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EVALUATION OF THE YIELD OF HIGHBUSH BLUEBERRY (*Vaccinium corymbosum* L.) CULTIVARS AND THEIR ECONOMIC EFFICIENCY ON COMMODITY PLANTATIONS IN POLAND IN THE YEARS 2020–2022

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ABSTRACT

The selection of suitable highbush blueberry cultivars is a prerequisite for obtaining an optimal yield that determines the profitability of production and competitiveness on the market. The study assessed the production efficiency of highbush blueberry cultivars concerning the fruiting period, taking into account the size of the plantation, and evaluated the economic efficiency of the fruiting period. Production efficiency was assessed based on yields obtained according to data from 15 production plantations from all over Poland in 2020–2022. Economic efficiency was determined by analysing the production value, the amount of costs, and the Gross Margin. It was shown that yields of highbush blueberry cultivars differed depending on the ripening time. Generally, the highest yields were obtained in cultivating varieties with middle ripening time. The analyses show that the most prolific varieties in the three-year study, starting from the early to late ones, were Spartan and Duke, Bluecrop, Chandler, Aurora and Nelson. The cultivation of highbush blueberries was profitable in all the analysed plantation groups in the analysed years, although the level of economic production efficiency differed depending on the fruiting period of the cultivated varieties.

Key words: blueberry, yield, production and economic efficiency, Poland

INTRODUCTION

Growing consumer demand for highbush blueberries is determined mainly by the taste and health-promoting qualities of the fruit and the widespread promotion of the berries as a 'superfood', according to Gilbert et al. [2014], Reszka et al. [2017], Kozos and Ochmian [2016], Mystkowska et al. [2017], Escrig [2020], Brazelton et al. [2021] causes the cultivation of this species to increase systematically, both in Poland and worldwide. According to data from the Food and Agriculture Organization of the United Nations [FAO], global production of blueberries has almost tripled since 2010, oscillating around 1.2 million tonnes in recent years. This trend, to an even greater extent, has affected Poland[1]. According to FAO data, the national production of highbush blueberry fruit in 2021 was 55.3 thousand tonnes, five times higher than in 2010 [https://www.fao.org].

This high increase in blueberry fruit supply in the world, including Poland, in addition to increasing demand, is a result of the globalisation of the fruit trade, including the expansion of the continuity of its supply

[1] Poland is the second largest blueberry producer in the European Union after Spain, and sixth in the world. In addition, Poland is one of the important exporters of fresh blueberries in the world, especially its dessert fruit. Between 2013 and 2022, exports of this fruit species totalled almost 100,000 tonnes [https://www.fao.org, https://blueberriesconsulting.com/en/polonia-se-moderniza-y-crece-rapidamente].

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in retail sales [Zmarlicki and Brzozowski 2020], the establishment of new commodity plantations, optimised for yield, and the markedly higher productivity of modern plantings entering the period of full fruiting in recent years [Zmarlicki and Brzozowski 2016]. Besides, according to Koszański et al. [2011], and Reszka et al. [2017], favourable natural conditions, a relatively large area of soils suitable for blueberry cultivation, and profitable fruit prices largely contribute to the growth of blueberry fruit production in Poland. It is confirmed in their considerations by Zmarlicki and Brzozowski [2016], according to whom, in the current market conditions, highbush blueberry fruit production is the most profitable of all fruit crops in Poland. The authors further add that highbush blueberry producers are the best-organised group in Poland, thanks to which blueberry prices are quite stable and the quality of fruit offered both for export and domestically is very high.

In research on highbush blueberry cultivation, in addition to economic and market conditions, natural, technological, and cultivation aspects that affect plant yield are widely considered[2]. From a review of Polish and foreign literature [Krzewińska et al. 2010, Komosa et al. 2017, Tryngiel-Gać and Treder 2017, Masłowska et al. 2018, Jiang et al. 2019, Piencek and Kukuła 2020, Hera et al. 2021, Messig et al. 2021, Merca (Laieș) et al. 2021, Smrke et al. 2021, Lenart et al. 2022, Appiah et al. 2023, Tartanus et al. 2023] show that blueberry yields depend both on the cultivar grown, soil conditions and weather factors prevailing in a given year, as well as on the agrotechnical practices used in cultivation, i.e. irrigation, fertilisation, mulching, pruning or plant protection, among others. Models for estimating yield under commodity conditions are also being developed that consider the influence of multiple variables, including climatic, agronomic, soil, and satellite imaging of vegetation data [Peng et al. 2017, Niedbała et al. 2022].

