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METHOD OF EXTERNAL ASSESSMENT OF THE QUALITY OF SUGAR BEET ROOTS

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Abstract. The research problem of the paper concerned verification whether applicable or known methods of post-harvesting evaluation of the roots of sugar beet may be applied to the assessment of the quality of work of technically varied new machinery for sugar beet harvesting. Tests of machines of varied solutions of working units, in particular a topping unit, were carried out in order to accomplish the objective of the paper. Two self-propelled combine harvesters of Ropa euro-Tiger V8-3 type and Kleine Beetliner Large and two sets for 2-stage harvesting by M.A.C.E (Spain) and Amity (USA) companies were used in the study. Ropa euro-Tiger and Kleine Beetliner Large combine harvesters and M.A.C.E. set were equipped with a beet topper but of a varied topping system, whereas, only a defoliator was used in the set by Amity company. Field research of machines included assessment of the topping quality, losses caused by the broken tip of roots and damages of the lateral surface of roots. Research assumptions were assumed according to the method of the International Institute for Beet Research (I.I.R.B.). Moreover, assessment of the topping quality with the method of the Netherlands Institute of Sugar Beet Research (IRS) and the Institute of Agricultural Engineering of the Bonn University was carried out. Assessment of roots after defoliation was carried out based on the Roller's classification (2010). Based on the research results and analyses which were carried out, it was proved that the methods of measurement of the quality of beet harvesting machines operation are not fully useful for assessment of the introduced technical and technological changes. It mainly concerns the assessment of the roots topping. Thus, two modified methods of assessment of the quality of roots topping were suggested. They may be used both for machines equipped with a topping device and a defoliator.

Key words: harvesting sugar beet, topping, defoliation, quality of roots

Introduction

Many factors, related and not related to a grower, decide on the value of the sugar beet roots as raw material for production of sugar. Related factors include, inter alia, technical production means, including harvesting machines, used by growers. Solutions of working units of harvesting machines and parameters of their operation have a decisive impact on

the so-called external quality of roots (Bzowska-Bakalarz, 1997; Gorzelany, 2000; Przybył, 2003; Przybył, 2006; Przybył et al., 2011).

External assessment of the quality of beet roots, including the quality of topping, damage and dirt translate into usefulness of roots and long storage in field prisms. Different types of tissue damage, for example after topping, after the broken tip of a root and damage to the lateral surface, except for mass losses, facilitate bacteria penetration, which speeds up sugar inversion and fungi penetration into deeper layers of tissue. Then, decaying focuses are formed, which threaten also healthy roots (Antkowiak, 1978; Beer et al., 2009; Becker et al., 2010). Heap putridity is developed as effect of high contamination of roots with soil, which hinders the exchange of heat with the surrounding, and as a result it influences the increase of temperature in the prism. German research show that during 10-day storage in 15°C degrees temperature of damaged beets, losses were 2.5% of the crop and in case of undamaged – only 0.5% (Beer et al., 2009). Thus, in the aspect of the possibility of long storing in prism, the beet roots should be topped high and should not be damaged neither mechanically nor by pathogens and should be non-contaminated (Beer et al., 2009; Bzowska-Bakalarz et al. 2005; Przybył 2006). In order to decrease the area of the damaged tissue of roots, it is aimed to replace topping with defoliation or cutting only a leaf rosette and to take out a whole root out of soil without breaking the tip.

The external quality of roots of the sugar beet is significant not only in case they are designated to be processed into sugar but also at the alternative use i.e. for production of bioethanol or biogas. If roots are designated for biogas purposes, their cleanness is particularly important. It considerably influences a correct operation of the biogas installation (Beer et al., 2009; Przybył et al., 2010).

Structural changes in the sugar industry influence the condition and the trends of development of specialistic technology for production of sugar beet, including development of beet harvesting machines and post-harvest roots processing machines. According to Szeptycki (2005) analysis of effectiveness of modernization of sugar beet harvesting technology, unanimously indicate that the use of new, highly-efficient, multi-row machines, allows obtaining more fully valuable crop with a high post-harvest quality of roots.

Development of the structure of machines for beet harvesting takes place in many directions and includes both new structures as well as improvement of particular components and optimization of machines in the aspect of the quality of machines and costs of exploitation. The most important changes introduced in the recent time, which affect the post-harvest quality of crop are as follows: new solutions of the topping unit, based on the cutter and the use of micro-toppers in order to decrease the losses of the roots crop during removal of leaves, propelled wheel lifters and beet lifter of a module structure, limiting braking the tips of roots and new solutions of the cleaning unit in order to decrease damage to roots (Przybył, 2013).

