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EFFECT OF HERBICIDE AND BIOSTIMULANTS ON THE ECONOMIC EFFECT OF EDIBLE POTATO CULTIVATION

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ABSTRACT

Background. Profitability is a measure of the economic effect of treatments in protecting potato plants against pests, thus the hypothesis that the applied mechanical and chemical treatments may contribute to an increase in commercial yield in relation to the control object and be profitable despite high costs for protection. The aim of the research was to evaluate the effect of herbicide and biostimulants on the economic effect of edible potato cultivation of the Oberon variety.
Material and methods. The field research was carried out in 2018–2020 at the Agricultural Experimental Station of the University of Natural Sciences and Humanities in Siedlce, on medium soil, in a split-plot arrangement, as two-factor in triplicate. The research material was the yields of potato tubers of the mid-early Oberon cultivar. To assess the impact of herbicide and biostimulants on the economic effect of table potato cultivation: 1. control object, 2. Avatar 293ZC (clomazone + metribuzin), 3. Avatar 293ZC + biostimulant PlonoStart, 4. Avatar 293ZC + biostimulant Aminoplant, 5. Avatar 293ZC + biostimulant Agro-Sorb-Folium was based on the standard gross margin method.
Results. Mechanical and chemical treatments increased the marketable yield of tubers by an average of 29.5%, and decreased the by-yield of tubers by an average of 32.4% in relation to the control object. The direct surplus per 1 ha of cultivation from PLN 5,770.0 on the control object to PLN 13,829.6 on the site where the Avatar 293 ZC herbicide and Agro-Sorb Folium biostimulant were used, which indicates that the use of various methods of plant care and nutrition with biostimulants despite high costs of protecting the potato from weeds was profitable.
Conclusion. The highest yields of the Oberon variety (general and commercial) and the best economic effect in relations to the control object were obtained using mechanical care and the Avatar 293 ZC herbicide and the Agro-Sorb Folium biostimulant.

Key words: gross margin, nutrition, weed control methods, yield of potato

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INTRODUCTION

Due to the long and slow development of plants, potatoes are easily weeded from planting tubers to emergence. Fertilization with manure is a source of nutrients not only for the cultivated plant, but also for weeds, which of all pests have the greatest potential to reduce yields (Praczyk and Skrzypczak 2011). Therefore, the potato requires many treatments carefully selected according to the condition and degree of weed infestation (Qasim *et al.* 2013, Urbanowicz, 2015), which at the same time guarantee high efficiency in destroying weeds, good yield and profitability of production (Nowacki, 2016). In order to protect edible potatoes, we managed to control weed infestation and plant nutrition with the use of biostimulants in various environmental conditions. The appropriate selection of the herbicide will improve the effectiveness of weed control, which in turn will contribute to increasing the yield and improving its quality and profitability of plant cultivation (Kebede *et al*., 2016; Nowacki, 2016). An important element in potato agrotechnics is the constant reduction of unit cultivation costs. In order to provide the cultivated plant with favourable conditions during growth and development, new solutions are sought, which are biostimulants (Wierzbowska *et al.*, 2015). Biostimulants are most often used as a foliar for prophylactic or intervention purposes. Their action is to stimulate the development of leaves, stems and roots of plants, to supplement the deficiency of nutrients during the growing season caused, among others, by intensive development of plants, drought, agrotechnical errors. Biostimulants enable a more effective uptake of nutrients from the substrate, and thus a better supply of plants with nutrients (Popko *et al.*, 2018). We are currently struggling with clearly perceptible climate change and the associated increasingly extreme weather condition, accompanied by various stress factors for plants (Sharma *at al.*, 2014). In the presence of such unfavourable conditions in plant production, the use of biostimulants is particularly justified, because their action boils down to increasing the naturally occurring plant resistance or tolerance to a given stress factor, increasing the vigour and vitality of plants, thanks to which they can more easily survive unfavourable conditions during vegetation (Shukla *at al*., 2019; Kocira *et al*., 2020, Trawczyński, 2020). The highest yields of edible potatoes can be obtained with proper and careful care, optimal plant protection against pests, irrigation and fertilization adjusted to the soil's nutrient content and plant requirements (Trawczyński, 2021).

