



Full Length Article

Influence of Harvesting Time on Yield and Yield Components of Sugar Beet

GHOLAMREZA HEIDARI, YOUSEF SOHRABI¹, BEHROOZ ESMAILPOOR[†]

Department of Agronomy and Plant Breeding, Faculty of Agriculture, University of Kurdistan, Sanandaj, Iran

[†]Department of horticulture, Faculty of Agriculture, University of Mohaghegh Ardabili, Ardabil, Iran

¹Corresponding author's e-mail: yousef1350@gmail.com

ABSTRACT

A split plot experiment was conducted to determine the effects of the harvest time on yield and yield components of four sugar beet genotypes (Rasoul, Shirin, Dorothea & BR₁). Sugar beet was harvested at five different times (123, 139, 155, 171 & 187 days after emergence). Results showed no significant difference between sugar beet genotypes for studied traits. Leaf area index was affected by year, which was greater in 2003 than 2004 at all harvest times, probably due to more favorable conditions in 2003. Total sugar and white sugar content were increased at all harvests. Late harvesting (187 days after emergence) resulted in greater yield of root, total and white sugar yield than earlier harvesting. The highest white sugar yield was obtained at the last harvest of the sugar beet when rainfall and low temperature did not occur.

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

INTRODUCTION

Sugar beet provides more than one-half of sugar produced in United States and about 40% of sugar production in the world. The root of this crop contains 13-22% sugar content (Cattanach *et al.*, 1991). In general sugar beet also has a major role in human diet and it is mainstay parts of agriculture economy in Iran. The leaves of sugar beet comprise as the main light receptor organ for crop. Leaf area development early during season causes more efficient use of sunlight, since it is important to the formation and expansion of canopy (Sarmadnia & Koocheki, 1997).

There is a close relationship between yield and production of leaf area. Yield is affected by the amount of radiation received by the leaves (Fortune *et al.*, 1999; Sarmadnia & Koocheki, 1997). Sugar beet yield include biomass, root and sugar yield, but economic characters are storable root and percentage of sugar (Koocheki *et al.*, 1996). In fact sugar yield is a portion of root dry matter and higher yield of sugar is obtained when higher amount of dry matter is produced in root (Lauer, 1995). Sugar yield comprises two aspects: total sugar yield that is obtained from root yield multiple by total sugar content and white sugar yield that is obtained from root yield multiple by white sugar content. White sugar yield is important to sugar industry (Koocheki *et al.*, 1996). Sugar beet in primary growth stages needs warm and sunny climate and optimum water supply for optimal photosynthesis and photoassimilate partitioning (Fortune *et al.*, 1999).

Time of harvest is one of the factors that affects on yield and quality of sugar beet crop. The root dry matter

percentage, increases with passing growth period of plant and the amount of sugar reaches to 20-26% at the time of harvest. This dry matter contains sugar (especially sucrose) and several organic and mineral sources (Koocheki, 1996). Brown (1997) reported that a delay in sugar beet harvest till the end of autumn leads to decrease in sugar beet root and sugar yield and sucrose percentage and white sugar content (Lauer, 1995). Jaggard and Scott (1999) and Burcky and Winner (1986) suggested that later harvest dates for sugar beet result in greater sugar yield under no rainfall and cold weather. Jozefyová *et al.* (2004) evaluated the harvest time effect on production of two different sugar beet varieties grown in five variants nitrogen fertilization and reported the postponement of the time of harvest (by 27 days) and increased average root yield by 11.35 t ha⁻¹. They also concluded that white sugar yield increased by delay in harvest by 1.69 t ha⁻¹. Kerr and Leaman (1997) in a two year experiment showed that the yield was increased under irrigation from the first till the last harvest.

An intense need to provide foodstuffs for population is growing and the establishment of food security demands increased agricultural productions (Tavakkoli, 2000). Evaluation on the yield and yield components during last stages of growth can determine the best time for the harvest of sugar beet. This may prevent the reduction of sugar and root yield at early or late harvesting.

MATERIALS AND METHODS

This experiment was conducted at Miandoab Agricultural Research Station in 2003 and repeated in 2004.

