THE INFLUENCE OF FACTORS ON THE YIELDS OF TWO RASPBERRY VARIETIES (*Rubus idaeus* L.) AND THE ECONOMIC RESULTS

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ABSTRACT

The research was carried out in the years 2015–2018 on the commercial plantations of a horticultural farm. The analysis focused on the yields of two raspberry cultivars: 'Polana' and 'Polka', factoring in the influence of cultivation methods (in the ground; in the beds with an agrotextile), soil classes (IIIa; IVb), and plantation age (2–5 and 6–10 years). The commercial yields of fruit intended for processing were determined. The economic efficiency analysis of the production of both varieties was carried out. It was shown that regardless of the factor under scrutiny, higher results (in t·ha⁻¹) were obtained from the 'Polana' variety. There were differences in the yields of the two varieties depending on the factors. In the case of both varieties, higher results were obtained in traditional cultivation and in class IIIa soil. The plantation age caused only slight differences in the yields of both varieties. The analyses showed statistical significance only in the case of the impact of the cultivation method on the yields of the 'Polana' cultivar. Regardless of the variety, the value of production decreased year after year, which resulted mainly from the downward trend in raspberry prices.

Key words: raspberry, yield, cultivation methods, soil classes, plantation age, economic effectiveness

INTRODUCTION

In Poland, the cultivation of raspberries (*Rubus idaeus* L.) is a salient and economically crucial branch of fruit production [Konopiński and Żuber 2013, Paszko et al. 2016]. For many years, Poland has been recognized as one of the largest raspberry producers in Europe, mainly for industry [Lewandowski et al. 2015, Apáti 2018, Greblikaite et al. 2019]. Globally, raspberry is grown on a commercial scale in many countries, including Serbia, Ukraine, Chile, USA, and Russia [Sredojević et al. 2013, Greblikaite et al. 2019]. However, unlike in Western European countries, the statistical raspberry yield for commercial purposes in Poland is very low. On the nation-wide scale, the raspberry production output is still too low, which in recent years has been within the range of 3.50–4.00 t·ha⁻¹ [Danek and Król 2008, Djurkovic 2012].

The yield level is one of the most crucial determinants of raspberry production profitability, and that in turn determines the functioning, development, and competitiveness of a raspberry farm. According to Vittori et al. [2018], the yield is the first factor taken into account by producers when selecting new cultivars. The profitability of raspberry production depends on many factors, including economic and natural ones, but also on individual decisions made by producers [Zarzecka et al. 2018]. Therefore, producers seek new production methods that would increase yield and production profitability. Hence the need for continuous research on the suitability of particular cultivars for cultivation under specific conditions and on the impact of various factors and production technologies on the yield and quality of raspberries. Research in this field

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is carried out both in Poland [Grajkowski and Ochmian 2007, Król et al. 2008, Konopiński and Żuber 2013, Lewandowski et al. 2015, Markuszewski et al. 2019] and abroad [Sønsteby and Heide 2012, Heflebower et al. 2013, Juhos et al. 2015, Leposavić et al. 2016, Xu 2016, Vittori et al. 2018, Stojanov et al. 2019].

The research objective was to evaluate the yields of two raspberry varieties with different production technologies, soil classes, and plantation ages in the production conditions of a commercial horticultural farm in the Lublin Province. As stated by Danek and Król [2008], Konopiński and Żuber [2013], Dresler et al. [2015] and Zarzecka et al. [2018], raspberry production in Poland is mainly located in the south-eastern part of the country. In recent years, approx. 80% of the entire domestic raspberry production has been concentrated in the Lublin Province. The studies also took into account the economic aspects of raspberry production. The results of the analyses will serve as a starting point for expanding and continuing the research on the influence of various factors on raspberry yields and economic effectiveness of production.

MATERIAL AND METHODS

The research was conducted on a specialist horticultural farm located in the Biłgoraj District, in the Lublin Province. The researched farm grows berries, mainly strawberries, raspberries, and blackcurrants, on the area of over 220 ha. Large fragmentation of the plantation is the farm's distinctive feature – raspberry is grown on over 46 plantations in total with an area ranging from 1 to 3.20 ha. In addition, the farm has its own cold store, where it freezes and stores fruit, including from its own production. The raspberries harvested on the farm were all intended for the processing industry; no raspberries were sold for fresh market purposes.