The aim of the research was to evaluate the effect of herbicide and biostimulants on the economic effect of edible potato cultivation, Oberon variety.

MATERIAL AND METHODS

The field research was carried out in 2018–2020 at the Agricultural Experimental Station of the University of Natural Sciences and Humanities in Siedlce, on medium soil, in a split-plot arrangement, as two-factor and three repetitions. The research material was the yield of potato tubers of the medium-early Oberon variety from a three-year experiment. The forecrop for potatoes in particular years of research was winter triticale. Soil parameters were determined each year before setting up the experiment Table 1.

In the experiment, various variants of mechanical and chemical protection of potatoes against weeds were used and compared with purely mechanical treatments, which were the control object (1) Table 2.

Before emergence, the control object was dredged twice and dredged once, combined with harrowing, and after emergence, it was dredged twice, without herbicide and biostimulators. On objects mechanically and chemically weeded (2–5) before emergence, two dredging processes were applied, and immediately after the last dredging – about 7 days before the appearance of the first emergence of potato plants (BBCH 00 – 08), chemical treatments with herbicide and herbicide with biostimulators, i.e.: (2) herbicide Avatar 293 ZC, (3) herbicide Avatar 293 ZC + PlonoStart 2 $dm^3 \cdot ha^{-1}$ – use in two doses: a) 1.0 $dm^3 \cdot ha^{-1}$ – full moon-end of emergence (BBCH phase 13–19) + b) 1.0 $dm^3 \cdot ha^{-1}$ – cover between rows 10-50% (BBCH phase 31–35), (4) herbicide Avatar 293 ZC + Aminoplant 1.5 $dm^3 \cdot ha^{-1}$ – use in two doses: a) 1.0 $dm^3 \cdot ha^{-1}$ – full moon-end of emergence (BBCH phase 13–19) + b) 0.5 $dm^3 \cdot ha^{-1}$ – cover between rows 10-50% (BBCH phase 31-35), (5) herbicide Avatar 293 ZC + Agro-Sorb Folium 4 $dm^3 ha^{-1}$ – use in two doses: a) 2.0 $dm^3 \cdot ha^{-1}$ – full moon-end of emergence

(BBCH phase 13–19) + b) 2.0 $dm^3 \cdot ha^{-1}$ – cover between rows 10-50% (before flowering) (BBCH phase 31–35). Herbicides and biostimulators were dissolved in 300 dm^3 of water per 1 ha. The selection of the herbicide Avatar 293 ZC was adjusted to the weed infestation. Other agrotechnical measures used in the experiment are presented in Table 3.

Table 1. Soil parameters

Year	Content of available macronutrients, $mg \cdot kg^{-1}$			Organic matter $G \cdot kg^{-1}$	Soil pH in KCl	Soil acidity
	P	K	Mg			
2018	35.2 (low)	102.1 (low)	36.6 (low)	20.9	5.25	acidic
2019	61.0 (medium)	149.0 (medium)	61.0 (medium)	22.3	5.42	acidic
2020	60.0 (medium)	140.0 (medium)	51.0 (medium)	21.1	5.32	acidic

Table 2. Description of herbicides and herbicide with biostimulants used in the experiment

