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ANALYSIS OF THE HARVESTING QUALITY OF REDCURRANT WITH A TRAILED COMBINE

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ABSTRACT

Field tests on the quality of shaking off redcurrant fruit Rosetta cultivar with a half-row trailer harvester "Marek" produced by Dom-Wid were carried out. The tests were performed at two average working speeds $\bar{v}_1$ = 0.47 m·s^{-1}; $\bar{v}_2$ = 0.60 m·s^{-1} and two rotational speeds of a tractor n_1 = 1500 rpm; n_2 = 1900 rpm. The length and diameter of shoots of redcurrant, length of a bunch, number of fruits in a bunch and mass of fruit were measured. Weather conditions were presented: rain fall, air temperature and moisture. Analysis of results showed that the working speed and the rotational speed has a significant impact on the quality and amount of the yield. At the highest rotations, the harvesting quality of fruit by a harvester was the worst and was 77.15%.

Introduction

A mechanised technology replaces manual harvesting which constitutes 80% of labour expenditure in berry production including redcurrant. In a several-hectare farm, planting of various redcurrant cultivars or species with a different degree of maturation is needed. Thanks to this, the harvesting may be extended in time and relevantly adjusted to the owned machines. When choosing a berry cultivar, one considers its resistance to diseases and pests, prolificity and a possibility of mechanical harvesting (Ochmian, 2013; Knjaziew, 2000). Bushes with stiff shoots and average and short bunches are the best adjusted for combine harvesting. More firm fruit are less susceptible to mechanical damage (Hansen, 2014, Rabcewicz, 2006). In a several-hectare big farm, it is profitable to use half-row combines. Majority of producers says that a combine harvests over 90% of the good-quality fruit due to relevant selection of work parameters. The speed of driving for redcurrant is 0.8 – 1.5 km·h^{-1} (Błaszczyńska, 2010; Nowakowski, 2005). The quality of harvesting of redcurrant is significantly influenced by the maturity of redcurrant, working speed, rotational speed of an engine, amplitude and frequency of vibrations, cultivar of redcurrant, size of bushes and manner of cultivation. The increase of the working speed causes simultaneously the increase in the number of damages to shoots. The quality is determined based on

the number of fruits not collected by the combine or thrown behind the combine, the number of contaminations and degree of damage to shoots (Kowalczuk, 2008; Salamon, 1997). A drawback of these combines is a necessity of a repeated crossing through each row of the plantation as a result of which bushes are divided two times (Wilczyński, 2017; Węgrzyn, 2005). The aim of the paper was to determine the size of losses of redcurrant fruit Rosetta cultivar during harvesting with the use of a half-row combine. Losses of fruit left on shoots and fruit that dropped to the ground were presented.

Materials and Methods

The object of field studies was a half-row trailed combine "Marek" designed for berry fruit harvesting (chokeberry, red currant, raspberry, gooseberry). The source of the combine drive is a farm tractor with the minimum power of 22 kW (30 KM). Half-row combines harvest fruit from a half of a row during one working crossing. The working length of a combine is 5.86 m, width 2.2 m and height 2.3 m. The half-row combine comprises a frame supported on two driving wheels and is equipped with working units (Fig. 1). A cross and longitudinal conveyor, shaker with metal fingers and a fan. In the harvesting unit of the combine there is one shaker with nine shaking elements mounted to the mobile frame. A hydraulic system supplies working units. Efficiency of the combine harvesting is 0.1 – 0.2 $ha \cdot h^{-1}$. The harvested fruit are cleaned of impurities and then the harvested fruit are placed in boxes.

Figure 1. Half – Row harvester „MAREK" producer Dom – Wid

The field trials were carried out for redcurrant Rosetta cultivar in Wierzchowiska Drugie, Province of Lipsko in Mazowieckie Voivodeship (Fig. 2,3). Bushes of redcurrant are adjusted to harvesting with a combine and the harvested fruit are designed mainly for the processing industry. The plantation with the area of 1.69 ha grows on the IV b and V soil bonification class. Two cultivars of redcurrant Rondom and Rosetta are cultivated on the plot with the distribution of 5.40 m between the rows and 0.45 m in a row. The average width of the investigated bushes was 0.82 m while the height of 1.11 m. Redcurrant Rosetta has bunches with the average length of 54.73 mm, with the average mass of 4.17 g. The number of fruits in one bunch was 3-18 pcs. Redcurrant fructifies on short shoots that grow from young shoots (Moyer et al., 2002, Pikuła, 2016). The investigated redcurrant produced from 8 to 106 pcs of this-year shoots and 3-22 pcs of skeleton shoots.

