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EFFECT OF SOIL CONDITIONS AND MECHANICAL CHARACTERISTICS OF SUGAR BEET ROOTS ON THE VALUE OF FORCE NECESSARY FOR PULLING THEM OUT

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A b s t r a c t. A specially constructed measuring apparatus, made in the Department of Agricultural Production Technology in Rzeszów, was used to measure the force necessary for extracting sugar beet roots from the soil. The effect of selected geometric characteristics of the roots (length, diameter) and their depth in the soil on the value of force necessary for removal of roots from the soil was determined. The variation of force necessary for root extracting was analysed with reference to beet variety, soil compactness and soil moisture content. Irrespective of the root size, variety and field (plantation), the recorded average values of force were found to vary widely in a range from 297.9 to 669.0 N. In some cases forces up to 1000 N were recorded

K e y w o r d s: sugar beet, extracting force, compactness of soil, soil moisture

INTRODUCTION

Harvesting machines increase mechanical damage and sugar beet root loss [5,7]. Correct operation of agricultural harvesting machines depends not only on their design, soil type and climatic conditions but also, to a large extent, on the physical characteristics of sugar beets themselves. Analysing these characteristics and their variability shall enable to define the ways of crop handling and processing [3,4]. It determines also the selection of machines and provides some information about sensitive points of roots and spheres susceptibility to mechanical damage [4,7,9,10].

From the point of view of cultivation, harvesting and processing technology the important characteristics of roots are: geometrical characteristics, force required for root extraction from the soil, root breakability, resistance to mechanical damage and limits of biological resistance [2,3,6,8,10]. However, the most basic factor required by designers of harvesting machines is the amount of energy consumed for digging the roots out of the soil [3]. Many authors [1,3,4] confirm that this force depends primarily on the environmental conditions and geometrical dimensions of roots. The effect of agrotechnology, fertilization and watering on root dimensions and their portion above soil level is well known but the evaluation of their effects on the value of force required for root extraction from the soil is still not available. The greater the root diameter and length the larger the force required for extraction. This force depends also on the meteorological and soil conditions [4] which, as proposed by the author, affect this parameter the most.

MATERIALS AND METHODS

Testing was carried out on two farms in the Zamość region. The objects of tests were four varieties of sugar beet: Kristall, Wiahilla F1, Tamino and Sonja cultivated on three crop

production fields (plantation), sown with the spacing of 18 cm after various forecrops:
Field I - loess soil of class II; forecrop: wheat, wheat-beet complex;
Field II - loess soil of class II; forecrop: red clover, wheat-beet complex;
Field III - degraded chernozem soil formed on the loess class I; forecrop: spring barley, wheat -beet complex.

Soil moisture content and compactness were measured in autumn 1997, directly before each series of measurements at the point of sugar beet processing maturity. Soil moisture content at the depth of 50 mm and 100 mm was measured using laboratory drier, separately for each plot. Measurement of soil compactness was taken with the use of a manual spring -penetrometer, designed and made by the Institute of Agrophysics of the Polish Academy of Sciences in Lublin, and provided with a recorder which enabled monitoring of compactness changes in the soil profile. A series of measurements (10-15 times) was carried out on each field to define the average soil compactness profile for that field. Once the measurement of soil compactness and moisture was complete, sugar beet root were topped manually with a knife. Sixty roots of different sizes (small roots of dia. 60-66 mm, medium-sized roots of dia. 100-135 mm and large roots of dia. 136-170 mm) and exhibiting characteristics of specific variety were chosen from each field. Prior to measurement of the force required for extracting roots from soil, the heights of the portions above the soil level were measured for individual beets. The measurement of force required for the removal of beet roots from the soil was carried out with an apparatus constructed in the Department of Agricultural Production Technology in Rzeszów. This consists of a stand with roll for steel line connected to the force gauge with 0-1 kN range. The force-gauge holder was connected to a bolt, previously screwed into the root, and a crank was used to steadily increase the pulling force to remove individual roots.

Each extracted root was then cleaned from soil and geometrical measurement of root length, diameter (average of two measurements of root thickness and width) were taken with a slide caliper.

The shape of each extracted root was also defined [3]. The removed sugar beet root was then weighed on a small electronic decimal balance (range up to 4 kg) with an accuracy of 1 g.

