

AGRICULTURAL AND ECONOMIC EFFECTS OF THE USE OF BIOSTIMULANTS AND HERBICIDES IN CULTIVATION OF THE TABLE POTATO CULTIVAR GAWIN

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ABSTRACT

Background. Integrating mechanical cultivation measures with herbicides adapted to the state and degree of weed infestation effectively reduces segetal vegetation. Biostimulants in turn have a positive effect on plant growth and development and increase plant resistance to the adverse effects of various stress factors. The aim of the study was to evaluate the production and economic effects of cultivation of the table potato cultivar Gawin after the use of mechanical measures, herbicides and herbicides with biostimulants.

Material and methods. The field study was carried out in the years 2012–2014 at the Przedsiębiorstwo Wielobranżowe Soleks, in the town of Wojnów located in the Mazovian Voivodeship, on light soil with quality class IVb which is classified as the very good rye complex. The test plant was the medium-early table potato cultivar Gawin. The experimental variants comprised of five methods of using mechanical and chemical measures: the control variant – only mechanical weeding and four variants with the use of herbicides or the use of herbicides and biostimulants: Harrier 295 ZC (linuron + clomazone), Harrier 295 ZC (linuron + clomazone) + Kelpak SL, Sencor 70 WG (metribuzin) and Sencor 70 WG (metribuzin) + Asahi SL. The standard gross margin method was used for the economic assessment of the methods of cultivation.

Results. The total tuber yield on variants with mechanical and chemical cultivation was 22.5% higher compared with the control variant, and the marketable yield was 39% higher. Despite the relatively high costs incurred to protect the potato from weeds, integrating mechanical measures, herbicides and biostimulants was cost-effective.

Conclusion. The highest yields of the cultivar Gawin (total and marketable) and the best economic effect in relation to the control variant were obtained using intensive mechanical weeding as well as the herbicide Sencor 70 WG and the biostimulant Asahi SL.

Key words: biostimulants, gross margin, herbicides, potato, yields

INTRODUCTION

The profitability of agricultural plant production depends on the amount of harvested yield, costs of means of production, the value of the harvested and

sold crop, as well as the humidity and thermal conditions in individual years (Zarzecka and Gugala, 2007; Nowacki, 2010; 2016). In potato cultivation, one of the most important factors determining crop yields and profitability is plantation protection

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against weeds (Pytlarz-Kozicka, 2002; Zarzecka and Gugala, 2010). The greatest threat to *Solanum tuberosum* L. occurs at the beginning of plant growth. This is due to the initial slow plant growth and the use of wide row spacing cultivation, which creates the optimal conditions for weeds to grow (Urbanowicz, 2015). According to Praczyk and Skrzypczak (2011), among all pests found on potato plantations, weeds are characterized by having the highest ability to reduce yield – on average by up to 34%. To reduce the occurrence of unwanted vegetation, various methods are used to reduce weed infestation. Appropriate selection of herbicides improves the effectiveness of weed control, which in turn contributes to an increase in yield and improvement in its quality and the profitability of plant cultivation (Pytlarz-Kozicka, 2002; Kebede *et al.*, 2016; Nowacki, 2016). In order to provide the crop with favourable conditions during growth and development new solutions are being sought, such as growth stimulants called biostimulants, which can be used in addition to traditional plant protection products. These are preparations that support the natural life processes of plants and increase plant resistance to stress conditions, e.g. drought or inaccessibility of nutrients. These stimulants improve the morphological, biochemical and physiological processes occurring in the plant (Paradikovic *et al.*, 2011; Baranowska *et al.*, 2018). The highest yields of table potatoes can be obtained using intensive cultivation technology, i.e. correct and careful cultivation, optimal plant protection against pests, irrigation, as well as fertilization adapted to the soil nutrient content and plant requirements (Nowacki, 2009; Mystkowska *et al.*, 2017).

The aim of this study was to evaluate the production and economic effects in the cultivation of the table potato cultivation Gawin after the use of mechanical measures, herbicides and herbicides with biostimulants.

