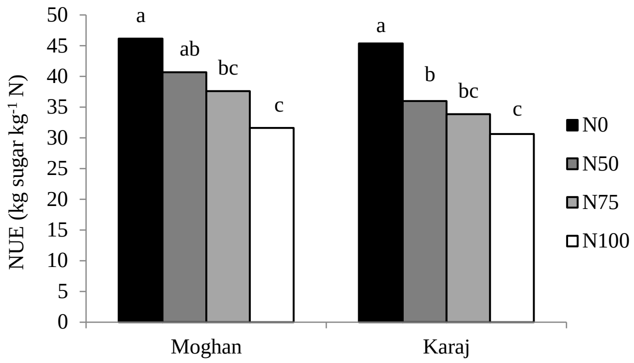

Figure 1. The effect of different nitrogen rates on NUE (kg sugar kg^{-1} N) in Moghan and Karaj regions.

Among varieties in Moghan, Rosire had the highest NUE (46.20 kg sugar kg^{-1} N) and Pars had the lowest (30.67 kg sugar kg^{-1} N). Whereas in Karaj experimental, Flores and Ekbatan varieties displayed the greatest and lowest NUE by 43.41 kg sugar kg^{-1} N and 30.06 kg sugar kg^{-1} N, respectively (Fig. 2). The value of NUE in Flores variety was found to be statistically on par with that of recorded with Rosire and the same trend was observed in Ekbatan and Pars varieties in both areas. In general, European varieties represented greater NUE than Iranian varieties, mostly as a result of higher produced sugar by European varieties. Using a drip irrigation system led to creating conditions that we can split N application coincident with the plant demand, which results in enhancing NUE. Ali and Talukder (2008) also confirmed that drip irrigation systems allow higher frequencies of N application, while high N split application is restricted under flood irrigation systems. Split N rate in drip irrigation systems causes improved NUE due to reduce the risk of leaching (Alva *et al.*, 1998; Paramasivam *et al.*, 2001) and continuous availability of N in the root zone (Martínez-Alcántara *et al.*, 2012).

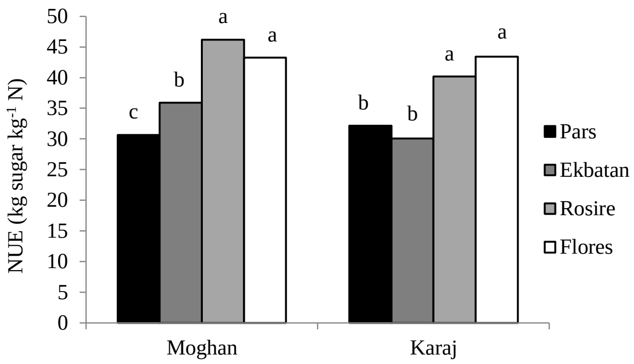

Figure 2. Values of NUE (kg sugar kg^{-1} N) for different sugar beet varieties in Moghan and Karaj regions.

4. Conclusion

According to the results, an extensive gap was observed among varieties. In essence, this result reveals the fact that sugar yield of Iranian varieties can be raised by improving breeding programs. As discussed above, more focusing on improvement of sugar concentration via reduction of non-substances can be considered the main approach in breeding projects. Although agronomical management affected sugar concentration it seems that breeding approach is needed to improve Iranian sugar beet varieties.

Our findings illustrated that there is a negligible difference between recommended N fertilizer rate and 75% of it (in some cases 50% of it) in terms of sugar production. Because optimum rate of N fertilizer has previously been adjusted for surface irrigation systems this amount of N application is not suitable for other irrigation systems such as drip systems. It is necessary to modify the standards for using N fertilizer under drip irrigation systems that is developing in most fields of the country. Therefore, N fertilizer consumption can be reduced under drip irrigation system and applying N fertilizer in lower amounts than recommended level could be the best fertilizer management for drip-irrigated sugar beet. On the other hand, splitting N fertilizer and reducing the risk of leaching in drip irrigation systems are the other advantages of this system. According to the researches that had been performed under surface irrigation systems in these regions, the results of this study confirmed that drip irrigation systems can increase NUE in comparison with surface irrigation.

Abbreviation

MS: Molasses Sugar, N: Nitrogen; NUE: Nitrogen Use Efficiency, RY: Root Yield, SBSI: Sugar Beet Seed Institute, SC: Sugar Content, SY: Sugar Yield, WSC: White Sugar Content, WSY: White Sugar Yield

Conflict of interests

All authors declare no conflict of interest.

Ethics approval and consent to participate

No human or animals were used in the present research.

Consent for publications

All authors read and approved the final manuscript for publication.

Availability of data and material

All the data are embedded in the manuscript.

Authors' contributions

Dariush Fathollah Taleghani found the concept, involved in the experimental design. Hamed Mansouri & Dariush Fathollah Taleghani performed manuscript preparation. Mehdi Sadeghi- Shoae & Hamid Noshad carried out the field experiments in Karaj and data acquisition. Hamed Mansouri & Mehdi Sadeghi- Shoae carried out statistical analysis. Majid Moharamzadeh carried out the field experiments in Moghan and data acquisition.

Informed consent

The authors declare not to use any patients in this research.

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