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DETERMINATION OF WORK QUALITY AT DIFFERENT TYPES OF SUGAR BEET HARVEST MACHINES

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ABSTRACT Turkey is an important sugar beet producer in the world. Turkey has produced 15 488 332 tones of sugar beet from 3 219, 806 ha of production area and has also produced 2 061 000 tones of sugar in 2008. Sugar beet harvesting by machine is common practice in Turkey. During mechanical harvesting several mechanical loaders have caused skin and tissue damages to sugar beets. The damages to the skin and tissue of the sugar beets results in quantitative and qualitative losses. After harvesting, comparisons of sugar beets quality are important in terms of sugar losses during transformation process. Three widely used types of harvesters have been operated in this study. One of these machines is fully hydraulic sugar beet harvest machine with ajustable depth and row, the second one is semi-hydraulic sugar beet harvest machine and the last one is a mechanical sugar beet harvest machine. Harvesters were tried in the same field conditions during the months of September and October 2009. Performance values were obtained from three different evaluation methods. These methods are topping quality determination, the determination of sugar beet injury rate and the soil removal rate of the sugar beet. The determinations of these factors are important to obtain the optimum harvest performance. Image process and analysis methods have been used for evaluations. Based on this data the harvest quality difference for harvesters was analyzed statistically.

Keywords: Sugar beet, Image Analysis, Precision Agriculture, Sugar beet Harvest Machine.

INTRODUCTION

Sugar production of the world obtained from 60% sugar cane and 40% sugar beet. Sugar cane generally produced in Africa, South America, Far East Asia and sugar beet generally produced in the cold zone in Europe, North America and Asia (Sarwar et al, 2008). The first three countries in the world sugar beet production are France, Germany and the United States respectively (Table 1). Turkey is also located 6th ranking at sugar beet production in the world (Anonymous, 2009).

Table 1.World production of sugar beet (Anonymous, 2009).

Rank	**Countries**	**Production(ton)**			
		2005	**2006**	**2007**	**2007 Rate%**
1	France	31,150	29,879	32,338	13.0
2	USA	24,887	30,631	31,912	12.9
3	Russia	21,420	30,861	29,000	11.7
4	Germany	25,387	20,647	26,114	10.5
5	Ukraine	15,468	22,421	16,978	6.8
6	Turkey	15,181	14,452	14,800	6.0
7	Polska	11,912	11,475	11,058	4.5
8	China	7,881	10,536	8,931	3.6
9	UK	8,687	7,150	6,500	2.6
10	Belgium	5,983	5,667	5,747	2.3
	Others				
	Total	251,672	253,213	247,879	100.0

Total crop production area in Turkey is 160,924 ha and about 150,000 families of farmers in the 3700 villages provides livelihood from the growing of sugar beet (Saripinar, 2009). Nowadays, harvest operations are done by using machines because of high operating speed, allowable level post-harvest mechanical damage, meet factory standards and low level post-harvest sugar losses. Domestic sugar beet harvest machines manufacturing leads to the development of spare parts supply industry. According to TSI 2008 data 3716 sugar beet harvest machine is available in Turkey.

This study is intended to assess machine performance of the domesticallymanufactured three different sugar beet harvest machines. For this aim, these machines were compared in terms of sugar beet mechanical damage, topping quality and the soil loss rate.

MATERIAL AND METHOD

Material

In this study three different types of sugar beet harvesters were used which manufactured in Turkey. These harvesters are mechanical type (Figure 1), semi hydraulic type (Figure 2) and full hydraulic type (Figure 3).

Figure 1. Mechanical sugar beet harvester

Figure 2. Semi hydraulic sugar beet harvester

Figure 3. Full hydraulic sugar beet harvester

These harvesters drivenbyPTO make topping, digging, cleaning, storage and loading during the harvesting. Also only one sugar beet row can be harvested by these machines. Specifications of the machines are given in Table 3.

Table 3. Specifications of the sugar beet harvest machines.

Specifications	Sugar Beet Harvest Machines		
	Mechanic	Semi-hydraulic	Full-hydraulic
Harvester weight without crop (kg)	1515	2100	2100
Length (at road conditions, mm)	4500	4400	4400
Width (at road conditions, mm)	3150	3350	3350
Height (at road conditions, mm)	3500	3000	3000
Number of tires	2	2	2
Storage capacity (kg)	1000	2500	2500
Row number	1	1	1

In these machines, at first, leafs of sugar beets have been cut by using an adjustable mechanism. This mechanism should make topping horizontally before diggingthe sugar beets from thefield. For this purpose parallelogram mechanismshave been widely used in the world. (Bulgakov, 2002).Topping slice thickness can be adjusted between 0-65 mm by slots on the blade connection. Full hydraulic type beet harvester can follows the rows automatically by using an optical sensor. Field conditions are given in Table 4.