No.	Methods/ Trade name	Active substance /Composition	Dose preparation	Usage
1	Control object	mechanical weeding – plants not treated with herbicides and biostimulators		
2	Avatar 293 ZC	clomazone (60 g dm^3) + metribuzin (233 g dm^3)	1.5 $dm^3 \cdot ha^{-1}$	7–10 days following tuber planting
3	Avatar 293 ZC and biostimulator PlonoStart	clomazone + metribuzin and PlonoStart (N_{total} – 16,4,%, K_2O – 0,75%, CaO – 0,07%, MgO – 0,02%, S – 941 mg kg^{-1}, lactic acid bacteria, actinomycetes)	1.5 $dm^3 \cdot ha^{-1}$ and 2.0 $dm^3 \cdot ha^{-1}$	herbicide – 7–10 days following tuber planting biostimulator twice – end of emergence and rows closure
4	Avatar 293 ZC and biostimulator Aminoplant	clomazone + metribuzin and Aminoplant (N_{total} – 9,48%, $N_{organic}$ – 9,2%, N-NH_4 – 0,88%, $C_{organic}$ – 25%, free amino acids – 11,57%, organic matter – 87,7%)	1.5 $dm^3 \cdot ha^{-1}$ and 1.5 $dm^3 \cdot ha^{-1}$	just before plants emergence
5	Avatar 293 ZC and biostimulator Agro-Sorb Folium	clomazone + metribuzin and Agro-Sorb Folium (N_{total} – 2,2%, B – 0,02%, Mn – 0,05%, Zn – 0,09%, total amino acids – 13,11%, free amino acids – 10,66%)	1.5 $dm^3 \cdot ha^{-1}$ and 4.0 $dm^3 \cdot ha^{-1}$	herbicide – just before plants emergence biostimulator twice – end of emergence and rows closure

Table 3. Agrotechnical treatments used in the field experiment

Agrotechnical treatments	Specification	Dates
Fertilization	25 t·ha^{-1} farmyard manure and mineral fertilizers: 44.0 kg·ha^{-1} P (46% TSP triple superphosphate), 124.5 k· ha^{-1} K (60% potash salt) and 100 kg·ha^{-1} N (34% ammonium salt)	autumn, spring – before planting
Planting of potato tubers	spacing 0.675 × 0.37 m	the third week of April
Weed control	mechanical weeding and herbicides with biostimulants (see Table 2)	after planting to rows closure
Colorado potato beetle control	insecticides: Actara 25 WG (thiamethoxam) at a dose of 0.08 kg·ha^{-1}, Decis Mega 50 EW (deltamethrin) at a dose of 0.15 dm^3·ha^{-1}, Karate Zeon 050 CS (lambdacyhalothrin) at a dose of 0.25 dm^3·ha^{-1}, Proteus 110 OD at a dose of 0.4 dm^3·ha^{-1} (thiacloprid, deltamethrin)	during vegetation
Late blight control	fungicides: Ridomil Gold MZ 68 WG (metalaxyl-M+mancozeb) at a dose of 2.0 kg·ha^{-1} and Dithane Neo Tec 75 WG (mancozeb) at a dose of 2.5 kg·ha^{-1}	during vegetation
Harvesting of potato tubers	physiological maturity	first week of September

At the time of harvest, the weight of tubers from each plot (with an area of 12.96 m^2) was determined and converted into the yield per 1 ha. A 10 kg sample of tubers was also collected and the yield structure was analysed (Roztropowicz *et al*., 1999). The marketable yield was potatoes with a diameter of more than 35 mm, and tubers with internal and external defects, which constituted a secondary crop, were rejected. In the analysis of the economic evaluation, the yields of the Oberon variety and prices in individual years of the study were (Dzwonkowski 2019; 2020). For the calculations, the values of the trade and secondary yield as well as the purchase prices of materials and the sale of the yield were adopted as the average values from the three years of research. The direct costs include: seed potatoes, mineral and natural fertilizers (manure 50%), plant protection chemicals, human work and operation of machines. Variable machine costs were calculated on the basis of the real parameters of the annual use of equipment and productivity on the farm as well as theoretical standards (Muzalewski, 2015). The measure of economic efficiency was the direct surplus, which is the difference between the value of the harvested crops and direct costs (without area payments) (Skarżyńska, 2008; Abramczuk *et al*., 2013).

Meteorological conditions during the potato vegetation period (April–September), the values of the Sielianinov hydrothermal coefficient were determined, which is a measure of the effectiveness of rainfall and air temperatures in a given month. The meteorological conditions in the years of the study were varied (Table 4). In 2018, the months of April, May and June were dry and very dry, but July and August, which determine the harvest, were relatively dry and dry. It was the most favourable season for potato yielding. Year 2019 was very dry (K = 0.66), and the humidity and thermal conditions were unevenly distributed in the individual months of vegetation. Year 2020 was relatively dry, but alternating months were extremely dry, relatively humid, humid, relatively dry.

