INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
07–445/MFA/2008/10–4–427–431
http://www.fspublishers.org

Full Length Article

Influence of Withholding Irrigation and Harvest Times on Yield and Quality of Sugar Beet (*Beta vulgaris*)

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ABSTRACT

In order to evaluate the effects of irrigation withholding and harvest times on yield and quality of sugar beet, field experiments were conducted in 2004 and 2005. The experiment was consisted of four harvest times (155, 170, 185 & 200 days after emergence) and four irrigation withholding dates (10, 20 30 & 40 days before harvest). Different harvest times and irrigation withholding dates significantly affected the root and sugar yield. Root and sugar yield and sugar content were increased significantly with the delay of harvest time. Increase in length of irrigation cutoff date from 10 to 40 days before harvest reduced root yield but increased total and white sugar content. The highest sugar and white sugar yield in our study were achieved at the last harvest time (200 days after emergence) and irrigation cutoff date of 10 days before harvest, that had no significant difference with irrigation cutoff dates of 20, 30 and 40 days before the last harvest time. Producing near equivalent amounts of sugar with less irrigation (irrigation cutoff date of 40 days before harvest) can increase the efficiency of sugar beet irrigation. Reduction of sugar beet irrigation during late growth season could decrease irrigation amounts and it is important for areas with water deficit in harvest period.

Key Words: Harvest time; Irrigation cutoff; Sugar content; Root and sugar yield

INTRODUCTION

All crops need adequate water supply to harvest maximum economic yield (Ghariani, 1981). Water supply is often regarded as one of the major factor affecting sugar beet (*Beta vulgaris* L.) growth and yield (Jaggard *et al.*, 1998). Water deficiency during the early growing season is the main cause of potential yield loss in sugar beet production (Abdollahian–Noghabi, 1999). Water deficit near the end of growth periods may have less effect on sugar beet yield and result in saving irrigation water (Kaffka *et al.*, 1997). Irrigation management and its cutting off in a short period prior to harvest have to be based on decreasing growth and at the same time with maintaining the size of photosynthetic machinery (Khajehpoor, 1991). Howell *et al*. (1987) reported that irrigation cutoff at 7 weeks prior to harvest significantly reduced water use in sugar beet without a significant decline in sucrose production. In another study, withholding water application during ripening stage saved nearly 22% water without any significant loss in sugar yield (Kirda *et al.*, 1999). An experiment for evaluating the effects of water stress near the end of growth season indicated that irrigation cutoff after irrigation sugar beet two months prior to harvest had no significant effect on total sugar production (Carter *et al.*, 1980).

Harvest time is one of the factors that affect yield and quality of sugar beet crop (Koocheki & Soltani, 1996). According to Minx (1999), an early beginning of the harvest season leads to considerable production losses. Likewise Jozefyova *et al*. (2004) reported that delay in harvesting resulted in increased the white sugar yield. Also Cakmakci and Oral (2002) found that delay in the harvest time would increase recoverable sugar yield. On the other hand, Alimoradi (1988) stated that sugar industry has accepted early harvest time of sugar beet, because early harvest protects it from the cold and freezing that reduce photosynthesis rate and sucrose accumulation. This experiment was undertaken in order to investigate the effects of irrigation cutoff and harvest time on yield and quality of sugar beet.

MATERIALS AND METHODS

In order to evaluate the effects of harvest times and irrigation cutoff dates on yield and quality of sugar beet a factorial experiment with two factors based on randomized complete block design with three replications was conducted in Mokrian Agricultural Extension Center near Mahabad, Western Azerbaijan, Iran during 2004 and repeated in 2005. Factors include harvest times (155, 170, 185 & 200 days after emergence) and four irrigation cutoff dates (10, 20 30 & 40 days before harvest). Weather data for 2004 and 2005 and long term average for 1985-2005 are presented in Table I. The soil type was clay loam.