Technical progress requires an appropriate assessment of machines based on indicess of post-harvest quality of crops, which should support the grower's decision at the selection of the technology of harvesting. Therefore, the paper investigates sugar beet harvesting machines, which differ with working units solutions, in particular with a topping unit and the analysis of the usefulness of presently applied methods of quality assessment of their operation.

Objective and the scope of the paper

The research problem of the paper concerned verification whether applicable or known methods of post-harvesting assessment of the sugar beet roots may be applied to the assessment of the quality of work of technically varied new machines for harvesting sugar beet.

In order to find an answer to the above questions, machines of varied working units solutions were selected including a topping unit, field research was carried out in order to determine indices of post-harvest quality of roots, usefulness of the applicable and known methods for assessment of post-harvest quality of roots was carried out and modified method was suggested for its assessment, which enables assessment of the quality of operation of technically new machines for harvesting sugar beets.

Field research of machines included evaluation of the topping quality, damages to the lateral surface of roots and losses caused with a broken tip of roots. Research assumptions were assumed according to the procedure of the International Institute for Beet Research (I.I.R.B.). (Vandergeten et al., 2004). For evaluation of the quality of topping beets, a method of the Netherlands Institute of Sugar Beet Research (Instituut voor Rationele Suikerproduktie, IRS) (Tijink, 2010) and the Institute of Agricultural Technology of the Bonn University (Schulze Lammers et al., 2012) were also used. Assessment of roots after defoliation was carried out based on the Roller's classification (2010).

Material and methods

Two self-propelled combines were selected for the research: Ropa euro-Tiger V8-3 and Kleine Beetliner Large and two sets for 2-stage harvesting of beets of M.A.C.E. (Spain) and Amity (USA) companies. The set by M.A.C.E. company was composed of a head topper and a suspended on the same tractor on the three-point hitch of the digger and a trailed loader. Amity set was composed of an trailed defoliator and an trailed harvester. All machines harvested beets from 6 rows. Ropa euro-Tiger and Kleine Beetliner Large combine harvesters and M.A.C.E. set were equipped with a beet topper but of a varied topping solution, whereas, only a leaf cutter (defoliator) was used in the set by Amity company.

A topping unit of combiners Ropa euro-Tiger and Kleine Beetliner Large and M.A.C.E is composed of a leaf cutter and the scalping system. Micro-Topper system (the so-called micro-topper) was used in the Ropa combine. Its aim is to cut leaves at their base. A similar task in Kleine Beetliner Large is executed by Opti-Cut system. Whereas, in the M.A.C.E set, a traditional topper with a permanent working gap was applied.

Research was carried out in 2011 on the territory of Wielkopolskie voivodeship in towns Chwalęcin (Ropa euro-Tiger V8-3) and Żołędnica (2-stage unit M.A.C.E.), Dolnośląskie voivodeship in towns Stary Jaworów (2-stage set Amity) and Małopolskie voivodeship in the town Rozkochów (Kleine Beetliner Large).

There is no methodology for external assessment of the quality of sugar beet. However, this assessment may be carried out with the use of the methodology of investigation of beet harvesting machines, that is a procedure of the International Institute for Beet Research (Vandergeten et al., 2004) or the Polish Norm PN-91-R-55023. On account of the possibil-

ity of comparing results, procedure of I.I.R.B. was applied in the research. Based on this methodology, the quality of topping, damage to roots and loss of crop in the form of broken ends of roots were determined. The last index indirectly proves damage to the beet roots. However, the higher was the value of this index, the higher was the surface of breaking the beet root and the higher was possibility of the loss of masses and sugar during a longer storage. No mineral or organic pollutions were determined in the research.

Before the research on the quality of machines was carried out, assessment of the condition of plantation based on five random trials composed on 100 subsequent beets in the row was carried out. The quality of topping and damage to beets was evaluated based on random five trails 100 roots each, collected form the prism. Evaluation of the quality of topping consisted in qualification of roots to one out of six categories: untopped beet with leaves remains above 2 cm, untopped with the leaves remains above 2 cm, over topped, correctly topped, under topped or angled topped (fig. 1).

