Research of sugar-beet tubers mechanical properties

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ABSTRACT: Approach to the problems of sugar-beet tubers surface damage dependence on harvesting technology. Investigation of sugar-beet tubers damage when falling on wood and iron surfaces and in the next case tuber damage caused by their fall on the tuber heap. Research of damage rate dependence on the fall height. Evaluation of damage rate was carried by the I.I.R.B. method (method used by all sugar-beet growing countries of Western Europe). The results refer that no considerable differences in damage rate after the fall on the wood or iron bottoms have been ascertained. The height of 1.5 m can be considered in all cases as the limit value of the tubers fall, when share of heavily damaged tubers reached acceptable values of 10–15%, but that the share increases significantly at higher falling height. The lifting bodies construction requires also a knowledge of dependence between root depth and force for tuber release from soil in relation to the tuber weight. Medium force needed for tubers lifting ranges from 17 to 27 kp, maximum value 50 kp was found out for tubers of weight above 3 kg.

Keywords: sugar-beet; tuber damage; fall height; root depth; force for tuber release

The sugar-beet growing on large areas of specialized agricultural enterprises requires the solution of quite new machines for particular working operations with regard to machine operational width, their performance, reliability, work quality and harvest loss amount. These tasks have brought many problems, for example tuber damage rate. The damaged spots on the tuber are attacked by moulds with consequence of storage loss increase and production decrease.

LITERATURE SURVEY

The sugar-beet damage during harvesting can have origin in all working nodes of the harvester. Its rate is affected in individual nodes differently. Damage can be divided into three basic groups:

– damage caused by lifting, or release from soil;
– damage caused by harvester cleaning elements;
– damage caused by tuber fall to the transport means or on the tuber heap during unloading.

The task of the first part of the sugar-beet tubers mechanical properties research was focused on the determination of the tubers damage rate caused by their fall to the transport means in dependence on the fall height and the impact on different materials.

For the lifting bodies construction, their work quality and the tubers damage rate caused by their operation it is necessary to know average and maximum forces needed for tuber lifting and withdrawing from soil. These dependences were also subjected to the research, as well SKALICKÝ (2001).

The sugar-beet tuber damage caused by the harvester cleaning elements will be subjected to the future verification because there exists a lot of cleaning principles and elements and thus measuring will be extensive.

The results of solution in the field of sugar-beet production will allow to complete knowledge and to make better decision on factors (booth internal and external) having principal effect on technical quality of sugar-beet tubers because there exists a very tight relationship between physical properties (e.g. strength or tendency to mechanical damage), chemical properties (substances content in tuber) and biological properties (stage of tuber ripeness and morphology) – BRINKMANN (1986). From these relationship can be derived dependencies of the surface damage on harvest technology, storage time and method and sugar-beet tuber handling. Controlling of these processes is problematic and is not even guaranteed as variety concomitant property. It has been proved that these properties can be effected in positive sense but for their deliberate controlling appropriate knowledge is not available. The need for such research is also evident from the foreign works. For example with similar problems deals e.g. Agricultural Faculty of Bonn University (KROMER et al. 1990).

METHOD

The purpose of the tests and measuring was to find the dependence between the fall height and tubers damage falling on wood and iron bottoms and on the tubers heap, i.e. to search for relationship between absolute damage and fall height for various types of impact bottom. On base of measuring the cross conveyer would be developed transporting tubers to the harvester hopper or to trailer. According to the measuring results the trailer or hopper bottom can be adapted with regard to the tuber minimum damage.

Purpose of force dependencies investigation necessary for lifting of tubers of different weight and root depth was to find medium and maximum forces for tubers withdrawal according to crop cover characteristics.

The measuring methodology has involved:

A – Testing place selection

Table 1. Tuber damage caused by their impact on wood

Tuber share (%)	Fall height (m)				
	0.5	1.0	1.5	2.0	2.5
Category A – undamaged tubers	90	82	70	62	43
	93	79	76	64	43
	93	85	78	72	49
	90	78	72	64	31
Category B – slightly damaged tubers	10	13	15	21	34
	17	12	16	21	34
	7	11	10	13	25
	11	7	11	11	36
Category C – heavily damaged tubers	0	5	15	17	23
	0	9	8	15	23
	0	4	12	15	26
	0	15	14	25	33

In the field were chosen four representative plots for investigation of 500 successive sugar-beets for each alternative according to the fall height and bottom type and 500 sugar-beets for finding the force necessary to sugar-beet withdrawal from soil.