Quarters of redcurrant are mechanically cultivated (bare fallow) with a cultivation unit and with herbicide fallow. Crop protection substances in the investigated plantation of redcurrant were used from the 4th quarter of March – 2nd quarter of July. Suitable cutting of bushes facilitates the combine operation during harvesting (Salamon, 2002). Bushes are cut before the vegetation starts (early spring) and after harvesting by thinning cutting.

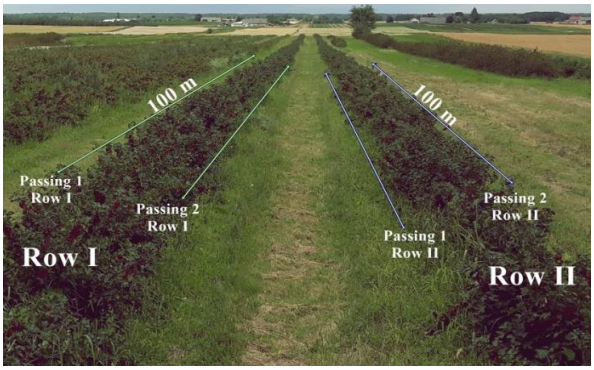

Figure 2. Rosetta redcurrant plantation

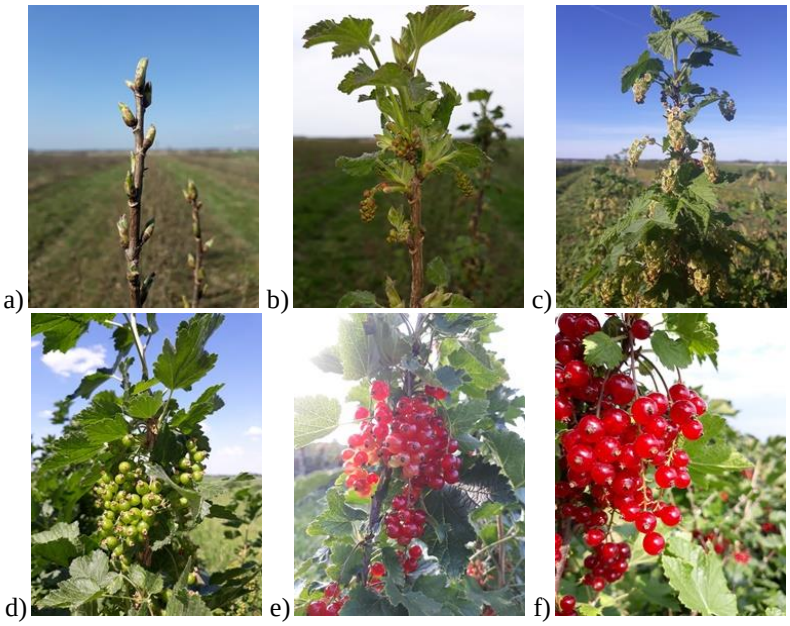

Figure 3. The stages of growth of Rosetta redcurrant in 2018:a) 8 April (beginning of vegetation, b) 15 April (ends f leaves except for bud scales), c) 22 April (beginning of flowering stage), d) 13 May (first fruit on bunches), e) 12 April (produced 50% of fruit), f) 30 April (harvesting)

Availability of water and suitable temperature are a factor that influences the size of redcurrant yield. Water scarcity and a high temperature reduce the number and quality of fruit (Lamont, 2012). The temperature was measured with an outside thermometer, it was placed in the shady place and the measurement range was – 50ºC to + 50ºC. The rain fall was measured with a rain gauge. Precision of the measurement scale of the device was 0.5 $mm \cdot m^{-2}$ and a single time measurement of precipitation was 35 $mm \cdot m^{-2}$. The measurement of the rain fall was checked and recorded daily. Measurements of the conditions of field studies were carried out from the start of vegetation to the end of harvesting of redcurrant 04 April2018 – 17July 2018 (table 1).

