Environmental and Experimental Biology (2018) 16: 169–175
DOI: 10.22364/eeb.16.16 *Original Paper*

Response of sugar beet to irrigation interval, harvesting time and integrated use of farmyard manure and nitrogen fertilizer

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Abstract

Considering the importance of interactive effects of irrigation, fertilizer and harvest date this experiment was aimed to study the growth and yield response of spring-sown sugar beet to the harvest date and the application of nitrogen and farmyard manure under two irrigation regimes: well watered and moderate drought stress. Results indicated that irrigation significantly affected taproot growth; moderate drought stress led to an increase in root diameter. Leaf dry weight was increased by the application of nitrogen fertilizer in the well watered condition but decreased under water deficit condition. The combined application of 50% nitrogen fertilizer and 50% farmyard manure resulted in increased root yield by 28 and 32% compared with single application of nitrogen and farmyard manure fertilizers, respectively. Interaction effect of factors showed that under the moderate drought stress and availability of the recommended dose of nitrogen in soil, a late harvest date can be recommended to prevent loss of sugar content in sugar beet roots.

Key words: harvest, drought stress, sugar beet, water regime.
Abbreviations: FYM, farmyard manure; WD, water defficit; WW, well watered.

Introduction

Optimum irrigation management is one of the most important factors in sugar beet production, as it can increase yield and reduce water costs, fertilizer leaching and soil erosion (Reddy et al. 2007). Sugar beet can grow in a wide range of water conditions and irrigation treatments (Davidoff, Hanks 1989). This crop is compatible with soil water deficit. With increasing irrigation interval, the root to shoot ratio is increased and water uptake from the lower layers of soil through the deep roots can be remarkably increased (Camposeo, Rubino 2003). Several studies have been conducted on the effects of irrigation regime changes on various traits of sugar beet (Hang, Miller 1986; Groves, Bailey 1997; Choluj et al. 2004; Monti et al. 2006; Mahmoodi et al. 2008; Morillo-Vellarde 2010; Kiymaz, Ertek 2015; Malik et al. 2018; Zare Abyaneh et al. 2017). Irrigation management in sugar beet cultivation, interacting with factors such as nitrogen fertilizer and harvesting date, can affect the quantity and quality of sugar beet root.

The optimum fertilizers application, especially nitrogen fertilizer, plays an essential role in enhancement of the beet sugar quantity and quality. Nitrogen is one of the most important nutrients for sugar beet. Hence its amount and application mode during plant growth is of great importance. Soil nitrogen deficiency can reduce vegetative growth and root yield while increasing sugar content. On the other hand, a rise in soil nitrogen increases root and sugar yield, as well as root impurities while decreasing the sugar content (Oliveira et al. 1993; Tsialtas, Maslaris 2005; Moore et al. 2009). High nitrogen mobility and its role in the environmental contamination especially groundwater resources pollution, as well as its negative impact on the sugar beet quality are considered as limiting factors for nitrogen application (Yousefabadi, Abdollahian-Noghabi 2011). In addition, since the soil of most Iranian farmlands are poor in organic matter, the application of organic fertilizers and manures can contribute to increase soil organic matter and fertility while reducing the dependence on nitrogen fertilizer. Sugar beet growers can use manure or compost to meet nitrogen requirements of sugar beet. A study conducted by Lehrsch et al. (2015) showed that the sugar and root yield resulting from the application of conventional manure or compost was equivalent to that resulting from urea application.

Many experiments have been performed on the benefits of manure and organic fertilizer application, instead of chemical fertilizers, in the production of various crops. The results of experiments on application of manure and compost on wheat growth and yield showed that these additions significantly improved wheat growth and yield parameters, and it was concluded that a combination of chemical fertilizer and manures could be more effective than pure chemical fertilizer (Ibrahim et al. 2008). Different chemical fertilizer and manure application treatments in sorghum cultivation indicated that simultaneous application of manure and 50% of the recommended inorganic fertilizer rate caused equal or greater yield than the application of 100% recommended inorganic fertilizer (Bayu et al. 2006). A study on the effects of different combinations of organic and inorganic fertilizers on faba bean yield in acidic soil recommended the application of 50% manure with a ratio of 4 t ha^{-1} combined with 15 kg of phosphorus and 3.2 t ha^{-1} of lime as the best treatment to increase faba bean yield (Fekadu et al. 2018). The effects of different levels of manure application including 0, 5 and 10 tons/ha in rice cultivation showed a significant increase in grain yield from 1.35 t ha^{-1} (in control treatment) to 3.05 and 3.31 t ha^{-1} in treatments of 5 and 10 t ha^{-1}, respectively, indicating that the use of farmyard manure as an organic soil amendment can be useful in increasing yield especially in areas with low fertility soils and low moisture content (Saidia, Mrema 2017).