Table 4.Field conditions specifications.

Specifications	Field conditions
The location of the field	Polatlı - Ankara –Turkey
The status of sugar-beet	Frequently leaves, Flat
Soil type	Silt-clay
Sowing procedure	Spacing within the row, beet thinning
Seed	Leila
Average leaf height (mm)	500
Distance between row (mm)	450
Distance on row (mm)	250
Number of beet (Sugar beet/ha)	36000
Average beet yield (kg/da)	8000

Method

Sugar beet harvest machine performances were assessed according to IIRB (International Sugar Beet Research Institute) and TS 4891 (Anonymous, 1999). Sugar beet harvesters were operated at 4km/h forward speed after optimum settings. For each harvester 1000 sugar beet were selected randomly. Thenthe working qualities of the harvesters were determined.

Determining dirtiness rate (TF)

Sugar beet, potatoes and carrots leads to soil losses during the harvest from field (Ruysschaert et al., 2006). Therefore, the stuck soil should be removed from the harvested beets. In this part of method, selected beets wereweighed before (T_1) and after (T_2)cleaning. Dirtiness rate of sugar beets were calculated by using equation 1.

$$TF = \frac{T_1 - T_2}{T_1} \times 100 \qquad (1)$$

Here;
TF: Soil loss (%)
T_1: First weighting (kg)
T_2: Second weighting (kg)

Determining of topping quality

The topping quality has been affected from distributions and the size differences of sugar beets. According to the method of IIRB topping quality are classified in 6 groups (Figure 4). In these method, groups were defined uncut head and leaf length greater than 2 cm (1), uncut head and leaf length shorter than 2 cm (2), head cut off cursory leafless and few leafy (3), head cut off smoothly(4), head cut off intensively (5), head cut off unevenly (6) respectively (Colak,1990). Randomly selected sugar beets are classified according to groups in Figure 4. The percentages of the topping quality were determined for each group. Topping yield losses were evaluated from multiplication of percentage of each topping group and loss factors of each topping group. Total topping yield losses were evaluated from the total of multiplication results. According to the method the value of the total yield loss should not exceed 5% andideal topping quality group is 4.

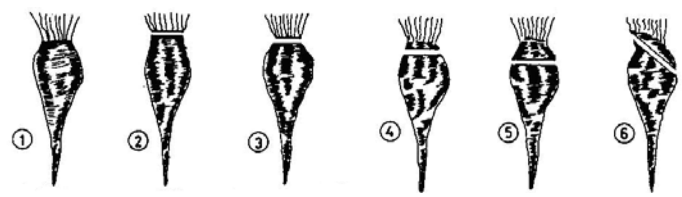

Figure 4. Quality groups according to IIRB

Determining root breakage loss

Diameters of the broken roots were taken into consideration for each sugar beet. Then average diameter of broken root was determined by measuring the widest and narrowest diameters . These values were divided into the groups as 0-20, 21-40, 41-60, 61-80, >81 mm.Root breakage losses were evaluated from multiplication of percentage of each root breakage group and loss factors. The total losses have been evaluated from the sum of the multiplication results. According to this method, the evaluated value of losses should not exceed 5%.

Surface damages

During the digging, storage and transportation, sugar beet has been affectedby friction and rotational movements (Gorzelany et al., 2000). And this cause mechanical damage. Damage values should not exceed 800 cm^2/100 sugar beet. In this study, image analysis technique used to determine surface damages of sugar beets. For this purpose, Myriad v8.0 image analysis software was used for evaluations. Measuring and verification process of digital images can be done by this program (Fig. 5).

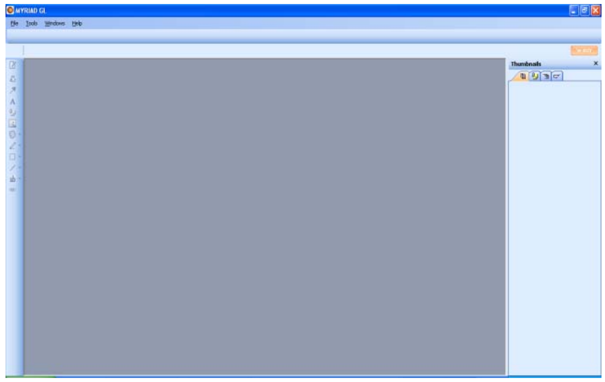

Figure 5. Interface of digital image analysis software Myriad v8.0

For the calibration, a calibration plate with known dimensions was used while taking digital images.Nikon D40X model digital camera and a tripod have been used for taking front, left and top view of sugar beets. Digital photos of sugar beets were taken with 5x8 cm size calibration plate then objects have been selected correctly at the software. Photos of the sugar beets were given in Figure 6.