MATERIAL AND METHODS

The yield assessment and economic analysis were based on the study results from the cultivation of the medium-early table potato cultivar Gawin. The field study was carried out in the years 2012–2014 at the

Przedsiębiorstwo Wielobranżowe Soleks (multi-branch company), in the town of Wojnów located in the Mazovian Voivodeship. The field experiment was conducted on light soil with pH from 5.60 to 6.35, quality class IVb, classified as the very good rye complex. The area of each plot was 18.75 m² (5.55 m × 3.375 m). During the experiment, the weather conditions in individual years were varied, hence the yield results were adopted as the means of the three years. The analysis comprised five research variants that differed in the use of mechanical measures, herbicides and herbicides with biostimulants (Table 1):

- 1 – control/standard variant – protection against weeds included only mechanical cultivation (without the use of herbicides and biostimulants), double ridging and single ridging with harrowing was performed until emergence, and double ridging after emergence,
- 2 – mechanical and chemical cultivation – the plantation was ridged once before emergence, then herbicide Harrier 295 ZC was used 7–10 days after planting the tubers,
- 3 – mechanical and chemical cultivation – before emergence the plantation was ridged once, then 7–10 days after planting the tubers, the herbicide Harrier 295 ZC was used, and after emergence of the crop, the variant was sprayed twice with the Kelpak SL biostimulant (at the end of potato emergence and when the covering of inter-rows was between 10–50%),
- 4 – mechanical and chemical cultivation – until emergence, double ridging and single ridging with harrowing were carried out, and the herbicide Sencor 70 WG was used just before emergence,
- 5 – mechanical and chemical cultivation – until emergence, double ridging and single ridging with harrowing, and directly before emergence of potato plants the herbicide Sencor 70 WG was used, and after the emergence of potato plants, the biostimulant Asahi SL was used twice (at the end of potato emergence and when the covering of inter-rows was between 10–50%).

During the experiment permanent natural fertilization (manure) at a rate of 25.0 Mg·ha⁻¹ as well as minerals

– potassium at a rate $124.5 \text{ kg}\cdot\text{ha}^{-1}$ K and phosphorus at a rate of $44.0 \text{ kg}\cdot\text{ha}^{-1}$ P was applied in autumn, and nitrogen $100.0 \text{ kg N}\cdot\text{ha}^{-1}$ N was applied in spring. Potatoes were planted by hand at a row spacing of $67.5 \times 37 \text{ cm}$, within the last ten days of April and the first ten days of May. Cultivation measures and application of plant protection agents against Colorado potato beetle and diseases were carried out in accordance with the recommendations of IOR-PIB. Immediately before harvest tuber samples from ten randomly selected plants from each of the variants were dug out manually, and the yield structure was determined in them according to the transverse diameter fraction: below 35, 35–50, 50–60 and above 60 mm. Tubers over 35 mm were the commercial fraction. Then, tubers with external and internal defects were rejected from the commercial fraction and the percentage weight of commercial tubers was determined (Roztropowicz *et al.*, 1999). The marketable yield included tubers with a diameter larger than 35 mm and without external or internal defects. Small tubers and those with defects were

classified as a side crop (MRiRW, 2003). The tubers were harvested with an elevator digger at the stage of technological maturity during the first ten days of September. Research results on the potato yields were statistically analysed by analysis of variance. The significance of differences at $P < 0.05$ between mean values was determined using the Tukey's test.

The analysis of economic assessment included: the mean tuber yields of the cultivar Gawin from 2012–2104, while the potato selling prices, purchase of materials and costs of measures were adopted from 2014, the last year of the study. The calculation of direct costs comprised: seed potatoes, natural fertilizers (manure 50%) and mineral fertilizers, plant protection agents (fungicides, insecticides, herbicides and biostimulants), the costs of labour and equipment operation. As a measure of economic efficiency the gross margin was adopted, which is the difference between the value of production obtained from 1 ha of crop, and the direct costs incurred for making this production (Abramczuk *et al.*, 2013).