Time of harvesting is another factor that can affect the yield and quality of sugar beet root. The results of experiments on the effects of time of harvesting on sugar beet are variable and largely depend on the climatic conditions of each region. In an experiment carried out by Davidoff and Hanks (1989), it was showed that the response of sugar beet yield to changing in time of harvesting depended on irrigation regimes whereas sugar content was not affected by harvesting date. In another study on autumn-sown sugar beet, Taleghani et al. (2011) examined the effects of four harvest dates with one-month intervals from late May to late August and found that the shift of harvest from May to June caused a significant increase in sugar and root yields, and in the sugar content of root.

Although much research has been conducted on the effects of different organic and inorganic fertilizers on sugar beet traits, there is limited information regarding the interactive effects of irrigation, fertilizer and harvest date on sugar beet growth and yield. Thus, this study was conducted to determine sugar beet response to changes in harvest dates and application of manure and nitrogen fertilizer under two different irrigation conditions in spring cultivation conditions.

Materials and methods

Characteristics of the experimental site

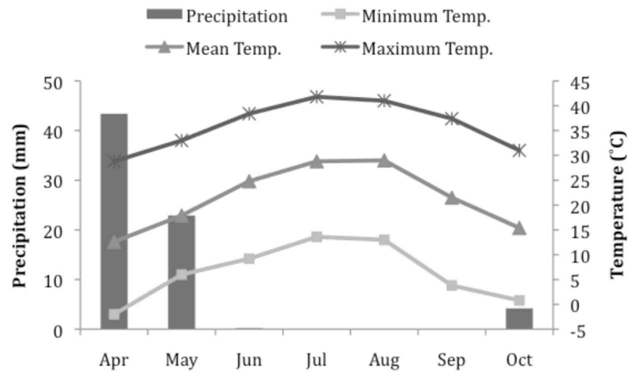

Fig. 1. Precipitation and temperature in the growing season of 2016 at the experimental site.

The study was carried out at the experimental farm of Islamic Azad University, Sanandaj Branch (35° 10' N and 46° 59' E; elevation 1393 m above sea level) during spring and summer 2016. The long-term annual rainfall and average temperature of the area are 471 mm and 13.4 °C, respectively. The monthly precipitation and temperature of the experimental site in the growing season are shown in Fig. 1, and the experimental farm soil characteristics in Table 1.

Experimental design, treatments and management

The experiment was performed as split-split plots in a randomized complete block design with three replications. The main factor was irrigation regime with two levels of well watered (WD, irrigation interval of 5 days) and moderate drought stress [water deficit (WD), irrigation interval of 10 days]. The sub-factor was fertilizer application with three levels: (i) N, recommended dose of nitrogen fertilizer (200 kg ha^{-1}); (ii) FYM, recommended dose of farmyard manure (30 t ha^{-1}) and (iii) N+FYM, a combination of 50% nitrogen (100 kg ha^{-1}) and 50% farmyard manure (15 t ha^{-1}). In addition, two harvest dates (October 1 and 31) were considered as sub-sub factor levels.

The Iranian sugar beet cultivar SBSI003 with monogerm seeds used in the study was obtained from Kermanshah Agricultural Research Center. Nitrogen fertilizer and manure were from the urea source and cow manure respectively. The properties of the cow manure are as given in Table 2. Each experimental plot consisted of five ridges, 7 m in length with 50 cm space between the ridges and 20 cm between the plants on each ridge. Sowing was carried out manually on May 18, 2016. Manual weed

Table 1. Physical and chemical properties of the soil of the experimental site. OC, organic carbon: TNV, total neutralizing value; EC, electrical conductivity