Figure 6. Front, left and top view sample photos of a sugar beet

Digging Loss

For determining digging losses of sugar beets larger than 4.5 cm head diameter and roots larger than 5 cm were collected and the losses were evaluated by equation 2.

$$K = \frac{TK}{HE - TK} \times 100 \qquad (2)$$

Here;
K: Percentage of digging loss (%),
TK: Total weight of the sugar beets which have been taken from the soil (kg),
HE: Total weight of the sugar beets harvested by the machine (kg).

The relationships between the results of measurements such as beet diameter, root diameter where the root broken, damaged surface area were evaluated by variance analysis technique (One way ANOVA).The differences between direct measurement and image processing results were calculated with the Pearson correlation coefficient.

RESULTS

According to ANOVA statistics, differences between sugar beets was not found statistically significant ($p < 0.05$). Head diameters, length, weight and volume of beets related to descriptive statistics of the harvesters are given in Table 5.

Table 5. Descriptive statistics of the sugar beet properties related to machines.

Variable	Sugar Beet Harvest Machines	Mean	SE Mean
Head diameter (mm)	Mechanical	133.1	3.8
	Semi hydraulic	124.5	3.8
	Full hydraulic	132.2	3.4
Length (mm)	Mechanical	225.0	9.1
	Semi hydraulic	224.5	8.7
	Full hydraulic	232.2	7.1
Weight (g)	Mechanical	1357.0	101.0
	Semi hydraulic	1206.4	81.0
	Fullhydraulic	1390.8	87.3
Volume (ml)	Mechanical	1030.3	95.0
	Semi hydraulic	940.6	79.6
	Full hydraulic	1072.0	75.0

Result of root breakage and surface damage differences was not found significant statistically between sugar beet harvest machines ($p < 0.05$). Root breakage descriptive statistics of three different sugar beet harvesters have been given in Table 6. Descriptive statistics of image processing and measured damaged surface area are given in Table 7.

Table 6. Descriptive statistics of root breakage.

Variable	Sugar Beet Harvest Machines	Mean	SE Mean
Root breakage (mm)	Mechanical	16.49	3.21
	Semi hydraulic	16.02	2.21
	Full hydraulic	11.98	1.80

Table 7. Descriptive statistics of measured surface area values and image processing surface area values.

Variable	Sugar Beet Harvest Machines	Mean	SE Mean
	Mechanical	685.0	161.0
Measured surface area values (mm^2)	Semi hydraulic	598.0	143.0
	Full hydraulic	542.2	68.5
	Mechanical	540.0	130.0
Image processing surface area values (mm^2)	Semi hydraulic	439.0	106.0
	Full hydraulic	483.3	63.1

The correlation coefficients between image processing and measured values related to heat diameter, length valuesand surface damageshave been found 0.98, 0.96 and 0.97 respectively. Total yield losses and topping losses are given in Table 8.

Table 8. Topping yield losses related to harvest machines.

Topping quality class	Sugar Beet Harvest Machines	Percentage	Image processing percentage	Loss factor	Yield loss in each group	Image processing yield loss
1	Mechanical	2.7	0	0.1	0.3	0
	Semi hydraulic	18.6	2.32	0.1	1.9	0.2
	Full hydraulic	5.0	2.32	0.1	0.5	0.2
2	Mechanical	12.1	10.8	0.1	1.2	1.1
	Semi hydraulic	27.6	25.6	0.1	2.8	2.6
	Full hydraulic	26.6	25.6	0.1	2.7	2.8
3	Mechanical	31.6	29.7	0.05	1.6	1.5
	Semi hydraulic	5.0	30.2	0.05	0	1.5
	Full hydraulic	33.3	30.2	0.05	1.7	0
4	Mechanical	45.5	44.5	0	0	0
	Semi hydraulic	48.8	41.9	0	0	0
	Full hydraulic	35.1	41.9	0	0	1.7
5	Mechanical	8.1	9.5	0.1	0.8	0.9
	Semi hydraulic	0	0	0.1	0	0
	Full hydraulic	0	0	0.1	0	0
6	Mechanical	0	5.4	0.05	0	0.3
	Semi hydraulic	0	0	0.05	0	0
	Full hydraulic	0	0	0.05	0	0

Total yield losses results has been calculated for imaged and measured values as 3.87% and 3.78% at the mechanical harvesting machine;4.86% and 4.29% at the semi hydraulic machine, 4.81% and 4.66% at the full hydraulic machine respectively by using the values from Table 8. According to the total topping yield loss values, the best machine is mechanical sugar beet harvester. The yield loss caused frombroken roots has been given in Table 9.

