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QUALITY IN POST-HARVEST SUGAR BEET CROPS

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Abstract. The aim of the study was to investigate whether and how the working speed of a harvesting machine affects the crop quality of sugar beet, i.e. to what extent it influences root contamination, topping quality, root damage and root mass loss. A one factor, random distribution experiment in four repetitions was performed. A Stoll V202 two-row trailed harvester and a Holmer Terra Dos self-propelled harvester were used. Both harvester's with four speeds ranging from 4 to 8.5 km h^{-1} (Stoll) and from 4 to 10 km h^{-1} (Holmer). The results were analysed statistically. The analysis revealed that an increase in the beet harvester's working speed gives rise to a reduction of crop quality.

Keywords: sugar beet, crop quality, working speed of a harvesting machine

INTRODUCTION

The working speed of a harvester is limited by engine power, tractive adhesion to the surface, crop size or the required crop quality. During sugar beet harvesting when the soil is wet, tractive adhesion or the necessity to properly clean the roots within the machine's cleaning unit are factors which limit speed. Under normal harvesting conditions speed is either limited by the harvester's capacity or the quality of the beetroot.

Crop quality is important both for the farmer and the sugar factory. Therefore the possibility of increasing speed without reducing crop quality is also economically important. No recommended speed for beet harvesting is given in the literature because in addition to the factors mentioned above, the spaces between the beetroots and the height of the root above the soil surface is also important [1,3,4,6,9]. According to Karwowski [5], on plantations with an equal distribution of beetroot, the harvester's speed should not be less than 6 km h^{-1} but also should not cross above 7 km h^{-1} whereas on plantations with a large number of spaces, this must be reduced to 4-5 km h^{-1}. In tests, the speed is usually around 5.5-6 km h^{-1} [6,8]. According to beet harvester manufacturers a speed of 10 km h^{-1} is possible [10]. This study was conducted to find out whether and to what extent the working speed of a harvester affects the quality of sugar beet.

MATERIALS AND PROCEDURES

To meet the objective, a one factor, random distribution experiment in four repetitions was designed. The experiment was conducted during the sugar-beet harvest with a Stoll V202 two-row trailed harvester and a Holmer Terra Dos self-propelled six-row harvester. Each harvester worked with four speeds ranging from 3.9 to 8.4 km h^{-1} for the Stoll harvester and from 4.2 to 10.1 km h^{-1} for the Holmer harvester. The experiment was performed during the 'Polish Beet Show' in Chodów in 1997-1998. Sugar beet plantations in those years were characterised by the following features: size – 102.9 and 85.8 thousand plants/ha, yield – 63.2 and 62.9 t ha^{-1}, soil humidity – 11.3 and 15%.
The average space between the plants was 21.6 and 25.9 cm, the average height of the roots above the soil surface – 4.3 and 2.7 cm.

During the experiment the effect of the harvester's speed on the following factors was tested: root organic contamination, percentage of properly topped roots, percentage of roots topped too high and un-topped roots, percentage of lightly damaged roots, percentage of heavily damaged roots and the total loss of root mass.

The experiment was conducted in accordance with the Polish standard „Methods for investigating sugar beet harvesters" (PN-91/R-55023). Root contamination, root damage and topping quality were determined for each speed based on the analysis of the four samples, taken in randomly selected sections of the measurement segment. Root samples were put into containers fixed under the unloading unit of the harvester. The sample mass was not less than 30 kg. Topping quality was determined on the basis of a separation of the root sample into properly topped, topped too high, topped too low, slanted and un-topped. Lightly damaged roots are roots whose separation place is 30 mm in diameter or with damage on the remaining area up to 10 mm. Heavily damaged roots are roots whose separation place is greater than 30 mm in diameter or with damage of the remaining area to a depth greater than 10 mm, or with damage up to 10 mm on about 1/3 of the root area.

To evaluate the losses, four measurement plots, 50 m in length and a width equal to six rows, were randomly designated. When the surface losses had been collected, the plots were cultivated and the sub-surface losses were collected. Losses included the mass of lost roots, root ends with a diameter greater than 1 cm, root segments with a diameter not smaller than 2 cm and mass losses due to too low a topping.

RESULTS AND DISCUSSION

The results were statistically analysed; for this purpose MINITAB software was used [2]. Tukey's test was used in all detailed tests of variance analysis and regression analysis, at the significance level of $\alpha = 0.05$. The zero hypothesis tested presumed that mean values for each speed are not different. The probability of error when the zero hypothesis was rejected is given in table 1.