To cite this paper: Sohrabi, Y. and G. Heidari. 2008. Investigating the influence of withholding irrigation and harvest times on yield and quality of sugar beet (*Beta vulgaris*). *Int. J. Agri. Biol.,* 10: 427–31

Before sowing, the experimental area was plowed, fertilized with 125 kg N ha^{-1}, (1/2 before sowing + 1/2 as top dressing), 100 kg P_2O_5 ha^{-1} and 100 kg K_2O ha^{-1} and disked in the spring prior to sowing in both years. Individual plots were 25 m^2 having 6 rows of 7 m length and were separated from each other by 1 m wide buffer plots. Sugar beet seeds were sowed on April 20^{th} and 25^{th} in 2004 and 2005 growing seasons respectively. Plots were irrigated immediately after sowing to assure uniform germination. Later on irrigation intervals were determined on the basis of sugar beet need. All plots were irrigated uniformly until the first irrigation cutoff treatment was initiated. Cutoff treatments were done 10, 20, 30 and 40 days before each harvest time in both years. Sugar beets in each plot were harvested from middle rows on 22 September, 7 and 22 October and 6 November in 2004 and on 27 September, 12 and 27 October and 11 November in 2005. After measuring the sugar beet root yield, a 30 kg sample from each plot was obtained randomly. About 150 g of pulp from each plot was prepared by Venema apparatus and kept in a freezer until analysis. Frozen sugar beet pulp samples were analyzed in sugar technology laboratory in Sugar Beet Seed Preparing and Breeding Center at Karaj of Iran for purity parameters with Betalyser (model OR-KERNCHEN). Betalyser is a computer-controlled system for automated routine analysis of sugar beet on sugar content and impurities including Na^+, K^+ and NH_4^+-N. Sugar content (SC) was measured by polarimetr, Na^+ and K^+ by flame-emission photometry and NH_4^+-N by double beam filter photometry using the blue number method (Sheikh_Aleslami, 1997). The combined effect of Na^+, K^+ and NH_4^+-N on the amount of sugar lost to molasses in the factory process was determined following the Reinfeld *et al.* (1974) method.

Molasses sugar (MS) = $0.343 * (K^{\pm} + Na^{\pm}) + 0.094 * NH_4^+\text{-N} – 0.31$.

[Na^+, K^+ and NH_4^+-N in meq (100 g^{-1} beet).

Standard factory loss (SFL = 0.6).

White sugar contents (recovered sugar content) were calculated using the formula of Reinefeld *et al*. (1974):

WSC = SC– MS– SFL

White sugar yield (WSY) = root yield (RY) * WSC.

An alkalinity coefficient (AC) was determined from the major non-sugars $K^{\pm}$, $Na^{\pm}$ and NH_4^+-N, as follows (Sheikh_Aleslami, 1997):

$AC = (K^+ + Na^+)/ NH_4^+\text{-N}$

Gross sugar yield and white sugar yield were obtained multiplying sugar content (SC) and white sugar content (WSC) by root yield.

The data obtained were subjected to the combined analysis of variance over years and the chi-square test was used to verify homogeneity of variance before combining data. Least significant difference (LSD) test was used for means separation by using the MSTATC statistical software (Anonymous, 1986). Graphs were drawn by Microsoft Excel software (Anonymous, 2005).

RESULTS AND DISCUSSION

Analysis of variance. Combined analyses of variance over years showed that harvest time and irrigation cutoff date were statistically significant for all traits. Interaction of harvest time and irrigation cutoff date was significant for sugar and white sugar content and root, gross sugar and white sugar yield. Effect of year was not significant for studied variables (Table II). Therefore, average of data from two years was used for interpretation.