B – Crops cover characteristics

Prior to the measuring the crop cover characteristics evaluation was conducted. Evaluated were tops shape, their height and length, tubers distance and cross tubers dislocation in row. During the measuring were identified characteristics of tubers, i.e. determination of their weight, diameter and length. Soil type and moisture were determined.

C – Tubers damage caused by fall

After tops cutting – off and characteristics finding the tuber was released from the horizontal position and the appropriate height on certain surface. After the tuber impact on the bottom the broken root diameter and damaged surface were measured. On basis of these values the tubers were classified to:

- non-damaged tubers according to Standard ČSN 47 0136;
- slightly damaged – damaged surface of length and width up to 40 mm and depth up to 10 mm and root diameter up to 30 mm according to Standard ČSN 47 0136;
- heavily damaged tubers – values of damage higher than in the previous point;
- damage evaluation according to the I.I.R.B. method determines the length and width of damage, their multiplication gives the area in cm^2 per 100 tubers;
- fall heights were chosen in intervals 0.5, 1.0, 1.5, 2.0, 2.5 cm; always 100 tubers in 3 repetitions were measured, the impact surface was wooden board, iron board and tubers heap.

D – Force needed to the tuber withdrawal

The sugar-beet tops were grasped by special pliers closely above the tuber head and withdrawn up vertically through the dynamometer of range 0–50 kp

Table 2. Tuber damage caused by their impact on iron surface

Tuber share (%)	Fall height (m)				
	0.5	1.0	1.5	2.0	2.5
Category A – undamaged tubers	98	80	63	64	33
	93	81	62	65	34
	92	82	82	70	50
	98	81	57	40	32
Category B – slightly damaged tubers	2	17	15	18	20
	6	16	15	19	20
	8	16	8	14	18
	3	8	16	5	11
Category C – heavily damaged tubers	0	3	22	18	47
	1	3	23	16	46
	0	2	10	16	32
	2	11	27	55	57