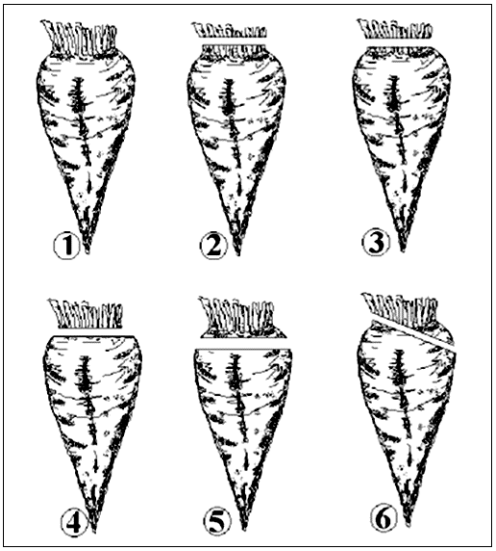


Figure 1. Topping sugar beet quality classification according to methodology of I.I.R.B: 1 – untopped with petioles longer than 2 cm, 2 – under topped with petioles shorter than or equal to 2 cm, 3 – under topped with no petioles, 4 – correctly topped, 5 – over topped, 6 – angled topped

Source: Vandergeten et al.., 2004

Assessment of root damage according to methodology of I.I.R.B. consisted in determination of the lateral surface of beet expressed in cm² per 100 roots. In order to assess the losses of crop in the form of broken tips of beets, a diameter was measured in the place where the tip was broken. Roots, which were collected for assessment of the quality of topping were used for measurements. Data from measurements were divided into five

classes, every 2 cm: 0-2 cm, >2-4 cm, >4-6 cm, >6-8 cm, >8 cm. Estimation of the loss of crops in the form of broken tips of roots was carried out according to the pattern:

$$\sum_{i=1}^{5}\left(\frac{\left((b_i \times c_i) - r_b\right)}{b_i \times 10^6} \times PD_h\right) \text{ (t·ha}^{-1}\text{)}$$

where:

b_i – number of class (%),
c_i – factor (0, 23, 60,130, 230) mass losses in a given class (g),
r_b – mass of broken ends of roots in the collected sample (g),
PD_h – final stocking of plantation, (item.·ha^{-1}).

Classification of sugar beet roots after defoliation with Amity defoliator was carried out based on Roller's method (2010). According to this method, a root may be classified to one of five classes: with petioles and undamaged, with petioles and damaged, with ends of petioles, without petiole, without leaves and damaged (fig. 2).

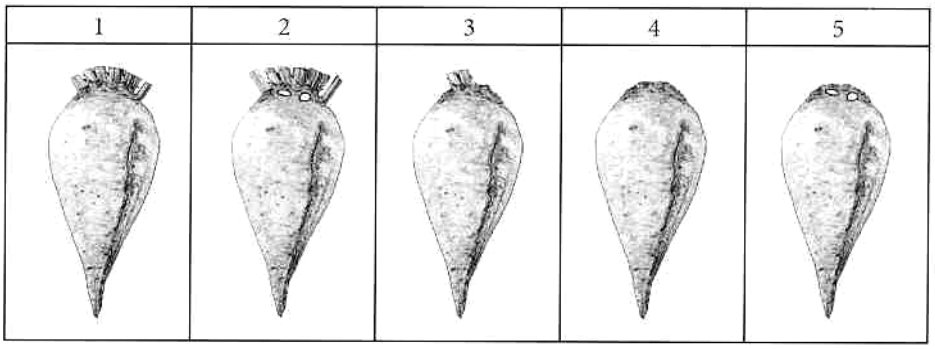


Figure 2. Sugar beets classification after defoliation: 1 – with petiole and without damage, 2 – with petiole and damaged, 3 – with ends of petiole, 4 – without petiole (defoliated), 5 – without petiole (defoliated) and damaged

Source: Roller, 2010

Research results on the quality of beets topping by the investigated machines, was additionally assessed with two methods suggested by the Dutch Institute of Sugar Beet (Tijink, 2010) and the Institute of Agricultural Technology of the Bonn University (Schulze Lammers et al., 2012). IRS methodology was used for testing the quality of machines operation during the show Beet Europe 2010, equipped both in topping devices and a defoliator. Assessment is based on the assumptions of I.I.R.B. methodology and differs with qualification of the topping quality to five categories: untopped beet with the remains of leaves above 2 cm, untopped with the leaves remains up to 2 cm, well topped, topped too low and angled topped. In the category "correctly topped beet" there are correctly topped

roots and over topped roots. According to the method of the Institute of Agricultural Engineering of the Bonn University, the quality of roots topping may be evaluated by allotting them to one of three categories: untopped, correctly topped and under topped.

