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EVALUATION OF MECHANICAL HARVEST QUALITY OF PRIMOCANE RASPBERRIES

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ABSTRACT

The aim of study was to evaluate the efficiency of a mechanical harvest of primocane (autumn) raspberry. The harvest was carried out using the tractor-pulled, one-row harvester "Natalia", equipped with four shakers. Two cultivars of raspberry: 'Polka' and 'Polana' were used in the evaluation of the quality of work. One amplitude (50 mm) and several frequencies (from 6.7 to 11.7 Hz) of shakers were applied. The following factors were evaluated during the conducted tests: amount of ripe and unripe picked fruits, amount of ripe fruits left on canes, and amount of fruits fallen on ground. The efficiency of mechanical harvest depended on the detachment forces of fruits and applied frequencies of shaker vibrations. Decrease of detachment forces during the vegetation season allowed application of lower shaking frequencies which reduced the percentage of unripe fruits harvested by the machine. Fruit loss on the ground was 1-5% and was independent of shaking parameters. A better quality of harvest was achieved for the 'Polka' cultivar. Depending on the used harvest parameters, 60-80% of 'Polka' fruits were successfully harvested. 'Polana' was characterized by higher detachment forces and significantly lower quality of harvest (50-70%).

Key words: mechanical harvest, raspberry, autumn raspberries, quality of harvest, harvester

INTRODUCTION

Over 60% of the direct cost of raspberry production is generated by fruit hand-picking (Brzozowski and Zmarlicki, 1994). Without mechanical harvesting the production of raspberry crop destined for further processing, may prove to be unprofitable. Collecting a high quality crop using a raspberry harvester is hindered by the necessity of harvesting fruits several times throughout the season due to the gradual ripening habit of raspberry and by the raspberry-fruit's distinctive features. These features are: vulnerability to mechanical damage and changes in the detachment forces of the fruit to the cane throughout the vegetation season. Repeated harvesting in one production cycle leads to the breaking off of the fruiting raspberry shoots, which, in turn, results in crop volume decrease. Damaging biennial raspberry shoots deteriorates the plantation condition and health.. The risk of fungal plant diseases caused by pathogens grows in plants with broken off shoots and/or branches. This type of plantation damage may cause a 30-40% decrease in the floricane (summer) raspberry crop, in the following year (Cormac and Waister, 1976). The production of raspberry crop destined for further processing becomes more efficient with primocane (autumn bearing) raspberry. When the production cycle is over, raspberry canes are pruned out by a tractor mower and in the following year fruits grow from healthy shoots. Primocane raspberry bushes are not fastened to wooden frames, thus a raspberry harvester construction is less complex. The quality of mechanical harvesting of primocane raspberries is affected by certain variety-specific parameters, the most important of which is attachment force of the fruit to the cane. Attachment forces can fluctuate during the vegetation season. The forces can vary substantially for each raspberry variety in the subsequent years of growing. The lower the attachment force, the more favorable are conditions for setting the harvester parameters. Optimal harvest parameters take the best harvester operating speed and adjust it to the amplitude and frequencies of the shakers. This adjustment is done so that the amount of picked ripe fruits is satisfactory. At the same time, losses of unripe fruit fallen on the ground or damages done either to ripening fruit or canes, are minimized.

The evaluation of the quality of the mechanical harvest was carried out in Kolonia Wierzbica near Kraśnik throughout the 2009 raspberry growing season, with the use of a specially equipped harvester. The quality of harvest was evaluated by the amount of picked ripe fruits, the amount of ripe fruits left on the canes and losses of fruits fallen on the ground, and green fruit harvested.

MATHERIAL AND METHODS

The aim of the study was to evaluate the efficiency of mechanical harvest of primocane (autumn) raspberry. The harvest was carried out with a tractor-pulled, one-row har-

vester "Natalia" designed by "Weremczuk Company" (Lublin). This type of a harvester is equipped with four shakers placed in a V-position. This unique shaker position is a key difference between the primocane raspberry harvester and the floricane raspberry harvester that uses shakers in a vertical position.

The raspberry harvester works in a similar manner to a blackcurrant harvester, i.e. the bushes are split into two halves by the machine and the canes are bent towards the ground on both sides of the harvester. This action minimizes losses of fallen fruit on the ground. The shakers are equipped into a unique picking structure; an attachment of vibrating fingers causing a shaking action. This shaking leads to the detachment of the fruit from the cane. The picked berries are conveyed, for a clean up, to a pneumatic cleaner and further to the sorting deck for inspection. At the sorting deck, the broken fruit is separated from the harvested sample by hand. The process is conducted by two people working on both sides of the harvester. The hydrostatic drive system allows for customizing shaking frequencies, conveyors speed as well as –capacity of fans. The indicators of the shaking frequencies were monitored and adjusted with a proportioning valve system.