The research carried out in the years 2015–2018 involved four regular raspberry fruiting periods. The subject of the research included the raspberry plantations of two varieties: 'Polka' and 'Polana', which bear fruit on one-year sprouts (i.e. autumn varieties). All plantations were set up in autumn (September). The seedlings came from certified nursery farms and were planted with the 4×0.5 m spacing. The first year of cultivation was treated as an investment period (without fruiting). The plantations were not irrigated.

A year before the plantation was established, the soil was fertilized with manure in the amount of 30 t·ha^{-1}, and mustard and buckwheat were planted as a forecrop. In the year of establishing the plantation, the soil was analyzed for macro- and micronutrients, which were then supplemented according to the recommendations of the District Chemical and Agricultural Station in Lublin. The plantations were protected and nurtured in line with the current Fruit Farming Plant Protection Programme and cultivation recommendations.

The research examined the influence of the cultivation method, soil class, and plantation age on the yielding of two varieties of raspberries – 'Polana' and 'Polka'. Three factors were distinguished within each variety, repeated for four years in the period of 2015–2018. A single factor analysis was applied, i.e. the impact of each individual factor on the yield of the two varieties was assessed separately. On each plantation, the commercial yield was assessed, i.e. fruits that met the requirements of the processing industry. The harvest obtained from the entire plantation area was counted per 1 ha. Therefore, it was the actual yield that reflected the genuine output of the plantation in the conditions of commercial production.

Factors that influenced the yield of the two raspberry varieties:

Production methods

Two cultivation methods were applied:
– plants planted directly in the ground (A);
– plants planted in the ground on low beds, covered with a black agrotextile (B).

The main purpose of using an agrotextile (black, PP 50 g·m^{-2}) was to protect the plants against weeds and warm the soil faster in order to start vegetation and fruiting earlier. All the plantations were started in 2013 on class IVb soils.

Soil class

The plantations were cultivated on two soil valuation classes:
– class IIIa soils – medium good arable soils; specific brown soils; characterized by large fluctuations in water levels depending on precipitation,
– class IVb soils – medium arable soils; mugwort soils produced on sands and clays, very susceptible to fluctuations in groundwater levels.

All plantations were founded in 2013. They were cultivated traditionally in the ground. Taking into account the influence of the soil class on raspberry yielding in the analyses, the researchers were aware that the relationship between yields and the soil is very strong and complex and depends on numerous interactions between the physical and chemical properties of soil and also on other external natural factors [Sys et al. 1991]. The analyzes did not take into account the impact of all these factors, with comments on the framework contained in this publication.

Plantation age

Plantations were divided into two age groups:
– planted in autumn 2013, age group 2–5 (C),
– planted in autumn 2009, age group 6–10 (D).
The raspberries were planted directly in the ground in class IVb soils.

The obtained results were subjected to statistical analysis using ANOVA one-factor variance. The statistical significance of the difference was estimated using Tukey's test with a significance level of $\alpha = 0.05$.

In addition, the research involved the analysis of the economic efficiency of the farm's raspberry production. The production value (calculated as the product of yield and sales price) and the gross margin (GM) calculated as the difference between the production value and direct costs [Augustyńska 2000] were used as selected indicators. Sales prices used for the analyses included the average annual raspberry purchase prices for the processing industry used on the farm. The average values are expressed in USD, according to the average exchange rate over four years (2015–2018). The average annual exchange rates were calculated as the average exchange rates during one year of all quotations, according to the exchange rate announced by the National Bank of England [www.bankofeng.clando.uk].