Table 4. The value of Sielianinov's hydrothermal coefficient (K) in the growing season (Zawady Meteorological Station in Poland)

Year	Month						
	April	May	June	July	August	September	April–September
2018	0.88	0.52	0.57	1.06	0.86	1.69	0.93
2019	0.20	1.44	0.67	0.51	0.71	0.41	0.66
2020	0.23	1.74	2.05	1.15	0.29	0.83	1.05

up to 0.4 – extremely dry, 0.41–0.7 – very dry, 0.71–1.0 – dry, 1.01–1.3 – relatively dry, 1.31–1.6 – optimal, 1.61–2.0 – relatively humid, 2.01–2.5 – humid , 2.51–3.0 – very humid, above 3.0 – extremely humid (Skowera *et al*., 2014)

RESULTS AND DISCUSSION

The research showed that the influence of herbicide and biostimulants on the economic effect of edible potato cultivation, Oberon cultivar, depended on the size of the obtained yield, especially the marketable yield, and the selling price. In the conducted experiment, while analysing the yielding of edible potato of the Oberon cultivar, it was found that it was differentiated by the methods of applying mechanical and chemical treatments. The highest commercial yield was obtained after the application of the herbicide Avatar 293 ZC with the Agro-Sorb Folium biostimulant – 390.6 dt·ha^{-1}, while the lowest in the control object (without herbicide and biostimulant) – 268.0 dt·ha^{-1}. In the sites where mechanical-chemical tending with the use of herbicide and herbicide with a biostimulant was applied (2.-5.), the commercial yield of tubers was on average 347.1 dt·ha^{-1} and was higher in relation to the control treatment by 79.1 dt·ha^{-1}. On the other hand, the secondary yield was 53.7 dt·ha^{-1} on average (Table 5).

Table 5. Yield of potatoes of variety Oberon (mean 2018-2020)

Methods of application of herbicide and biostimulants	Yield of potato dt·ha^{-1}			Increase of yield as compared to that of object 1.	
	total	market	side	market, %	side, %
1. Control object – mechanical weeding	347.3	268.0	79.3	----	-----
2. Avatar 293 ZC 1.5 dm^3·ha^{-1}	367.0	308.7	58.3	15.2	26.5
3. Avatar 293 ZC 1.5 dm^3·ha^{-1} + PlonoStart 2.0 dm^3·ha^{-1}	409.5	356.1	53.4	32.9	-32.7
4. Avatar 293 ZC 1.5 dm^3·ha^{-1} + Aminoplant 1.5 dm^3·ha^{-1}	389.6	333.1	56.5	24.3	-28.8
5. Avatar 293 ZC 1.5 dm^3·ha^{-1} + Agro-Sorb Folium 4 dm^3·ha^{-1}	437.0	390.6	46.4	45.7	-41.5
Mean	400.8	347.1	53.7	29.5	-32.4

In the studies by Ilić *et al*. (2016), the effective production of potatoes is influenced by many agrotechnical elements, one of the most important is a properly selected care method, which, as a result of removing the competition of weed infestation, will enable obtaining high yields of good quality. According to Urbanowicz (2015) and Mystkowska *et al*. (2022), the size of the harvested crop was determined by the use of herbicides, which are the most effective way to reduce weed infestation, and biostimulants that effectively support plant life processes and contribute to reducing the negative impact of environmental stress on plants (Trawczyński, 2020). Abramczuk *et al.* (2013) reported in their research that achieving good production results in edible potato cultivation also requires correspondingly high expenditure on plant protection. Nowacki (2016) stated that an important element of the functioning of the potato market is the profitability of edible potato production resulting from the relations between the costs incurred by farmers and the obtained value of the harvested yields. When analysing the direct costs incurred for growing potatoes of the Oberon variety for research facilities, it can be concluded that they differed in terms of costs incurred for the purchase of plant protection products (herbicide with the biostimulants), equipment operation and labour inputs. The costs of the herbicide and herbicide with biostimulants used in the research, compared to the total direct costs, ranged from 195.0 to 579.0 PLN/ha (Table 6), which accounted for 1.6–4.6% of the cost structure of potato cultivation, the most expensive was the use of the herbicide Avatar 293 ZC with the Agro-Sorb Folium biostimulant, and the cheapest single application of spraying the herbicide Avatar 293 ZC on object 2 with single ridging. On the other hand, in variants 3 and 4, the costs of security were lower in relation to the control object where only mechanical treatments were performed.