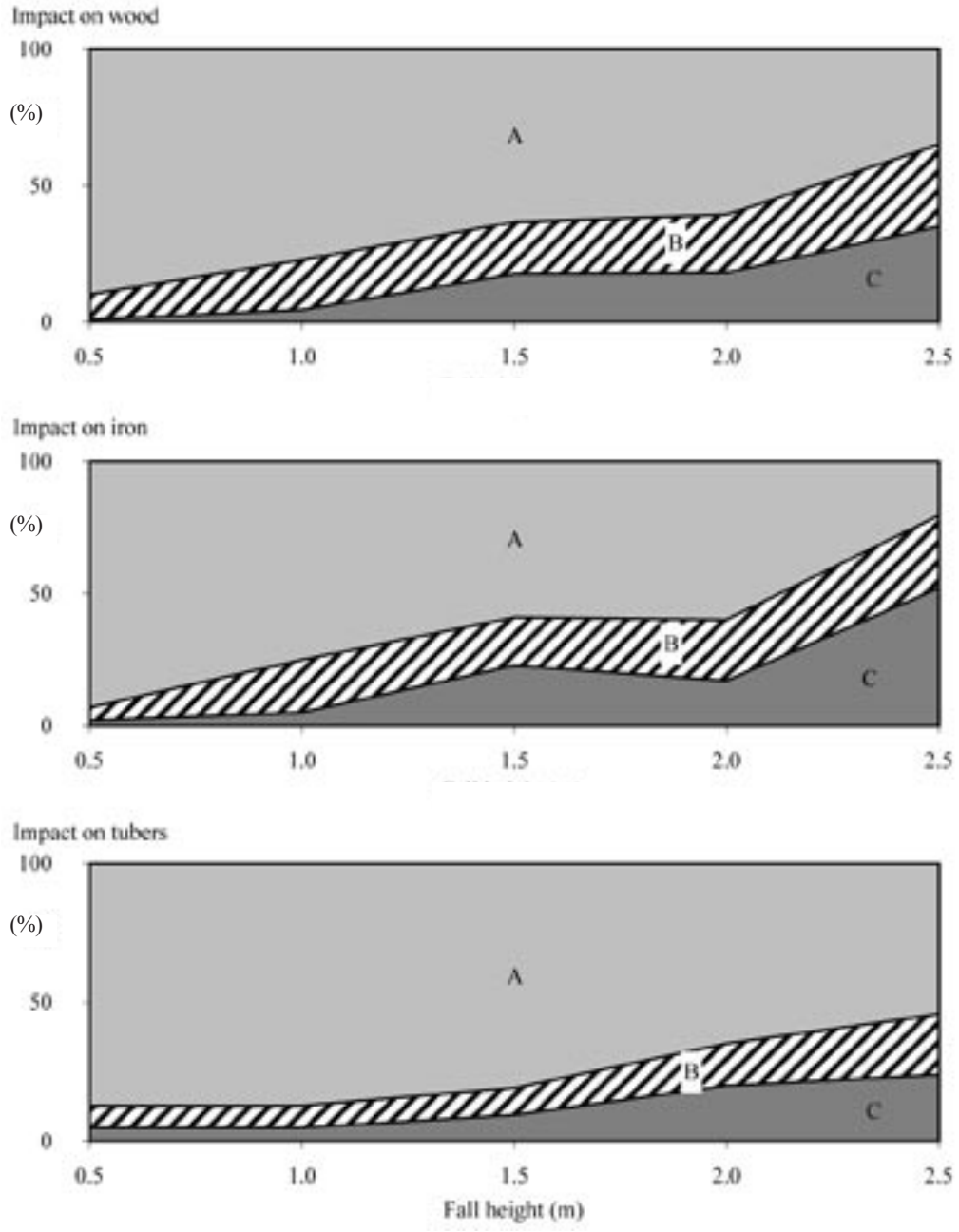

Fig. 1. Tuber damage in dependence on surface and fall height

(seldom dynamometer of range to 200 kp was used). After the lifting from the soil and force reading-off the tops were cut and tuber characteristics was found out.

RESULTS

The testing plots were selected with regular cover corresponding with requirements for high-quality mechanized harvest. The values of soil moisture were found measured in 3 different depths 0–50, 51–100, 101–150 mm. The values are reported in Table 4. The soil types of testing plots are presented in Table 5.

The found values of tuber damage in dependence on fall high and impact surface were worked-up in Tables 1–3 and expressed graphically. From the graphical dependences is evident that tuber damage has increased linearly with the fall height. Effect of different impact surfaces was minimal despite significant difference between impact on wooden surface and tuber heap and impact on wooden and iron surfaces. From this resulted conclusion that these phenomena are different within all the impact height interval. At fall heights 1.0 and 1.5 m the damage is bigger when the wooden surface in used in comparison with iron surface. In all the measuring the tuber impact on heaps is characterized by the lowest

Table 3. Tuber damage caused by their impact on tuber heap

Tuber share (%)	Fall height (m)				
	0.5	1.0	1.5	2.0	2.5
Category A – undamaged tubers	90	91	83	67	63
	89	90	80	67	63
	87	83	76	64	48
	91	64	52	36	33
Category B – slightly damaged tubers	8	6	10	18	20
	8	6	12	18	20
	10	10	13	20	27
	7	30	37	34	20
Category C – heavily damaged tubers	2	3	7	15	17
	3	4	8	15	17
	3	7	11	16	25
	2	6	11	30	47

Notice: number of measuring 4, average values of 3 repetitions

share of heavily damaged tubers. It is evident that other factors (physical, biological) which had not been investigated have also considerable effect on impact damage. It concerns particularly tuber specific weight, their shape, way and direction of impact on surface. The tuber was released from appropriate height in the horizontal position which is the most suitable for impact. Before the impact the tubers turned and fell in different direction owing to mass layout around the centre of gravity and tuber shape.

The force required for tuber withdrawal from soil in dependence on its mass and root depth was investigated according to previously described methodology. The values were written into tables and assessed. It is evident that the force required for tuber withdrawal is directly proportional to the tuber mass. This is valid for average values. Ratio of scattering between mass classes and even inside the classes is small. Similarly small also is the difference between testing plots sites. Comparison of particular measuring has shown that with the soil moisture increasing the force required for tuber withdrawal decreases in all mass categories. The medium force for tuber withdrawal ranges from 17 to 27 kp in dependence on crop cover and soil moisture. Maximum force is needed for tubers of mass above 3 kg.

Relationship between the force required for withdrawal and root depth is linear. The scattering ratio between mass classes and inside the classes is small. The statistical dependence measuring between the force required for tubers withdrawal from soil (variable y) and their mass (variable x) is evaluated and given in the form of regressive straight line:

$$y = a_{yx} + b_{yx} (x - \bar{x})$$

where: a_{yx} – shift coefficient,
b_{yx} – regression coefficient,
$x - \bar{x}$ – value deviations of the independently variable from their average value substituted the proper values.