Research results and their analysis

Through introduction of structural changes, producers of beet combine harvesters aim at collecting the whole crop of roots at the simultaneous increase of its quality. Obtaining "whole beets" means aiming at minimization of losses caused by breaking the roots tips and leaving a head on the root, but defoliated. Thus, this concept consists in replacement of roots topping with defoliation. The second concept consists in micro-topping, that is, cutting leaves at their base. Sugar beet harvested with a head and even with the remains of petioles is also a great substrate for biogas production.

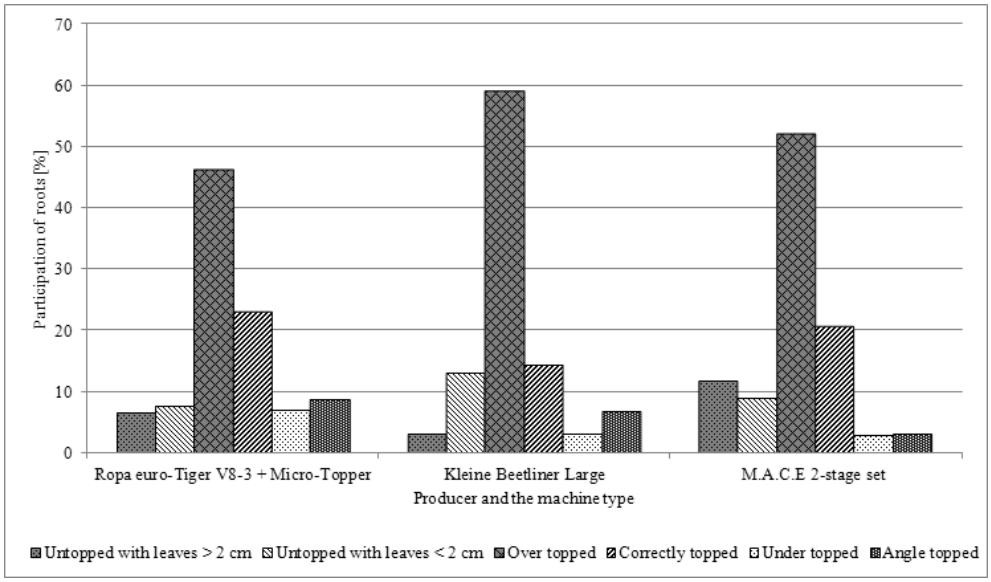


Figure 3. Evaluation of topping quality of sugar beet roots by the investigated machines on the basis of I.I.R.B method

New approach to the quality of sugar beet topping and the introduced structural changes in topping units, cause that the previous assessment method of the post-harvest quality of roots hinders comparison of machines. The use of micro-toppers or defoliators assumes that leaving a head on the roots is correct. However, according to the I.I.R.B. methodology, these roots are qualified to the "over topped" category (fig. 1). Therefore, as the research show (fig. 3) combine harvesters with micro-toppers, over topped the highest number of beets, i.e. Ropa 46.4% and Kleine 59% and correctly only respectively 23.2 and 14.4%. For comparison, M.A.C.E. set topper with a standard topping device, set purposefully at high

topping, over topped 52.2% and correctly topped 20.8 %. Such interpretation of results proves, that methodology of the International Institute of Research on Beets does not respond to new concepts of beets harvesting.

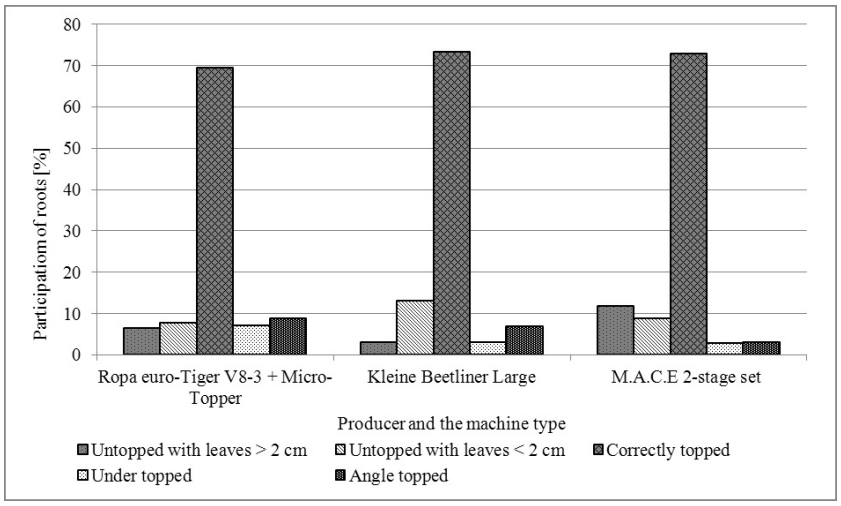


Figure 4. Quality of topping sugar beet roots by the investigated machines on the basis of the method of the Netherlands Institute of Sugar Beet Research (IRS)