The study aimed to assess the yield and profitability of the production of selected highbush blueberry cultivars under the production conditions of horticultural holdings in Poland in 2020-2022. To conduct this research, the following questions were defined for implementation: What is the yield potential of highbush blueberry cultivars grown in Poland? How does the selection of varieties during the fruiting period affect yield under commodity production conditions? What is the profitability of highbush blueberry production in Poland? How can selecting varieties during the fruiting period affect the growing economic efficiency?

MATERIAL AND METHODS

The study was conducted in 2020–2022 in 15 specialised farms (226 plantations) with commercial cultivation of highbush blueberry. A form entitled "The economic and production efficiency of highbush blueberry production on the farm" was constructed for the study. Each farm owner filled in the above sheet independently during the period under study. The farms were located all over Poland, mainly in the following provinces: Mazowieckie, Lubelskie, and Podkarpackie (Fig. 1).

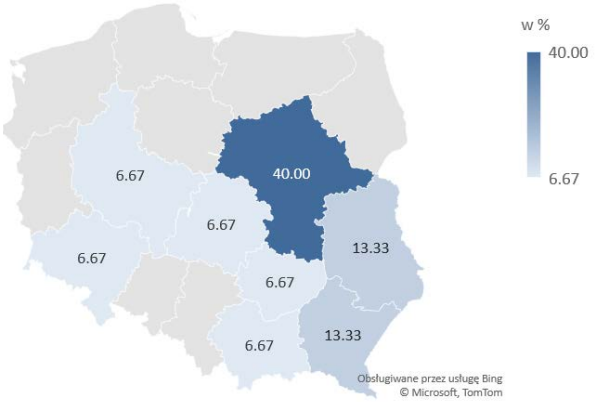

Fig.1. Location of surveyed farms (%)

The yield of selected highbush blueberry cultivars in Poland was assessed, considering the effect of the date of fruiting of cultivars and the size of plantations[3]. The commercial yield of fruit destined for the dessert market was determined. On the farms, the blueberry

[2] The study determines, among other things, the size and weight of the berries, the number of berries per plant, the time of ripening, as well as the overall yield per hectare.

[3] According to Blueberries Magazine Consulting, varieties of North American origin are most commonly grown in our climate zone. The most common are the so-called old varieties, including Duke, Bluecrop, Spartan, Patriot, Nelson, Brigitta, Chandler, Bluegold, Toro, and Elliot, as well as a few new ones such as Draper, Liberty, and Aurora [https://blueberriesconsulting.com/en/polonia-se-moderniza-y-crece-rapidamente].

fruit was harvested manually from the whole plantation area and then referred to the area unit, which made it an actual yield reflecting the possibilities of the plantation under conditions of actual commercial production. All surveyed blueberry plantations were managed with the same soil and open-field cultivation technology. Blueberries were cultivated on raised beds lined with mulching materials (wood chips, bark, peat, etc.) in a single-row system. All plantations were irrigated, and nutrition was provided using the traditional method (sprinkling) and fertigation. All plantations completed the investment period (their yield potential was similar). All cultivation treatments used generally accepted principles for highbush blueberry plantations. The influence of the following factors was analysed:

1. plantation size (the plantations studied were divided into three groups):
– small plantations – up to 2 ha,
– medium plantations – with an area between 2 and 10 ha,
– large plantations – with an area of more than 10 ha.
2. maturity (the plantations studied were divided into three groups)[4],
– early varieties, including Duke, Earliblue, Spartan, and others,
– medium maturing varieties, including Bluecrop, Chandler, Elizabeth, and others,
– late varieties including Liberty, Nelson, Aurora, and others.