Table 1. Methods of application of herbicides and biostimulants (objects)

Objects	Herbicides and biostimulants
1	Control variant – mechanical weeding – without herbicides and biostimulants
2	Herbicide Harrier 295ZC at a dose of $2.0 \text{ dm}^3\cdot\text{ha}^{-1}$
3	Herbicide Harrier 295ZC at a dose of $2.0 \text{ dm}^3\cdot\text{ha}^{-1}$ and biostimulant Kelpak SL at a dose of $2.0 \text{ dm}^3\cdot\text{ha}^{-1}$
4	Herbicide Sencor 70 WG at a dose of $1.0 \text{ kg}\cdot\text{ha}^{-1}$
5	Herbicide Sencor 70 WG at a dose of $1.0 \text{ kg}\cdot\text{ha}^{-1}$ and biostimulant Asahi SL at a dose of $1.0 \text{ dm}^3\cdot\text{ha}^{-1}$

RESULTS AND DISCUSSION

The effectiveness of potato production is influenced by many agricultural elements, and one of the most important is an appropriately selected weeding method which, as a result of removing weed competition, will allow obtaining high yields of good quality (Krzysztofik *et al.*, 2009; Ilić *et al.*, 2016; Gugala *et al.*, 2017). In the present experiment potato tuber yields – total, marketable and side – were significantly differentiated by the methods of

mechanical and chemical weeding (Table 2). On variants with mechanical and chemical weeding (variants 2–5), the total tuber yield averaged $40.03 \text{ Mg}\cdot\text{ha}^{-1}$ and was higher in relation to the control variant by $7.35 \text{ Mg}\cdot\text{ha}^{-1}$, which is equivalent to 22.5%. The marketable yield on the mechanical and chemical variants was higher by $10.04 \text{ Mg}\cdot\text{ha}^{-1}$ compared with the control, which in percentage terms amounted to 39.0%. The highest yields (total and marketable) as compared with the control variant were collected from the variants in which mechanical

measures were used and the herbicide Sencor 70 WG and the biostimulant Asahi SL were applied, and after spraying with Sencor 70 WG. The side yield of potato tubers ranged from 2.57 Mg·ha⁻¹ in variant 5 (Sencor 70 WG + Asahi SL) to 6.97 Mg·ha⁻¹ in the control variant. According to Urbanowicz (2015) and Gugala *et al.* (2017), harvest yields are determined by the use of herbicides, which are the most effective way to reduce weeds, and by biostimulants, which effectively support the life processes of plants. Gugala *et al.* (2017) and Trawczyński (2014) showed that biostimulants contribute to reducing the negative impact of environmental stress on plants. Ilić *et al.* (2016) showed that the application of herbicides in potato cultivation led to a significant reduction in weed infestation and that in variants with herbicides the potato yield was 32% higher compared with the

yield obtained from variants without the use of chemical agents. According to Abramczuk *et al.* (2013), achieving good production results in table potato cultivation also requires a correspondingly large expenditure on plant protection.

In the present study, the largest share of the marketable yield in the total yield was noted in the variant with the herbicide Sencor 70 WG and the biostimulant Asahi SL. Krzysztofik *et al.* (2009) found that mechanical and chemical measures used on a plantation have a positive effect on the share of the marketable yield in the total yield, and Mystkowska *et al.* (2017) showed a beneficial effect of these measures in relation to only mechanical weeding on the share of large tubers in the total harvested yield.