Table 6. Costs of protecting the potato from weeds, in PLN·ha^{-1}

Specification	Methods of application herbicides and biostimulants				
	Control object	Avatar 293 ZC	Avatar 293 ZC + PlonoStart	Avatar 293 ZC + Aminoplant	Avatar 293 ZC + Agro-Sorb Folium
1. Total costs of human labour	219.28	109.64	164.46	164.46	164.46
– ridger	164.46	82.23	82.23	82.23	82.23
– ridger with harrow	54.82	-----	-----	-----	-----
– spraying	----	27.41	82.23	82.23	82.23
2. Total costs of machine operation	1060.00	530.00	795.00	795.00	795.00
– ridger	795.00	397.5	397.5	397.5	397.5
– ridger with harrow	265.00	----	----	----	----
– spraying	-132.5	132.5	397.5	397.5	397.5
3. Costs of herbicides	-	195.00	195.00	195.0	195.0
4. Costs of biostimulants	-	-	80.00	67.5	384.00
5. Direct costs (1 + 2 + 3 + 4)	1279.28	834.64	1234.46	1221.96	1538.46
6. Indirect costs (10% direct costs (5))	127.93	83.46	123.45	114.20	153.84
7. Other costs	153.51	100.16	148.13	146.63	184.6
8. Total costs (5 + 6 + 7)	1560.72	1018.26	1506.04	1490.79	1876.9

On the other hand, the costs of applied plant protection products (herbicides, insecticides, fungicides, biostimulants) accounted for 4.6 to 8.7% of all costs. The lowest share in the structure of potato cultivation costs was attributed to equipment operating costs – from 26.6% in the site where the herbicide Avatar 293 ZC was applied to 29.7% in the control object (Table 8).

According to Gołaś (2016), the cultivation of root crops depends on the technologies used related to the introduction of modern equipment, the use of which reduces the labour intensity of potato harvesting. The purchase costs of qualified seed potatoes had a significant share in the cost structure – 35.9 to 37.8% of all costs. These results were confirmed in the studies by Skarżyńska (2010), Wereszczak and Marczakiewicz (2014), who stated that the purchase of certified seed potatoes is one of the most expensive expense in potato cultivation. Manure fertilization on average accounted for 12% of the cost structure, while mineral fertilization on average accounted for 8.45% of the cost structure (Table 8). Direct costs per 1 ha of potato cultivation, Oberon cultivar, ranged from 13,624.4 in the control object to 13,883.6 PLN·ha^{-1} after the application of the herbicide Avatar 293 ZC with the Agro-Sorb biostimulant (Table 7). The most expensive was the use of the herbicide Avatar 293 ZC with the Agro-Sorb biostimulant and the highest yield value was obtained from this object. The research shows that the production value of edible potatoes, Oberon variety, varied and ranged from 19,394.4 PLN·ha^{-1} to 27,713.2 PLN·ha^{-1}. The differences in the value of production were caused by the variation in the size of the yields. The performed calculations show that the direct surplus per 1 ha of edible potato of the Oberon cultivar was the highest in objects 3 and 5, ranging from 11,774.6 PLN·ha^{-1} to 13,829.6 PLN·ha^{-1} and was approx. 3 times higher than in the control object 57,770.0 PLN·ha^{-1}, from which the lowest crops were harvested, tended only mechanically (Table 7). This was confirmed by the results of studies by many authors (Nowacki, 2009; Mystkowska *et al*., 2022).

The economic effect of potato cultivation, expressed in direct margin, was determined by direct and indirect costs per 1 ha and mainly the value of the marketable yield – sold. In the structure of costs, seed potatoes were the most expensive, followed by machine operation (Table 7). Also Wereszczaka and Marczakiewicz (2014) found that qualified seed material is one of the most expensive costs in potato cultivation. This is confirmed by the analyses of Abramczuk *et al.* (2013), who showed that despite high direct costs, but good yielding and favourable price, edible potato at the level of gross margin is a profitable activity.