The production value and gross margin were used as selected indicators and measures of economic production efficiency. In the analysis of total direct costs, labour costs, crop protection costs, fertiliser costs and other direct costs (including, among others, mulching materials, irrigation water, bumblebee hire, and mechanical labour costs) were detailed, as well as costs of preparation for sale and costs of the sale itself. The different types of costs and income were converted per ha of UAA. The above data are presented as averages of the plantations analysed each year and averages of the three years analysed. The value of costs, production, and income were expressed in USD, according to the average exchange rate for the three years 2020–2022, announced by the National Bank of Poland [https://www.nbp.pl/]. The average exchange rates were calculated as the average rates over one year.

The results obtained for highbush blueberry yield were subjected to analysis of variance (ANOVA). Tests of multiple comparisons allowed detailed comparative analyses of means by separating statistically homogeneous groups of means (homogeneous groups) and determining the so-called least significant difference of means (LSD). The significance of the difference was estimated using the Tukey test for different N, with a significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

The systematic worldwide breeding and selection of highbush blueberry cultivars, according to Pliszka et al. [2010], results in a release of new varieties characterised by increasingly complex pedigrees and better economic traits. The most important, however, according to the authors, remain prolificacy and ripening time. It is confirmed in their considerations by Mystkowska et al. [2017], who state that the basis for obtaining a high yield is the proper cultivation and protection and the right selection of prolific varieties that give fully stable yields. Zydlik et al. [2019] add that, from the producer's point of view, selecting varieties with desirable biological properties and economic characteristics is essential[5]. They are critical from the point of view of both production effects and production profitability or farm competitiveness. Furthermore, they are closely linked to a significant market factor, i.e., ensuring fruit sales' continuity over the most extended possible period. This makes it possible to achieve prolonged sales, differentiated price levels, and thus revenues. Hence, one of the most critical decisions modern growers have to make is selecting suitable varieties[6].

[4] In accordance with the Integrated Production of Highbush Blueberries Methodology [https://piorin.gov.pl/download/gfx/piorin/pl/defaultstronaopisowa/1328/5/1/metodyka_ip_borowki_wysokiej__-_zatwierdzona_2023_do_obligatoryjnego_stosowania_od_01.01.2024.pdf]

[5] Biological characteristics consist of bush longevity, soil and climatic requirements, time of the start and end of vegetation, time of the start of berry fruiting, disease, and pest resistance as well as berry prolificacy and ripeness. On the other hand, the 'evenness' of the fruit (size and number of berries in clusters) and its taste and handling qualities, the resistance of the fruit to transport, and shelf life in the commodity market are economic characteristics [Zydlik et al. 2019].

[6] Highbush blueberry varieties are grouped based on ripening period, distinguishing early, mid-ripening, and late-ripening varieties [Pliszka 2010].

The study shows that the yields of highbush blueberry cultivars varied according to the ripening time and significantly differed between the years included. The lowest yields were obtained in 2022 – on average from 5.72 t ha^{-1} to 6.99 t ha^{-1}, depending on the ripening time of highbush blueberry cultivars (Tab. 1). Compared to the previous year, in which the highest yields were obtained, in the analysed three-year period, the decrease in yields ranged from 28.67% to 36.34% depending on the ripening period of particular groups of varieties. Compared to 2020, the yield decrease for middle ripening varieties was 2.66 t (27.56%), and for late ripening varieties, 1.67 t (21.30%). Weather conditions, especially spring frosts, primarily influenced it. In the analysed year, April and May frosts on many blueberry plantations caused significant losses of up to 70% in some surveyed farms.

As indicated by the data in Table 1, the highest blueberry fruit yields in all the years included in the study were obtained from cultivars with an average ripening period. Depending on the year, they ranged from 6.99 to 10.98 t ha^{-1} (average 9.21 t ha^{-1}). On the other hand, the average yield of cultivars with early and late fruiting periods was similar and amounted to 7.32 and 7.55 t ha^{-1}, respectively. According to Paszko [2022][7], the profitability threshold in highbush blueberry cultivation is 7.10 t ha^{-1}. Thus, in the plantati-

[7] https://doradcajagodowy.pl/kongres-2022/

Table 1. Yields of selected highbush blueberry cultivars in three groups according to the fruiting period in the surveyed farms 2020–2022 (t ha^{-1})