For comparison, an assessment of the topping quality of roots by those three machines was carried out, with the method suggested by the Netherlands Institute of Sugar Beet Research. In this method, after adding "correctly topped" and "over topped" roots, Ropa combine topped "correctly" 69.6% and Kleine 73.4% of roots (fig. 4). In case of M.A.C.E set, this index was 73%. The analysis of the remaining data shows that Ropa combine did not top 14.4% of roots and Kleine 16.4%, whereas there were 16.1 and 10.2% of angle topped roots.

Because "angle topped" roots also require correction of topping, this according to Schulze Lammers et al. (2012) the quality of roots topping may be assessed by assigning them to one of three categories: untopped, correctly topped and under topped. At such classification of roots, Ropa combine failed to top 23.2% and Kleine 23.4% of roots. There were respectively 7.2 and 3.2% of roots topped too low. Graphic interpretation of this classification was presented in fig. 5. For comparison during the test in Seligenstandt in 2012 as a part of Beet Europe exhibition, Ropa combine topped correctly 77% of roots and 22.2% were untopped, whereas, Kleine combine respectively: 61.4 and 37.8% (Schulze Lammers et al., 2012).

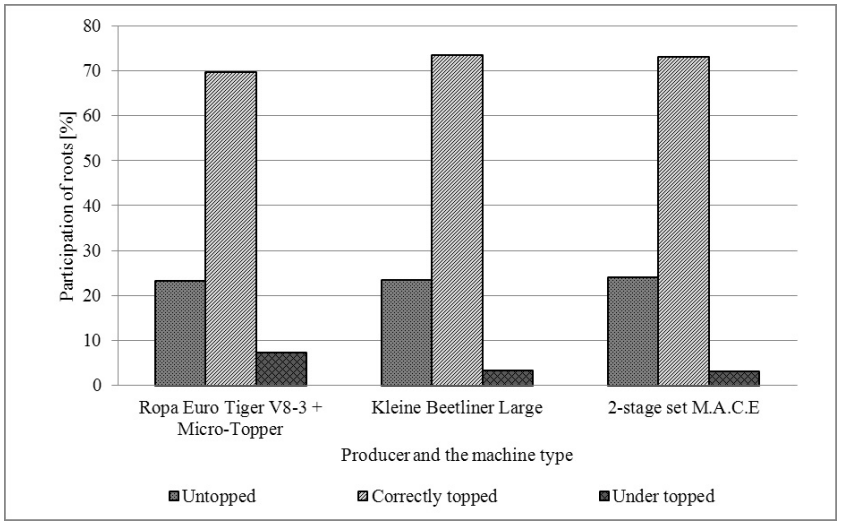


Figure 5. Quality of topping sugar beet roots by the investigated machines according to the procedures of the Institute of Agricultural Engineering of the Bonn University

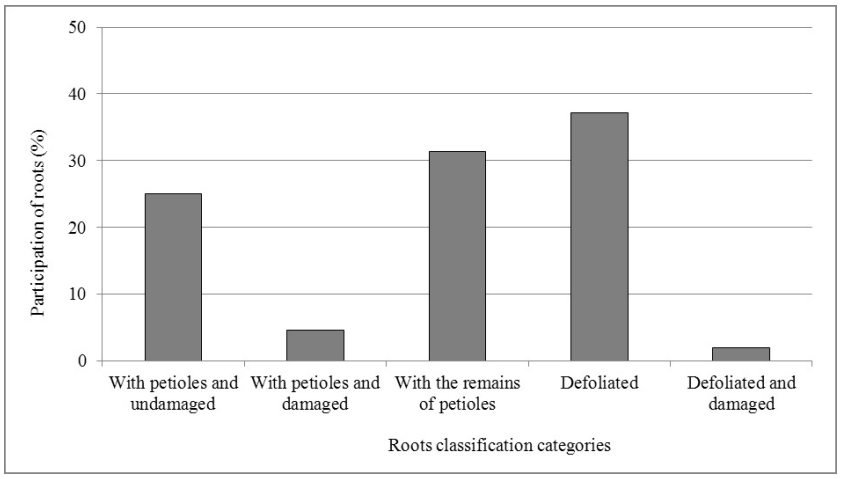


Figure 6. The roots of sugar beets after leaf defoliation with leaf stripper Amity company based on the classification Roller (2010)

In case of Amity set, the roots assessment after defoliation was carried out according to the method suggested by Roller (fig. 2). In this method, roots are qualified to the appropriate category based on the leaves remains and damage. The sugar industry accepts roots without the leaves remains, that is, from two last categories. There were 39.1% of such roots (fig. 6). Over 60% of roots had petioles. Such roots are accepted in case of their use e.g. as a substrate for biogas production. Analysis of the quality of defoliation indicates a low participation of damaged roots (6.6%).

