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MECHANICAL PROPERTIES OF SUGAR BEET ROOTS DURING HARVEST AND STORAGE

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A b s t r a c t. Comparative study of root mechanical properties of four sugar beet cultivars over harvest and storage periods in the conditions of static loads were carried out including determination of some mechanical parameters of beet root skin in two measurement zones within the applicability range of the Hook's law. Tests concerning the effect of cultivar and measurement zone on tested parameters were performed on a micro tensile tester, Zwick model 1425 in the Department of Agricultural Production Technology. The average values of skin destruction forces were 241.22 - 254.1 N and 227.4 - 245.8 N for freshly harvested sugar beet roots and after 45 days of storage, respectively.

K e y w o r d s: sugar beet, root skin, destructive force, deformation

INTRODUCTION

During mechanical harvesting, transportation and storage various mechanical loads are exerted through skin onto tissue of sugar beet roots. As long as those loads are small the root tissue behaves as an elastic material as most of other solids [2,10]. Applying of stronger loads, impacts or bending forces causes permanent deformations resulting from the damage of skin and tissue [2,12], which in turn results in quantitative and qualitative losses [7,8]. Many researchers made attempts to determine mechanical properties of sugar beet roots on the basis of classical methods employed in the mechanics of materials but failed to account for individual and plant-environment variance [3,4,6,10].

Laboratory investigations aimed at determining the modulus of elasticity, Poisson's ratio and the normal stress at failure [1,5]. Processing qualities, including mechanical properties, depend on the conditions of production (climatic, soil and agro-technical) [4-6]. Mechanical harvest time and storage conditions are important factors affecting the looses of technological value of sugar beet roots [5,9]. Obviously, variation in the root characteristics is closely related to the loss of tissue turgor [6,12]. Loss of moisture and thus turgor drop and increase of the degree of wilting changes processing properties of the crop as well as the strength parameters of the root [11,12].

Having in mind diversity of the new cultivars of sugar beets introduced to Poland, diversified conditions of production (fertilization, agro-technology, soil), as well as time and conditions of storage after harvesting, a study to define the effect of some selected factors on the root resistance to static loading was carried out. Learning about the effect of those factors shall enable to define the optimum conditions for harvesting and storage of the tested cultivars as well as to determine some operational parameters of machines in the course of harvesting and further processing.

MATERIALS AND METHODS

The study subject were roots of four cultivars of sugar beet: Prisma, Matador, Amelia and Milla, sample from one crop production plot. Beets were grown on the plantation with row spacing of 45 cm and 16-cm plant spacing in rows. Roots used for testing were manually headed, dug out, cleaned from soil and weighed. Ten healthy roots of each variety and in three sizes (small, medium, large, dia. 7-9; 9-12; 12-15 cm, respectively) were sampled in the identical manner.

After harvest the root samples were washed, marked and stored in jute bags in one place in natural conditions under roof (at the average temperature of 5 ^{o}C, relative humidity of 75%), as well as in a room (the average temperature of 20 ^{o}C, relative humidity of 55%). The storage period from harvest and first measurement to the final measurement was 45 days (five dates of measurements). Laboratory measurements were taken in a steady room conditions at the temperature of 18 ^{o}C and relative humidity of 45%. Measurements of root skin resistance to puncture were carried out with a steel plunger with 8 mm dia. in conditions of static loading were performed on 1425 Zwick microbreaker. Roots were placed on the tester base and a specific position: A zone - in root top part; B zone - in the middle (Fig. 1). All the measurements were done keeping perpendicular direction of the test plunger. In the compression process the root skin became deformed until the moment of its puncture. The maximum value of force F (N) causing puncture of the root skin, as well as skin deformation L (mm), were recorded with a printer. Tests were carried out under the following measurement parameters:

F_v - 5 N (sample pre-load),

V_1- 0.3 mm s^{-1} speed of mandrel approach to sample,

V_2 - 0.50 mm s^{-1} speed of mandrel stroke in loading process,

V_3 - 6.70 mm s^{-1}speed of return of the measuring-head.

During storage of sugar beet roots in various conditions a mass loss (wilting) takes place as a result of evaporation and respiration. From the moment of harvesting (first measurement) to the last measurement the recorded root mass loss was significant (Table 1). It was the highest for the Matador beet variety and the lowest for the Prisma variety. The average root mass loss during storage in natural conditions and in room conditions was 12.4 and 37.6%, respectively.