Table 5. Soil type

Measuring point number	Soil type
1	loamy
2	loamy
3	loamy
4	clay-loamy

DISCUSSION

The tuber damage values determination during harvesting caused by their fall into transport means is one part of the whole complex of tuber damage possibility. Si-

Table 4. Force required for tuber release from soil

Measured point	Moisture (%)*	Mass interval average (kg)									
		0.35	0.65	0.95	1.25	1.55	1.85	2.15	2.45	2.75	3.05
1	12–13	21.4	23.1	28.1	28.8	33.0	30.2	29.8	33.0	36.7	38.3
2	13–14	17.8	18.8	20.3	21.3	21.8	22.4	26.6	29.2	33.0	33.4
3	14–16	19.4	24.3	27.2	29.2	26.9	26.9	31.1	31.0	35.8	37.5
4	18–20	17.5	18.0	18.8	20.8	21.5	23.4	23.5	28.1	34.3	35.4

*average values

Table 6. Effect of root depth on force required for tuber release from soil

Root average depth (cm)	5.0	7.5	9.6	11.6	13.5	15.4	17.4	19.5	21.5
Average force for withdrawal (kp)	15.2	16.0	17.4	19.2	21.3	21.6	23.8	24.8	28.0

milarly also lifting or withdrawal from soil is important to obtain as big as possible share of undamaged tubers. For there reasons the force was investigated required to their release from soil. The tuber damage values lead to following conclusions:

– At present sugar-beet is purchased according to the purchase contract between producer – agricultural enterprise and processing plant – sugar factory. Conditions stated in the purchase contracts are combination of the Standards ČSN 47 0136, ČSN 46 2110 requirement, some requirements of the I.I.R.B. method and other additional requirements of the processing plants. The most important, besides sugar content, is considered the mineral impurities content, crop admixtures, free tops and incorrectly cutt (too high) tubers, i.e. indicators of tuber quality determination as raw material. Other qualitative indicator is the tuber damage during lifting cleaning and transport and by their falling into transporting means or harvesters hoppers.
– Tuber damage values caused by their fall into transport means can be decreased by the fall height. Considerable differences in tubers damage rate caused by the fall onto wood or iron surface have not been found-out. The limit value of the fall height is considered in all cases for distance to 1.5 m when heavily damaged tubers share has reached the acceptable value of 10–12%. At higher impact height the share increases significantly.
  The designers can use our values of tubers damage for development of combine harvester transporters.
– The dependence between root depth and force required for tuber release from soil and its mass can be used for designing of lifting bodies. Medium force required for the tuber withdrawal ranges from 17 to 27 kp, maximum value 50 kp was found for tubers exceeding the mass of 3 kg. Significant effect of the soil type has not been proved. With increasing moisture the force required for withdrawal from soil decreases to values 15–17 kg. Regular sugar-beet cover, i.e. such with high number of individual plants per 1 ha (optimum about 80 thousands), small differences in weight of particular tubers (tuber average mass 0.5–0.7 kg) and regular root depth lead to the high – quality undamaged tubers as raw material.

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Received for publication April 25, 2003
Accepted after corrections July 28, 2003

Výzkum mechanických vlastností bulev řepy

ABSTRAKT: Je řešena problematika závislosti povrchového poškození bulev řepy na technologii sklizně. Bylo zjišťováno poškození bulev řepy pádem na dřevěnou a železnou podložku a v dalším případě poškození bulev pádem na hromadu bulev. Byla sledována závislost velikosti (četnosti) poškození na výšce pádu. Hodnocení velikosti poškození bylo provedeno podle metody I.I.R.B. (metoda uznávaná všemi řepařskými státy západní Evropy). Z výsledků lze uvést, že výrazné rozdíly ve velikosti poškození po pádu na dřevěnou nebo železnou podložku nebyly zjištěny. Za limitní hodnoty výšky pádu lze ve všech případech považovat vzdálenost 1,5 m, kdy podíl silně poškozených bulev dosahuje přijatelných hodnot 10–15 %, při vyšších dopadových výškách výrazně stoupá. Pro konstrukci vyorávacích těles lze využít i zjištění závislosti mezi hloubkou zakořenění a silou potřebnou k uvolnění bulvy z půdy ve vztahu ke hmotnosti bulvy. Střední síla potřebná k vytažení bulvy se pohybuje v intervalu 17–27 kp, maximální hodnota 50 kp byla zjištěna pro bulvy s hmotností převyšující 3 kg.

Klíčová slova: cukrovka; poškození bulev; výška pádu; hloubka zakořenění; síla na uvolnění bulvy

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