Table 1. Results of variance analysis. Probability of error when the zero hypothesis is rejected ($\alpha = 0,05$)

Feature	Stoll V202	Holmer Terra Dos	General form
Percentage of correctly topped roots	0.000	0.000	0.000
Percentage of roots topped too high and un-topped roots	0.000	0.000	0.000
Root organic contamination	0.031	0.002	0.000
Percentage of lightly damaged roots	0.212	0.066	0.005
Percentage of heavily damaged roots	0.402	0.020	0.839
Total loss of root mass	0.069	0.000	0.050

Conclusions from the table as the percentage of properly topped roots, percentage of roots topped too high and untopped roots and root organic contamination allows the zero hypothesis in the case of the Stoll harvester to be rejected. In the case of the Holmer self-propelled harvester the zero hypothesis was rejected for every feature, except for slightly damaged roots. Generally, i.e. for the whole analysis of the figures obtained for both machines, the zero hypothesis was not rejected except for one feature: the percentage of badly damaged roots. A regression analysis was done for features with different means for each speed. Regression equations and correlation coefficients are given in table 2 and table 3 and the graphic interpretation of the relationships is given in figures 1-6. The diagrams also characterise the variability curves of the features for which no significant relationship was found in the variance analysis. The relation between the researched features is meaningful, where the correlation factor is at least 0.35.

Table 2. Regression equations of the working quality of sugar beet harvesting machines

Stoll V202		Holmer Terra Dos	
Regression equation	Correlation coefficient	Regression equation	Correlation coefficient
Percentage of correctly topped roots			
$y = 24.9 + 20.1v - 2.21v^2$	0.73	$y = 86.8 - 5.46v$	0.63
Percentage of roots topped too high and un-topped roots			
$y = 58.2 - 16.1v + 1.86v^2$	0.72	$y = -1.48 + 5.32v$	0.65
Root organic contamination			
$y = -1.01 + 0.465v$	0.38	$y = -1.85 + 0.542v$	0.53
Percentage of lightly damaged roots			
Irrelevant relation	–	Irrelevant relation	–
Percentage of heavily damaged roots			
Irrelevant relation	–	$y = -0.37 + 2.02v$	0.41
Total loss of root mass			
Irrelevant relation	–	$y = 1.37 - 0.385v + 0.0435v^2$	0.82

Table 3. General regression equation of the evaluated figures of the sugar beet harvesting machine's working quality

Regression equation	Correlation coefficient
Percentage of correctly topped roots	
$y = 86.9 - 3.31v - 0.234v^2$	0.68
Percentage of roots topped too high and un-topped roots	
$y = -7.3 + 7.19v - 0.123v^2$	0.66
Root organic contamination	
$y = -1.28 + 0.482v$	0.46
Percentage of lightly damaged roots	
$y = 75.6 - 16.6v + 1.30v^2$	0.40
Percentage of heavily damaged roots	
Irrelevant relation	–
Total loss of root mass	
$y = 18.0 - 7.65v + 1.11v^2 - 0.0509v^3$	0.35

The percentage of properly topped roots (fig. 1) decreases with the increase in speed and this effect is faster for the Stoll harvester than for the Holmer self-propelled harvester. When the speed of Holmer harvester is increased by 1 km h^{-1}, the percentage of properly topped roots decreases by 5.5%. In case of the Stoll harvester high topping quality (70%) is maintained in the speed range from 4.0 to 5.5 km h^{-1} and quickly decreases up to 40% at a speed of 8 km h^{-1}.