Cultivars	Years			
	2020	2021	2022	Average from 2020–2022
Plantations of early varieties				
Total, of which:	7.88 ^{AB}	8.37 ^{A}	5.72 ^{B}	7.32
Duke	8.24 $^{a.b.c}$	8.44 $^{a.b.c}$	6.86 $^{b.c.d}$	7.84 $^{A.B}$
Earlyblue	4.00 ^{d}	5.00 $^{c.d}$	4.68 $^{c.d}$	4.56 ^{B}
Spartan	10.00 $^{a.b}$	12.00 ^{a}	6.13 $^{b.c.d}$	9.37 ^{A}
Other	5.25 $^{c.d}$	6.25 $^{b.c.d}$	4.59 $^{c.d}$	5.36 ^{B}
Plantations medium maturing varieties				
Total, of which:	9.65 ^{A}	10.98 ^{A}	6.99 ^{B}	9.21
Bluecrop	11.06 $^{a.b}$	12.26 ^{a}	9.37 $^{a.b}$	10.90 ^{A}
Chandler	9.50 $^{a.b}$	10.94 $^{a.b}$	6.83 $^{b.c}$	9.09 $^{A.B}$
Elizabeth	6.50 $^{b.c}$	7.67 $^{a.b.c}$	8.33 $^{a.b.c}$	7.50 ^{B}
Other	8.16 $^{a.b.c}$	9.62 $^{a.b}$	3.59 ^{c}	7.12 ^{B}
Plantations of late varieties				
Total, of which:	7.84 ^{A}	8.65 ^{A}	6.17 ^{B}	7.55
Liberty	6.94 $^{b.c}$	7.63 $^{a.b.c}$	5.00 ^{c}	6.52 ^{B}
Nelson	10.86 $^{a.b}$	11.92 ^{a}	7.94 $^{a.b.c}$	10.24 ^{A}
Aurora	9.00 $^{a.b.c}$	11.00 $^{a.b}$	12.00 ^{a}	10.67 ^{A}
Other [3]	6.51 $^{b.c}$	6.94 $^{b.c}$	4.63 ^{c}	6.03 ^{B}

Source: author's study
Values marked with the same do not differ statistically significantly within varieties of the same earliness group; ABC – within years, while abc.... – for the interaction years × cultivar

ons studied, the BEP was obtained for cultivars of each fruiting period but significantly exceeded for cultivars with an average fruiting period. The study shows, moreover, that the average yield of highbush blueberry fruit on the surveyed farms (regardless of the fruit ripening time) was more than 30% higher than the national average, which for 2019–2021 was 4.98 t ha^{-1} [https://www.fao.org].

In the group of analysed cultivars with an early fruiting period, yields above the average of all cultivars were obtained in the case of Spartan and Duke (9.37 and 7.84 t ha^{-1}, respectively). The yields of Spartan differed significantly from those of Earlyblue and the so-called 'other varieties', whose cultivation yields were significantly lower (by 2.76 and 2.31 t ha^{-1}, respectively). In the group of varieties with a medium fruiting period, the highest yields, above the group's average, were only recorded for the Bluecrop variety – 10.90 t ha^{-1} (a statistically significant difference compared to Elizabeth and the other varieties). The Chandler variety yielded at a similar level to the entire group of medium-fruiting varieties. In contrast, Elizabeth and the other varieties showed a lower average yield from the analysed three-year period than the group average (1.74 and 2.21 t ha^{-1}, respectively). On the other hand, among varieties with a late fruiting period, the highest yields were obtained for Aurora and Nelson – higher than the average of all analysed varieties in the group by 3.12 and 2.69 t ha^{-1}, respectively (statistically significant differences compared to Liberty and the other varieties). The Liberty variety had an average yield of 6.52 t ha^{-1} in the years analysed, about 1 t lower than the average of the varieties in this group. The other varieties within the late fruiting group showed an average three-year yield lower by 1.52 t ha^{-1} compared to the average of all varieties in this group. The analyses show that the most prolific varieties in the three-year study, starting from the early to late ones, were Spartan and Duke, Bluecrop, Chandler, Nelson and Aurora.