For the purposes of this research, an experimental plantation was conducted in Kolonia Wierzbica near Kraśnik since 2007. The quality of work was evaluated using the 'Polka' and 'Polana' cultivars. The three field rows of each cultivar were about 167 meters long and were spaced at 3.25 x 0.5 m. There were five terms of harvest in the 2009 vegetation season. The dates of the harvest terms were: 18 VIII, 26 VIII, 1 IX, 15 IX and 23 IX. During time intervals between the subsequent mechanical harvest terms, raspberries were handpicked to avoid over-ripening of fruit. One amplitude (50 mm) of the shaking frequencies, which was pre-tested in some initial research in the 2008 season, was applied. Several frequencies of shaker vibrations oscillated from 6.7 to 11.7 Hz. Shaking frequencies were customized to the detachment force of the fruit, that was checked daily before the harvest (compare Table 4). The detachment force of the fruit was measured with a precision of up to 0.01 N daily on 92 samples of raspberries picked at random in four sectors of the field row. Each day of the harvest, the average detachment force of the fruit was estimated and all the other obtained force values classified respectively, for ranges: < 1 N; $1 \div < 1.5$ N; $1.5 \div < 2$ N; ≥ 2 N.

The operating speed of the machine was between 0.8 and 1.02 km/h. The amount of fruit recovered by the machine was measured per 5m long field row units. For each shaking, parameter measurements were retaken 5 times. The following factors were evaluated in the conducted tests: amount of picked ripe fruit, amount of ripe fruit left on canes, amount of picked unripe fruit, and amount of fruit fallen on the ground. The amounts in the above mentioned

categories were presented in relation to the total amount of fruits, i.e. amount of picked ripe fruits, amount of left on canes and amount of fruits fallen on the ground. Four frequency ranges (6.7 Hz; 8.3-9.2 Hz and 10.8-11.7 Hz) were taken into consideration while comparing the impact of frequencies of shaker vibrations on the quality of harvest for both the 'Polka' and 'Polana' cultivars. Percentage of fruits in each evaluated group was elaborated by analysis of variance followed by a comparison of means using Duncan's Multiple Range Test, $p < 0.05$.

RESULTS

The detachment forces of the ripe fruit were characterized by high diversity (Tab.1). At the beginning of the harvest on 18 and 26 August the detachment force of the ripe fruit to the cane was above 1 N, for 75% of 'Polana' fruits. Lower force rates were observed in the 'Polka' sample, where more than half of ripe fruits showed detachment forces below 1 N. However, in both cultivars, many fruits with the detachment force rates extending beyond 2 N were observed. In the subsequent days of the tests, a declining tendency was observed for the detachment force rates and from 1 September the majority of fruits in both cultivar samples showed detachment force values beyond 1.5 N. In conclusion, 'Polka' was characterized by lower detachment forces at different times of harvest as compared to 'Polana' raspberry.

The quality of the mechanical harvest depended on both the detachment forces of the ripe fruit and the applied frequencies of shaker vibrations. 'Polka' cultivar harvest results were worse in August (Tab. 2). Using a shaking vibration frequency of 10 Hz, between 60 and 68% of ripe fruit was harvested and between 22 and 26% of ripe fruit left on the canes. A significant part of the harvested sample was unripe fruits – above 8%. In September, the same shaking parameters were used and 73-75% of fruits were successfully harvested. In September, the amount of unripe fruit picked, decreased to 5-8%. The 'Polana' harvest results were more varied and less satisfactory. Using a shaking vibration frequency of 10 Hz, between 50 and 72% of ripe fruits were successfully harvested, and the lowest quality of harvest was observed in the second term (15 September) (Tab. 3).

Losses of fruit fallen on the ground were between 1 and 5% at all harvest terms. Only in the first term of the mechanical harvest of 'Polana', did a significantly high percentage (5.6-7.0%) of the fruits fallen on the ground appear. The appearance of the high percentage of fallen fruit was independent of applied shaking parameters or the detachment force value.