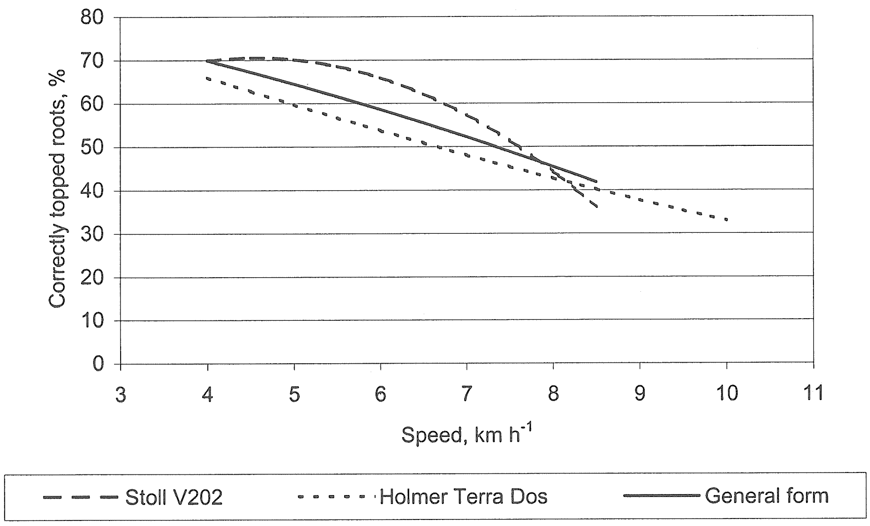

Fig. 1. The effect of the speed of the harvesting machine on the percentage of correctly topped roots

The situation is reversed in the case of roots topped too high and un-topped roots (fig. 2). In case of the Stoll harvester, for a speed range around 4-8 km h^{-1}, the percentage of such roots increases from 23 to 50%. Whereas in the case of beetroot harvested by the 'Holmer' every 1 km h^{-1} increase in speed resulted in an increase of incorrectly topped roots by 5.3%, i.e. from 20 to 41%.

As the topping quality significantly decreases with the increase of speed, a modified design for the topping unit is the only way to improve it. This option is also advanced by Kromer and Thelen [6].

The percentage of organic contamination (remains of leaves, uncut heads (fig. 3) increases with the increase of the percentage of roots that require a correction to the topping. The correlation of this feature with speed is relatively low but it can be explained by the influence of the plantation features, e.g. unequal space between the roots in the rows and the different height of the roots above the field's surface [9].

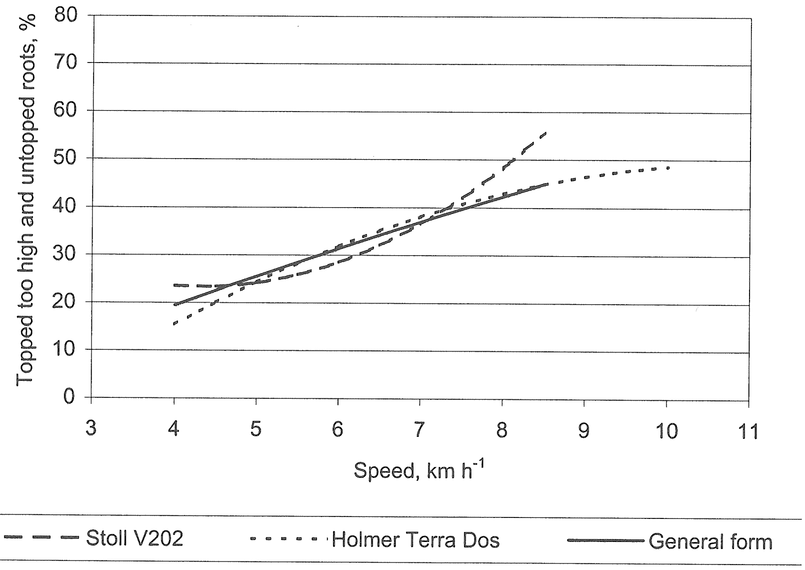

Fig. 2. The effect of the speed of the harvesting machine on the percentage of roots topped too high and un-topped roots

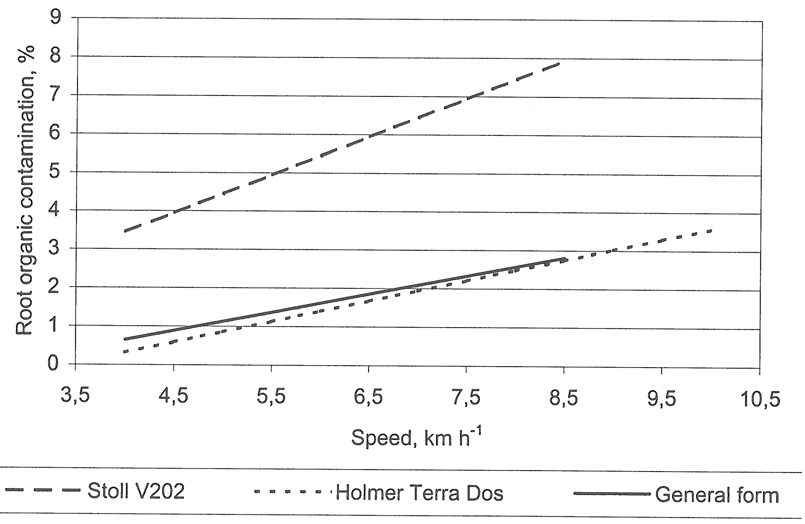

Fig. 3. The effect of the speed of the harvesting machine on organic contamination of the root

The loss of root mass also increases with the increase of speed (fig. 4) – when the Holmer harvester is used, losses grow more slowly; at a speed from 4 to 10 km h^{-1} the increase ranges from 0.5 to 2.0%. When the Stoll harvester is used, losses are minimal at the speed of 5.0-6.5 km h^{-1} and increases up to 3% at a speed of 8 km h^{-1}.

