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Effects of Sowing Date and Limited Irrigation on Root Yield and Quality of Sugar Beet (*Beta vulgaris* L.)

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Abstract: This field study was conducted in order to investigate the yield and quality of sugar beet Cv zargan in relation to sowing date and different irrigation regimes during 2005 at Ardabil conditions. The experimental design was a randomized complete block design with factorial arrangement in four replicates. In this experiment two factor with four levels were used: Sowing date (S_1 = 5 Apr, S_2 = 20 Apr, S_3 = 5 May and S_4 = 20 May) and irrigation including: I_1 = Irrigation at 13.3 FC (30% FC), I_2 = Irrigation at 15.5 FC (50% FC), I_3 = Irrigation at 17.7 FC (70% FC) and I_4 = Irrigation at 19.9 FC (90% FC). The SAS software package was used to analyze all the data and means were separated by the least significant difference (LSD) test at $p<0.01$. In this study adjectives such as root yield (t ha^{-1}), leaf yield (t ha^{-1}), sugar content (%), Molasses (%), pure sugar content (%), white sugar yield (t ha^{-1}), Na (mmol/100 g root), K (mmol/100 g root) and α-amino N (mmol/100 g root) were evaluated. Sowing date and irrigation had a significant effect on sugar yield and its quality. Potassium concentration was not significantly affected by irrigation treatments. Interaction effects between sowing date and irrigation treatments were significant ($p<0.01$) for all adjectives. Both early and late sowing decreased beet root and leaf yield. Results of irrigation treatments showed that the optimum soil water content for root yield is 70% of field capacity with 66.5 t ha^{-1}. The minimum root yield (47.36 t ha^{-1}) observed at 90% of field capacity. Sugar content (%) affected by sowing date and irrigation treatments. However irrigation at 30, 50 and 70% of field capacity (I_1, I_2 and I_3) had same effect on sugar content while sugar content decreased at 90% field capacity (I_4). Therefore the optimum sowing date in Ardabil condition is 20 April that maximum yield and quality observed on this treatment. When the available soil water content was at 70% of field capacity, maximum root yield observed.

Key words: *Beta vulgaris*, sowing date, irrigation, root yield, sugar quality

INTRODUCTION

The sustainability of cropping systems can be achieved through the choice of certain field crops which are better able than others to exploit natural resources, like solar radiation-which is a no-cost resource-and water-which is becoming more and more expensive. One of these crops is the sugar beet (*Beta vulgaris* L.), a crop cultivated for the production of sucrose and potentially, for the production of energy (bio-ethanol). In the cropping areas from 38 to 60°N beet is usually sown in spring (March-April) and harvested in autumn. In the southern areas of Iran, Spain, Italy and Greece (at varying latitudes according to the climatic zones, between 35 and 45°N), the beet is sown in autumn, using lines resistant to bolting, with several advantages that can be summarized as: extension of growing period, early harvest (end of July), reduction of the irrigation requirements and reduced risks of a low root sugar content (Rinaldi and Vonella, 2006). In the Mediterranean region and Iran, adequate sugar beet production requires irrigation, but in recent years drought stress has become a major constraint to sugar beet cultivation even in Northern Europe, causing serious reductions in productivity (Jaggard *et al*., 1998; Pidgeon *et al*., 2001). Also, sugar beet tolerates mid and late-season plant water stress and this characteristic make it a suitable crop for production with limited irrigation. Under irrigation conditions, the sugar beet is regarded as

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a highly water-consuming crop, which prevents its expansion in areas with limited availability of water resources.

Many studies have led us to assume that water rationing can take place on a highly selective basis in certain phonological periods without causing any significant losses in terms of quality and quantity of the final output (Groves and Bailey, 1997; Urbano and Arroyo, 2000; Urbano *et al*., 2000). Controlled deficit irrigation may well prove to be an efficient tool for further research in this respect (English, 1990; English *et al*., 1990).

Wittenmayer and Schilling (1998) showed that sugar beet plants respond to water stress by an increase in tap-root proportion in relation to whole plant dry matter. Richter *et al*. (2001) found that drought stress is the major cause of yield loss on sugar beet in the UK. It causes an average annual yield reduction of 10% (Jaggard *et al*., 1998) and in every dry year it decreased yields by as much as 50%, corresponding to 4 t ha^{-1}. There are conflicting reports about the sensitivity of sugar beet to water stress conditions (Dunham, 1993).