The frequency of shaker vibrations had a huge impact on the quality of the mechanical harvest. An increase of the shaking parameters was reflected in the growing percentage of fruits successfully harvested (Tab. 2 and 3). However, at the same

Table 1. Detachment forces of ripe raspberry fruits at five different terms of harvest. (Kolonia Wierzbica 2009)

Term of harvest	Cultivar	Percentage of fruits for different ranges of detachment force [%]			
		< 1 N	1 ÷ < 1.5 N	1.5 ÷ < 2 N	≥ 2 N
18 VIII 2009	Polana	25.0	31.5	27.2	16.3
	Polka	54.3	23.9	9.8	12.0
26 VIII 2009	Polana	44.6	38.0	12.0	5.4
	Polka	71.7	17.4	7.6	3.3
01 IX 2009	Polana	72.8	25.0	2.2	-
	Polka	87.0	13.0	-	-
15 IX 2009	Polana	65.2	27.2	6.5	1.1
	Polka	91.3	6.5	1.1	1.1
23 IX 2009	Polana	96.7	3.3	-	-
	Polka	90.2	7.6	2.2	-

Table 2. Quality of the 'Polka' harvest at different harvest terms (Kolonia Wierzbica. 2009)

Term of harvest /average detachment force of fruits [N]	Shaking frequency [Hz]	Percentage of harvested fruits [%]			
		ripe picked	left on canes	unripe picked	ground
18 VIII / 1.090	8.3	52.84 a*	37.12 b	6.47 a	3.57 a
	10.0	60.76 b	26.18 a	8.39 b	4.68 b
	11.7	63.21 b	22.80 a	10.57 c	3.42 a
26 VIII / 0.807	8.3	62.56 a	29.21 c	6.26 a	1.97 a
	10.0	67.57 b	21.71 b	8.42 b	2.30 a
	11.7	70.25 b	14.57 a	12.79 c	2.39 a
01 IX / 0.588	8.3	73.90 b	18.24 a	5.96 a	1.90 a
	10.0	75.24 b	14.98 a	8.02 b	1.76 a
	11.7	69.09 a	16.87 a	12.25 c	1.79 a
15 IX / 0.523	8.3	70.77 a	21.59 b	3.76 a	3.88 ab
	10.0	72.65 a	18.68 b	5.34 b	3.33 a
	10.8	79.61 b	9.49 a	6.32 c	4.58 b
23 IX / 0.510	8.3	71.42 a	19.15 a	4.87 a	4.56 a
	10.0	74.44 a	14.87 a	5.65 b	5.04 a
	10.8	73.56 a	14.97 a	6.78 c	4.69 a

*Means in columns (for each separate harvest term) followed by the same letter are not significantly different (ANOVA, Duncan Multiple Range Test, $p < 0.05$)

Table 3. Quality of harvest of 'Polana' at different harvest terms (Kolonia Wierzbica, 2009)

Term of harvest /average detachment force of fruits [N]	Shaking frequency [Hz]	Percentage of harvested fruits [%]			
		ripe picked	left on canes	unripe picked	on ground
26 VIII / 1.110	6.7	20.53 a*	66.73 c	5.76 a	6.98 a
	8.3	42.40 b	43.21 b	7.40 b	6.99 a
	10.0	61.07 c	25.40 a	7.94 b	5.59 a
01 IX / 0.788	8.3	47.95 a	47.51 c	3.47 a	1.07 a
	10.0	61.42 b	27.50 b	9.43 b	1.65 b
	11.7	68.25 c	20.40 a	9.81 b	1.54 b
15 IX / 0.852	6.7	21.61 a	71.64 c	4.48 a	2.27 a
	8.3	40.86 b	52.40 b	4.48 a	2.40 a
	10.0	49.62 c	37.42 a	9.86 b	3.10 a
23 IX / 0.458	8.3	59.18 a	33.68 b	4.98 a	2.16 a
	10.0	72.27 b	20.18 a	5.49 b	2.06 a
	10.8	67.91 b	20.42 a	8.56 c	3.11 a

*Explanations, see Table 2

time the percentage of the unripe fruits harvested by the machine grew significantly. Using a shaking vibration frequency of 11.7 Hz, about 10.5-12.8% of unripe fruits were harvested in the case of the 'Polka' cultivar. The average detachment forces slightly exceeding 0.5 N (1 IX, 15 IX and 23 IX) and the applied lower shaking frequencies of 8.3 Hz allowed for successful harvesting of 70% of ripe fruits, while the percentage of the unripe fruits was minor (5%).