Blueberry cultivation in Poland is carried out on plantations of various sizes. However, currently, there is a trend of small plantations[8]. This is mainly due to the diversification of farm production and the search for new sources of agricultural income [Masłowska et al. 2018]. However, in the above trend – Zmarlicki and Brzozowski [2016] see quite a significant threat to the development of the highbush blueberry market in Poland. They draw attention to the difficulties growers may face in ensuring optimal production conditions with increasing water deficit and high unit costs on small plantations (with a cultivation area of up to 1 ha). It is due, among other things, to the necessity and often the requirement to implement costly quality control systems in production, which customers and small suppliers of fresh blueberry fruit increasingly demand. A great burden for small plantations is also the dynamically increasing costs of labour (hourly and piecework) and non-labour costs, such as health and safety requirements, accommodation, food, and insurance for employees.

The results of the analyses indicate that the size of the plantation also influenced the yield under commodity production conditions of the individual highbush blueberry cultivars. It was observed that irrespective of the fruit ripening time, yields above the average of all cultivars were obtained on medium and large plantations. Moreover, as can be seen from the data in Table 2, in all years covered by the study, the highest yields were obtained from large plantations, compared with small and medium ones. The differences noted were statistically significant. The average yields in the years 2020–2022 for early-, medium- and late-fruiting cultivars from the most extensive plantations were 10.17, 13.83 and 12.00 t ha^{-1}, respectively, while yields from the smallest plantations were 6.76 t ha–1 for the earliest-fruiting cultivars and 8.43 t ha^{-1} for cultivars with medium fruit maturity and 7.13 t ha^{-1} in plantations of late-fruiting cultivars. Thus, the yield difference between the plantations with the largest and smallest cultivation areas reached approximately 50.00%, 64.00 and 68.00%, respectively. In the case of plantations with an average acreage, the average yield of early-fruiting varieties was 7.85 t ha^{-1}, medium-fruiting varieties 10.64 t ha^{-1}, and late-fruiting varieties 9.02 t ha^{-1}. In this case, the yield surplus between large and medium-sized plantations was approximately 30.00% for early- and mid-fruiting varieties and 27.00% for late-fruiting varieties. Notably, the average size of plantations in the small group was 0.82 ha, medium 3.22 ha, and large 16.46

[8] It is estimated that there are about 2,000 blueberry growers in Poland, the vast majority of whom run small or medium-sized farms. About 70% of growers in Poland plant less than 5 hectares of blueberries and another 17% plant less than 10 hectares, with the largest being 600 hectares. [Pliszka 2010, Zmarlicki and Brzozowski 2016, https://blueberriesconsulting.com/en/polonia-se-moderniza-y-crece-rapidamente, https://www.fao.org].

Table 2. Blueberry yields according to the fruiting period of the plantation size in the surveyed farms 2020–2022 (t ha^{-1})

Plantation size	Years			
	2020	2021	2022	Average from 2020–2022
Plantations of early varieties				
Small plantations	7.15 $^{a.b}$	8.03 $^{a.b}$	5.09 ^{b}	6.76 ^{B}
Medium plantations	8.29 $^{a.b}$	8.39 $^{a.b}$	6.86 $^{a.b}$	7.85 ^{B}
Large plantations	10.00 ^{a}	11.00 ^{a}	9.50 ^{a}	10.17 ^{A}
Plantations medium maturing varieties				
Small plantations	9.27 $^{b.c}$	10.35 $^{a.b.c}$	5.68 ^{c}	8.43 ^{C}
Medium plantations	10.08 $^{a.b.c}$	11.79 $^{a.b}$	10.04 $^{a.b.c}$	10.64 ^{B}
Large plantations	13.00 $^{a.b}$	15.00 ^{a}	13.50 $^{a.b}$	13.83 ^{A}
Plantations of late varieties				
Small plantations	7.66 ^{b}	8.26 $^{a.b}$	5.48 ^{b}	7.13 ^{C}
Medium plantations	8.19 $^{a.b}$	9.38 $^{a.b}$	9.50 $^{a.b}$	9.02 ^{B}
Large plantations	-	-	12.00 ^{a}	12.00 ^{A}

Source: author's study
Values marked with the same do not differ statistically significantly within varieties of the same earliness group; ABC – within years, while abc.... – for the interaction years × cultivar

ha. However, it seems that the 'small plantations' lack more financial resources for more yield-forming inputs, such as innovative production technologies (e.g. growing in containers or under covers), more modern irrigation techniques, and fertigation.