Based on the defoliation quality assessment, the method suggested by Roller can hardly be recognized as correct and fully useful. Dividing roots with the leaves remains into three categories is unnecessary. Roots damaged by beaters of the stripper may be qualified to a separate category. Theoretically, also under topped roots and angled topped roots can be placed in this category. Roots without leaves (defoliated) are the most important category in this assessment.

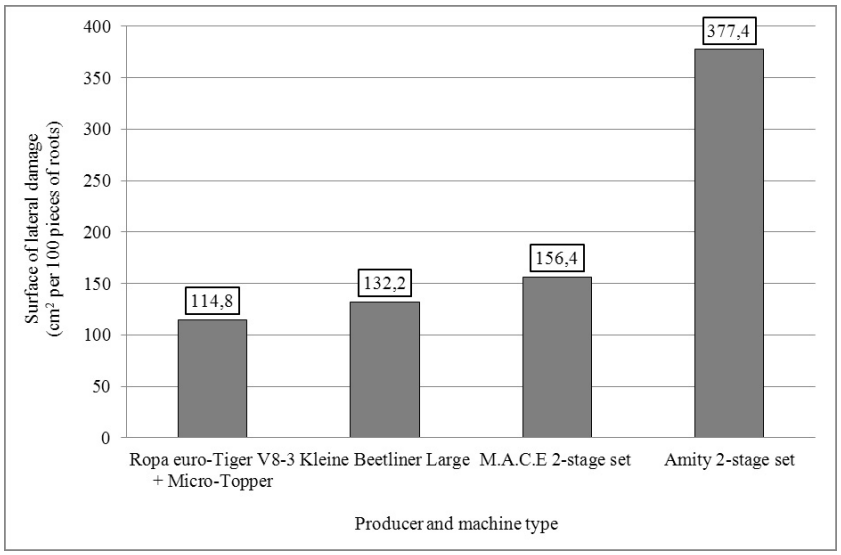


Figure 7. Damage to the lateral surface of sugar beet roots

For determination of the remaining indices of the external post-harvest quality of roots analysed in the paper, that is damage to lateral surface and the losses of crops in the form of broken tipss of beets, the I.I.R.B. procedure was applied. On their basis, one may conclude usefulness of roots for longer storage, thus on the usefulness of machines or technology.

Results of research on lateral surface damage of roots were presented in figure 7. The lowest damage of beets was caused by Ropa euro-Tiger combine. Total surface of damage referred to 100 roots was 114.80 cm^2. The surface of beets damaged by Kleine combine was higher by 15%. Out of two investigated sets for 2-stage harvesting, the M.A.C.E set caused less damage of roots. Lateral damage surface of roots caused by this set of machines was 156.4 cm^2, whereas Amity set was 377.4 cm^2 per 100 pieces of roots. During previous research on the quality of beet harvesting machines operation, this index was within 127 and 151 cm^2·per 100 pieces of roots (Przybył, 2006; Schulze Lammers, 2005).

Moreover, in the assessment of the yield losses as a result of breaking tips of roots, the Amity set obtained three times higher index than the remaining machines. Losses as a result of breaking root tips, caused by a harvester from Amity set were 10.50% of the crop, whereas, losses after the digger from M.A.C.E. set were 3.44% and losses of self-propelled combines Ropa and Kleine were respectively 3.75 and 3.625 (fig. 8). Losses caused by

self-propelled combines are higher than during the test in Seligenstadt. Average losses of crop caused by breaking root tops for 9 investigated combines were 2.6%. Losses of Ropa combine were 2% and Kleine 3.1% (Schulze Lammers et al., 2012).