Some climate data for 2003 and 2004 and long term average for 1984-2004 are presented in Table I. The experiment was conducted using a split plot design arranged in randomized complete block design with three replications. Four genotypes of sugar beet (Rasoul, Shirin, Dorothea & BR₁) were allocated to the main plots and five harvesting dates (123, 139, 155, 171 & 187 day after germination) were placed in subplots. Plot size was of 4×15 m. Spaces between blocks and plots were three and one meter respectively. There were 11 rows each spaced 25 cm apart in each plot. Seeds were sown on 28 April during 2003 and 2004 at 4 cm depth. All recommended agronomic practices were carried out. Some chemical properties of soil at experimental field have been presented in Table II.

The first harvest was carried out 123 days after emergence and the subsequent harvests were carried at intervals of 15 to 17 days till the last harvest. Each time nine m² areas from each plot were harvested after omitting margin effect and 35 plants were evaluated as standard of that plot. For measurement of leaf area, four leaves per plant were harvested in determined intervals once in several days. Leaf area was measured by leaf area meter (Model LI-3100, Li-Cor, Inc. Lincoln NE), and leaf area index was also determined. The root weight per plot was taken and converted to yield per hectare. After washing the roots a sample of pulp (150 g) was prepared by Venema apparatus and set in special containers. After setting nylon cover, the samples were immediately transferred to freezer and were maintained till analysis at -20°C.

Frozen sugar beet pulp samples were analyzed in sugar technology laboratory in Sugar Beet Seed Preparing and Breeding Center at Karaj, Iran for purity parameters with Betalyser (a computer-controlled system) i.e., sugar content and impurities like sodium, potassium and amino-

nitrogen. Sugar content (SC) was measured by polarimetry, Na and K by flame-emission photometry and amino-N by double beam filter photometry using the blue number method (Sheikh_Aleslami, 1997). Combined effect of Na, K and amino-N on the amount of sugar lost to molasses (MS) was calculated with the method of Reinefeld *et al.* (1974):

$$MS = 0.343 * (K + Na) + 0.094 * \text{amino-N} - 0.31. \\ [K, Na \text{ and amino-N in meq } (100 \text{ g}^{-1} \text{ beet})]$$

White sugar content (Recovered sugar content) calculated using the Reinefeld *et al.* (1974) formula:

$$WSC = SC - MS - SFL$$

Where standard factory loss, SFL = 0.6).

$$\text{White sugar yield (WSY)} = \text{root yield (RY)} * \text{WSC.}$$

Total and white sugar yield were obtained multiplying sugar percent and white sugar percentage by root yield. Leaf area index determined according to observed data and following formula for each plot in each year:

$$LAI = a + bt + ct^2$$

The data were subjected to the combined analysis of variance over years and LSD test was used for means separation by using the MSTATC statistical software.

RESULTS AND DISCUSSION

Combined analysis of variance over years (Table III) showed that the effect of harvest times and interaction between crop harvest time and year was significant ($P < 0.01$) on leaf area index, sugar content, white sugar content, total sugar and white sugar yield. However the cultivars have not significant difference for these traits. The highest amount for this trait was obtained in the first harvest (123 days after plant emergence) in both years, which reduced slightly at the last harvest (Fig. 1). This decline occurred due to decreased plant growth as result of falling temperature and decreases in light absorption during the end growth stages and to grow old and falling of leaves. As could be seen (Fig. 1), in all of the crop harvest time the amount of leaf area index almost has the highest value at 2003 in comparison to 2004, which is probably due to existence more favorable conditions climate in the first year.

The amount of sugar content increased from the first harvest till the last harvest in both years but the increasing procedure of that decreased at the last harvests (Fig. 2). This enhancement can be related to increased root dry weight, which contained sucrose as a major portion (Koocheki, 1996). This decrease at the end of growth season at 2004 resulted from decrease in plant growth rate due to unfavorable climatic conditions (especially light) in autumn, which reduced production and storage of sugar. In relation to harvesting date effect on sugar yield, Jaggard and Scott (1999) and Burcky and Winner (1986) have suggested that at later harvest dates produced more sugar yield under no rainfall and cold weather.