RESULTS AND DISCUSSION

On the basis of measurements of roots skin resistance to puncture with a steel plunger in two different zones, the effect of variety, storage time and root size on the value of skin rupture force and deformation were determined. The results obtained are shown in Tables 1 and 2 and in Figs 2-4. The average values of the force

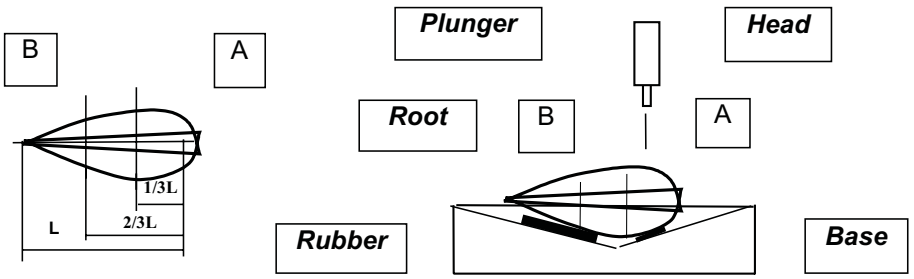

Fig. 1. Zones of sugar beet roots tested by 8 mm steel plunger: A -top zone , B - middle zone.

Table 1. Loss of root mass of sugar beets during storage. I- storage in the natural conditions, II- storage in room conditions

Variety	Mass of roots (kg)				Loss of mass roots (%)	
	directly after harvest		last measurement			
	15.10.1996		02.12.1996			
	I	II	I	II	I	II
Prisma	28.2	33.5	25.2	21.5	10.6	35.8
Matador	27.3	31.1	23.6	18.4	13.5	40.8
Amelia	28.7	30.3	24.8	19.7	13.6	35.0
Nilla	24.8	30.0	21.9	18.3	11.7	39.0
$\bar{x}$	27.3	31.2	23.9	19.5	12.4	37.6

F (N) causing root skin rupture and deformation until the moment of its puncture *L* (mm) for various varieties of sugar beets in the course of their storage are presented in Table 2. Fresh roots of the Matador variety exhibited the highest resistance to mechanical damage; the value of skin rupture force was the highest at 254.1 N.

For all the tested varieties, the value of this force had the average value of 246.4 N. After 45 days of storage in the natural conditions the force necessary to rupture the skin through dropped to 237.2 N while the samples kept in room conditions described above showed higher resistance to damage - the force required to rupture the skin had the mean value of 262 N.

Tests results specified in Table 2 confirm observations made earlier by Bzowska-Bakalarz [4,5] that root tissue turgor is reduced in the course of storage while the degree of wilting, skin elasticity resulting from water loss and the value of deformation were all rising.

The average value of deformation of fresh root skin till the moment of rupture through was 5.07 mm and rose after a 45-day storage period to 8.01 and 13.01 mm for the natural storage and storage in the room conditions described, respectively.

Widely varying natural conditions during storage period (temperature: minimum 6.0 ^{o}C to max. 18 ^{o}C and relative air humidity from 63% to 92%) resulted in varying mechanical

Table 2. Average values of force to rupture *F* (N) and deformation *L* (mm) of different varieties of sugar beets directly after harvest and during storage. I - storage in the natural conditions, II - storage in room conditions

Variety	Storage place	Measurement dates									
		directly after harvest		during storage							
		15.10.96		26.10.96		6.11.96		18.11.96		02.12.96	
		F	*L*	*F*	*L*	*F*	*L*	*F*	*L*	*F*	*L*
Prisma	I	241.2	4.56	241.5	6.00	242.7	6.08	253.8	7.21	239.6	8.02
	II	241.3	4.56	224.4	7.11	219.6	10.59	257.0	11.12	273.8	13.01
Matador	I	254.1	4.35	242.0	5.73	242.9	5.80	240.3	7.25	227.4	7.68
	II	254.1	4.35	230.4	7.39	227.2	9.87	248.6	10.67	258.0	12.76
Amelia	I	245.3	6.12	247.5	5.97	246.9	6.43	249.6	7.30	245.8	8.17
	II	245.3	6.12	238.4	7.59	224.6	10.19	256.7	11.99	266.9	13.52
Nilla	I	244.9	5.24	255.1	16.01	244.6	6.24	255.4	7.89	236.1	8.15
	II	244.9	5.24	225.0	6.83	203.8	10.16	225.3	10.61	251.5	12.73
-	I	246.4	5.07	246.5	5.93	244.3	6.14	249.8	7.41	237.2	8.01
	II	246.4	5.07	229.6	7.23	218.8	10.20	246.9	11.09	262.6	13.01