Table 7. Direct costs and production value of ware potatoes of the Oberon variety (on average from years 2018–2020), in PLN·ha^{-1}

Specification	Control object	Avatar 293 ZC	Avatar 293 ZC + PlonoStart	Avatar 293 ZC + Aminoplant	Avatar 293 ZC +Agro-Sorb Folium
Seed potato	4987.5	4987.5	4987.5	4987.5	4987.5
Manure (50%)	1625.0	1625.0	1625.0	1625.0	1625.0
Mineral fertilizers:	1148.3	1148.3	1148.3	1148.3	1148.3
– nitrogen	328.8	328.8	328.8	328.8	328.8
– potassium	450.0	450.0	450.0	450.0	450.0
– phosphorus	369.5	369.5	369.5	369.5	369.5
Plant protection agent	630.0	825.0	905.0	892.5	1209.0
– herbicides	-	195.0	195.0	195.0	195.0
– insecticides	297.0	297.0	297.0	297.0	297.0
– fungicides	333.0	333.0	333.0	333.0	333.0
– biostimulatores	-	-	80.0	67.5	384.0

Table 7. continue

Human work	1192.3	1082.7	1137.5	1137.5	1137.5
Operation of the equipment	4041.3	3511.3	3776.3	3776.3	3776.3
Direct costs per 1 ha	13624.4	13179.8	13579.6	13567.1	13883.6
Value of market yield	18760.0	21609.0	24927.0	23317.0	27342.0
Value of side yield	634.4	466.4	427.2	452.0	371.2
Total production value	19394.4	22075.4	25354.2	23769.0	27713.2
Gross margin for 1 ha of cultivation	5770.0	8895.6	11774.6	10201.9	13829.6

Table 8. The direct costs structure in potato cultivation of the Oberon variety, %

Specification	Control object	Avatar	Avatar+ PlonoStart	Avatar+ Aminoplant	Avatar+ Agro-Sorb-Folium
Seed potato	36.6	37.8	36.7	36.7	35.9
Manure (50%)	12.0	12.3	12.0	12.0	11.7
Mineral fertilizers	8.4	8.8	8.45	8.46	8.3
Plant protection agents	4.6	6.25	6.7	6.64	8.7
Input of labour	8.7	8.2	8.4	8.4	8.2
Machine operation	29.7	26.65	27.8	27.8	27.1
Total	100.0	100.0	100.0	100.0	100.0

CONCLUSIONS

1. The highest yields of the Oberon variety – general 437.0 dt·ha^{-1} and commercial 390.6 dt·ha^{-1} – compared to the control object 268.0 dt·ha^{-1} were collected from object 5, where intensive mechanical tillage and the herbicide Avatar 293 ZC and the Agro-Sorb Folium 4 biostimulant were applied. In the sites where mechanical-chemical tending with the use of herbicide and herbicide with a biostimulant was applied (2.-5.), the commercial yield of tubers was on average 347.1 dt·ha^{-1} and was higher in relation to the control treatment by 79.1 dt·ha^{-1}. The costs of potato protection against weeds were determined mainly by the number of mechanical and chemical treatments as well as the prices of herbicides and biostimulants.
2. The best economic effect was obtained in variant 5, in which mechanical and chemical treatments included double ridging and single ridging with harrowing and the application of the herbicide Avatar 293 ZC and the Agro-Sorb Folium 4 biostimulant.
3. The factor determining the profitability of cultivation was the value of harvested crops (mainly commercial).
4. The basis for making decisions on the intensity of treatments in potato cultivation should be: expected yield, treatment costs and prices of preparations.

REFERENCES

Abramczuk, Ł., Augustyńska-Grzymek, I., Czułowska, M., Idzik, M., Jabłoński, K., Skarżyńska, A., Żekadło, M. (2013). Gross margin on selected agricultural products in 2012 and income projection for 2015. Warsaw: IERiGŻ-PIB, 1–99.

Dzwonkowski W. (2019). Potato market. Status and prospects. Analizy rynkowe, 46, 1–34.