Table 1.
Characteristics of weather conditions in the vegetation period to harvesting

Parameter	Date	Amount of precipitation [mm]	Temperature [°C]	Moisture [%]
MAX	4.4.2018 - 30.5.2018	8.5	28	70
	1.5.2018 - 30.5.2018	25	30	90
	1.4.2018 - 30.4.2018	12.5	31	80
	1.7.2018 - 17.7.2018	17.5	30	95
MIN	4.4.2018 - 30.4.2018	12	12	35
	1.5.2018 - 30.5.2018	15	15	25
	1.6.2018 - 30.6.2018	16	16	30
	1.7.2018 - 17.7.2018	15	15	30
Standard deviation	4.4.2018 - 30.4.2018	2.92	3.90	8.05
	1.5.2018 - 30.5.2018	9.42	4.45	18.04
	1.6.2018 - 30.6.2018	3.43	4.48	13.61
	1.7.2018 - 17.7.2018	7.77	4.26	18.12
Total	4.4.2018 - 30.4.2018	22.5	-	-
	1.5.2018 - 30.5.2018	43	-	-
	1.6.2018 - 30.6.018	36.5	-	-
	1.7.2018 - 17.7.2018	23.75	-	-

The size of bushes influences the quality of harvesting and appropriate setting of combine shakers and adjustment of the speed to fruit harvesting (Wawrzyńczak, 2003). Measurements of the plantation taken included: shoots length, diameter of shoots, number of shoots, width, and height of a bush. A diameter of shoots was measured in the half-length and at the base of a bush. An analogue calliper was used for determination of the diameter of redcurrant shoots. The measurement range of a device is 0-500 with a precision up to 0.05 mm. A measurement tape STANLEY with 3 m length and precision of 1 mm was used for measurement of the length of shoots, width and height of a bush, distance of shoots and planting of bushes. The distance of shoots in a row was measured at the height of 0.20 m

over the redcurrant fallow. The length of annual and skeleton shoots was measured. The width of a bush was measured perpendicularly to the row.

The measurement of the fruit mass that fell on the ground before (m_r) and after harvesting with a combine (m_o), that remained on shoots (m_p) were carried out with a weighting machine with a precision of 0.1 g. With one working crossing the combine harvested fruit from more than one half of the row of 100 m long distance. Then, six measurement trials of fruit loss were made on the distance. The measurement of the mass of the combine harvesting of redcurrant (m_z) was made with a platform scales with a measurement system. The maximum load capacity of the scales is 1500 kg with a weighting precision of 300 g.

The total mass harvested by a combine from one whole row was determined acc. to the formula:

$$m_g = m_{z1} + m_{z2}$$

where:

m_{z1} – mass of fruit harvested with a combine from a half of the row from the first crossing in the row, [kg]

m_{z2} – mass of fruit harvested with a combine from a half of the row from the second crossing in the row, [kg]

m_g – mass of fruit harvested with a combine from the entire row, [kg]

The total losses of redcurrant fruit were determined from the following formula:

$$S_c = \sum_{i=1}^{n} m_p + \left(\sum_{i=1}^{n} m_o - \sum_{i=1}^{n} m_r\right)$$

where:

S_c – total loss, [kg]

m_p – mass of fruit from i-th measurement of the fruit that remained on shoots, [kg]

m_o – mass of fruit from i-th measurement of the fruit that remained on ground, [kg]

m_r – mass of fruit from i-th measurement on the ground before harvesting, [kg]

Fruit losses that fell to the ground and their percentage participation was determined according to the formula:

$$S_z = \sum_{i=1}^{n} m_o - \sum_{i=1}^{n} m_r$$

$$S_{z\%} = \frac{S_z}{m_c} * 100\%$$

where:

S_z – fruit loss that fell to the ground, [kg]

m_c – total mass of fruit, [kg]

Fruit losses that remained on shoots and their percentage participation was determined according to the formula:

$$S_p = \sum_{i=1}^{n} m_p$$

$$S_{p\%} = \frac{S_p}{m_c} * 100\%$$

where:
S_p – left on shoots, [kg]
m_p – mass of fruit from i-th remained on shoots, [kg]

Results and Discussion

The average values of a plantation were obtained from 50 measurement trials. The results of measurements of properties of fruit and bunches of the investigated redcurrant was obtained selected randomly from 100 trials (table 2).