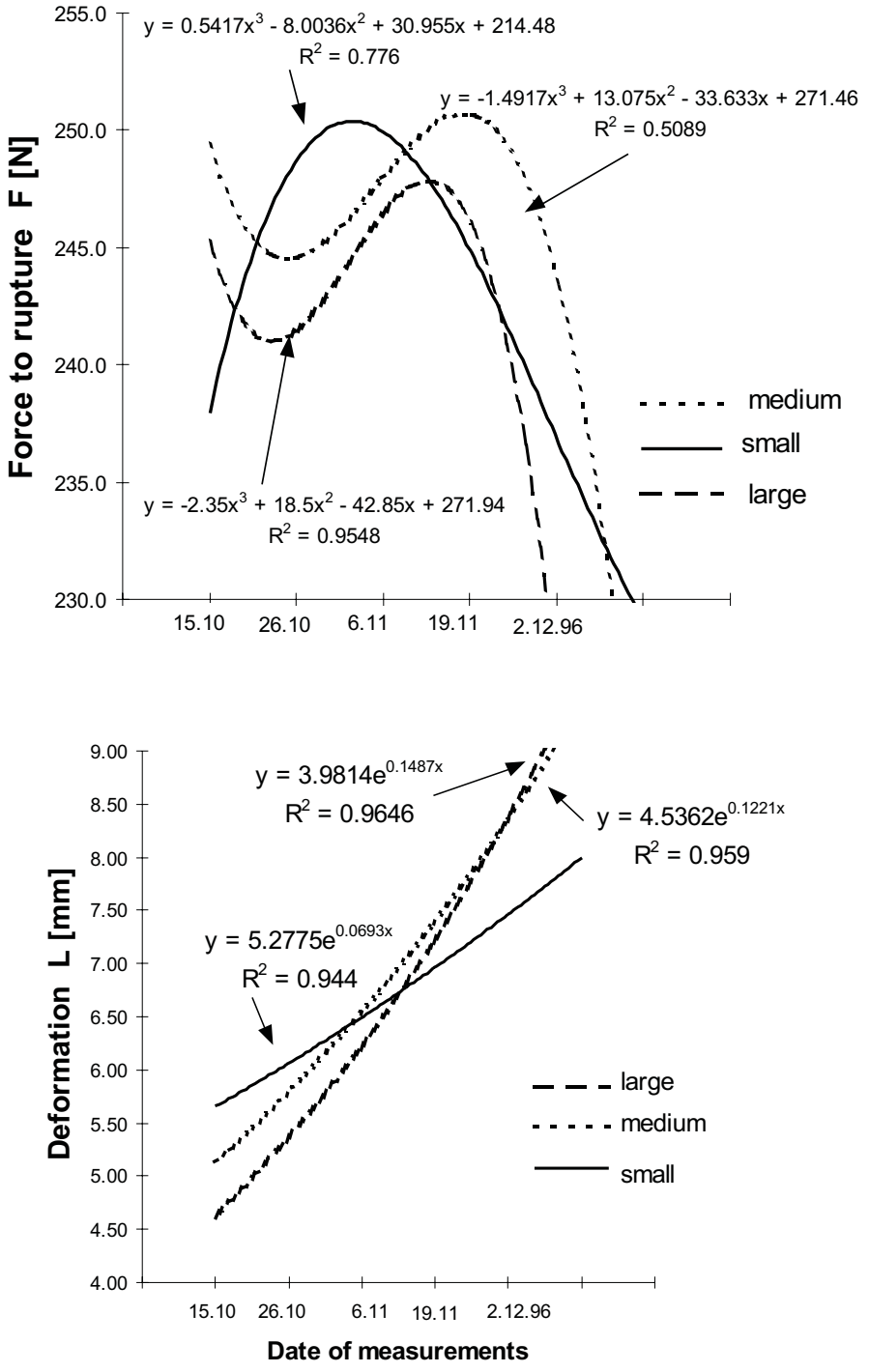

Fig. 2. Effect of storage time (date of measurements) and size of sugar beet roots on rupture force and deformation in natural conditions.