White sugar content increased during growth season

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

Month	rainfall (mm)			Average temperature		
	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. Some chemical properties of soil at experimental field

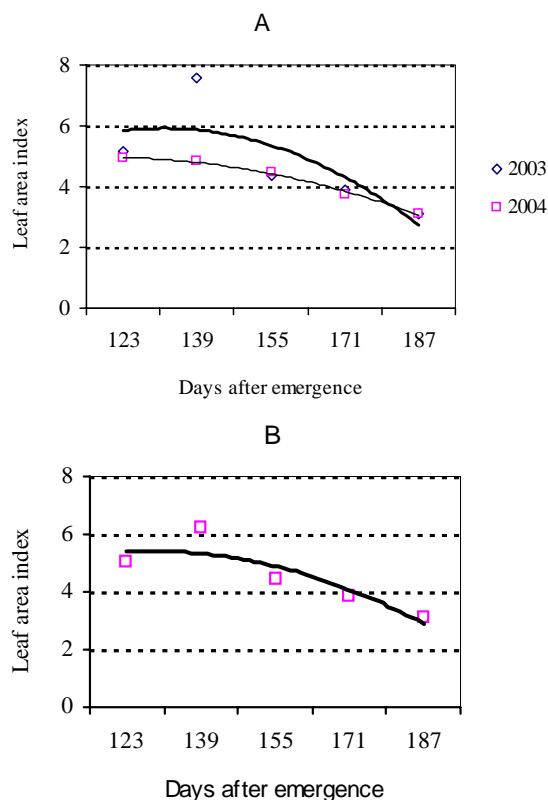
Soil depth (cm)	Available K (ppm)	Available P (ppm)	Total N (%)	Organic carbon (%)	Acidity of mud saturation (pH)	ECe (dS m ⁻¹)
0-30	209	10.65	0.08	0.78	9.97	8.62
30-60	108	5.49	0.04	0.33	9.67	3.67

Table III. Combined analysis of variance over years for sugar beet cultivars and harvest time on some traits

Source of variation	Degrees of freedom	Mean squares					White sugar yield
		Leaf area index	Sugar content	White sugar content	Root yield	Sugar yield	
year	1	10.906 ^{n.s}	5.963 ^{n.s}	17.741 ^{n.s}	4233.082 [*]	94.340 [*]	49.404 [*]
error 1	4	14.548	5.572	13.076	352.102	6.636	4.591
cultivar	3	5.764 ^{n.s}	0.800 ^{n.s}	0.523 ^{n.s}	1.342 ^{n.s}	0.709 ^{n.s}	0.561 ^{n.s}
cultivar×year	3	6.115 ^{n.s}	2.138 ^{n.s}	6.110 ^{n.s}	702.087 ^{n.s}	24.343 ^{n.s}	22.696 ^{n.s}
error 2	12	2.712	8.351	14.987	201.769	11.115	11.439
harvesting time	4	33.861 ^{**}	50.709 ^{**}	69.349 ^{**}	25.433 ^{**}	129.807 ^{**}	121.568 ^{**}
harvest time×cultivar	12	0.467 ^{n.s}	0.617 ^{n.s}	0.643 ^{n.s}	0.495 ^{n.s}	0.304 ^{n.s}	0.310 ^{n.s}
harvest time×year	4	8.721 ^{**}	16.281 ^{**}	20.622 ^{**}	111.125 ^{n.s}	14.401 ^{**}	16.440 ^{**}
harvest time×cultivar×year	12	1.254 ^{n.s}	3.242 ^{n.s}	4.883 ^{n.s}	33.133 ^{n.s}	1.882 ^{n.s}	2.260 ^{n.s}
error 3	64	2.137	1.729	2.605	72.368	2.654	2.422
coefficient of variation		32.326	7.988	11.729	14.999	17.295	19.657