Table 2.
Characteristics of Rosetta redcurrant plantation

Specification	Min	Max	Average	Standard deviation	Standard error	Distribution	Coefficient of variation
Distribution of rows [m]	4.4	4.4	4.4	0	0	0	0
Distance between bushes in a row [m]	0.45	0.45	0.45	0	0	0	0
Length of shoots	0.2	1.4	0.85	0.34	0.03	1.2	0.4
Number of skeleton shoots in a bush [pcs]	3	22	9.4	3.87	0.39	19	0.41
Number of this year's shoots in a bush [pcs]	8	106	51.72	21.77	2.18	98	0.42
Height of bushes [m]	0.65	1.5	1.11	0.18	0.02	0.85	0.16
Width of bushes [m]	0.2	1.5	0.82	0.33	0.03	1.3	0.4
Diameter of shoots at the base [mm]	8	18	12.42	2.71	0.27	10	0.22
Diameter of shoots inside a shoot [mm]	5	13	8.14	1.64	0.16	8	0.2
Distance between shoots (20 cm) [cm]	3.	29	15.41	6.23	0.62	26	0.4

Table 3.
Characteristics of fruit for Rosetta redcurrant

Specification	Min	Max	Average	Standard deviation	Standard error	Distribution	Coefficient of variation
Length of bunches [mm]	37	79	54.73	9.07	0.91	42	0.17
Number of fruits in a bunch [pcs]	3	18	10.24	2.89	0.29	15	0.28
Mass of 10 pcs of fruit [g]	2	6	4.17	0.87	0.09	4	0.21

The most efficiently shaken was redcurrant with the tractor speed of 0.47 $m \cdot s^{-1}$ (table 4, figure 4). Mass harvested from the entire row was two time bigger at the speed of 1500 rpm than the speed of 1900 rpm (table 5).

Table 4.
Characteristics of harvesting of Rosetta redcurrant with a combine

Row	Crossing in a row	Date	Rotational speed of a tractor	Length of a distance	Working speed (v_t)	Average working speed (v_g)	Mass of fruit harvested with a combine from half of the row (m_z)	Mass of fruit harvested with a combine from the entire row (m_g)
-	-	-	rpm	[m]	$m \cdot s^{-1}$	$m \cdot s^{-1}$	[kg]	[kg]
1 row	1 crossing	03.07.2018	1500	100	0.45	0.47	129	209
1 row	2 crossings	03.07.2018	1500	100	0.48		80	
2 rows	1 crossing	03.07.2018	1900	100	0.56	0.6	74	108
2 rows	2 crossings	03.07.2018	1900	100	0,64		34	

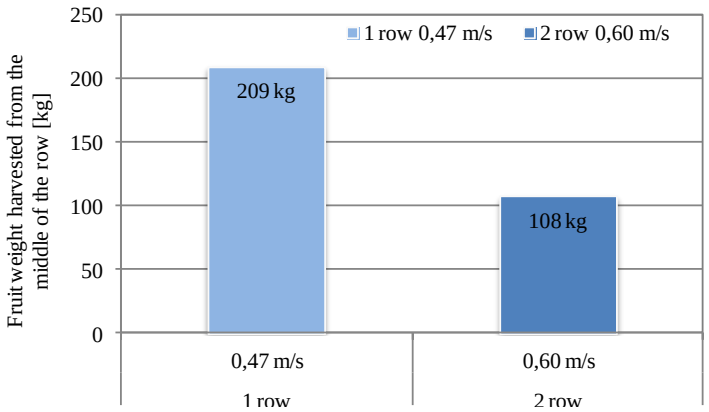

Figure 4. Mass of fruit harvested with a combine from a row depending on the working speed of a unit

Table 5.
Results of research on quantitative losses of redcurrant fruit harvested with a combine