Root yield. Sugar beet root yield was increased as the harvest was delayed and the length of the cutoff period was decreased. The highest root yield was achieved at the last harvest time (200 days after emergence) and irrigation cutoff date in 10 days before harvest, but was not significantly different from harvest time 185 days after emergence and irrigation cutoff date in 10 days before

Fig. 1. Sugar beet root yield at different harvest times and irrigation cutoff dates, Symbols represent mean values of two years (2004 & 2005)

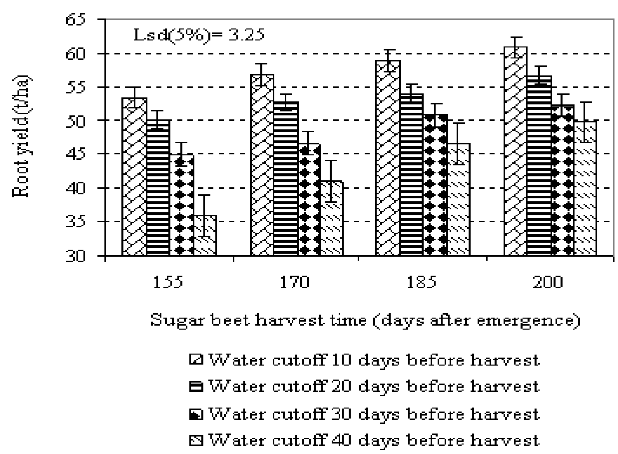


Fig. 2. Sugar beet sugar and white sugar content at different harvest times and irrigation cutoff dates, Symbols represent mean values of two years (2004 & 2005)

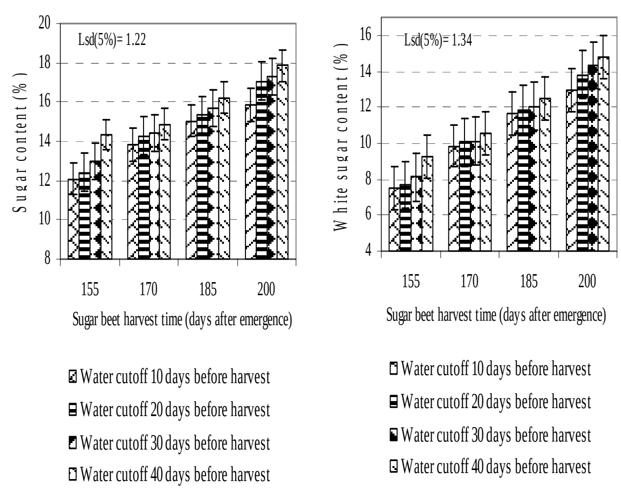


Table I. Some meteorological data for the growing seasons of 2003 and 2004 in Mahabad, Iran

	rainfall (mm)			Average temperature (°C)		
Month	**2003**	**2004**	**long term average ***	**2003**	**2004**	**long term average ***
April	13	18	54	10.5	8.9	9.9
May	94	135	49	17.7	12.2	15.7
June	5	9	3	19.9	17.1	23.2
July	3	14	2	27.6	22.9	23.2
August	0	0	1	26.3	25.6	23.0
September	0	0	1	23.5	21.0	21.7
October	17	16	27	19.7	18.3	16.2
November	45	31	48	10.7	9.7	8.2

*Long term average from 1984 to 2004

Table II. Combine analysis of variance over years (2004 & 2005) for sugar beet yield and quality characters at four harvest time and four irrigation dates

		Mean saquares					
Source of variation	**DF**	**Root yield**	**Gross sugar yield**	**White sugar yield**	**Sugar content**	**White sugar yield**	**Sugar content of molasses**
Year (Y)	1	591.23	1.99	0.14	10.63	13.59	0.18
R/Year	4	1163.13	1.60	0.14	69.15	67.86	0.13
Harvest time of sugar beet (H)	3	427.01**	61.99**	73.66**	60.18**	126.72**	10.54**
H*Y	3	1.90	0.14	0.22	0.05	0.07	0.10
Irrigation cut off date (1)	3	1061.27**	15.61**	7.09**	15.68**	10.57**	0.28**
I*Y	3	1.32	0.12	0.08	0.06	0.04	0.01
H*I	9	21.39*	0.85*	0.49*	2.40*	2.82*	0.04
H*I*Y	9	0.24	0.05	0.05	0.01	0.01	0.01
Error	60	7.96	0.36	0.17	1.13	1.36	0.04
CV (%)		5.77	7.35	6.94	7.14	10.47	5.38