A vital incentive to establish or develop plantations is economic viability, determined not only by the size or quality of the yield but also by the level of prices obtained. An appropriate price level covers production costs and generates a surplus, allowing investment and the expansion or modernisation of plantations. Higher prices were generally obtained for blueberries of late and early varieties, but this study shows that this trend has weakened in recent years. Indeed, as late as 2020, early- and late-maturing blueberries were 26 and 33% more expensive than medium-maturing blueberries, and in 2022, this relationship dropped to 4 and 13%, respectively. Producer prices are exogenous, so producers must adapt to them [Hamulczuk and Stanko 2011]. On the other hand, yield levels depend on natural factors, including weather conditions beyond the producer's control, but are nevertheless largely endogenous, depending on the producer's choice of variety or production technology.

The study results indicate that the production value in the analysed plantations, depending on their fruiting period in 2020–2022, was similar and ranged from USD 25191.50 to 28082.04 ha^{-1} (Tab. 3). The highest production value was obtained in plantations of varieties with a medium fruiting period and the lowest in plantations with an early fruiting period. The yield and the level of prices obtained influenced the average production value in the analysed years. It should be noted that the effect of the recorded lowest yield level in all plantation groups in 2022 also resulted in a relatively lower production value. Compared to 2021, when the highest yields were recorded, the production value 2022 was lower by 35.33, 34.78 and 27.93% in early, medium, and late fruiting plantations, respectively. During the analysed period, the highest level of direct production costs was recorded for plantations with a medium fruiting period. They amounted to USD 18936.83 ha^{-1}, i.e. 2.00 and 10.75% higher than plantations with a late and early fruiting period. The structure of direct costs in all analysed plantation groups was similar. In the structure of average direct production costs, irrespective of the plantation fruiting period, labour costs accounted for the largest share and ranged

Table 3. Assessment of the economic efficiency of highbush blueberry production concerning the fruiting period on the surveyed farms 2020–20222 (USD ha^{-1})

Specification	Years				Average cost structure 2020–2022 (%)
	2020	2021	2022	Average from 2020–2022	
Plantations of early varieties					
Production value	29240.84	28136.66	18197.01	25191.50	–
Total direct costs, of which:	15748.80	19915.86	15036.17	16900.28	100.00
Labour costs	7669.81	9037.62	6649.23	7785.56	46.07
Fertilisation costs	732.90	782.66	939.68	818.41	4.84
Plant protection costs	700.75	765.64	714.46	726.95	4.30
Other direct costs	1753.63	3021.59	2647.85	2474.36	14.64
Preparation for sale and costs of the sale	4891.71	6308.34	4084.95	5095.00	30.15
Gross margin	13492.04	8220.79	3160.84	8291.22	–
Plantations medium maturing varieties					
Production value	28258.67	33885.73	22101.72	28082.04	–
Total direct costs, of which:	17825.89	22221.00	16763.58	18936.83	100.00
Labour costs	8052.65	9636.69	8141.61	8610.31	45.47
Fertilisation costs	822.14	868.84	1020.05	903.67	4.77
Plant protection costs	808.82	805.94	766.49	793.75	4.19
Other direct costs	1555.08	3134.33	2908.34	2532.58	13.37
Preparation for sale and costs of the sale	6587.21	7775.21	3927.10	6096.51	32.19
Gross margin	10432.79	11664.72	5338.14	9145.21	–
Plantations of late varieties					
Production value	30224.78	30767.93	22175.51	27722.74	–
Total direct costs, of which:	17418.80	21251.39	17021.10	18563.77	100.00
Labour costs	8075.47	9788.29	7812.24	8558.67	46.10
Fertilisation costs	871.83	916.54	1120.02	969.46	5.22
Plant protection costs	824.42	854.30	858.29	845.67	4.56
Other direct costs	1833.40	2964.02	2867.60	2555.01	13.76
Preparation for sale and costs of the sale	5813.69	6728.26	4362.96	5634.97	30.35
Gross margin	12805.97	9516.54	5154.41	9158.97	–