No.	Row	Length of a distance	Rotational speed of a tractor	Mass of fruit that remained on shoots (m_p)	Mass of fruit that fell on the ground (m_o)	Mass of fruit on the ground before harvesting (m_r)	Losses (S)	Losses fallen fruit (S_z)
-	-	[m]	[rot·min^{-1}]	[kg]	[kg]	[kg]	[kg]	[kg]
1	1	20	1500	2.739	2.24	0.316	4.663	1.924
2	1	20	1500	1.043	5.241	0.254	6.03	4.987
3	1	20	1500	1.741	4.749	0.252	6.238	4.497
4	1	20	1500	1.374	3.501	0.366	4.509	3.135
5	1	20	1500	2.088	3.844	0.116	5.816	3.728
6	1	20	1500	2.04	3.326	0.058	5.308	3.268
					ROSETTA			
1	2	20	1900	0.24	5.062	0.242	5.06	4.82
2	2	20	1900	0.968	4.025	0.316	4.677	3.709
3	2	20	1900	1.002	6.488	0.238	7.252	6.25
4	2	20	1900	0.452	5.6	0.082	5.97	5.518
5	2	20	1900	1.099	2.81	0.196	3.713	2.614
6	2	20	1900	0.541	5.087	0.318	5.31	4.769

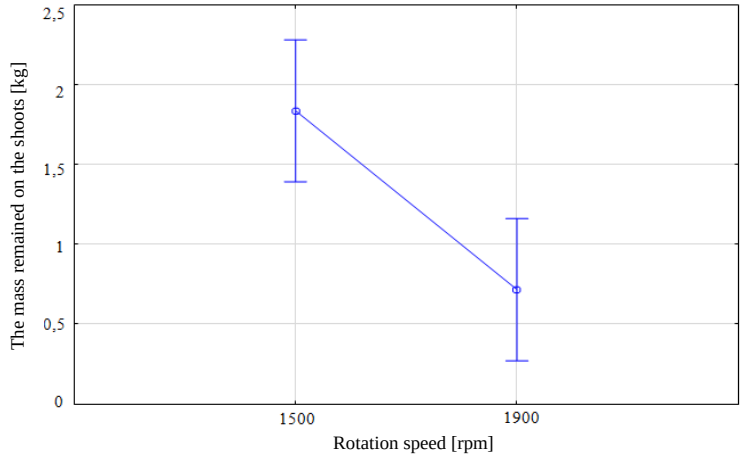

Figure 5. Change in the value of fruit remaining on shoots (m_p) depending on the rotational speed of the shaker drive motor (n) for ROSETTA red currant

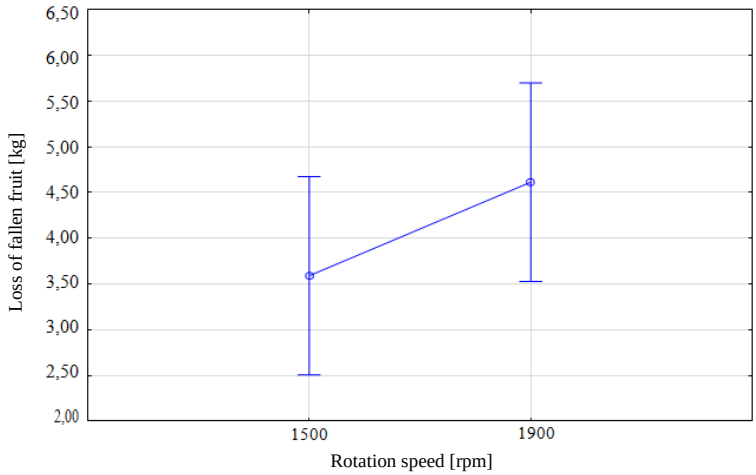

Figure 6. Change in the value of currant fruit that fall to the ground (S_z) depending on the rotational speed of the shaker drive engine (n) for ROSETTA red currant

Number of losses of fruit remaining on shoots and fallen to the ground depends on the rotational speed of a combine. The highest loss of mass was 32.564 kg for the speed of 1500 rpm (table 4,5). Thus, more fruit remained on shoots at the speed of 1900 rpm (figure 4). To avoid such losses manual harvesting after combine crossing may be introduced. At a higher rotational speed, losses that fell to the ground are higher.

