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Effect of Time and Amount of Leaf Harvest on Root Yield and Quality of Sugar Beet (*Beta vulgaris* L.)

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***Abstract*—** *The experiment was established to define the response of sugar beet (Beta vulgaris L.) to three leaf harvest regimes (30, 45 and 60 days before harvesting) and five leaf harvest intensities (0, 25, 50, 75 and 100%) in 2020 growing season. It was determined that the effect of leaf harvest regimes in sugar beet plant was not significant for all investigated parameters except α–N content. Leaf harvest at 60 days before harvesting gave the highest α–N content. All the investigated characteristics except root diameter and length were significantly affected by leaf harvest intensities. With increasing leaf harvest intensities, root weight, root yield, dray matter, sugar content and sugar yield significantly tended to decrease. When leaf harvest intensity was increased from 25% to 100%, the root weight, root yield, dray matter, sugar content and sugar yield were reduced approximately 26%, 26%, 6%, 9% and 32% respectively.*

***Keywords*—** *Sugar beet, leaf harvest regimes, leaf harvest intensities, root and sugar yield.*

I. INTRODUCTION

Sugar is a strategically important product obtained by fabrication from sugar cane (*Saccharum officinarum* L.) and sugar beet (*Beta vulgaris* L.). Sugar beet accounts for 20% of world sugar production, while the remaining 80% of sugar produced is obtained from sugar cane (Varga et al., 2021). In Turkey, sugar is produced entirely from sugar beet. Turkey comes after countries such as Russia, USA, Germany and France with an annual production of approximately 16 million tons of beet and 2 million tons of sugar. Sugar beet plays an important role in the agriculture sector and agriculture-based industry in Turkey and maintains its importance with the added value it creates. The main target in sugar beet production is to grow high yield and quality sugar beet. Variety, climate, soil, pest and disease are the leading factors affecting yield and sugar content of sugar beet root. Sugar beet roots usually contain 13-20% sugar (Hoffmann, 2010). The yield potential of sugar beet depends primarily on the location and year effects (Kenter et al., 2006). The influence of the environment accounts for about 80% of the total variance (Hoffmann et al., 2009). The effect of a year reflects the weather conditions during the vegetation period, which directly influence plant growth, and also affects sowing and harvest dates and thus the length of the growing season. Some field experiments concerning the impact of environmental variables on the growth of sugar beet were carried out by Jaggard et al. (1998), Qi et al. (2005) and Kenter et al. (2006). The number of living leaves in sugar beet affects root and sugar yield. Sugar beet leaves increases to a maximum of about 30 per plant in mid-August to early-September, then decreases to harvest (Follett et al., 1970). Increase in leaf area index depends on the rate at which new leaves appear and expand, on their final sizes and on how long they are retained by plants (Lemaire et al., 2008). All these factors are strongly influenced by the environmental factors such as climate, irrigation, fertilization and disease (Miford et al., 1985). Cercospora leaf spot is the most serious and destructive foliar disease of sugar beet in the world. The disease is caused by the air-born fungus *Cercospora beticola*. There are several factors biotic (weed and pests attack) and abiotic factors (excessive rainfall, and drought stress) which can also reduce the plant number per unit area, leaf number per plant and also reduce yield and quality (Jursik et al., 2008; Varga et al., 2021). The aim of this study was to determine the sugar beet response at different time and amount of leaf harvest on root yield and quality of sugar beet under field conditions.

II. MATERIALS AND METHODS

Experimental Site and Conditions

Field study was conducted in Elbistan district of Kahramanmaras city, which is located in the intersection of the Mediterranean, central Anatolia and Eastern Anatolia region of Turkey (between 38º 13.2' north parallel and 37º 12' east meridians). The climate type in this area is continental, with hot and dry summers and cold and snowy winters. The study area had monthly air temperature between -7.3 and 32.1 °C. Annually total precipitation is average about 436 mm but the total precipitation of during the sugar beet crop season is about 121 mm. Soil had a loam-clay texture, 2.15% low organic matter, available phosphorous (11.0 mg kg-1) and potassium (473 mg kg-1) and pH of 7.9 slightly alkaline.

Experimental Material, Design and Cultural Practices

The high root and sugar yielding sugar beet variety “Danicia KWS” were planted with a planting density of 10 plants per m^2 in the second week of April and treated with three leaf harvest regimes (30, 45 and 60 days before harvesting) and five leaf harvest intensities (0, 25, 50, 75 and 100%) in split plot design with 3 replications. The experimental area received 80 kg N and 80 kg P_2O_5 ha^{-1} as a seedbed application. Additional band-dressing of 160 kg N ha^{-1} was applied in two splits in the form of urea (1/2th at 20 days and 1/2th at about 40 days after emergence). After emergence, plants were hoed 2 times by hand and machine. Overall 7 furrow irrigations were applied. The harvest was done by hand at the beginning of October.