Dzwonkowski W. (2020). Potato market. Status and prospects. Analizy rynkowe, 47, 1–34.

Gołaś Z. (2016). Economics, organization and income situation of farms in the European Union countries focused on the production of root crops. Roczniki Naukowe Ekonomii Rolnictwa i Rozwoju Obszarów Wiejskich 103(1), 35-45 [in Polish].

Ilić, O., Nikolić, L., Ilin, Ž, Mišković, A., Vujasinović, V., Kukić, B. (2016). Effect of cultural practices on weeds community in function of potato yield. Acta Sci. Pol. Hortorum Cultus, 15(5), 31–43.

Kebede, G., Sharma, J.J., Dechassa, N. (2016). Evaluation of chemical and cultural methods of weed management in potato (*Solanum tuberosum* L.) in Gishe District, North Shewa, Ethiopia. J. Natural Sci. Res., 6(5), 28–47.

Kocira, A., Lamorska, J., Kornas, R., Nowosad, N., Tomaszewska, M.,Leszczyńska, D., Kozłowicz, K., Tabor, S. (2020) Changes in biochemistry and yield response to biostimulants applied in bean (*Phaseolus vulgaris* L.). Agronomy, 10, 189.

Krzysztofik, B., Marks, N., Baran, D. (2009). Wpływ wybranych czynników agrotechnicznych na ilościowe cechy plonu bulw ziemniaka. Inż. Rol., 5(114), 123–129.

Muzalewski, A. 2015. Principles of selection of agricultural machinery under the RDP for 2014-2020. Warszawa: Wyd. ITP, 5–122.

Mystkowska, I., Zarzecka, K., Gugała, M., Sikorska A. (2022). Profitability of using herbicide and herbicide with biostimulators in potato production. J. Ecol. Eng., 23(4), 223–227.

Nowacki, W. (2009). Factors influencing the profitability of potato production in Poland. Scientific Annals SERiA, XI(1), 320–323.

Nowacki, W. (2016). Rynek ziemniaków jadalnych w Polsce – stan obecny i perspektywy rozwoju. Roczniki Naukowe SERiA, XVIII(1), 196–201.

Popko, M., Michalak, I., Wilk, R., Gramza, M., Chojnacka, K., Górecki, H. (2018). Effect of the new plant growth biostimulants based on amino acids on yield and grain quality of winter wheat. Molecules 23(2), 470.

Praczyk, T., Skrzypczak, G. (2011). Stan aktualny i kierunki rozwoju herbologii. Prog. Plant Prot., 51(1), 354–363.

Qasim, M., Khalid, S., Naz, A., Khan, M.Z. (2013). Effects of different planting systems on field of potato crop in Kaguan Valley: A mountainous region of Pakistan. Agric. Sci., 4(4), 175–179.

Roztropowicz, S., Czerko, Z., Głuska, A., Goliszewski, W., Gruczek, T., Lis, B., Lutomirska, B., Nowacki, W., Rykaczewska, K., Sowa-Niedziałkowska, G., Szutkowska, M., Wierzejska-Bujakowska, A., Zarzyńska, K., Zgórska, K. (1999). Methodology of observation, measurement and sampling in agrotechnical experiments with potatoes. Wyd. IHAR Radzików, Oddział Jadwisin, 1–50.

Sharma, H.S.S., Fleming, C., Selby, C., Rao, J.R., Martin, T. (2014). Plant biostimulants. A review on the processing of macroalgae and use of extracts for crop management to reduce abiotic and biotic stresses. J. Appl. Phycol., 26, 465–490.

Shukla, P.S., Mantin, E.G., Adil, M., Bajpai, S., Critchley, A.T., Prithiviraj, B. (2019) *Ascophyllum nodosum*-Based biostimulants: Sustainable applications in agriculture for the stimulation of plant growth, stress tolerance, and disease management. Front. Plant. Sci., 10, 655.

Skarżyńska, A., red. (2008). Production, costs and direct surplus of selected agricultural products in 2007, 9–20. Warszawa: IERiGŻ-PIB. ISBN 978-83-60798-02-7.