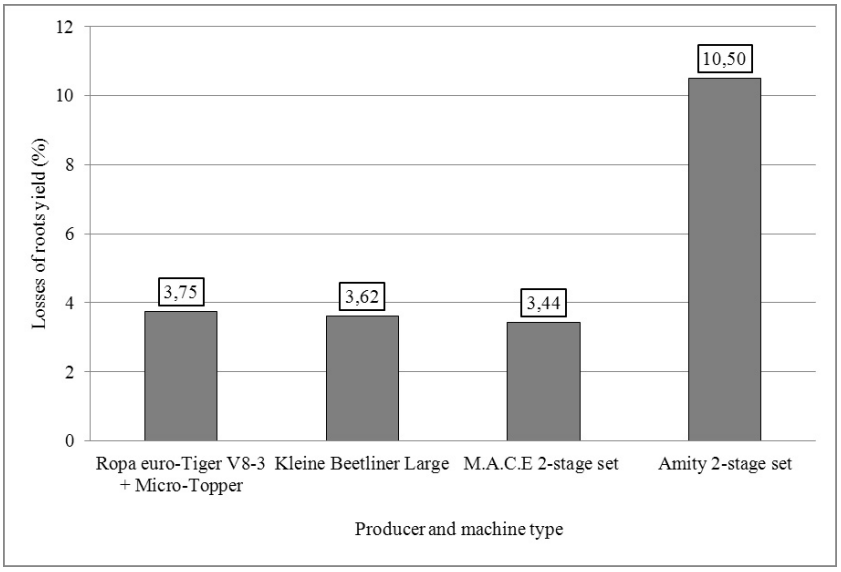
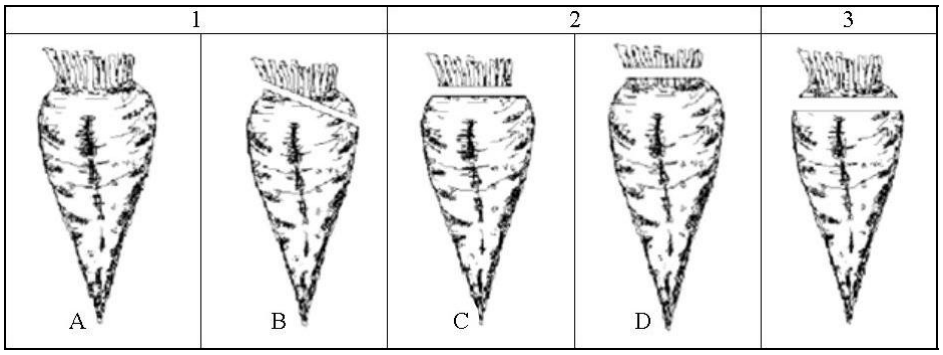


Figure 8. Root yield losses due to breakage of roots tips

The research results show that higher external quality characterizes roots after harvesting with self-propelled combines. A comparable quality of roots was determined after beet harvesting with M.A.C.E. 2 – stage set. Amity set is characterised with a considerably lower quality of work, particularly within the scope of roots damage. Despite, the use of a defoliator in this set, a great surface of the remaining spots of roots damage will be a hindrance for their longer storing.

The analysis, which was carried out, shows that the applicable methods of post-harvest assessment, after adaptation, may be used for assessment of the quality of operation of technically varied new sugar beet machines, in particular for assessment of the quality of topping or assessment of removing leaves (defoliation). The basis of proceeding in the assessment of the external quality of crop, should consist in the methodology of the International Institute for Beet Research, which is used during the European tests of sugar beet harvesting machines (Bzowska-Bakalarz et al., 2006). It may be used without changes for assessment of the size of losses, damage and roots dirt. Changes must concern the assessment of topping or defoliation of beets. It results from the present use of a traditional topper in the topping set (place of cutting within the root's neck, that is a knife cuts the beet head) and new solutions in the form of a micro-topper (knife cuts the leaf rosette at its base) or a defoliator (removes leaves with beaters). The research and analysis of the obtained results showed that introduction of two assessments is justified: separate for machines with a micro-topper and the other for a machine with a defoliator.



Source: author's own study based on Vandergeten et al., 2004

Figure 9. Proposition of classification of roots topping quality: 1 – untopped (A – with rest petioles, B – angled topped), 2 – correctly topped (C – without the head, D – under topped with no petioles or after micro-topping), 3 – over topped

In the first case, the most favourable solution is dividing roots into three categories: untopped roots, correctly topped roots, under topped roots (fig. 9). Untopped roots not related to the length of the remains of petioles and angled topped roots are in the first category. The second category, taking into consideration fig. 1, includes correctly topped roots and over topped roots as well as micro-topper.