Table 2. Tuber yields of potato cultivar Gawin, Mg·ha⁻¹ (mean for 2012–2014)

Methods of application of herbicides and biostimulants	Tuber yields			
	total	marketable	side	% share of the marketable yield in the total yield
1 – Mechanical weeding	32.68d*	25.71d	6.97a	78.7
2 – Harrier 295 ZC	36.49c	31.57c	4.92b	86.5
3 – Harrier + Kelpak SL	39.78b	35.42bc	4.36b	89.0
4 – Sencor 70 WG	41.04ab	35.77b	5.27b	87.1
5 – Sencor 70 WG + Asahi SL	42.81a	40.24a	2.57c	94.0
Mean for variants 2–5	40.03	35.75	4.28	89.4

* mean yield values in the columns marked with the same letters do not differ significantly at $P < 0.05$

The total costs incurred for the protection of potatoes against weeds varied depending on the methods of use of mechanical and mechanical-chemical measures and ranged from 578.2 to 1702.7 PLN·ha⁻¹ (Table 3). The highest costs were incurred on variant 5, in which intensive mechanical weeding and herbicide and biostimulant spraying were used, while the lowest costs were on variant 2 with single ridging and single herbicide spraying. In variants 2, 3 and 4, the costs of protection were lower in relation to the control variant, in which only mechanical measures

were performed. The study by Nowacki (2009) also showed that double spraying with herbicides in an integrated system was cheaper than only mechanical weeding measures performed in an organic system.

The profitability of potato cultivation, expressed as gross margin, was determined by direct and indirect costs incurred per 1 ha and mainly by the value of marketable (sold) yield (Table 4). The value of side yield on particular variants was varied, but small in relation to the marketable yield and was only a supplement to the value of sold production. In the

cost structure, seed potatoes were the most expensive, followed by machine operation. Wereszczaka and Marczakiewicz (2014) and Zarzecka *et al.* (2017) also found that certified seed material is one of the most expensive costs in growing potatoes. The highest gross margin, despite the largest costs, was obtained on variant 5 from which the highest yields

were harvested, and the lowest margin was obtained by growing potato on the mechanically cultivated control variant. This is in line with the analyses of Abramczuk *et al.* (2013), who showed that despite high direct costs, but due to good yield and a favourable price, growing table potato at the gross margin level is a profitable activity.

Table 3. Costs of protecting potato from weeds, PLN·ha⁻¹

Specification	Methods of application of herbicides and biostimulants				
	1	2	3	4	5
a) total costs of human labour	195.2	61.0	109.8	146.4	195.2
– ridger	146.4	36.6	36.6	73.2	73.2
– ridger with harrow	48.8	–	–	48.8	48.8
– spraying	–	24.4	73.2	24.4	73.2
b) total costs of machine operation	790.4	247.0	444.6	592.8	790.4
– ridger	592.8	148.2	148.2	296.4	296.4
– ridger with harrow	197.6	–	–	197.6	197.6
– spraying	–	98.8	296.4	98.8	296.4
c) costs of herbicides	–	166.0	166.0	190.0	190.0
d) costs of biostimulants	–	–	212.0	–	220.0
e) direct costs (a + b + c + d)	985.6	474.0	932.4	929.2	1395.6
f) indirect costs (10% direct costs, a + b + c + d)	98.0	47.4	93.2	92.9	139.6
g) other costs	118.3	56.8	111.9	111.5	167.5
h) total costs (f + g + h)	1202.5	578.2	1137.5	1133.6	1702.7

Table 4. Costs and profitability of potato cultivation

Specification	Methods of application of herbicides and biostimulants				
	1	2	3	4	5
Seed potatoes	3250.0	3250.0	3250.0	3250.0	3250.0
Manure	1250.0	1250.0	1250.0	1250.0	1250.0
Mineral fertilizers:					
– nitrogen	305.0	305.0	305.0	305.0	305.0
– phosphorus	400.0	400.0	400.0	400.0	400.0
– potassium	350.0	350.0	350.0	350.0	350.0
Plant protection agents + biostimulants:					
– herbicides	–	166.0	166.0	190.0	190.0
– fungicides	217.0	217.0	217.0	217.0	217.0
– insecticides	93.0	93.0	93.0	93.0	93.0
– biostimulants	–	–	212.0	–	220.0
Human labour	988.2	610.0	902.8	939.4	988.2
Machine operation	2815.8	2272.4	2470.0	2618.2	2815.8
Direct costs per 1 ha of crop	9 669.0	8913.4	9615.8	9612.6	10 079.0
Value of marketable yield	14 911.8	18 310.6	20 543.6	20 746.6	23 339.2
Value of side yield	418.2	295.2	261.6	316.2	154.2
Value of total yield	15 330.0	18 605.8	20 805.2	21 062.8	23 493.4
Gross margin, PLN·ha ⁻¹	5661.0	9 692.0	11 189.4	11 450.2	13 414.4