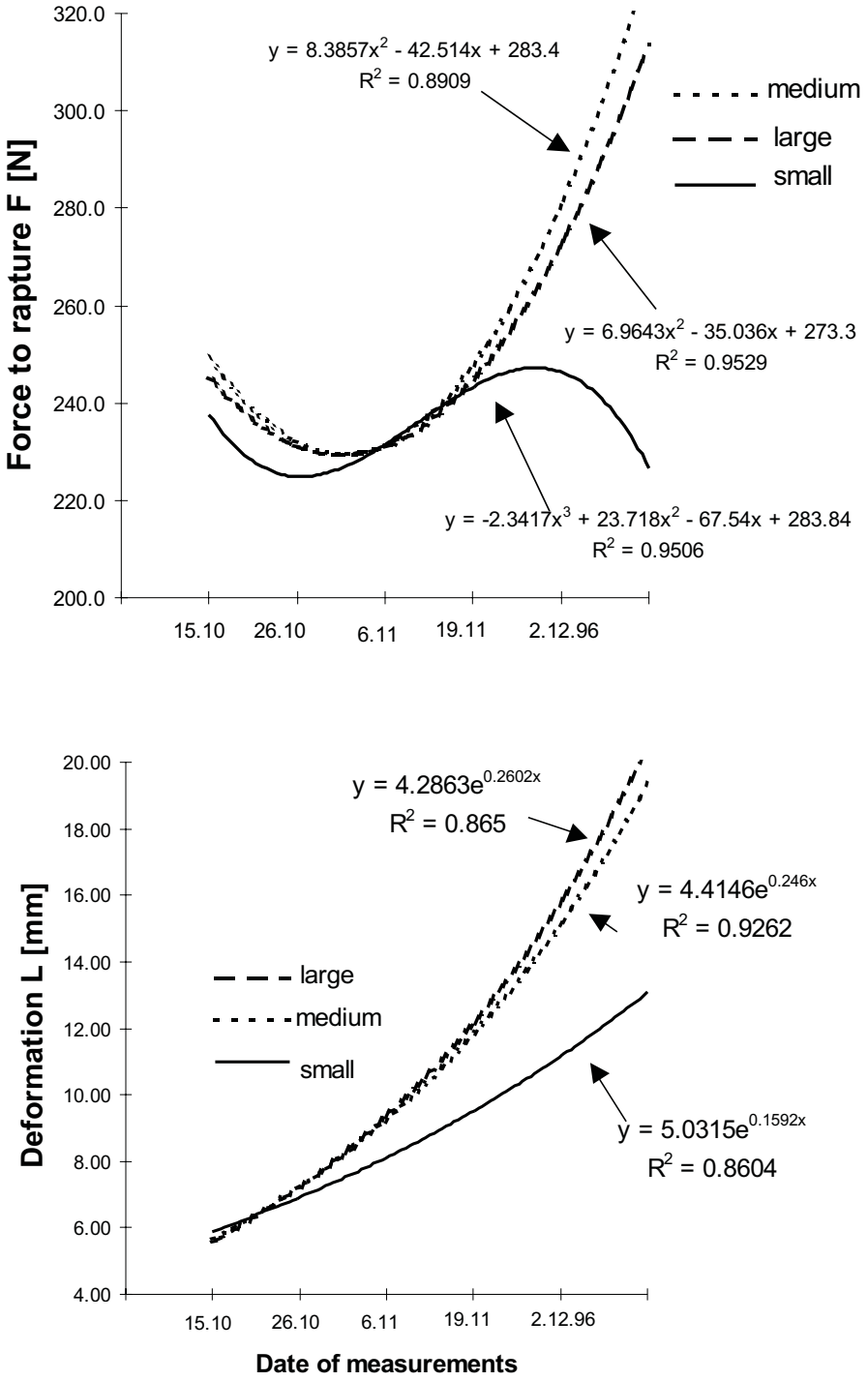

Fig. 3. Effect of storage time (date of measurements) and size of sugar beet roots on rupture force and deformation in room conditions.