After completing a series of measurements on a specific plot the remaining roots were removed manually. All the roots collected, either manually or with the special fixture, were packed into jute bags and weighed. It enabled determining of planting (density) and theoretic yield for individual varieties for a particular field (plantation).

RESULTS

On the basis of measurements, the planting (density) and theoretic yield of sugar beet roots per ha were calculated (Table 1).

Geometrical characteristics of sugar beets and average values of F(N) force required for removal are presented in Table 2.

The longest sugar beet roots were recorded for Tamino and Sonja varieties on field III. Roots of those varieties were 44.4 % deeper seated in the soil in comparison to fields I and II.

The subsoil plough tooth employed in the plot II contributed to a reduction of plough soil compactness. This suggest that the conditions of soil moisture content and compactness affect the value of the force required for extracting roots

Table 1. Planting (density) and yield of roots of sugar beets

Field	Variety	Planting (density) (10^3 roots/ha)	Root yield (t/ha)
I	Kristall	56.4	55.18
	Wiahilla	55.5	55.12
II	Kristall	59.6	41.05
	Wiahilla	60.5	41.94
III	Tamino	67.3	57.69
	Sonja	63.4	55.39

Table 2. Morphological traits of sugar beet and average value of F (N) force required for extracting sugar beet roots from the soil

Variety	Size of roors	Average dimensions and mass of roots			Average height of root heads above ground (mm)	Average placing depth (mm)	Force F (N)
		lengh (mm)	diameter (mm)	mass (g)			
				Field I			
Kristall	small	146	77	470.8	35	111	297.9
	medium	191	116	1125.9	63	128	377.6
	large	222	148	1971.0	81	141	452.3
Wiahilla F1	small	147	79	416.9	39	108	297.9
	medium	201	113	1081.2	59	143	441.5
	large	225	146	1917.1	85	140	491.4
				Field II			
Kristall	small	150	75	389.2	31	118	308.6
	medium	181	110	914.5	51	131	416.7
	large	204	139	1385.1	64	139	469.1
Wiahilla F1	small	138	77	374.6	27	111	317.7
	medium	177	108	875.7	50	127	409.0
	large	207	141	1479.1	69	138	471.6
				Field III			
Tamino	small	190	79	464.8	29	161	418.0
	medium	243	110	1110.2	50	192	601.4
	large	272	139	1964.0	70	202	669.0
Sonja	small	184	79	470.9	17	167	391.7
	medium	236	110	1085.0	38	198	593.7
	large	255	143	1896.5	67	189	630.0

Average moisture of soil (depth 50 and 100 mm). Field I - 19.0 and 21.4%, field II - 17.4 and 18%, field III - 18.7 and 18.1%.

from the soil. The highest moisture content at the depth of 50-100 mm, at an average of 20.2%, was recorded in the field I. Soil compactness at the depths of 50-250 mm during measurements on all the studied fields was within the range of 0.37 to 1.78 MPa (Fig. 1).

Irrespective of root sizes, variety and field, the average values of force required for extracting

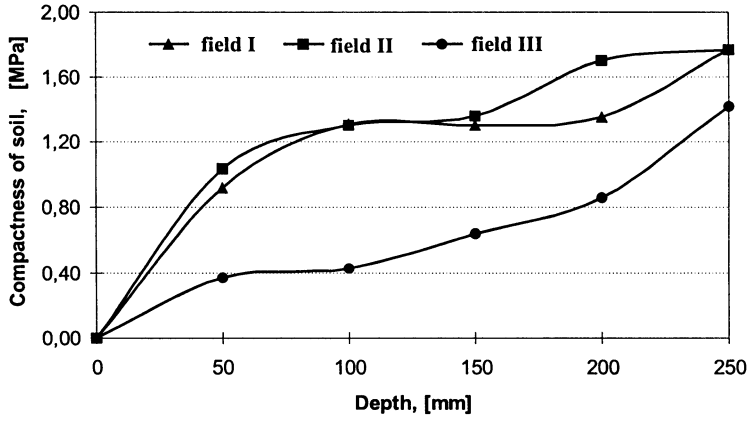

Fig. 1. Changes in the soil compactness for the three fields.

roots from the soil varied widely from 297.9 N to 669.0 N. In individual cases forces as high as 880 N were recorded on the fields I and II, and even up to 1000 N on the field III.