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Data Collection

The number of tubers was determined by counting of tubers from 20 plants in the middle two rows of each plot and averaged. Root weight was determined by weighing the total roots of 10 plants from the center 2 rows of each plot. Root yield was determined for each treatment plot at crop maturity. The harvested sugar beet roots in the middle two rows of each plot were weighted and root yield (kg ha^{-1}) was calculated. Root samples were cut into two pieces from head to tail and root diameter and length was measured from the widest part and the longest part of the beet root respectively. The harvested sugar beets were made into paste at the Elbistan Sugar Factory. 10-15 g of crushed beet samples were taken and dried in an atmospheric oven at 105 °C until its weight remained constant. When it comes to constant weight, it is cooled in a desiccator for approximately 45 minutes with the mouth closed, and then the dry matter amount (%) is calculated by weighing (Altunbay, 2014). Sugar analysis was done in Elbistan Sugar Factory. Sugar content (%) was measured with a polar meter after extraction of sugar from the pulp with lead acetate (Carruthers and Oldfield (1960). Sugar yield was determined according to the equation given by (Altunbay, 2014); Sugar yield (kg ha^{-1}) = Sugar content (%) *x* Root yield (kg ha^{-1}). Alfa amino (α–N) content was measured using Kubadinow-Weninger method in Elbistan Sugar Factory. The α–N content was determined by means of a spectrophotometer at a wave length of 600 nm. α–N data were calculated in mg per 100g fresh beet root (Altunbay, 2014).

Statistical Analyses

Data of yield and quality parameters from the study were analyzed using the MSTAT-C statistical programming. The significant of the difference between means was compared by least significant difference test (Protected LSD, $P < 0.05$).

III. Results and Discussion

The results of the analysis of variance of investigated parameters are shown in Table I. It could be seen in Table I, only α–N content for leaf harvest regimes and all investigated parameters except root diameter and length for nitrogen levels were statistically significant, but LR x LI interaction was not significant for all examined traits.

TABLE I. Effects of different regime and intensity of leaf harvest on root diameter, root length, root weight, root yield, dry matter, sugar content, sugar yield and α–N content of sugar beet.

	Root diameter (cm)	Root length (cm)	Root weight (kg)	Root yield (ton ha^{-1})	Dry matter (%)	Sugar content (%)	Sugar yield (ton ha^{-1})	α–N content (mg 100 g^{-1})
Leaf harvest regimes (LR) (days before harvesting)								
30	12.4	24.8	1.35	77.54	17.6	14.8	11.59	0.043 b
45	12.9	24.7	1.61	92.21	17.5	14.8	13.37	0.044 b
60	12.8	23.7	1.57	90.18	17.4	14.2	12.87	0.053 a
$LSD_{0.05}$	Ns	Ns	Ns	Ns	Ns	Ns	Ns	0.005
Leaf harvest intensities (LI) (%)								
0	13.2	25.0	1.65 ab	94.65 ab	18.8 a	15.7 a	14.86 a	0.052 a
25	12.9	24.9	1.77 a	101.43 a	17.4 a	14.6 b	14.80 a	0.050 a
50	11.9	23.3	1.42 bc	81.20 bc	18.0 ab	15.2 ab	12.35 ab	0.046 a
75	12.7	23.6	1.42 bc	81.10 bc	17.0 b	14.2 bc	11.56 b	0.048 a
100	12.9	25.0	1.31 c	74.84 c	16.3 b	13.3 c	10.07 b	0.037 b
$LSD_{0.05}$	Ns	Ns	0.29	16.7	1.24	1.10	2.97	0.008
Analysis of variance for traits								
LR	0.59	0.25	2.68	2.61	0.61	1.77	1.95	14.51**
LI	1.02	1.12	6.69**	6.77**	9.52**	10.54**	7.93**	6.04**
LR x LI	1.52	0.89	0.80	0.80	0.58	0.76	0.74	2.54

*, ** significant at the 0.05 and 0.01 level, respectively; for each trait, values within columns followed by the same letter are not significantly at P=0.05; Ns, non-significant

There were no significant differences among the leaf harvest regimes all studied parameters except α–N content. Leaf harvest at 30 (LR_{30}) and 45 (LR_{45}) days before harvesting produced similar α–N content, but leaf harvest at 60 (LR_{60}) days before harvesting produced the highest α–N content (0.053 mg 100 g^{-1}). Leaf harvesting as early as 60 days caused an increase in α–N content. This may be due to the stress of the sugar beet plant. Alfa N content increases under stress conditions (Roslon et al., 2005; Jakli et al., 2018).

All studied characters except root diameter and length were significantly affected by leaf harvest intensities (Table I). Leaf harvest intensities significantly decreased root weight, root yield, dray matter, sugar content and sugar yield. The results generally indicated that root weight, root yield, dray matter, sugar content and sugar yield increased in lower leaf harvest intensities of 0% and 25%. Yield (root and sugar) and yield components of sugar beet are related to leaf area index (Varga et al., 2021). The optimum leaf area index (LAI) for most field crops is around 3–4 m^2 m^{-2} (Roslon et al., 2005). The development of the leaves affects the productivity of photosynthesis and the sucrose storage in the root (Varga et al., 2021). With increasing leaf harvest intensities, root weight, root yield, dray matter, sugar content and sugar yield significantly tended to decrease. When leaf harvest intensity was increased from LI_{25} to LI_{100}, the root weight, root yield, dray matter, sugar content and sugar yield were reduced approximately 26%, 26%, 6%, 9% and 32% respectively.

IV. Conclusion

It can be concluded that the effect of leaf harvest regimes in sugar beet plant was not significant in all studied parameters except α–N content, but all investigated parameters except root diameter and length were affected from leaf harvest intensities. Leaf damage and loss of leaves that may occur in the period up

to 2 months before harvest do not adversely affect root and sugar yields, but increase α–N content. However, leaf harvest density affects yield and quality more than leaf harvest time. This situation determines that the damage or loss of leaves in the plant at a rate of 50% or more causes significant yield and quality losses. It is important to take the necessary precautions to keep the leaves healthy in sugar beet.

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