Skowera, B., Jędrszczyk, E.S., Kopcińska, J., Ambroszczyk, A.M., Kołton, A. (2014). The Effects of Hydrothermal Conditions during Vegetation Period on Fruit Quality of Processing Tomatoes. Pol. J. Envir. Stud., 23(1), 195–202.

Trawczyński, C. (2020). The effect of biostimulators on the yield and quality of potato tubers grown in drought and high temperature conditions. Biul. IHAR, 289, 11–19. https://doi.org/10.37317/biul-2020-0017 (in Polish).

Trawczyński, C. (2021). Assessment of mineral nitrogen fertilization of early potato varieties in integrated production. J. Elem., 26(1), 109–123. https://doi.org/10.5601/jelem.2020.25.4.2066

Urbanowicz, J. (2015). Herbicides recommended for potato protection. Ziemniak Polski, 2, 25–29 [in Polish].

Wierzbowska, J., Cwalina-Ambroziak, B., Głosek-Sobieraj, M., Sienkiewicz S. (2015). Effect of biostimulators on yield and selected chemical properties of potato tubers. J. Elem. 20(3), 757–768. https://doi.org/10.5601/jelem.2014.19.4.799

Wereszczaka, J., Marczakiewicz, J. (2014). Sustainable agriculture and a healthy environment. Good practices and the role of beneficial microorganisms in the cultivation of potatoes with the use of innovative, natural technologies. Warszawa: MRiRW, Fundacja Pomocy dla Rolnictwa FAPA, 1–97.

WPŁYW HERBICYDÓW I PREPARATÓW BIOSTYMULUJĄCYCH NA WYNIK EKONOMICZNY UPRAWY ZIEMNIAKA JADALNEGO

Streszczenie

Opłacalność jest miarą efektu ekonomicznego wynikającą m.in. z zastosowania zabiegów w ochronie roślin ziemniaka przed szkodnikami. Stąd hipoteza, że zastosowane zabiegi mechaniczne i chemiczne mogą przyczynić się do wzrostu plonu handlowego bulw w stosunku do obiektu kontrolnego i mogą być opłacalne pomimo wysokich kosztów ochrony. Celem badań była ocena wpływu herbicydu i biostymulatorów na wynik ekonomiczny uprawy ziemniaka jadalnego odmiany Oberon. Badania polowe prowadzono w latach 2018–2020 w Rolniczym Zakładzie Doświadczalnym Uniwersytetu Przyrodniczo-Humanistycznego w Siedlcach, na glebie średniej, w układzie split-polot, dwuczynnikowo w trzech powtórzeniach. Materiał badawczy stanowiły plony bulw ziemniaka średnio wczesnej odmiany Oberon. Ocenę wpływu herbicydów i biostymulatorów na opłacalność uprawy ziemniaka jadalnego: 1) obiekt kontrolny, 2) Avatar 293ZC (chlomazon + metrybuzyna), 3) Avatar 293ZC + biostymulator PlonoStart, 4) Avatar 293ZC + biostymulator Aminoplant, 5) Awatar 293ZC + biostymulant Agro-Sorb-Folium oparto o standardową metodę marży brutto. Zabiegi mechaniczno-chemiczne zwiększyły plon handlowy bulw średnio o 29,5%, a zmniejszyły plon uboczny bulw średnio o 32,4% w stosunku do obiektu kontrolnego. Nadwyżka bezpośrednia z 1 ha uprawy wynosiła od 5770,00 zł na obiekcie kontrolnym do 13829,60 zł na obiekcie, na którym stosowano herbicyd Avatar 293 ZC i biostymulator Agro-Sorb-Folium, co wskazuje, że stosowanie różnych metod pielęgnacji i odżywiania roślin z biostymulatorami, pomimo wysokich kosztów ochrony ziemniaka przed chwastami, było opłacalne. Największe plony odmiany Oberon (ogólnie i towarowo) oraz najlepszy efekt ekonomiczny w stosunku do obiektu kontrolnego uzyskano stosując pielęgnację mechaniczną oraz herbicyd Avatar 293 ZC i biostymulator Agro-Sorb-Folium.

Słowa kluczowe: metody zwalczania chwastów, nadwyżka brutto, odżywianie, plon ziemniaka