^{n.s} non significant, * and ** significant at 0.05 and 0.01 levels

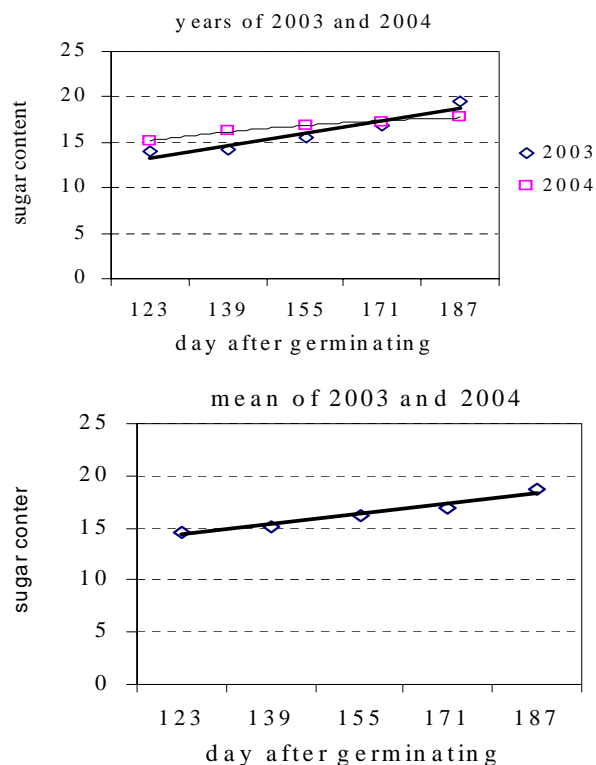
Fig. 1. The alterations procedure of sugar beet leaf area index, during growth season in two years of 2003, 2004 and the mean of two years



from the first harvest till the last harvest during 2003 and 2004 and mean of two years (Fig. 3), which was consistent with the findings of Lauer (1995). During both the years, the amount of root yield indicated additional procedure during growth season and the highest root yield was obtained at the last harvest (Fig. 4). Kerr and Leaman (1997) also showed that yield was increased from the first harvest till the last harvest in both years.

The amount of sugar yield increased till the last

Fig. 2. The alterations procedure of sugar beet sugar content, during growth season in two years of 2003, 2004 and mean of two years



harvest (187 day after plant emergence). This increasing trend was decreased at the final harvests during 2004, because of un-favorable climatic conditions (especially light) in this year. Also growth and production of assimilates decreased and resulted in reduction of sugar and dry matter reserving in root (Fig. 5). The amount of sugar yield in 2003 was higher than 2004, due to greater leaf area index as the main organ of photosynthesis that provided more photosynthetic matters for plant growth, root development and dry matter reserving in root, during the

Fig. 3. The alterations procedure of sugar beet white sugar content, during growth season in two years 2003, 2004 and mean of two years

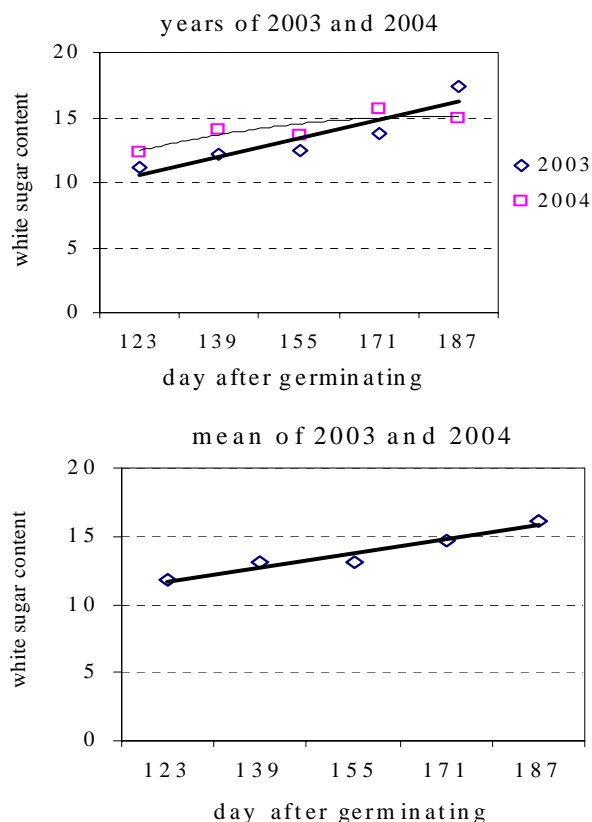
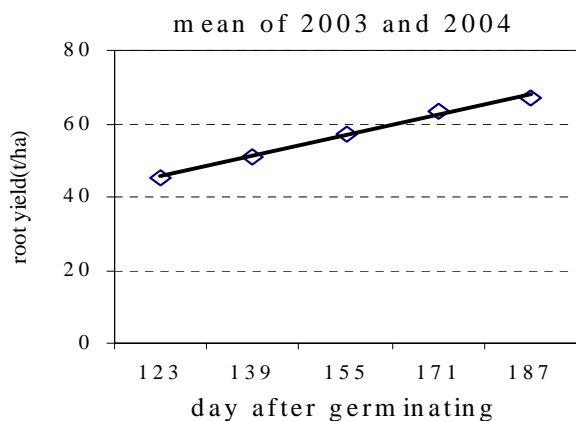