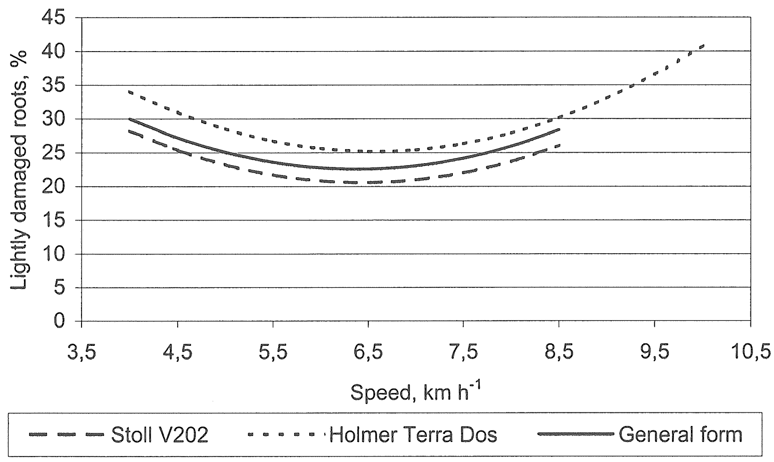

Fig. 4. The effect of the speed of the harvesting machine on the percentage of lightly damaged roots

The percentage of slightly damaged roots (fig. 5) for both harvesters is described by the second order equation. The curves have their minimum at the speed around 6.5 km h^{-1}; the amount of roots slightly damaged by the Holmer harvester is about 5% higher than those damaged by the Stoll harvester. The difference decreases with the increase of speed.

The effect of speed on the quantity of heavily damaged roots is interesting. The percentage of these roots grows from 8% to 20% together with the increase of the speed when the harvest is done by a Holmer machine. On the other hand, when beetroot is harvested with a Stoll harvester, damage decreases from 25 to 18%. One can suppose that the difference is due to the longer cleaning route of the Holmer harvester, i.e. longer contact between the root and the cleaning unit and conveyors, which leads to damage.

The probability of creating basic working units for the researched machines allows us to generalise the analysed relations. From the regression analysis we can conclude that the speed of a sugar beet harvesting machine greatly influences the root topping quality, the percentage of organic pollution, the percentage of

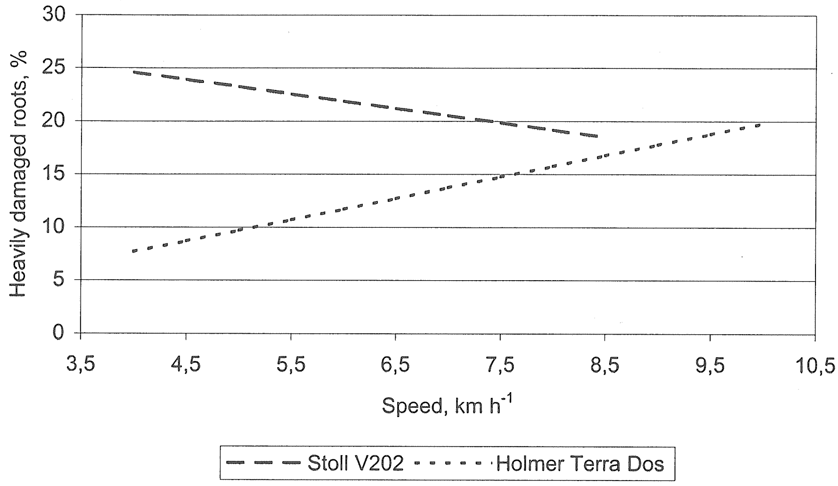

Fig. 5. The effect of the speed of the harvesting machine on the percentage of heavily damaged roots