Results showed that planting date significantly affected the plant yield and its quality (Bakheit *et al*., 2001; Dapaah *et al*., 1999; Ozel *et al*., 2004; Salmasi *et al*., 2006). Sowing times affect plant canopy development (growth, number, size and age of green leaves) in relation to global and intercepted solar radiation throughout the crop season (Smit, 1993; Rinaldi and Vonella, 2006). Cakmakci and Oral (2001) found that Each day sowing was delayed from mid-April to the end of May resulted in a 703 and 134 kg ha^{-1} decrease in root and sugar yield, respectively. A delay in emergence of 43 days from the beginning of May reduced sugar content by 10.9% and estimated extractable sugar content by 15.2%. Javaheri *et al*. (2006) reported that the best autumn planting date was 22 August with sugar yield of 9.4 t ha^{-1}, root yield of 8.5 t ha^{-1} and white sugar content of 11.44% and suggested that autumn planting of sugar beet in Orzoih-Kerman can be successful. Late harvesting increased beet root yield from 440 to 675 g and sugar content (%) from 16.09 to 18.02 (Cakmakei and Tingir, 2001; Jozefyova *et al*., 2002). Late sowing enhanced percentage emergence and shortened emergence time (Durr and Boiffin, 1995) but developing soil moisture deficit later reduced emergence and increased gaps in plant stands (Jaggard *et al*., 1995). Gale *et al*. (1990) showed that early sowing increased root soluble carbohydrates and sugar content. Studies from different locations and years showed that late and poor emergence in earlier sowings and short vegetation period in late sowing rapidly reduced sugar beet root yield (Marlander, 1992; Durrant *et al*., 1993). Late sowing especially decreased sugar content, white sugar content and white sugar yield (Marlander, 1992; Smit, 1993; Lauer, 1997). Early sowing enhanced plant growth and leaf number per unit area. Despite adequate plant growth in early sowings, root yield decreased due to inadequate plant number and uneven distribution. In the late sowings, root yield also decreased because of a short vegetation period and below optimum plant stands. Yield in the first sowing was restricted by cold, while in the last sowing it did not develop adequate leaf area (Cakmakci and Oral, 2001).

This study was proposed to evaluate the effects of four sowing times and four different irrigation Regimes on beet yield and quality to determine optimum sowing date and suitable amount of soil water condition.

MATERIALS AND METHODS

This field study was conducted in order to investigate the yield and quality of sugar beet Cv zargan in relation to sowing date and difference irrigation regimes during 2005 at Ardabil conditions. Ardabil is located in the north-west of Iran (Lat 38°, 11' N; Long 48°, 17' E and Elevation 1400 m) with mean 30 year averages of 303.9 rainfall per year and 9.0°C temperatures.

According to soil analysis carried out prior to sowing, the soil texture was a Sandy-clay-loam with EC = 0.753 dS m^{-1}, pH = 7.4, Organic Mater (%) = 1.9, Soil P_2O_5 = 12 ppm, K_2O = 379 ppm Field Capacity = 21% W/W, Wilting Point = 10% W/W and the Volume weight of the soil was 1.21 g cm^3.

Climate temperature and rainfall from sowing to harvest are presented in Table 1.

During growth season, the average temperature in Ardabil is within the optimum range for root development and below the retarding sugar accumulating temperature of 30°C (Kipps, 1981) while the drop in temperature in August-September period is conducive to raising the sugar content of the beet.

The experiment field received 80 kg ha^{-1} of P_2O_5, 2/3 of which was applied during deep ploughing in autumn and 1/3 in spring prior to disk harrowing. Nitrogen at a rate of 100 kg ha^{-1} was applied, in the form of urea, the first half of which during disk harrowing in spring and the remaining half before hoeing when the plants reached the 6 leaf stage.

The experimental design was a randomized complete block design with factorial arrangement in four replicates. In this experiment two factor with four levels were used: Sowing date (s_1 = 5 Apr, S_2 = 20 Apr, S_3 = 5 May and S_4 = 20 May) and irrigation including: I_1 = Irrigation at 13.3 of field capacity (30% FC).