RESULTS AND DISCUSSION

Just like in the studies by Król et al. [2008] and Heflebower et al. [2013], various yield levels were observed depending on the cultivar. When the farm used the traditional method of cultivation in the ground (A), higher yields were obtained on the 'Polana' plantations – an average of 6.04 t·ha^{-1} (for 'Polka', it was on average 2.64 t·ha^{-1}) – Table 1. This may be due to the fact that 'Polana' is a variety with lower cultivation requirements and bears more fruit in the absence of irrigation as compared to 'Polka' [Krawiec and Rybczyński 2010]. The results of the analyses indicate that the choice of the production method influenced the yield of individual raspberry varieties. Significant differences in yields were observed in the case of the 'Polana' variety. Considerably higher yields were recorded with method A than B. In the years 2015–2018, the harvest was 1.60 times higher than in the case of method B. When planted on beds with an agrotextile cover (B) due to no irrigation, the 'Polana' cultivar,

Table 1. The yield of two raspberry cultivars depends on production technology in the years 2015–2018 in t·ha^{-1}

Years	Production technology	Varieties	
		'Polana'	'Polka'
2015	A	4.85	3.54
	B	4.01	4.63
2016	A	6.32	1.00
	B	2.96	2.66
2017	A	5.57	2.51
	B	3.93	2.11
2018	A	7.42	3.50
	B	4.30	2.55
Average from 2015–2018[1]	A	6.04b	2.64a
	B	3.80a	2.99a

A – plants planted directly in the ground, B – plants planted in the ground on low beds, covered with a black agrotextile
[1] The means followed by the same letters do not differ at $\alpha = 0.05$

characterized by high flowering potential, is much weaker in fruiting when there are water deficiencies in the soil. In the case of cultivation method B, water from precipitation is less accessible. For the 'Polka' cultivar, average yields obtained in the years 2015–2018 for both production methods were comparable, i.e. those obtained with B were only 1.10 times higher than in the case of A and amounted to 2.99 t·ha^{-1}. The variance analysis showed a significant impact of the cultivation method on yielding only for the 'Polana' variety. Also, the research conducted by Konopiński and Żuber [2013] showed no significant influence of the type of mulch on the yield of raspberries. However, the research carried out by Warmund et al. [1995] proved a relationship between mulch type and plantation yield, with bark and sawdust mulch yielding better results than the black polyethylene mulch.

The Integrated Raspberry Production Methodology [Łabanowska et al. 2016] points out that the fertile soils of III and IV valuation class are the most conducive to growing raspberries. The research results indicate that there are differences in the yield levels of the two researched varieties depending on the soil class of the plantation. It was shown that higher yields on the soils of both classes were generally obtained from the 'Polana' variety, except in 2015, when the higher yield of 'Polka' probably resulted from the young age of the plantation (2 years). As reported by Cieślińska [2009], older 'Polka' plants are more susceptible to viral diseases, which could substantiate the lower yields obtained in the subsequent years of the plantation. In 2015, the 'Polka' yield from class IIIa and IVb soils was higher than the 'Polana' yield by 0.62 and 1.19 t·ha^{-1}, respectively (Tab. 2). However, given the four-year research period, it was noted that the average yield from the plantations of the 'Polana' variety grown on class IIIa and IVb soils was higher than the yield of the 'Polka' variety by 0.83 and 0.66 t·ha^{-1}, respectively.

In the case of both varieties, higher results were recorded on the plantations grown on class IIIa soils. In the years 2015–2018, the average yields amounted to 4.55 t·ha^{-1} for the 'Polana' variety and 3.72 t·ha^{-1} for the 'Polka' variety. During the years covered by the research, the average crops of the 'Polana' and 'Polka' cultivars obtained on class IIIa soils were higher by 1.39 and 1.22 t·ha^{-1}, respectively, compared with the

crops harvested from class IVb soils. These results indicate the legitimacy of establishing raspberry plantations on better quality soils, because raspberry is quite high maintenance in terms of nutritional needs, and with the same level of top dressing, better soils have higher yields. Although the statistical analysis did not confirm the significance of these differences, any rise in yield resulting from better soil quality with the same outlays on fertilization and protection may prove economically significant for the producer.