Soil depth (cm)	Clay (%)	Silt (%)	Sand (%)	Texture	OC (%)	TNV (%)	pH	EC (dS m^{-1})	N (%)	P (mg kg^{-1})	K (mg kg^{-1})
0 – 30	32.28	34	33.72	Loam	1.13	4.50	7.69	0.489	0.11	14.03	234.4
30 – 60	32.28	28	39.72	Clay loam	0.83	7.25	8.01	0.535	0.08	10.86	205.0

Table 2. Composition of the cow manure used in the experiment. EC, electrical conductivity; OC, organic carbon; OM, organic matter

pH	EC ($dS\ m^{-1}$)	Moisture (%)	Ash (%)	OC (%)	OM (%)	N (%)	P (%)	K (%)	C/N ratio
7.7	6.75	18	55	26.1	45	0.84	0.23	0.7	31.07

control was performed at different growth stages of sugar beet. Diazinon insecticide was used twice with seven days interval to control the beet armyworm (*Spodoptera exigua*). All of the experimental plots were well watered until 8 leaves stage to ensure plant establishment and then the irrigation treatments were implemented. Irrigation interval was determined based on soil moisture discharge. Soil moisture was measured by gravimetric method. According to the irrigation depth for sugar beet, the irrigation interval was determined such that the water requirement of the plant was fully met with 5-day irrigation intervals and a moderate water stress imposed with irrigation intervals of 10 days. All cow manure was mixed with soil prior to sowing. In addition, one third of the urea fertilizer was applied during planting and two thirds at 4 to 6 leaves stage. Other recommended fertilizers including triple superphosphate (75 kg ha^{-1}) and potassium sulfate (100 kg ha^{-1}) were incorporated into the soil prior to sowing.

Measurement of traits

Sugar beet plants were harvested manually on October 1 and 31, excluding some plants to exclude a border effect. The harvested taproots were separated from the leaves and their fresh weight was measured and converted to tons per hectare and considered as root yield. The leaves were open air dried and their weight was measured. Ten taproots were randomly selected and their mean diameter was recorded. The percentage of root sugar was measured by the colorimetric method described by DuBois et al. (1956) at the Laboratory of Food Science & technology, Faculty of Agriculture, Sanandaj Branch, Islamic Azad University. Sugar yield per unit area was obtained through multiplying the sugar percent by root yield.

Statistical analysis

The recorded data were subjected to analysis of variance and the least significant difference (LSD) test was used to compare the means. The statistical analyses were performed using SAS software (SAS Institute Inc., Cary, NC, USA).

Results

Root yield

Analysis of variance showed that fertilizer treatment statistically affected root yield while irrigation interval, harvest date and interactive effects were not significant (Table 3). The highest yield per unit area was in the N+FYM treatment (50% cow manure + 50% nitrogen) with increase rates of 28 and 32% compared to the N (100% nitrogen) and FYM (100% cow manure) treatments, respectively (Table 4).

Sugar content and yield

Sugar content was affected by harvest date and the interactions of three factors, but irrigation interval and fertilizer did not have independent significant effect on the sugar content of roots (Table 3). The triple interactive effects of factors on sugar content was shown. This was due to the significant interaction effect of two harvest dates on root sugar content at the water deficit conditions, and the application of 100% nitrogen fertilizer (WD and N treatment composition). A one-month delay in harvesting increased the sugar content by about two times more than that of the early harvesting date. In other cases, there was no significant difference between the two harvesting dates in root sugar content (Fig. 2A). A similar result was observed in terms of the response of sugar yield to the interaction of the three factors. When sugar beet was under water deficit

Table 3. Analysis of variance of sugar beet traits. ns, * and **: Non-significant and significant at 5 and 1% levels of probability, respectively

Source of variation	df	Root yield	Sugar content	Sugar yield	Root diameter	Leaf dry weight
Replication	2	ns	ns	ns	ns	ns
Irrigation (I)	1	ns	ns	ns	*	ns
E_a	2	-	-	-	-	-
Fertilizer (F)	2	*	ns	ns	**	*
I × F	2	ns	ns	ns	ns	*
E_b	8	-	-	-	-	-
Harvest date (H)	1	ns	*	ns	ns	ns
I × H	2	ns	ns	ns	ns	ns
F × H	2	ns	ns	ns	ns	ns
I × F × H	2	ns	*	*	ns	ns
E_c	12	–	–	–	–	–