Table 1: Mean temperature (°C) and rainfall (mm) of site from sowing to harvest

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Temp (°C)	-0.8	-2.0	5.5	10.3	13.6	15.7	20.0	19.0	16.5	12.5	6.0	4.9	10.1
Rainfall (mm)	16.3	13.9	33.5	24.6	81.1	16.1	5.2	1.9	14.9	22.1	45.2	5.6	280.4

I_2 = Irrigation at 15.5 F.C (50% F.C), I_3 = Irrigation at 17.7 F.C (70% F.C) and I_4 = Irrigation at 19.9 F.C (90% F.C).

To measure require water for each plot, following equation used:

Field capacity = 21% w/w
Wilting point = 10% w/w
Plot area = 5 × 8 = 40 m^2
Root depth = 45 cm

If Soil volume weight = 1.21 g cm^3 Therefore 1 m^3 (soil) = 1210 kg
Soil volume for irrigation = 40 (m^2) × 0.45 (m) = 18 m^3 → 18 m^3 soil = 21780 kg
I_1 = 21780 × 0.133 (w/w) = 2897 liter water per plot
I_2 = 21780 × 0.15.5 (w/w) = 3376 liter water per plot
I_3 = 21780 × 0.177 (w/w) = 3855 liter water per plot
I_4 = 21780 × 0.199 (w/w) = 4334 liter water per plot

The first sowing was done as soon as the soil conditions permitted and other sowings followed at approximately 15 day intervals. Each plot measured 5×8 m (= 40 m^2). The beet crop is grown at a density of eight plants m^2 (Smit, 1993; Akinerdem *et al.*, 1994; Lauer, 1995) by over-sowing and hand thinning to the required density.

The sugar beet was established with furrow irrigation on single row planting system. Irrigation treatments were done during June-August and then soil water content remained at field capacity for all treatments. Seedbed was prepared using the appropriate field machinery. Weeds were controlled by hand when necessary. Harvesting is done by pulling the beet manually and topped by cutting the crown at the base of the leaves. The topped beets were weighted for yield measurements and samples were taken for the determination of sugar content using the Pol method (Payne, 1968). Harvesting was done on 25 October and data were collected. Data were collected at harvest on root yield (t ha^{-1}), leaf yield (t ha^{-1}), sugar content (%), Molasses (%), pure sugar content (%), white sugar yield (t ha^{-1}), sodium (Na), potassium (K) and α-amino N.

Data given in percentages were subjected to arcsine transformation before statistical analysis. The SAS software package was used to analyze all the data (SAS, 2001) and means were separated by the least significant difference (LSD) test at $p<0.01$.

RESULTS AND DISCUSSION

Sowing date and irrigation had a significant effect on sugar yield and its quality. Potassium concentration was also significantly affected by sowing date but not by irrigation treatments. Interaction effects between sowing date and irrigation treatments were significant ($p<0.01$) for all adjectives. Mean yield and other studied adjectives which affected by sowing date, irrigation and interaction effects are presented in Table 2 and 3.

Mean root and leaf yield as affected by sowing date ranged from 48.75 to 65.5 t ha^{-1} and 24.37 to 30.16 t ha^{-1}, respectively (Table 2). Plants sown on 20 April had greater root and leaf yield compared on other treatments. Both early and late sowing decreased beet root and leaf yield. Yield in the early sowing restricted by cold while in the late sowing by shortened growth season. This was in agreement with previous findings by Cakmakci and Oral (2001) and Lauer (1997). Results of irrigation treatments showed that the optimum soil water content for root yield is 70% of field capacity with 66.5 t ha^{-1} (Table 2). The minimum root yield (47.36 t ha^{-1}) observed at 90% of field capacity.

Maximum leaf yield observed at sowing on 20 April and leaf yield reduced in other sowing dates. Irrigation at 50%, 70% of field capacity (I_2 and I_3) and 30%, 90% of field capacity (I_1 and I_4) had same effect on leaf yield. Abayomi (2002) found that Leaf growth showed high sensitivity to soil water deficit. Water deficit early in the growing season had larger effects on leaf growth. Mid- or late-season soil water deficit showed relatively smaller effects on leaf growth. Both early and late soil water deficit decreased sugar yield and sugar concentrations.

Sugar content (%) affected by sowing date and irrigation treatments (Table 2). However irrigation at 30, 50 and 70% of field capacity (I_1, I_2 and I_3) had same effect on sugar content while sugar content decreased at 90% field capacity (I_4).