According to Wieniarska [1992], apart from the weather, raspberry yield is also impacted by the plantation age. Furthermore, the differences in the yield of the two varieties based on the plantation age have also been observed in this study. However, compared with the analysis of the influence of the cultivation method and soil class, the differences between the average yields depending on the age of plantations were less obvious. In most years covered by the research, the crop was higher in the older plantations (6–10 years, D) than on 3–5 years old plantations (C), regardless of the variety. One of the reasons may be the fact that autumn raspberries, which bear fruit on one-year sprouts, have a lot of sprouts growing out of the root mass, forming a more extensive and wider row on older plantations with age. Thus, the plants are bigger and have stronger and deeper roots, which boosts their yielding potential. Depending on the year, the yield on plantations D of 'Polana' and 'Polka' fluctuated from 2.52 to 5.00 tonnes per ha^{-1} and from 2.33 to 4.64 t·ha^{-1}, respectively (Tab. 3). On plantations C, the yield of the 'Polana' cultivar ranged from 3.91 to 4.91 t·ha^{-1}, while the yield of the 'Polka' cultivar – from 1.01 to 4.40 t·ha^{-1}. Younger plants on the 'Polana' plantations yielded exceptionally better in 2016, while the 'Polka' variety was unusually abundant in fruit in 2018, which could have been caused by other factors outside the scope of this paper. This fact influenced the average yield from 2015–2018. The average yields on plantations C and D were similar for the 'Polana' variety and slightly higher for 'Polka' on plantations D, with the difference in yield of less than 0.50 t·ha^{-1} in comparison with plantations C. Therefore, the differences in yield between plantations C and D of both varieties were not substantial, and no statistically significant differences were found between them.

Table 2. The yield of two raspberry cultivars depends on soil class/ quality in the years 2015–2018 in t·ha^{-1}

Years	Soil class	Varieties	
		'Polana'	'Polka'
2015	IIIa	4.58	5.20
	IVb	2.56	3.75
2016	IIIa	3.88	3.74
	IVb	2.64	1.24
2017	IIIa	4.32	2.93
	IVb	4.04	2.02
2018	IIIa	5.41	3.00
	IVb	3.40	3.00
Average from 2015–2018[1]	IIIa	4.55a	3.72a
	IVb	3.16a	2.50a

[1] The means followed by the same letters do not differ at α = 0.05

Table 3. The yield of two raspberry cultivars depends on age plantation in the years 2015–2018 in t·ha^{-1}

Years	Age	Varieties	
		'Polana'	'Polka'
2015	C	4.04	2.98
	D	4.70	4.64
2016	C	3.91	1.01
	D	2.52	2.33
2017	C	4.15	1.77
	D	4.69	2.48
2018	C	4.91	4.40
	D	5.00	2.57
Average from 2015–2018[1]	C	4.25a	2.54a
	D	4.23a	3.01a

C – age group 2–5, D – age group 6–10
[1] The means followed by the same letters do not differ at α = 0.05

Table 4. Economic aspects in the raspberry production in the surveyed farms in the years 2015–2018 in USD/ha

Varieties	Years				Average from 2015–2018[1]
	2015	2016	2017	2018	
production value					
'Polana'	8,528.41	4,778.73	4,855.96	3,273.57	5,367.74a
'Polka'	8,508.81	2,569.16	2,597.66	2,057.14	3,926.29a
direct costs					
'Polana'	2,758.81	3,404.12	4,015.39	4,712.32	3,707.76a
'Polka'	2,958.93	2,417.84	2,511.95	3,003.63	2,713.48b
gross margin					
'Polana'	5,769.60	1,374.61	840.57	–1,438.75	1,659.99a
'Polka'	5,549.88	151.32	85.71	–946.49	1,212.81a

[1] The means followed by the same letters do not differ at α = 0.05

Regardless of the plantation age, 'Polana' yields were generally higher than 'Polka' yields. The average crops of the 'Polana' variety on plantations D amounted to 4.23 t·ha⁻¹ and were higher than the yields of the 'Polka' variety by 1.22 t·ha⁻¹. On the other hand, yields from plantations C totaled 4.25 t·ha⁻¹ for 'Polana' and 2.54 t·ha⁻¹ for 'Polka'. Raspberries are plants with high water requirements. In the absence of irrigation, especially in the period of unfavorable climatic conditions, there is a decrease in raspberry yielding capacity [Rolbiecki et al. 2002].