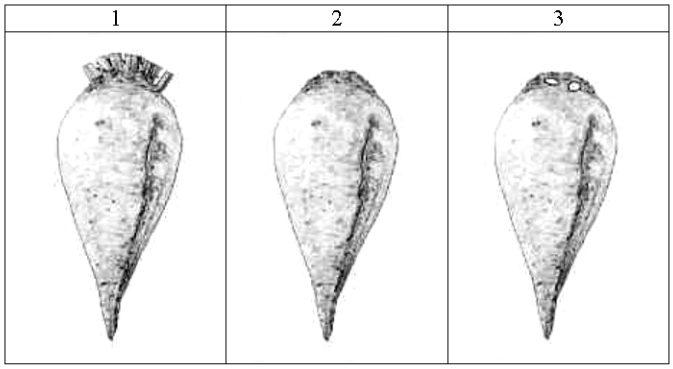


Figure 10. Proposition of classification of sugar beet roots after defoliation: 1 – with petiole, 2 – without petiole (defoliated), 3 – without petiole (defoliated) and damaged

Source: author's own study based on Roller 2010

In the second case, at the assessment of roots after defoliation, it is justifiable to divide roots into three categories: with petioles, without leaves and without leaves with damage (fig. 10). Under topped roots may be qualified to the third category.

Summary and conclusions

The basic assumption of modern beet harvest technology is harvesting the whole produced root crop with a head and the tip of the root of the high external quality. High quality of roots limits losses of mass and sugar during a longer storage of beets in field prisms. External quality of the beet roots is significant also at the alternative use e.g. for bioethanol or biogas production. Technical progress requires appropriate assessment of machines based on the post-harvest crop quality of indices. Research results and their analysis proved the following:

1. Despite the lack of methodology for external, post-harvest assessment of the quality of sugar beets, for this purpose, after adaptation, presently applied procedures of assessment of the quality of sugar beet harvesting machines operation may be used.
2. Methodology of the International Institute for Beet Research should be the basis for proceeding in the external assessment of the crop quality. It may be used without changes for assessment of the size of losses, damage and roots dirt. Changes should concern the assessment of topping and defoliation of beets.
3. Because, presently, a traditional topper and new solutions in the form of micro-topper or a defoliator are used in the topping unit, introduction of two assessments of the quality of topper operation was suggested: for machines with a topper or a micro-topper and the second assessment - for machines with a defoliator.
4. Higher external quality characterizes roots after harvesting with self-propelled combines.
5. Micro toppers, have not meet the assumptions, according to which, all roots should be topped.

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METODA OCENY ZEWNĘTRZNEJ JAKOŚCI KORZENI BURAKÓW CUKROWYCH

Streszczenie. Problem badawczy pracy dotyczył sprawdzenia, czy obowiązujące lub znane metody oceny pozbiorowej jakości korzeni buraka cukrowego można stosować do oceny jakości pracy zróżnicowanych technicznie nowych maszyn do zbioru buraków cukrowych. Dla zrealizowania celu pracy przeprowadzono badania maszyn o zróżnicowanych rozwiązaniach zespołów roboczych, a w szczególności zespołu ogławiającego. Do badań wyznaczono dwa kombajny samojezdne typu Ropa euro-Tiger V8-3 i Kleine Beetliner Large oraz dwa zestawy do zbioru 2-etapowego firm M.A.C.E. (Hiszpania) i Amity (USA). Kombajny Ropa euro-Tiger i Kleine Beetliner Large oraz zestaw M.A.C.E. były wyposażone w ogławiacz, ale o różnym rozwiązaniu dogławiacza, natomiast w zestawie firmy Amity zastosowano wyłącznie defoliator. Badania polowe maszyn obejmowały ocenę jakości ogłowienia, strat spowodowanych obłamanym końcem korzeni oraz uszkodzeń powierzchni bocznej korzeni. Założenia badawcze przyjęto zgodnie z metodą Międzynarodowego Instytutu Buraka Cukrowego (I.I.R.B.). Wykonano również ocenę jakości ogłowienia metodą Holenderskiego Instytut Buraka Cukrowego (IRS) oraz Instytutu Inżynierii Rolniczej Uniwersytetu w Bonn. Ocenę korzeni po defoliacji przeprowadzono na podstawie klasyfikacji Rollera (2010). Na podstawie wyników badań i przeprowadzonych analiz wykazano, że stosowane obecnie metody pomiaru jakości pracy maszyn do zbioru buraków nie są w pełni przydatne do oceny wprowadzanych zmian technicznych i technologicznych. Dotyczy to przede wszystkim oceny ogłowienia korzeni. Dlatego zaproponowano dwie zmodyfikowane metody oceny jakości ogłowienia korzeni, które można zastosować zarówno do maszyn wyposażonych w ogławiacz, jak i defoliator.

Słowa kluczowe: zbiór buraków cukrowych, ogławianie, defoliacja, jakość korzeni

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