The values of force required for extracting individual roots from the soil differed very widely as confirmed by high values in the standard deviation from the average force specific to variety, size of root and field. The high variability of forces required for removal of the roots from the soil within each fraction (size of roots) resulted from various depths of

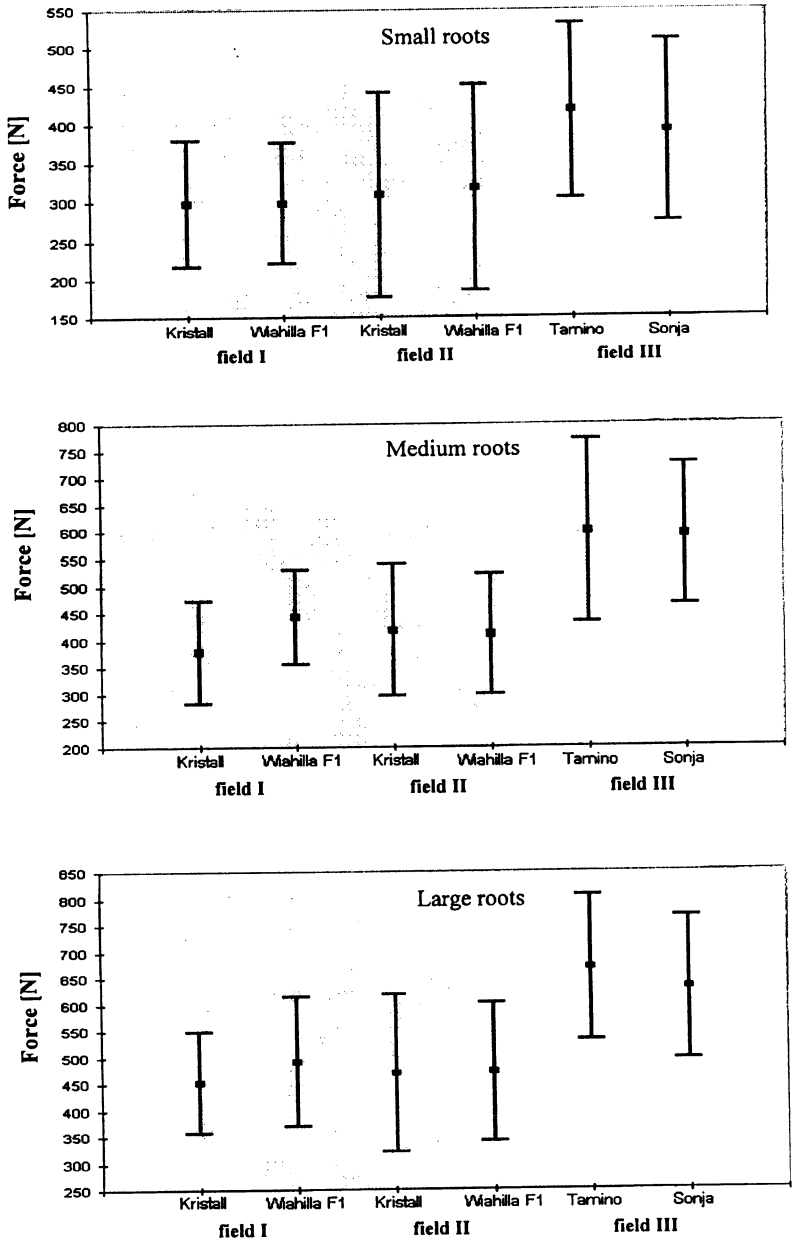

Fig. 2. Variation in values of force (N) neseccary for extraction roots from the soil.

individual roots in soil and their varying diameters (Fig. 2).

The value of variation coefficient (c.v. %) for root size and their immersion in the soil on each field, variety within one fraction are presented in Table 3. The value of force required for extracting sugar beet roots from soil depended on the diameter and depth in the soil, as presented in Fig. 3.

The curves of force required for extracting from the soil versus root diameter and depth can be represented quadratically as follows:

$$F = ax^2 + bx + c$$

$$F = az^2 + bz + c$$

where: F - value of force required for extraction of sugar beet root from the soil (N), x - root diameter (mm), z - root depth in soil (mm), a,b,c - function coefficients.

CONCLUSIONS

1. The average values of force required for extraction of roots from the soil varied widely from 297.9 N to 669.0 N. In some cases forces up to 1000 N were recorded.