Table 4. Interactive effects of irrigation, fertilizer and harvest date on root yield (t ha^{-1}). N, 100% recommended dose of nitrogen fertilizer; FYM, 100% recommended dose of farmyard manure; N+FYM, combination use of 50% nitrogen and 50% farmyard manure. Means of treatments with the same letter (for each factor separately) are not significantly different at $P \leq 0.05$ according to the LSD test

Irrigation	Harvest date	Fertilizer			Means of irrigation treatments
		N	FYM	N+FYM	
Well watered	October 1st	33.40	23.96	43.66	
	October 31st	33.82	36.42	46.20	
					36.24 a
Water deficit	October 1st	36.92	40.10	49.66	
	October 31st	36.90	36.02	41.32	
					40.15 a
Means of fertilizer treatments		35.26 b	34.13 b	45.21 a	

stress and much nitrogen fertilizer was available, early harvesting resulted in a significant drop in sugar yield (Fig. 2B).

Root diameter

Root diameter was affected by irrigation interval and fertilizer application, but harvesting dates had no significant effect (Table 3). Increased irrigation interval (moderate drought stress conditions) caused a significant increase in sugar beet root diameter (Table 5). The highest root diameter was obtained by application of combined nitrogen fertilizer and cow manure treatment, resulting in increased root diameter by 21 and 24% compared to individual application of nitrogen fertilizer and cow manure, respectively (Table 5).

Leaf dry weight

ANOVA analysis showed no significant effect of irrigation interval and harvesting date on leaf dry weight, while the effect of fertilizer and interaction of irrigation and fertilizer were significant (Table 3). Interactive effect of irrigation interval and fertilizer indicated that in the well watered conditions the plant response to nitrogen was better in terms of leaf growth, but under water deficit stress, the application of 100% nitrogen fertilizer caused loss of leaf dry weight (Fig. 3). Comparison of fertilizer treatments showed that the integrated treatment (N+FYM) produced the highest dry weight of leaves (Table 6). The application of integrated fertilizer treatment in both irrigation regimes especially under water deficit conditions, was beneficial in increasing leaf dry weight (Fig. 3).

Discussion

The significant improvement in root yield of sugar beet was obtained by fertilizer treatment of N+FYM (urea fertilizer and cow manure) than when these fertilizers were applied separately. A study by Lehrsch et al. (2015) suggested that the application of cattle manure or compost in sugar beet cultivation could be effective to meet plant nitrogen requirements. Faraji et al. (2015) also reported that the application of chemical fertilizers combined with organic fertilizers such as cow manure improved qualitative and quantitative traits of sugar beet. Similar results were obtained by Amini et al. (2017) who showed thst combined application of manure and urea fertilizer

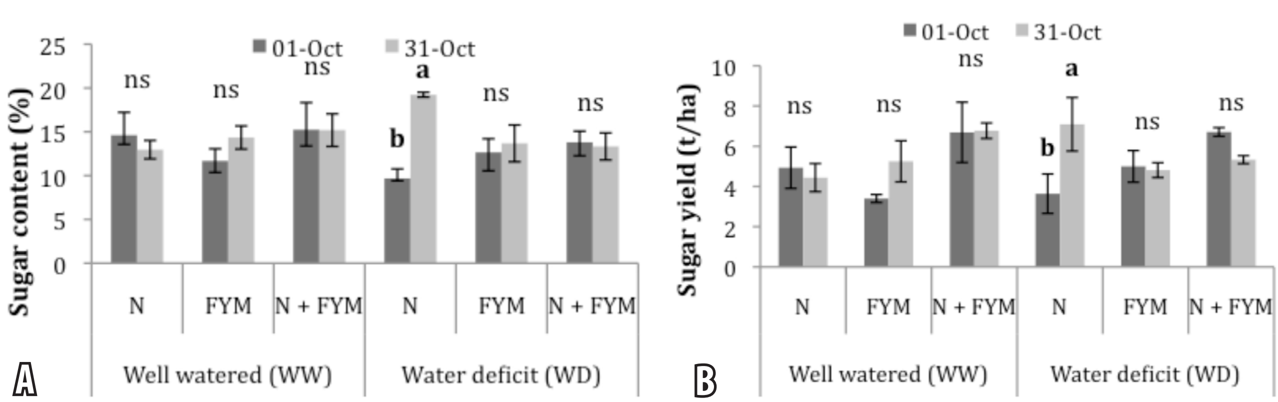

Fig.2. Interactive effects of irrigation, fertilizer and harvest date on sugar content (A) and sugar yield (B). N, 100% recommended dose of nitrogen fertilizer; FYM, 100% recommended dose of farmyard manure; N+FYM, combination use of 50% nitrogen and 50% farmyard manure. The means of two harvest dates are compared by the LSD test and slicing method. Vertical bars indicate the standard error of the means.