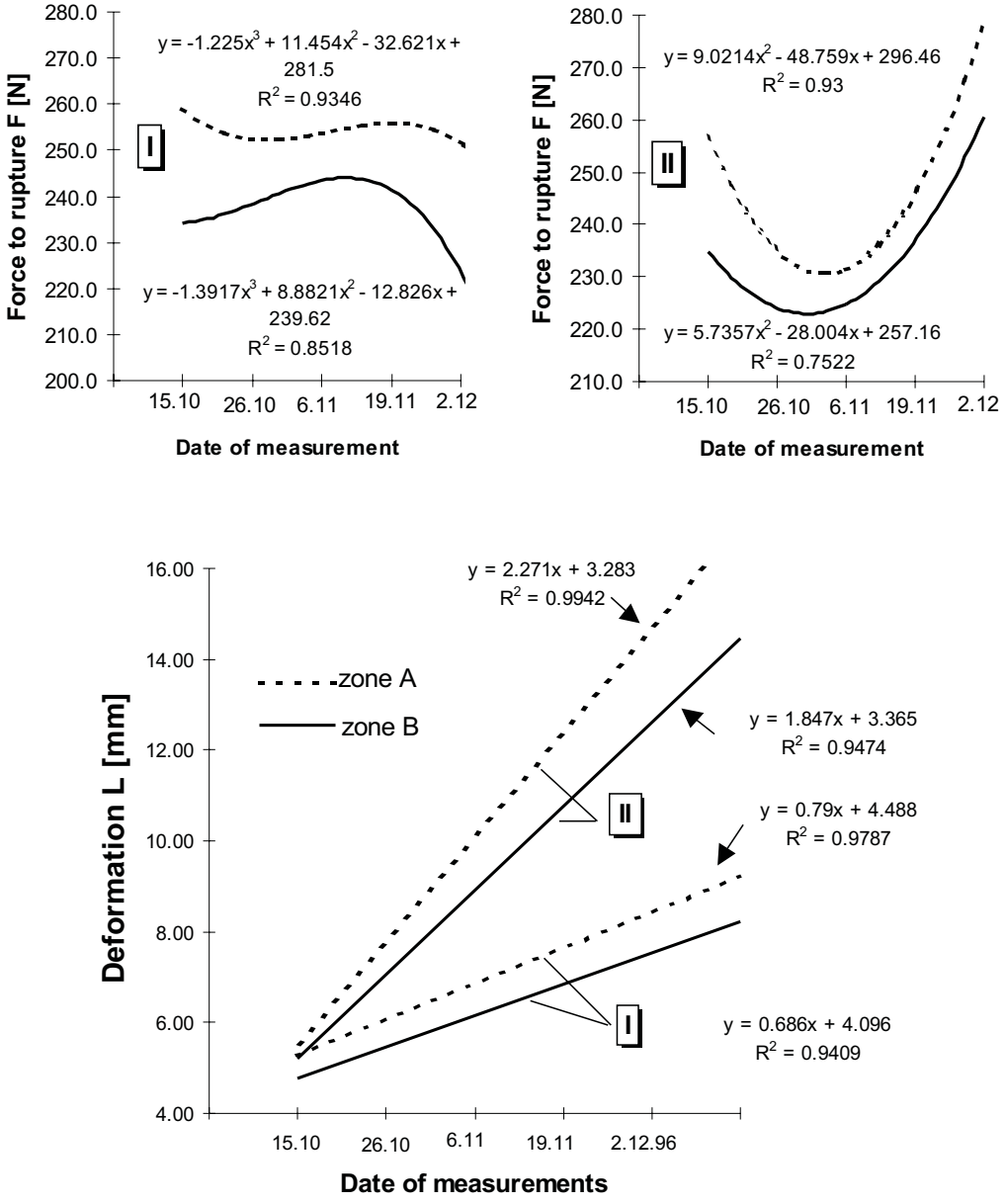

Fig. 4. Effect of storage time (date of measurements) and loading zone on force to rupture and deformation in I - natural conditions and II - room conditions.

properties of sugar beet root tissue at various dates of measurement. Therefore, lower correlation coefficients were obtained for the effect of storage duration on the value of root skin breaking force (Fig. 2). On the other hand, for the room storage conditions of this experiment relation between the date of measurement and the value of force causing skin puncture, or the

deformation at the moment of skin rupture was very precise (Fig. 3).

Differences in skin resistance to rupture in the two zones of roots became clearly marked over storage period (Fig. 4). Roots stored in natural conditions had an average skin resistance to rupture lower by 8% for the middle zone (B) while for those stored in present room storage conditions - the resistance to rupture was approx. 5% lower.

CONCLUSIONS

1. During static loading cv. Matador after harvest had largest resistance to mechanical damage. The average value of skin rupture force was 254.1 N.

2. Storage conditions and size of root significantly affected the resistance to mechanical damage.

3. Tissue of roots stored in room conditions exhibited larger deformation to its puncture than the one stored in the natural conditions.

4. The top root zone became more resistant to skin rupture than middle zone for both harvest and storage.

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