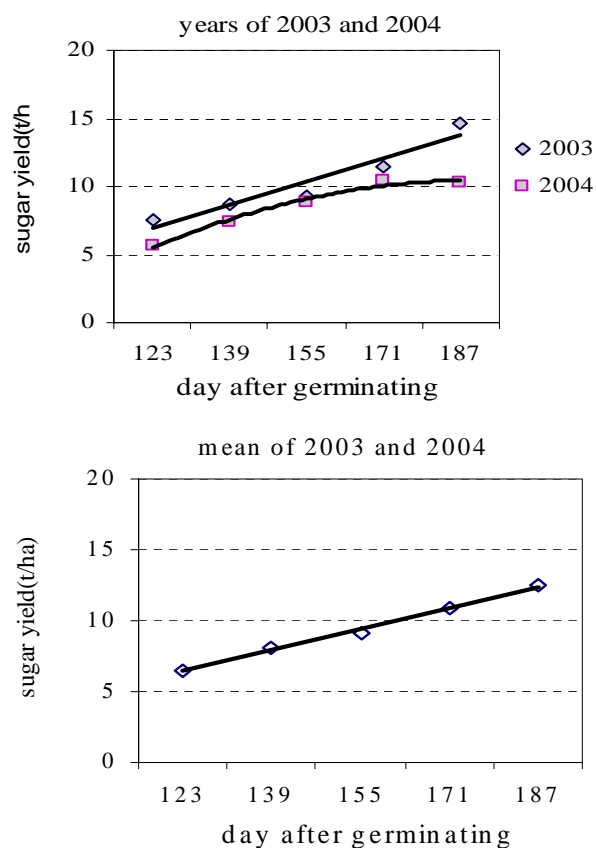
Fig. 4. The alterations procedure of sugar beet root yield, during growth season in mean of two years of 2003 and 2004



first year.

White sugar yield, which is the most important economic indicator in sugar beet production, was increased during growth season from the first up to the last harvest during both the years. This increase was due to increase in root yield and white sugar content during this period. Laure

Fig. 5. The alterations procedure of sugar beet sugar yield, during growth season in two years 2003, 2004 and mean of two years



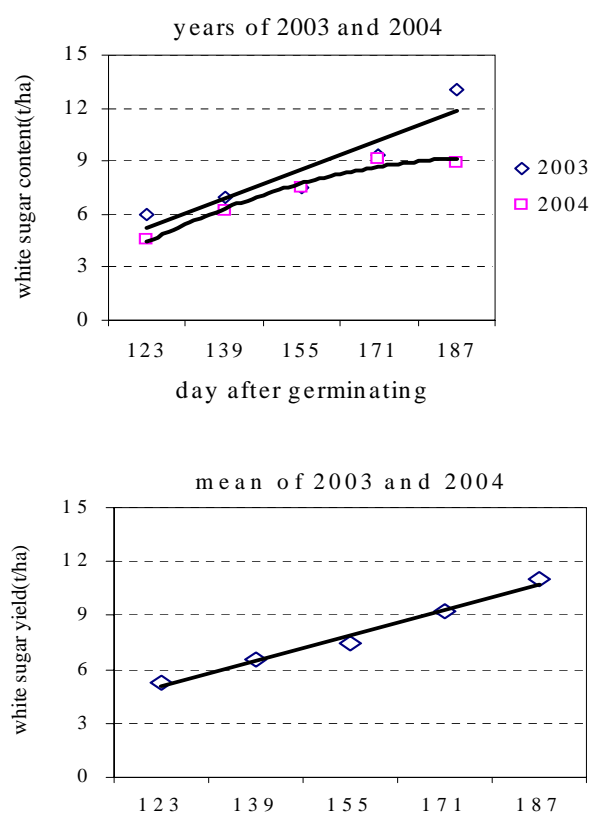
(1995) showed that the later harvesting dates produce more root yield, sucrose percentage and white sugar content, because of extended growth period under no rainfall and cold weather, which was in agreement with the findings that the postponement of the time of harvest by 27 days increased root yield and white sugar yield on average by 11.35 and 1.69 t ha⁻¹, respectively (Jozefyová *et al.*, 2004). A comparison of years indicated that over the mean of three last harvests, the amount of white sugar yield was greater in 2003 (Fig. 6), because both these factors forms the white sugar yield, root yield and white sugar content were greater in 2003 than 2004 due to better vegetative growth photosynthesis (Figs. 3 & 4).