2. The value of force required for extracting a root from the soil was affected by the root diameter (correlation coefficients: 0.93 for the field I, 0.86 for field II and 0.99 for the field III) and by the degree of its depth (correlation coefficients: 0.84 for the field I, 0.86 for the field II and 0.35 for the field III).

3. On the basis of the multifactor analysis of variance it was found that depth of roots in the soil, their size and type of field (soil compactness and moisture content) had a significant effect on the value of force required for extraction of sugar beet roots from the soil.

4. Roots on the field III, which were longer (on average by 26 %) and deeper seating in the

Table 3. Coefficient of variation (c.v. %) for diameter (mm), placing depth (mm) in soil and force (N) in relation to field and variety of sugar beets

Variety	Size of roots	Diameter		Placing depth		Force F	
		x (mm)	c.v. (%)	x (mm)	c.v. (%)	x (mm)	c.v. (%)
				Field I			
Kristall	small	77	15.4	111	28.1	297.9	27.0
	medium	116	9.5	128	24.6	377.6	25.1
	large	148	7.8	141	25.1	452.3	21.2
Wiahilla F1	small	79	14.2	108	28.2	287.9	26.0
	medium	113	8.5	143	22.0	441.5	19.9
	large	146	6.4	140	30.1	491.4	25.0
				Field II			
Kristall	small	75	17.3	118	37.7	308.6	43.0
	medium	110	9.1	131	27.2	416.7	29.3
	large	139	4.1	139	35.3	469.1	31.7
Wiahilla F1	small	77	17.9	111	32.9	317.7	42.1
	medium	108	8.0	127	28.1	409.0	27.0
	large	141	5.2	138	24.6	471.6	27.6
				Field III			
Tamino	small	79	12.9	161	19.2	418.0	27.2
	medium	110	9.2	192	24.2	601.4	28.2
	large	139	5.9	202	17.5	669.0	20.5
Sonja	small	79	15.5	167	17.2	391.7	30.3
	medium	110	8.0	198	16.9	593.7	22.2
	large	143	6.3	189	15.6	630.0	21.4

x - average values (mm), c.v. - coefficient of variation (%).

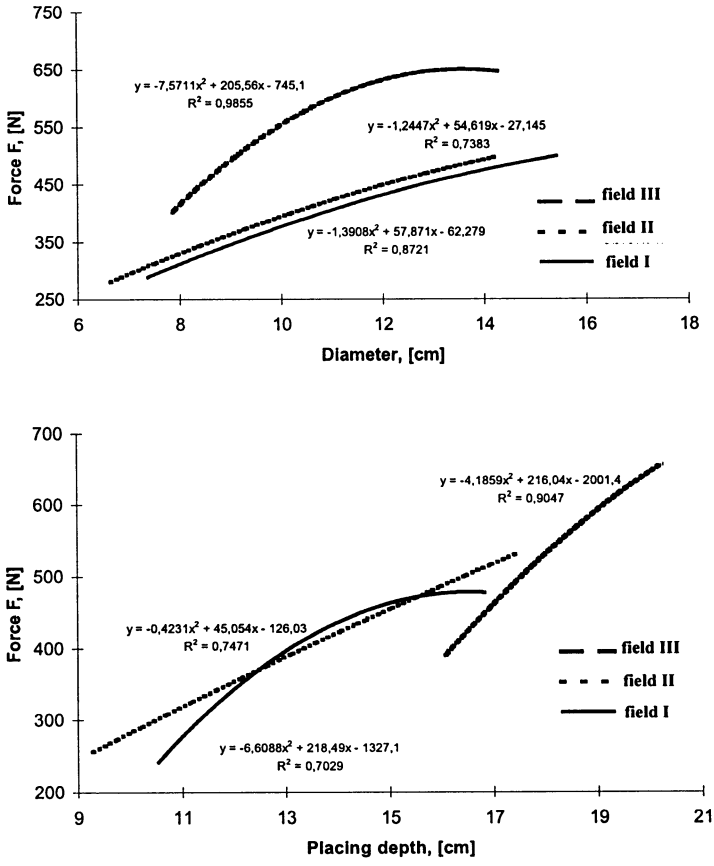

Fig. 3. Extraction force F (N) versus root diameter and placing depth in soil.

soil (by 33%) caused an increase in force required for extracting from soil by 39 % (approx. 150 N).

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