Javaheri *et al.* (2006) concluded that sugar beet yield was related to root yield and not to sucrose content and that sucrose content was not affected by irrigation treatments. Also, Jaggard *et al.* (1998) and Wittenmayer and Schilling (1998) mentioned that if sugar beet subjected to water stress, the root yield decreased. Dunham (1993) found that early water stress (June and early July) decreased root yield more than late stress. Results of this study showed that mean white sugar yield

Table 2: Mean sugar beet yield and its quality as affected by sowing date and limited irrigation

Treatment	Sowing date				Irrigation			
Adjective	5 Apr.	20 Apr.	5 May	20 May	30% FC	50% FC	70% FC	90% FC
Root yield (t ha^{-1})	58.56^{ab}	65.50^{a}	55.50^{bc}	48.87^{c}	53.75^{bc}	60.81^{ab}	66.50^{a}	47.36^{c}
Leaf yield (t ha^{-1})	27.36^{ab}	30.16^{a}	26.15^{ab}	24.37^{b}	25.03^{b}	28.86^{a}	28.96^{a}	25.18^{b}
Sugar content (%)	17.27^{a}	16.77^{ab}	16.44^{b}	16.71^{ab}	16.82^{a}	17.26^{a}	17.19^{a}	15.92^{b}
Pure sugar content (%)	13.43^{a}	12.21^{b}	11.95^{b}	12.56^{ab}	12.71^{ab}	13.04^{a}	12.31^{ab}	12.08^{b}
Molasses (%)	3.86^{b}	4.56^{a}	4.49^{ab}	4.15^{ab}	4.11^{b}	4.22^{ab}	4.89^{a}	3.85^{b}
White sugar yield (t ha^{-1})	7.88^{a}	8.02^{a}	6.61^{b}	6.17^{b}	6.82^{a}	7.93^{a}	8.21^{a}	5.72^{b}
α-amino N*	1.67^{bc}	2.12^{a}	2.00^{ab}	1.56^{c}	1.57^{b}	1.88^{ab}	2.10^{a}	1.80^{ab}
Potassium (K)*	7.65^{a}	6.86^{b}	7.16^{ab}	6.71^{b}	7.33^{NS}	7.04^{NS}	7.06^{NS}	6.95^{NS}
Sodium (Na)*	1.60^{c}	2.14^{b}	2.05^{bc}	3.11^{a}	1.74^{b}	2.31^{a}	2.39^{a}	2.46^{a}

Means followed by the same latter(s) within row were not significantly different at the 0.01 probability level, according to the LSD test, NS: Not Significant. *: mmol/100 g root

Table 3: Interaction effects of sowing date and limited irrigation on beet yield and its quality