Table 5. Interactive effects of irrigation, fertilizer and harvest date on root diameter (cm). N, 100% recommended dose of nitrogen fertilizer; FYM, 100% recommended dose of farmyard manure; N+FYM, combination use of 50% nitrogen and 50% farmyard manure. Means of treatments with the same letter (for each factor separately) are not significantly different at $P \leq 0.05$ according to the LSD test

Irrigation	Harvest date	Fertilizer			Means of irrigation treatments
		N	FYM	N+FYM	
Well watered	October 1st	5.0	5.1	7.1	
	October 31st	6.0	4.9	7.2	
					5.9 b
Water deficit	October 1st	6.8	7.0	7.5	
	October 31st	6.7	6.9	7.7	
					7.1 a
Means of fertilizer treatments		6.1 b	6.0 b	7.4 a	

reduced the concentration of nitrate in potato tubers while yields were similar to these after 100% urea application. Bokhtiar et al. (2008) studied the effects of different fertilizer combinations on growth, yield and quality of sugarcane and recommended the combination of organic and inorganic fertilizers in order to maintain soil fertility and achieve high yields. Also, the results of experiments on sugarcane production in calcareous soils showed that the integrated use of organic and inorganic fertilizers improved sugar yield, sugar quality and soil fertility (Umesh et al. 2013). Miri et al. (2009) showed that the effect of manure application on improving potato yield was due to supply of some nutrients required by the plant, improvement of soil physical and chemical properties, elevation of soil water holding capacity and enhancement of micronutrient uptake.

The interactive effects of irrigation, fertilizer and harvest date on sugar content and yield (Fig. 2) demonstrated that when the plant is under moderate water deficit stress while being supplied with high availability of nitrogen, it is essential to delay the planting date in order to avoid the loss of root sugar. The changes in root sugar content depend on the weather conditions during the last growth stage of sugar beet. A fall of air temperature in late October in this area (Fig. 1) can be considered as a key factor that increases sugar accumulation in the presence of sufficient nitrogen and reduced soil moisture. Positive effects of delayed harvesting on root sugar have been reported by some other authors. The results of a 4-year study on two sugar beet cultivars showed that a one-month delay in harvest resulted in an average 17% increase in sugar yield in both cultivars (Jozefyova et al. 2003). Yousefabadi and Abdollahian-Noghabi (2011) in a study on the effect of nitrogen fertilizer splitting and four harvesting dates with one-month intervals on sugar beet, found that with a delay in harvesting, the root sugar content increased from 12.8% in the first harvest to 15.2% in the last harvest. In addition, sugar yield increased from 5.1 tons per hectare in the first harvest to 10.4 tons per hectare in the last harvest.

The growth of sugar beet root was promoted by moderate drought stress (Table 4). It seems that sugar beet allocates more photo-assimilates to root growth under deficit irrigation conditions, which can lead to greater root development and as a result, an increase in the root diameter. Under soil water deficit, root growth is less affected than shoot growth, and the root to shoot ratio is typically increased in response to drought stress (Marschner 1995). Drought stress can reduce leaf growth and relatively increase the allocation of dry matter to the roots and thus increase the root/shoot ratio (Shaw et al. 2002; Rauf, Sadaqat 2007). Under water deficit stress, plants respond to growth constraints by exporting more carbon resources to the roots to maintain root efficacy (Durand et al. 2016).