*and ** significant at 1% and 5% Probability levels, respectively

harvest (Fig. 1). The main reason for increasing root yield due to the delay of harvest time is attributed to the increase of growth duration and photo-assimilation (Burcky & Winner, 1986; Koocheki & Soltani, 1996). On the other hand having enough moisture on the whole of vegetation period is one of the key preconditions of increasing root yield of sugar beet (Minx, 1999). More production of root yield in irrigation cutoff date of 10 days before the latter harvest times (185 & 200 days after emergence) shows that water take up at the end of growth season could cause plants to have active leaves with more strong photosynthetic apparatus and subjected to it the growth of root to be continued. Other researchers reported decreasing of sugar beet root yield due to decreasing growth period (Marlander, 1992) and increasing the length of irrigation cutoff period (Asad *et al*., 2000).

Sugar and white sugar content. Sugar beet sugar and white sugar content increased as harvest was delayed and the length of irrigation cutoff period increased. The highest sugar and white sugar content were achieved at the last harvest time (200 days after emergence) and irrigation cutoff date in 40 days before harvest, but was not significantly different from irrigation cutoff dates of 30 and 20 days before harvest at harvest time of 200 days after emergence (Fig. 2). Bajci (1990) found that root formation and sugar accumulation in the root would occur with different intensity throughout the whole vegetative period. Root growth slows down at the end days of growth season and is followed by an intensive accumulation of dry mass (increasing sugar content). In our experiments, the difference among all harvest times was significant for sugar and white sugar content (Fig. 2), but sugar beet root yield in harvest time of 200 days after emergence had no significant difference with harvest time of 185 days after emergence (Fig. 1). This shows slower growth of root yield in comparison with sugar and white sugar content. Sugar and white sugar content were higher in beets grown with larger cutoff duration at all harvest times (Fig. 2). Saffarian *et al*. (2006) also reported that sugar and white sugar content of sugar beet decrease due to the increase of irrigation cutoff duration.

Gross and white sugar yield. Gross sugar and white sugar yield in harvest time of 200 days after emergence and irrigation cutoff date of 10 days before harvest were the highest among all harvest times and irrigation cutoff dates but were not significantly different from the other irrigation cutoff dates in harvest time of 200 days after emergence (Fig. 3). Increasing of gross sugar and white sugar yield due to delay in harvest time was the result of effects on the root yield and sugar and white sugar content of sugar beet (Fig. 1 & 2). According to Jozefyova *et al*. (2004), postponement of the time of harvest brings an increase of white sugar yield by 0.69% for each day of extension of vegetation period in autumn. Gross sugar and white sugar yield were equivalent when irrigation was cutoff over 10 to 40 days before the last harvest (200 days after emergence) (Fig. 3). This means that in last harvest time of our experiment, reduction in sugar beet root yield due to increasing the length of the cutoff

Fig. 3. Sugar beet gross sugar and white sugar yield at different harvest times and irrigation cutoff dates, Symbols represent mean values of two years (2004 & 2005)