CONCLUSIONS

1. The highest yields of the cultivar Gawin – total and marketable – as well as the best economic effect compared with the control variant were obtained from variant 5, where intensive mechanical weeding as well as the herbicide Sencor 70 WG and the biostimulant Asahi SL were used.
2. The cost of protecting the potato against weeds was mainly determined by the number of mechanical and chemical measures used as well as by the prices of herbicides and biostimulants. Hence, the basis for making decisions about the

intensity of measures in potato cultivation should be the expected yield, the costs of measures and the prices of preparations.

3. The economic analysis conducted showed that the decisive factor for the crop profitability was the value of harvested yields (mainly marketable ones).

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ROLNICZY I EKONOMICZNY EFEKT STOSOWANIA BIOSTYMULATORÓW I HERBICYDÓW W UPRAWIE ZIEMNIAKA JADALNEGO ODMIANY GAWIN

Streszczenie

Integrowanie mechanicznych zabiegów pielęgnacyjnych z herbicydami dostosowanymi do stanu i stopnia zachwaszczenia skutecznie redukuje roślinność segetalną. Natomiast biostymulatory korzystnie wpływają

na wzrost i rozwój roślin oraz zwiększając odporność roślin na niekorzystne działanie różnych czynników stresowych. Celem badań była ocena efektu produkcyjnego i ekonomicznego w uprawie ziemniaka jadalnego odmiany Gawin po zastosowaniu zabiegów mechanicznych, herbicydów i herbicydów z biostymulatorami. Badania polowe przeprowadzono w latach 2012–2014 w Przedsiębiorstwie Wielobranżowym Soleks, w miejscowości Wojnów, w województwie mazowieckim, na glebie lekkiej, klasy bonitacyjnej IVb, zaliczanej do kompleksu żyniego bardzo dobrego. Rośliną testową była średnio wczesna odmiana ziemniaka jadalnego Gawin. Obiekty doświadczalne obejmowały pięć sposobów stosowania zabiegów mechaniczno-chemicznych: obiekt kontrolny – pielęgnacja wyłącznie mechaniczna – i cztery obiekty z wykorzystaniem herbicydów i biostymulatorów: Harrier 295 ZC (linuron + chlomazon), Harrier 295 ZC (linuron + chlomazon) + Kelpak SL, Sencor 70 WG (metrybuzyna) oraz Sencor 70 WG (metrybuzyna) + Asahi SL. Do oceny ekonomicznej sposobów pielęgnacji wykorzystano metodę standardowej nadwyżki bezpośredniej. Na obiektach pielęgnowanych mechaniczno-chemicznie plon ogólny bulw, w odniesieniu do obiektu kontrolnego, był większy o 22,5%, a plon handlowy o 39%. Mimo dość wysokich kosztów poniesionych na ochronę ziemniaka przed chwastami, integrowanie zabiegów mechanicznych, herbicydów i biostymulatorów było opłacalne. Największe plony odmiany Gawin (ogólny i handlowy) oraz najlepszy efekt ekonomiczny w odniesieniu do obiektu kontrolnego uzyskano stosując intensywną pielęgnację mechaniczną oraz herbicyd Sencor 70 WG i biostymulator Asahi SL.

Słowa kluczowe: biostymulatory, herbicydy, nadwyżka bezpośrednia, plony, ziemniak