Table 9. The yield loss at the machines caused by the broken roots.

The brokenroot diameter(mm)	Beet Harvesters	Percentage	Loss factor	Yield loss
0-20	Mechanical	59.46	0	0
	Semi hydraulic	64.37	0	0
	Full hydraulic	66.66	0	0
21-40	Mechanical	29.73	0.05	1.48
	Semi hydraulic	30.23	0.05	1.51
	Full hydraulic	33.34	0.05	1.66
41-60	Mechanical	5.41	0.10	0.54
	Semihydraulic	5.4	0.10	0.54
	Full hydraulic	0	0.10	0
61-80	Mechanical	5.4	0.21	1.13
	Semi hydraulic	0	0.21	0
	Fullhydraulic	0	0.21	0
>80	Mechanical	0	0.3	0
	Semi hydraulic	0	0.3	0
	Full hydraulic	0	0.3	0

Total yield loss of harvesters was 2.88%, 2.05% and 1.66% for mechanical, semi hydraulic and full hydraulic machine respectively. The lowest value of broken root diameter was obtained from the full hydraulic harvester. General quality values for sugar beet harvesters can be seen in Table 10.

Table 10. General quality values for sugar beet harvester.

Quality Values	Sugar Beet Harvesters		
	Mechanical	Semihydraulic	Fullhydraulic
Dirtiness rate (%)	8	7	8
Total topping error loss (%)	3.87	4.61	4.81
Digging loss (%)	0.8	0.9	0.8
Broken root loss (%)	2.88	2.05	1.66
Surface damage (cm^2/100 sugar beet)	685	598	542.2

CONCLUSION

In Turkey, generally combined harvest systemsare being used for sugar beet harvesting. Because of this,combined harvestmachines have been examined in this research. According to test results the best topping quality has been obtained at the mechanical harvester.On the other hand the smallest broken root diameter has been found at the full hydraulic machine.Besides the lowest surface damage has been got at full hydraulic harvester. In the light of all results, full hydraulic harvesterhas been found the most appropriate for optimum harvesting.

REFERENCES

Anonymous, 1999. Experimental Principles and Methods of Agricultural Mechanization Tools.(in Turkish)T.C. Ministry of Agriculture and Rural Affairs General Directorate of Agricultural Production,Agricultural Equipment and Machinery Development.

Anonymous, 2009.Undersecret Ariat of the Prime Ministry for Foreign Trade. Sugar and Sugar Products Sector Report.(in Turkish)Web site. http://www.iib.org.tr/iib_portal/dokuman/IIB_Sektor_Raporlari/0906_Haziran_2009_Seker_ve_Sekerli_Urunler_Sektor_Raporu.pdf. Access Date: 30.10.2009

Bulgakov, V.M., 2002. Study on the Interaction of feeler and roots within the topping process of sugar beet. Bulletin of the Transylvania University of Braşov (2002), P:44

Colak, A., 1990. Development of the Method to Determine the Main Characteristic Which Effect Operating Conditions of Sugar Beet Topping Knives in the Field Operating Conditions. (summary in English)Ankara University, Graduate School of Natural and Applied Sciences, Department of Agricultural Machinery PhD Thesis.

Gorzelany, J., Puchalski, C., 2000. Mechanical Properties Of Beet Roots During Harvest And Storage. Int. Agrophysics (2000), P: 173-179

Oztürk, B. B., 2007. Determination of Mass Losses Resulted from Its Root Breakage in Varieties of Genetic Monogerm Sugar Beet Cultivated in Region of Ankara Sugar Beet Factory.(in Turkish) Ankara University, Graduate School of Natural and Applied Sciences, Department of Agricultural Machinery Master Thesis.

Ruysschaert, G., Poesen, J., Verstraeten, G., Govers, G., 2006. Soil losses due to

mechanized potato harvesting. Soil and Tillage Research 86 (2006) , P: 52-72
Sarıpınar, Z., 2009. Sugar Beet Seed Processing Technologies. (in Turkish)Ankara University, Graduate School of Natural and Applied Sciences, Department of Agricultural Machinery Seminars.
Sarwar, M. A., Hussain, F., Ghaffar, A., Nadeem, A., Ahmad, M. M., Bilal, M., Chattha, A. A., Sarwar, M., 2008. Post – Harvest Studies in Sugarbeet (Beta vulgaris) Journal of Agriculture and Social Sciences ISSN Print: 1813-2235; Online : 1814-960X 07-340/AWB/2008/04-2-89-91
TSI Agricultural Equipment and Machinery Statistics, 2010. Web site http://www.tuik.gov.tr/VeriBilgi.do?tb_id=49&ust_id=13TÜİK, Access Date: 10.02.2010. (in Turkish)