The data presented in Table 4 shows that in the years 2015–2018 the average value of raspberry production on the farm (without direct subsidies) differed depending on the variety. In the case of the 'Polana' variety, it amounted to 5,367.74 USD per 1 ha, and it was lower by over 1,200 USD per 1 ha for 'Polka'. The difference was mainly due to the lower 'Polka' yields compared with 'Polana', which in 2015–2018 amounted to 1.38 t·ha⁻¹. The analysis of the value of production also shows that irrespective of the variety, the average production value decreased every year. In 2015, it was 8,528.41 USD per 1 ha for 'Polana' and 8,508.81 USD per 1 ha for 'Polka'. However, in 2018 the production value for 'Polana' amounted to only 3,273.57 USD per 1 ha and for 'Polka' – only 2,057.14 USD per 1 ha. This was caused by the downward trend in the sales prices, which in 2015 amounted to an average of 2.04 USD per 1 kg and to only 0.66 USD per 1 kg in 2018.

On the farm subject to the research, the average direct costs of raspberry production in 2015–2018 varied. For the 'Polana' cultivation, they fluctuated from 2,758.81 USD per 1 ha to 4,712.32 USD per 1 ha, with an upward trend over the years and ultimately amounting to an average of 3,707.76 USD per 1 ha. This was due to increasing demand for employees who could harvest the fruit. This stems from the natural feature of this variety, i.e. the tendency to produce small-sized fruit, which reduces the yield of fruit harvest and elevates labor costs. In contrast, the direct costs for the 'Polka' variety from 2016 onwards were lower compared to 'Polana' and amounted to 2,713.48 USD per 1 ha. Lower direct costs in the cultivation of 'Polka' resulted mainly from lower harvesting costs (lower yield) and higher harvesting productivity.

The fundamental factors determining the plantation profitability include the obtained sales price, the size of yields, and the level of incurred costs [Paszko 2006, Sredojević et al. 2013]. In the years 2016–2018, the prices of raspberries for the processing industry were relatively low compared to 2015. The average price of one kilogram of raspberries, regardless of the variety, was 1.32 USD in 2016, 1.14 USD in 2017, and 0.66 USD in 2018. The prices influenced the value of the gross margin for the 'Polana' plantations, which in 2016–2018 ranged from –1.438,75 to 1.374,61 USD per 1 ha. However, in the case of the 'Polka' variety, the gross margin ranged from –946.49 to only 151.32 USD per 1 ha. The above analyses show that, for the farm in question, the production of both raspberry varieties was profitable only in 2015, when the gross margin amounted to 5,769.60 USD per 1 ha for 'Polana' and 5,549.88 USD per 1 ha for 'Polka'.

The statistical analysis of the economic results showed significant differences between the varieties only in the direct costs category, which were significantly higher for the 'Polana' cultivar than for the 'Polka' cultivar (Tab. 4). However, the differences in production costs did not affect the significance of the differences in the gross margin between the varieties despite the fact that the gross margin for 'Polana' was 36.87% higher than the gross margin for 'Polka'. This was due to many reasons, including the lack of significant differences in the value of production between the two varieties.

CONCLUSIONS

The results of the research analyses indicate that, regardless of the factor, higher yields were obtained from the plantations of the 'Polana' variety. However, the individual factors caused the differences in the yield of the two varieties. In the case of both varieties, higher yields were obtained in traditional cultivation (A) and on class IIIa soils. The plantation age differentiated the yields of both raspberry cultivars to the smallest extent. The analyses have shown statistical significance only in the case of the impact of the cultivation method on the yield of 'Polana'. The average gross margin could indicate that the cultivation of raspberries in the years 2015–2018 on the farm covered by the research was profitable. However, this was

caused by the high gross margin from 2015. During the entire researched period, the downward trend in the price of raspberries intended for processing, combined with low yields, did not have any economic justification. Maintaining the raspberry plantations near or below the limit of profitability was justified by the nature of the farm and the fact that it had its own cold store and allocated its entire production for the needs of its own processing plant. The losses incurred from growing raspberries were probably compensated by the profits gained from the processing business.

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