Sowing date × Irrigation	Root yield (t ha^{-1})	Leaf yield (t ha^{-1})	Sugar content (%)	Pure sugar content (%)	Molasses (%)	White sugar yield (t ha^{-1})	α-amino N*	Potassium (K)*	Sodium (Na)*
S_1I_1	51.50^{efgh}	25.68^{bcde}	17.17^{bc}	13.45^{ab}	3.73^{fgh}	6.93^{cdef}	1.20^{i}	7.82^{ab}	1.21^{f}
S_1I_2	63.75^{cd}	29.48^{ab}	17.80^{a}	14.22^{a}	3.58^{gh}	9.06^{a}	1.62^{fgh}	6.92^{bcd}	1.49^{ef}
S_1I_3	73.25^{ab}	28.63^{abc}	17.63^{ab}	13.27^{abc}	4.42^{bcde}	9.69^{a}	2.05^{abcd}	7.82^{ab}	1.85^{de}
S_1I_4	45.75^{ghi}	25.66^{bcde}	16.48^{def}	12.76^{bcd}	3.72^{fgh}	5.85^{fg}	1.80^{cdefg}	7.99^{a}	1.84^{de}
S_2I_1	63.00^{cd}	29.59^{ab}	16.92^{cde}	12.26^{def}	4.67^{bcd}	7.73^{bc}	1.87^{abcdefg}	7.48^{abc}	1.52^{ef}
S_2I_2	68.00^{bc}	31.77^{a}	17.45^{abc}	12.63^{bcde}	4.83^{bc}	8.60^{ab}	2.23^{ab}	7.15^{abcd}	2.38^{c}
S_2I_3	78.50^{a}	32.03^{a}	17.23^{abc}	12.15^{defg}	5.08^{ab}	9.54^{a}	2.24^{ab}	6.26^{d}	2.39^{c}
S_2I_4	52.50^{efgh}	27.24^{abcd}	15.50^{h}	11.81^{defg}	3.67^{gh}	6.2d^{ef}	2.16^{abc}	6.55^{cd}	2.27^{c}
S_3I_1	56.75^{def}	23.25^{cde}	16.85^{cde}	12.72^{bcd}	4.14^{defg}	7.21^{cd}	1.70^{defg}	7.32^{abc}	1.30^{f}
S_3I_2	58.00^{de}	28.02^{abc}	16.45^{def}	11.74^{efg}	4.71^{bcd}	6.82^{cdef}	2.01^{abcde}	7.55^{abc}	2.37^{c}
S_3I_3	58.25^{de}	27.71^{abc}	16.90^{cde}	11.22^{g}	5.68^{a}	6.52^{cdef}	2.32^{a}	7.06^{abcd}	2.21^{cd}
S_3I_4	48.75^{fghi}	25.60^{bcde}	15.50^{gh}	12.13^{defg}	3.45^{h}	5.90^{efg}	1.98^{abcdef}	6.73^{cd}	2.34^{c}
S_4I_4	43.75^{hi}	21.60^{e}	16.33^{ef}	12.40^{cdef}	3.92^{efgh}	6.18^{def}	1.52^{ghi}	6.69^{cd}	2.94^{b}
S_4I_2	53.25^{efg}	26.19^{bcde}	17.33^{abc}	13.58^{ab}	3.74^{fgh}	7.24^{cd}	1.67^{efg}	6.56^{cd}	3.02^{ab}
S_4I_3	56.00^{def}	27.47^{abcd}	17.02^{bcd}	12.65^{bcde}	4.38^{cdef}	7.08^{cde}	1.78^{defg}	7.06^{abcd}	3.12^{ab}
S_4I_4	42.50^{i}	22.23^{de}	16.17^{fg}	11.61^{fg}	4.56^{bcde}	4.93^{g}	1.26^{hi}	6.53^{cd}	3.38^{a}

Means followed by the same latter(s) within column were not significantly different at the 0.01 probability level, according to the LSD test,*: mmol/100 g root

(t ha^{-1}) was decreased by late sowing and not affected by early sowing (Table 2). Sowing on 5 and 20 April (S_1, S_2) had same effect on sugar yield and obtained maximum sugar yield. Sugar yield decreased at sowing on 5 and 20 May (S_3, S_4). In fact only late sowing decreased sugar yield and early sowing was not affected sugar yield. Also sugar yield was not affected by irrigation treatments exception I_4.

The concentrations of K, Na and α-amino N present as impurities in extracted root sap have been shown to be inversely related to the amount of extractable sugar (Last *et al*., 1983).

Potassium concentration was not affected by irrigation treatments but it was affected by sowing date. At this case, no significant effect was shown between S_2 and S_3 (Table 2).

Cakmakci and Oral (2001) and Javaheri *et al*. (2006) showed that Potassium concentration increased with late sowing. Late sowing caused increasing at sodium concentration (Table 2). α-amino N showed significantly effect on different sowing date (Table 2). This was in line with the results of Cakmakci and Oral (2001) who showed sodium concentration increased with late sowing. Irrigation at 50, 70 and 90% of field capacity (I_2, I_3 and I_4) had same effect on sodium concentration, but irrigation at 30% of field capacity (I_1) decreased sodium concentration. Interaction effects of fresh root and leaf yield of sugar beet are shown in Table 3.

Comparison of treatments showed that the high root yield obtained at sowing on 20 April (S_2) and irrigated at 70% of field capacity (I_3). Low root yield in S_4I_4 returned to short season at this treatment (Table 3). The highest and lowest leaf yield was obtained at S_2I_2, S_3I_3 and S_4I_1 respectively. Therefore early and late sowing can decrease root yield but only late sowing can decrease leaf yield. Kenter *et al.* (2006) concluded that irrigation (soil water content) had no significant influence on leaf growth rate but root growth rate increased significantly with increasing soil water content.

CONCLUSION

Results showed that the optimum soil water content for root yield in Ardabil condition is 70% of field capacity.

Optimum sowing date in Ardabil condition is 20 April for root yield. Sugar content was not affected by I_1, I_2 and I_3 but it was decreased at 90% of field capacity. Therefore sowing at 20 April and remaining soil water content at 70% of field capacity was suggested in beet cultivating in Ardabil condition.

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