CONCLUSION

A delay at the time of harvest increased leaf area index, root yield and root sugar content due to extending the growth period, sunny days and cool nights of autumn, which are the best conditions for sugar producing and reserving in sugar beet.

Acknowledgement. We are thankful to Mr. Fotoohi from Sugar Beet Seed Institute of Iran for his permission to carry out the experiment in Miandoab Agricultural Research Station and his help in the analysis of quality characters.

Fig. 6. The alterations procedure of sugar beet white sugar yield, during growth season in two years 2003, 2004 and mean of two years



REFERENCES

- Brown, S., 1997. Quality harvesting program. *Bri. Sugar Beet Rev.*, 65: 12-3
- Burcky, K. and C. Winner, 1986. The effect of plant population on yield and quality of sugar beet at different harvesting date. *J. Agron. Crop Sci.*, 157: 264-72
- Cattanach, A.W., A.G. Dexter and E.S. Oplinger, 1991. *Sugarbeets. Alternative Field Crops Manual.* University of Wyoming Cooperative Extension and University of Minnesota Center for Alternative Plant and Animal Products and Minnesota Extension Service, (<http://www.hort.purdue.edu/newcrop/afcm/sugarbeet.html>)
- Fortune, R.A., J.I. Burke, T. Kennedy and E. O'Sullivan, 1999. *Effect of Early Sowing on the Growth, Yield and Quality of Sugar Beet.* Crops Research Centre, Oak Park, Carlow
- Jaggard, K.W. and K. Scott, 1999. The origins of yield improvement in the national sugar beet crop science 1970. *Bri. Sugar Beet Rev.*, 67: 7-11
- Jozefyová, L., J. Pulkrábek and J. Urban, 2004. Effect of harvest time on sugar beet fertilized with increased nitrogen. *J. Food Agri. Environ.*, 2: 232-7
- Kerr, S. and M. Leaman, 1997. To water or not. *Bri. Sugar Beet Rev.*, 65: 11-3
- Koocheki, A., 1996. *Agriculture in Arid Regions.* Publications of Agriculture Science, Iran
- Koocheki, A., M. Hosieni and M. Nasiri Mahallati, 1996. *Relation of Water and Soil in Crops.* Publications of Agriculture Science, Iran
- Lauer, J.G., 1995. Sugar beet performance and interactions with planting date, genotype and harvest date. *Agron. J.*, 89: 469-75
- Reinefeld, E., A. Emmerich, G. Baumgarten, C. Winner and U. Beiss, 1974. Zurvoraussage des melassezuckers aus rubenanalysen. *Zucker*, 27: 2-15
- Sarmadnia, G.H. and A. Koocheki, 1997. *Crops Physiology.* Publications of Mashhad University Jahad, Iran
- Sheikh_Aleslami, R., 1997. *Laboratorial Methods and their Application to Control Food and Sugar Industries Process.* Mersa Publications, Tehran, Iran
- Tavakkoli, A., 2000. The first step in irrigation. *Iranian Natl. Committee Irrig. Drain.*, 142: 41-4

(Received 23 October 2007; Accepted 21 January 2008)