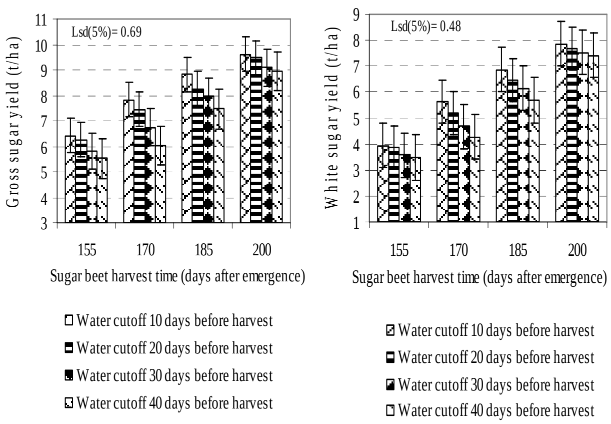


Fig. 4. Effect of harvest time on sugar beet sugar content of molasses (Mean of 2004 & 2005)

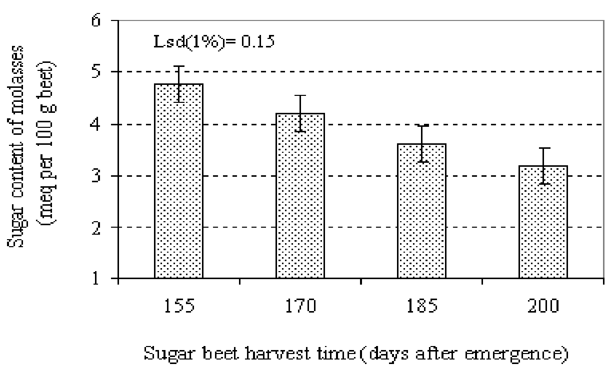
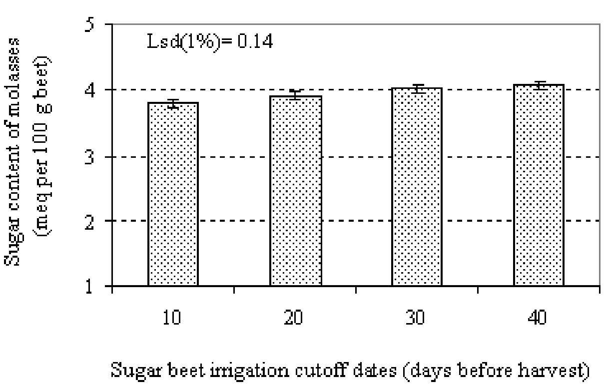


Fig. 5. Effect of irrigation cutoff date on sugar beet sugar content of molasses (Mean of 2004 & 2005)



period is coincided with increasing percentage of sugar and white sugar content, and then the gross and white sugar yield did not change significantly. In an experiment, increasing the length of irrigation cutoff period from 2 weeks to 8 weeks prior to harvest significantly increased sucrose percentage within the root and resulted in similar total sugar yields (Noorjoo & Baghaiikia, 2004).

Sugar content of molasses. The delay in harvest time of harvest reduced sugar content of molasses within sugar beet root. Sugar content of molasses was significantly higher in the last harvest time (200 days after emergence) (Fig. 4). According to the results published by Marlander (1990), the postponement of harvest time reduces root impurities concentration and resulted in decreasing in sugar content of molasses. Sugar content of molasses increased as the length of irrigation cutoff period increased (Fig. 5). Saffarian *et al.* (2006) also reported the increase of sugar content of molasses within root due to increasing the length of cutoff period.

CONCLUSION

Present study showed that gross and white sugar yield increased significantly with the delay of the harvest time. This was due to the increase of root yield and sugar and white sugar content. The increasing the length of cutoff period decreased root yield and increased sugar and white sugar content from 10 to 40 days before all harvest times. Producing near equivalent amounts of sugar with less irrigation (irrigation cutoff date of 40 days before harvest) can increase the efficiency of sugar beet irrigation.

Acknowledgement. We are thankful to Mr. Fotoohi from Sugar Beet Seed Institute of Iran for his help in the analysis of quality characters. We are grateful to Mr. Keykhosravi and Mr. Sheikh Aghaii for their permission to carry out the experiment in Mokrian Agricultural Extension Center.

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(Received 21 December 2007; Accepted 26 February 2008)