A similar percentage of successfully harvested 'Polana' fruits was obtained by the use of higher frequencies of shaker vibrations (10.0-11.7 Hz). The results, however, were only achieved when the average detachment force of the fruit to the cane was below 0.8 N. In the conditions when the detachment force was higher than 0.8 N, the 10 Hz shaking parameters allowed for removal of only 50% of ripe fruits, while 10% of the harvested sample was unripe fruits picked by the machine.

The influence of shaking frequencies on the harvest quality of 'Polka' and 'Polana' during the whole season, was measured for several frequencies: 6.7 Hz; 8.3-9.2 Hz; 10.0 Hz and 10.8-11.7 Hz (Tab. 4). Lower shaking frequencies were applied for the 'Polka' harvest. A frequency of 6.7 Hz allowed for the successful removal of above 55% of 'Polka' fruits, while the same parameters allowed for a lower quality harvest (above 20%) of 'Polana' fruits.

Table 4. The influence of shaking frequencies on harvest quality of 'Polana' and 'Polka' during the whole season (Kolonia Wierzbica, 2009)

Shaking frequency [Hz]	Cultivar	Percentage of harvested fruits [%]			
		ripe picked	left on canes	unripe picked	on ground
6.7	Polana	21.07 a*	69.18 f	5.12 a	4.63 bc
	Polka	55.06 c	35.32 d	4.57 a	5.05 c
8.3-9.2	Polana	47.60 b	44.20 e	5.05 a	3.15 a
	Polka	68.45 e	23.03 b	5.24 a	3.28 ab
10.0	Polana	61.10 d	27.62 c	8.18 c	3.10 a
	Polka	71.63 e	18.11 a	6.85 b	3.41 ab
10.8-11.7	Polana	68.08 e	20.41 ab	9.19 cd	2.32 a
	Polka	71.20 e	15.79 a	9.68 d	3.33 ab

*Explanations, see Table 2

A frequency of 8.3-9.2Hz allowed for the successful removal of 68% of 'Polka' fruits. A similar harvest efficiency was obtained for 'Polana' with the highest frequency of shaker vibrations: 10.8-11.7 Hz. However, by the use of these frequency parameters, unripe fruit losses picked by the machine grew up to 10%.

DISCUSSION

The research proved that the detachment forces of the fruit to the cane had a significant impact on the quality of the mechanical harvest. Decrease of the detachment forces during the season, allowed for improving the quality of the harvest and for using lower frequencies of shaker vibrations, which, in turn, reduced the percentage of unripe fruits harvested by the machine. High shaking frequencies (10-11.7 Hz) caused an unripe fruit harvest of 9-12%. This type of fruit loss is extremely significant, as it directly leads to lower crop volume. Less significant is the percentage of fruit left on the canes, as it can be picked in the next harvest term, if it will not have rotted by this time. Between 1 and 5% of the harvested sample were fruits fallen on the ground. The rate observed, was much lower than in the previous research. During the harvest of floricane raspberries carried out by the 'Peco' harvester, losses of fruit on the ground were between 10 and 16% (Rabcewicz et al., 1995; Grochulski, 1990). 'Natalia' raspberry harvester performance was better due to the more appropriate positioning of canes against the shaker fingers – harvested fruits could not leave the machine through a clearance between canes.

The detachment force of the fruit to the cane for both 'Polana' and 'Polka' decreased throughout

the vegetation season. However, 'Polka' was characterized by the detachment forces causing more favorable harvest conditions. Even at the beginning of the harvest season, in the second decade of August, more than 50% of fruits were characterized by detachment forces below 1 N. Low detachment forces of 'Polka' allowed for a higher quality harvest as compared to 'Polana'. A shaker vibration frequency of 8.3 Hz allowed for the removal of 70% - 80 % of the ripe fruits. The harvest quality results are comparable with the prior research carried out for the floricane raspberry cultivar. According to Ramsay (1983), about 50-70% of ripe red raspberry fruits can be successfully harvested by the machine. Trials conducted at the Institute of Pomology and Floriculture proved that 'Canby' was characterized by a 74-91% quality harvest, while 'Bristol' by a 64-74% quality harvest (Rabcewicz et al., 1995; Grochulski, 1990). The research of Kowalczuk et al. (2008), in turn, produced less satisfactory results, with 52% fruits successfully harvested.

'Polana' was characterized by a much lower quality of harvest as compared to 'Polka'. Only 50-68% of fruits were successfully harvested, and the highest quality of harvest was achieved on the last day of harvest when the detachment force fell beyond 0.5 N. Despite the favorable harvest conditions, a high frequency of shaker vibrations (10.0 Hz) had to be applied, which shows clearly that 'Polana' is less practical for mechanical harvest.