Table 6.
Loss of fruit after combine harvesting

Losses at harvesting of blackcurrant and redcurrant							
No.	Redcurrant species	Redcurrant cultivar	Rotational speed of a tractor	MIN	MAX	Arithmetical mean	Standard deviation
-	-	-	[rot·min^{-1}]	[kg]	[kg]	[kg]	[kg]
Losses (S)							
1	Red	Rosetta	1 500	4.509	6.238	5.427	0.723
2	Red	Rosetta	1 900	3.713	7.252	5.33	1.202
Losses in the form of fallen fruit (Sz)							
4	Red	Rosetta	1 500	1.924	4.987	3.59	1.084
5	Red	Rosetta	1 900	2.614	6.25	4.613	1.295
Losses in the form of fruit that remained on shoots (m_p)							
6	Red	Rosetta	1 500	1.043	2.739	1.8375	0.595
7	Red	Rosetta	1 900	0.240	6.488	0.717	0.352

Table 7.
Mass of harvested fruit of redcurrant

Specification	Unit of measurement	Rosetta redcurrant 1900 [rpm]	Rosetta redcurrant 1500 [rpm]
Total mass of fruit	[kg]	139.982	241.564
Mass harvested by a combine	[kg]	108	209
Total loss	[kg]	31.982	32.564
Losses that remained on shoots	[kg]	4.302	11.025
Losses that fell to the ground	[kg]	27.68	21.539
Percentage participation of fruit			
The total amount of harvested fruit	[%]	100	100
Amount harvested by a combine	[%]	77.15	86.52
Total loss	[%]	22.85	13.48
Losses that remained on shoots	[%]	3.07	4.56
Losses that fell to the ground	[%]	19.77	8.92

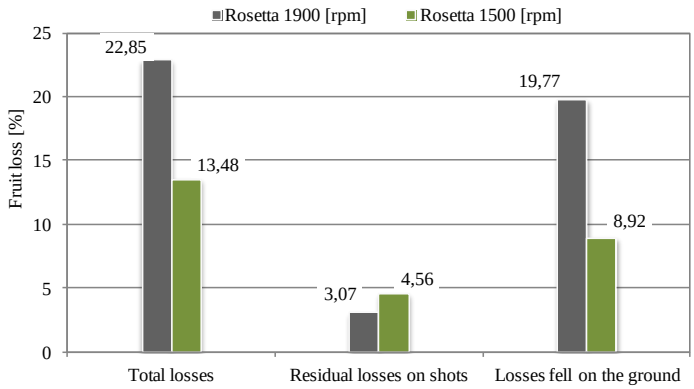

Figure 7. Percentage share of redcurrant fruit losses

Conclusion

In the mechanical combine harvesting, the size of the rotational speed of the shaker drive engine, working speed influence the precision of harvesting (Salamon, 2007). The optimal working speed at the redcurrant harvesting with a combine is 0.45 $m \cdot s^{-1}$ for redcurrant. The highest percentage of shaken fruit was obtained at the rotational speed of a tractor shaker drive that was 1500 rpm, and the precision of harvesting was 85.11%. The lowest value of the harvesting precision was 77.15%, it was obtained at the highest revolutions of the tractor shaker drive 1900 rot/min and the working speed within the range of 0.56 m/s – 0.64 $m \cdot s^{-1}$. The increase of the rotational speed of a tractor shaker drive to 1900 rot/min during harvesting caused that the sum of fruit losses was lower than the rotational speed of 1500 $rot \cdot min^{-1}$ and amounted to 77.15%.

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ANALIZA JAKOŚCI ZBIORU PORZECZKI CZERWONEJ KOMBAJNEM PRZYCZEPIANYM

Streszczenie. Przeprowadzono badania polowe nad jakością otrząsania owoców porzeczki czerwonej odmiany Rosetta kombajnem półrzędowym przyczepianym „Marek", produkowanym w firmie Dom – Wid. Badania wykonano przy dwóch średnich prędkościach roboczych $\bar{v}_1$ = 0,47 m/s; $\bar{v}_2$ = 0,60 m/s oraz dwóch prędkościach obrotowych ciągnika n_1 = 1500 obr./min; n_2 = 1900 obr./min. Wykonano badania pomiaru długości i średnicy pędów porzeczki czerwonej, długości gron, liczby owoców w gronie oraz masy owoców. Przedstawiono warunki pogodowe: opad deszczu, temperatura i wilgotność powietrza. Analiza wyników wykazała, że prędkość robocza oraz prędkość obrotowa ma znaczący wpływ na jakość i ilość uzyskanego plonu. Przy najwyższych obrotach jakość zbioru owoców przez kombajn była najgorsza.

Słowa kluczowe: porzeczka czerwona, jakość zbioru