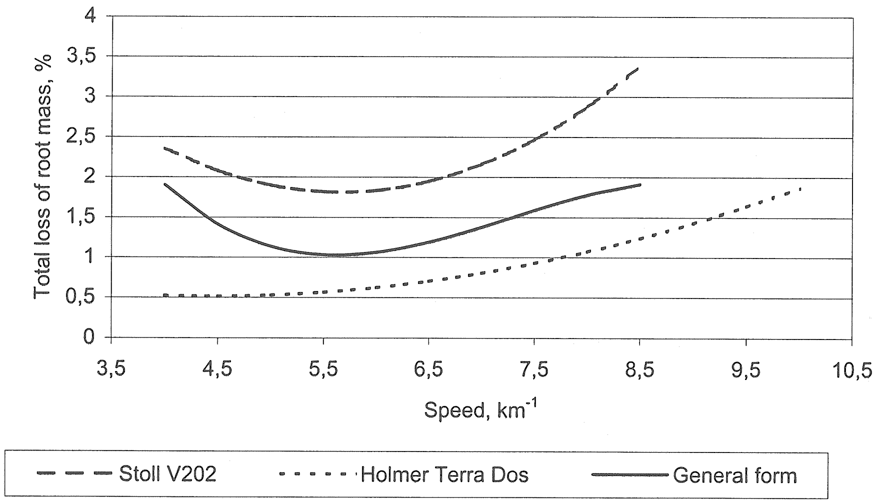

Fig. 6. The effect of the speed of the harvesting machine on the total loss of root mass

slightly damaged roots, and the loss of root mass. An increase in working speed causes a fast decrease in the percentage of properly topped roots and an increase in the percentage of the roots that need manual assistance, i.e. the roots that are topped too high as well as those that aren't topped at all. At the same time there is an increase in the organic pollution of the roots. The relationship that describes the total loss of root mass has its minimum in the working speed range from 5 to 6 km h^{-1}, whilst the percentage of the slightly damaged roots has its minimum when the speed reaches about 6 km h^{-1}.

The results obtained, both for separate machines and in the general analysis allow us to claim that although sugar beet harvesting machines can work with speeds reaching 10 km h^{-1}, when taking into consideration the quality of the crop, which is equally important for the farmer and for the sugar factory, the working speed of the machines should not exceed 6.5 km h^{-1}.

CONCLUSIONS

1. Based on a two year study it was found that the higher working speed of beetroot harvesters the worser crop quality of sugar beet. In the case of the Holmer self-propelled harvester speed significantly affected the topping quality, root damage (heavy damage), organic contamination and root mass loss. In the case of the trailed Stoll harvester speed affects only the topping quality and percentage of organic contamination in the yield.
2. Based on these results, one can conclude that the speed of the Stoll harvester should be within the range from 4.5 to 6.5 km h^{-1}. A similar speed should be recommended for the Holmar harvester, mainly because of the loss level of root yield.
3. The probability of creating basic working units of the researched machines allows us to generalise analysed relations. From the regression analysis we can conclude that the speed of a sugar beet harvesting machine greatly influences root topping quality, the percentage of organic pollution, the percentage of slightly damaged roots, and the loss of root mass.
4. As the topping quality significantly decreases with the increase of speed, a modified design for the topping unit is the only way to improve it.

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POZBIOROWA JAKOŚĆ PLONU BURAKA CUKROWEGO

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S t r e s z c z e n i e. Celem pracy było stwierdzenie czy i jak prędkość robocza maszyny zbierającej wpływa na jakość plonu buraka cukrowego. Ocenie poddano wpływ prędkości na jakość ogłowienia, udział zanieczyszczeń korzeni, uszkodzenia oraz straty plonu korzeni. Dla zrealizowania celu pracy przeprowadzono badania, które miały charakter eksperymentu jednoczynnikowego dla układu doświadczalnego w układzie całkowicie losowym z czterema powtórzeniami. Do badań użyto 2-rzędowego kombajnu Stoll V202 i kombajnu samojezdnego Holmer Terra Dos, które pracowały z czterema prędkościami z przedziału od 4 do 8,5 $km \cdot h^{-1}$ (Stoll) i do 10 $km \cdot h^{-1}$ (Holmer). Wyniki badań poddano analizie statystycznej. Analiza wyników wykazała, że zwiększenie prędkości roboczej maszyny do zbioru buraka cukrowego pogarsza jakość zbieranego plonu.

S ł o w a k l u c z o w e: burak cukrowy, jakość plonu, prędkość maszyny zbierającej