Different parameters for the frequencies of the shaker vibration had to be applied on different days of harvest, due to the fluctuation of the detachment forces throughout the season. The best frequency range for 'Polka' was between 8.3 and 9.2 Hz. Statistically, the percentage of fruits successfully harvested with the use of these shaking parameters was comparable to the amount of fruit successfully harvested with higher frequency parameters (10.0-11.7 Hz). However, a higher percentage of unripe fruits was observed for the latter frequency parameters. The 'Polana' fruit harvest required much higher frequency ranges compared to 'Polka'. Slightly more than 60% of ripe fruits were successfully harvested with the use of 10 Hz of shaker vibration frequencies, which is not a satisfactory result. In addition, above 8% of the losses were caused by the unripe fruit harvest.

CONCLUSIONS

1. 'Polka' ripe fruits are characterized by lower detachment forces than 'Polana' raspberry.
2. The quality of primocane raspberry harvested by machine depends on attachment forces of the fruit to the cane and the shaking frequency parameters.
3. The 'Polka' cultivar proved more usable for the mechanical harvest than 'Polana'. In accordance with the selected shaking parameters, the harvester successfully removed

60-80% of 'Polka' ripe fruits and 50-70% of 'Polana' fruits.
4. Losses of fruits fallen on the ground were 1-5%, irrespective of shaking parameters.
5. The best 'Natalia' harvester shaker vibration frequency ranges, for 'Polka' and 'Polana', were respectively: 8.3-9.2 Hz and 10.8-11.7 Hz within one amplitude (50 mm).

REFERENCES

Brzozowski P., Zmarlicki K. 1994. Koszty zbioru truskawek i malin od 1988 roku. XXXIII Ogólnopolska Naukowa Konferencja Sadownicza, pp. 440-443.

Cormack B.F., Waister R. 1976. Effects of machine harvesting raspberries on yield in the following year. HORT. RES., London 16: 121-129.

Grochulski G. 1990. Efektywność kombajnowego zbioru malin odmiany 'Bristol'. Praca magisterska, AR Lublin, pp. 42.

Kowalczuk J., Zarajczyk J., Leszczyński N. 2008. Analiza jakości zbioru malin kombajnem „Natalia" firmy Weremczuk. INŻ. ROL. 2 (100): 89-93.

Rabcewicz J., Cianciara Z., Wawrzyńczak P. 1995. Wstępna ocena zmechanizowania zbioru malin., Ogólnopolska Konferencja Naukowa, AR Lublin, pp. 183-186.

Ramsay A.M. 1983. Mechanical harvesting of raspberries – a review with particular reference to engineering development in Scotland. J. AGRIC. ENG. RES. 28: 183-206.

OCENA JAKOŚCI MASZYNOWEGO ZBIORU MALIN POWTARZAJĄCYCH

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S T R E S Z C Z E N I E

Celem badań była ocena jakości mechanicznego zbioru malin owocujących na pędach jednorocznych. Owoce zbierano zaczepianym jednorzędowym kombajnem "Natalia", wyposażonym w cztery otrząsacze palcowe. Jakość zbioru oceniano na odmianach 'Polka' i 'Polana'. Zastosowano jedną amplitudę drgań otrząsaczy (50 mm) oraz kilka częstotliwości drgań o wartościach z przedziału 6,7÷11,7 Hz. Określano masę owoców: zebranych poprawnie, owoców dojrzałych pozostawionych na krzewach, opadłych na ziemię oraz zebranych owoców niedojrzałych. Efektywność zbioru kombajnowego zależała od sił wiążących owoce z dnem kwiatowym oraz zastosowanych częstotliwości drgań otrząsaczy. Wraz ze spadkiem wartości sił moż-

liwe było wykorzystywanie niższych częstotliwości drgań, co ograniczało ilość odrywanych od krzewów owoców niedojrzałych. Straty spowodowane opadaniem owoców na ziemię wynosiły od 1% do 5% i nie zależały od zastosowanych parametrów pracy otrząsaczy. Lepszą przydatność do zbioru maszynowego wykazała 'Polka'. W zależności od zastosowanych parametrów pracy kombajn zbierał z krzewów od 60% do 80% owoców tej odmiany. Dla odmiany 'Polana' obserwowano wyższe wartości sił wiązania owoców i istotnie gorszą jakość zbioru (50-70%).

Słowa kluczowe: zbiór mechaniczny, maliny, maliny powtarzające, jakość zbioru, kombajn