Source: author's study

from 46.10% (USD 8558.67 ha^{-1}) in plantations with a late fruiting period to 45.47% (USD 8610.31 ha^{-1}) in plantations with a medium fruiting period. The highest level of labour costs was recorded in 2021, dictated by the need for labour, in the year with the highest yields. The second cost category in terms of contribution to direct costs was preparation and marketing costs, which, irrespective of the type of plantation, accounted for just over 30.00% on average in 2020–2022. In individual years, their level varied according to fruit yield and harvest; hence, the lowest level was recorded in 2022. On the other hand, the share of fertilisation costs ranged from 5.22 to 4.77% (in value from USD 818.41 to USD 969.46 ha^{-1}) in plantations with an early and late fruiting period, respectively. The level and share of crop protection costs were similar in the plantations analysed, accounting for between 4.19 and 4.56% of direct costs. The share of other costs ranged from 14.64 to 13.37% (in value terms, approximately USD 2.5 thousand ha^{-1}) in plantations with an early and medium fruiting period, respectively. The results of the analyses indicate that the cultivation of highbush blueberry was profitable in all the plantation groups in the analysed years. However, the level of economic production efficiency differed depending on the fruiting period of the cultivated varieties. The average level of gross margin obtained from highbush blueberry cultivation on the analysed plantations in the years 2020–2022 ranged from USD 8291.22 ha^{-1} on plantations with early-fruiting varieties to about USD 9150 ha^{-1} on plantations with varieties with an average late fruiting period (Tab. 3). The average value of the gross margin in the years analysed was mainly influenced by its low level in 2022 due to relatively lower fruit yields than in previous years. In the case of plantations with an early fruiting period, the value of the lowest gross margin in the years under study represented only 23.43% of the highest level obtained in 2020, and the average surplus from 2020 to 2022 was as much as 38.55% lower than in 2020. However, in the case of late- and mid-fruiting period plantations, the value of the lowest gross margin in 2022 represented 40.25 and 45.76% of the surplus from the years with the highest level, i.e. 2020 and 2021, respectively. The average level of surplus from the analysed years in late-fruiting period plantations represented 71.52% of the 2020 surplus, and in mid-fruiting period plantations, 74.40% of the 2021 surplus.

CONCLUSIONS

The study has been an aid in finding answers to the research questions posed. The obtained yields of highbush blueberry from the plantations included in the study were significantly different in individual years. Generally, on the analysed farms, the highest yields were obtained in 2021, while the lowest in 2022. The difference in average yields of highbush blueberry cultivars in 2021/2022, depending on their ripening period, ranged from 2.48 to 3.99 t ha^{-1}. Such a big difference in yields resulted from spring frosts recorded in 2022 during shrub flowering, which also significantly affected the approximately 30% drop in the production value. Blueberry yields under commodity production conditions were determined by varietal characteristics, i.e. the time of fruit ripening, but also by the size of the plantation. Generally, the highest yields and production values were obtained from cultivar plantations with an average ripening time. However, irrespective of the fruit ripening time of the cultivars studied, average fruit yields on the surveyed farms were about 30% higher than the national average. The analyses show that the most prolific varieties in the three-year study, starting from the early to late ones, were Spartan and Duke, Bluecrop, Chandler, Nelson and Aurora. It should be emphasised that while there is a tendency in Poland for small blueberry plantations to be established, which are often treated as, among other things, diversification of income sources on farms, the research carried out indicates that, irrespective of the fruit ripening time, in all the years covered by the study, the highest yields were obtained from large plantations. The difference in yield between large and small plantations ranged from 50 to 68%. Even though blueberry cultivation was profitable on the analysed farms in all the years covered by the study, the level of economic effectiveness was a derivative of the yields determined by weather conditions in particular years and the selection of cultivars with different fruiting periods, as well as the level of prices for which fruit was sold. The lowest gross margin value was obtained, regardless of the fruiting date of the varieties, in 2022. Plantations provided the highest and most comparable gross margin level with medium and late fruiting varieties (influenced by the yield size and price level). These plantations also incurred a higher level of direct costs than

small plantations. The structure of these costs in all plantation groups was similar, and, irrespective of the fruiting period of the varieties, the largest share was accounted for by labour costs (about 45%) and preparation and marketing costs (about 30%).

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