Table 6. Interactive effects of irrigation, fertilizer and harvest date on leaf dry weight (g plant^{-1}). N, 100% recommended dose of nitrogen fertilizer; FYM, 100% recommended dose of farmyard manure; N+FYM, combination use of 50% nitrogen and 50% farmyard manure. Means of treatments with the same letter (for each factor separately) are not significantly different at $P \leq 0.05$ according to the LSD test

Irrigation	Harvest date	Fertilizer			Means of irrigation treatments
		N	FYM	N+FYM	
Well watered	October 1st	21.30	12.47	18.63	
	October 31st	20.10	13.63	21.47	
					17.94 a
Water deficit	October 1st	12.53	14.03	19.70	
	October 31st	15.53	16.70	17.70	
					16.03 a
Means of fertilizer treatments		17.37 a	14.21 b	19.38 a	

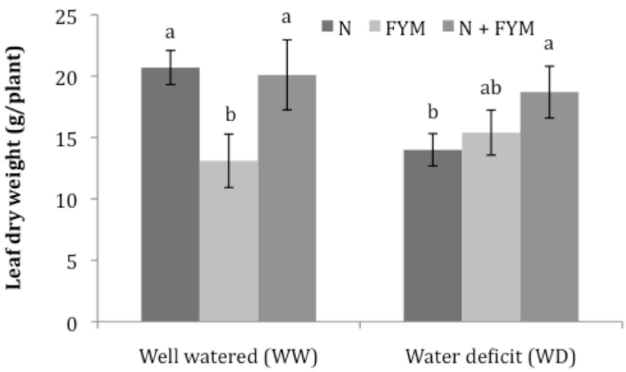

Fig.3. Interactive effects of irrigation and fertilizer on leaf dry weight. N, 100% recommended dose of nitrogen fertilizer; FYM, 100% recommended dose of farmyard manure; N+FYM, combination use of 50% nitrogen and 50% farmyard manure. The means of two harvest dates are compared by the LSD test and slicing method. Vertical bars indicate the standard error of the means.

The increase in root diameter due to the application of N+FYM treatment can be explained by the role of manure in improving soil texture and allowing further root growth, the effect of nitrogen fertilizer on improving vegetative and root growth. The addition of organic fertilizers, including cow manure to soil increases the aggregate stability, the water infiltration rate, water holding capacity and decreases soil bulk density (Barzegar et al. 2002). The application of organic fertilizer that included compost and cow manure in a three-year experiment in potato cultivation reduced soil bulk density. In addition, organic fertilizers generally increased the potato yield by 23, 27 and 11% compared to the control, during three consecutive years, respectively (Porter et al. 1999). Bandyopadhyay et al. (2010) found that the integrated application of farmyard manure and conventional chemical fertilizers, on the one hand significantly reduced the soil bulk density and resistance and, on the other hand increased the hydraulic conductivity and organic matter content of soil, as well as increased soybean yield through increasing water and nutrient use efficiency.

Response of sugar beet leaf growth to the interaction of irrigation interval and fertilizer (Fig. 3) indicated that the presence of farmyard manure in the fertilizer composition can improve leaf growth under drought stress conditions, which may be due to increased soil water holding capacity imparted by the application of cow manure. Studies have shown that animal manure increases water storage in soil and improves uptake of nutrients by plants, thereby improving photosynthesis and shoot growth (Barzegar et al. 2002; Miri et al. 2009). The results of experiments conducted by Bandyopadhyay et al. (2010) also indicated that combined farmyard manure and chemical fertilizer treatment increased leaf area index and shoot growth in soybean plants. They attributed the increase of leaf area index in combined treatment to the production of new leaves and increase in the size of leaves.

Conclusions

The prominent feature of the present study was that the growth and yield responses of sugar beet to the combined effects of harvest time, fertilization and irrigation factors were examined. The results showed that the integrated use of 50% FYM and 50% nitrogen fertilizer increased root growth and yield, such that the need of application of 100% of the recommended nitrogen fertilizer was eliminated. Therefore the removal of half of the recommended nitrogen dose and substitution of it with FYM can reduce the costs and the risks of soil, water and plant contamination with nitrogen fertilizer residues as well as increase crop yields. The significant interactive effect of irrigation, fertilizer and harvest date on sugar content and yield in this study showed a need to consider the harvest date. Under conditions of 100% nitrogen fertilizer application and moderate drought stress, late harvest of sugar beet can be recommended to prevent the loss of root sugar content and yield.

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Received 15 July 2018; received in revised form 25 September 2018; accepted 25 September 2018