https://doi.org/10.17221/103/2024-PSE

Biostimulants and herbicides shape the structure of potato tuber yield

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Citation: Zarzecka K., Gugała M. (2024): Biostimulants and herbicides shape the structure of potato tuber yield. Plant Soil Environ., 70: 468–473.

Abstract: The aim of the study was to assess the impact of three biostimulants and a herbicide on selected unit parameters of potato yield. The research results came from a three-year field experiment that was established using the randomised sub-blocks method in three replications. In the experiment, two cultivars of edible potato were grown and the yield-protective effect of treatments was assessed: (1) control object without protection with preparations; (2) herbicide clomazone + metribuzin; (3) biostimulant PlonoStart and herbicide clomazone + metribuzin; (4) biostimulant Aminoplant and herbicide clomazone + metribuzin, and (5) biostimulant Agro-Sorb Folium and herbicide clomazone + metribuzin. As a result of the limited competition of weeds in the objects with the use of biostimulant and herbicide, a higher average weight of one potato tuber, a higher share of commercial tubers > 35 mm and a higher share of large tubers > 50 mm was obtained compared to the control object. The highest average weight of one tuber (108.2 and 85.4 g, respectively) and the highest share of commercial (97.1 and 96.3%, respectively) and large tubers (60.6 and 60.5%, respectively) were obtained in the objects where the Agro-Sorb Folium biostimulant + Avatar 293 ZC herbicide were used. and PlonoStart + Avatar 293 ZC. The correlation analysis confirmed a significant negative relationship between the number of weeds and average weight of one potato tuber, share of commercial tubers and share of large tubers. Weather conditions during the conduct of the research also significantly differentiated weed numbers and quality parameters of potato yield.

Keywords: *Solanum tuberosum* L.; growth regulators; structure of yield; weed infestation

Potato yield potential and the quality of the tuber yield obtained depend on three groups of factors: the use of biological progress (the use and agrotechnical value of the cultivated cultivar), treatments carried out during the growing season (soil cultivation, fertilisation, planting, cultivation, plant protection against agrophages, irrigation, harvesting), and soil and climatic conditions with particular attention to the distribution of precipitation and temperatures (Nowacki 2019, Lemma et al. 2020). Among agrotechnical measures, one of the most important is properly protecting plantations against weeds. Weeds cause at least a 20–30% reduction in yields, and high weed infestation can reduce yields by up to 90%. Hence, their destruction is one of the key technological measures in potato cultivation (Čepl et al. 2021). Siddiqui et al. (2023), based on a review of many studies, report that weeds reduce the number of potato tubers by 25–53%, marketable tubers by 50–65%, and the total tuber yield by 10–80%. Caldiz et al. (2016) and Barbaś and Sawicka (2020), using herbicides and their mixtures, obtained a high protective effect of chemical treatments, increased the total and marketable yield as well as improved the yield structure and reduced tubers defects compared to the control object.

One of the pro-ecological approaches in agriculture is using biostimulants that stimulate and improve the development of plants. These preparations increase the efficiency of water use, support the uptake of nutrients, which translates into higher yields and quality, make

Supported by the Ministry of Education and Science of Poland, Project No. 162/23/B

https://doi.org/10.17221/103/2024-PSE

plants resistant to abiotic stresses, and at the same time are environmentally friendly (Brown and Saa 2015, Cataldo et al. 2022, Naqve et al. 2023). Baranowska et al. (2019), after the application of the herbicide Avatar 293 ZC and the biostimulant GreenOK Universal-PRO, obtained the lowest share of small tubers (< 35 mm) in the yield and the highest share of large tubers (> 51 mm) compared to the standard object without biostimulants and herbicide. Kołodziejczyk and Gwóźdź (2022) also obtained an increase in potato yields and an improvement in the yield structure after using plant growth regulators. The beneficial effects of biostimulants on the growth, yield and quality of plants, including potatoes, have been reported by many authors (Mystkowska 2019, Trawczyński 2020, Malik et al. 2021, Zarzecka et al. 2021, Karak et al. 2023). The aim of the study was to determine the impact of biostimulants and herbicides on selected unit parameters of the yield and its structure.

MATERIAL AND METHODS

A three-year field experiment was conducted at the Agricultural Experimental Station belonging to the University of Siedlce, Poland. The experiment was designed using a split-plot method with three replications. Two factors were considered: the first-order factors were two medium-early, edible potato cultivars – Oberon and Malaga, while the second-order factors were five objects where biostimulants and herbicide were applied: (1) control object – mechanical treatments, without protection with preparations; (2) herbicide Avatar 293 ZC (clomazone + metribuzin); (3) biostimulant PlonoStart and herbicide Avatar 293 ZC (clomazone + metribuzin); (4) biostimulant Aminoplant and herbicide Avatar 293 ZC (clomazone + metribuzin), and (5) biostimulant Agro-Sorb Folium and herbicide Avatar 293 ZC (clomazone + metribuzin). Soil properties, description of cultivars, biostimulants and herbicides are presented in a work by Zarzecka et al. (2021), and agronomic characteristics of the experiment and detailed weather conditions in another work (Zarzecka et al. 2022).

Seed samples were taken from each plot a few days before the potato harvest. The determinations were made using a rectangular frame measuring 0.33 × 1.5 m. The frame was thrown across the ridges at three locations in each plot. The number of weeds was calculated per 1 m^2 area (Roztropowicz 1999, Badowski et al. 2001). Before harvesting, tubers from ten randomly selected potato bushes were dug out from each plot. These samples were weighed, the tubers were counted, and the average weight of one tuber was determined. Then, using a square calibrator, the yield structure was determined and divided into fractions: < 35 mm, 36–50 mm, 51–60 mm and > 60 mm. Tubers with a diameter of < 35 mm were small tubers, > 35 mm were commercial tubers, and > 50 mm were large tubers (Regulation 2003). The results of the study were statistically evaluated using analysis of variance. The significance of differences (*HSD*) between the compared averages was verified by Tukey's test at a significance level of $P \leq 0.05$ (Trętowski and Wójcik 1991). The relationship between the analysed features was determined using the correlation analysis. According to the Sielianinow hydrothermal index described by Skowera et al. (2014), 2018 was dry, 2019 was very dry, and 2020 was relatively dry (Table 1). The most unfavourable weather conditions during potato vegetation were recorded in 2019, as June, July, August, and September were very dry and dry. In contrast, 2020 was the most favourable year for potato growth, development and yield.

Table 1. Sielianinov hydrothermal index (K) during the potato growing seasons

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

According to Skowera et al. (2014), ranges of values of this index were classified as follows: $K \leq 0.4$ – extremely dry; $0.4 < K \leq 0.7$ – very dry; $0.7 < K \leq 1.0$ – dry; $1.0 < K \leq 1.3$ – relatively dry; $1.3 < K \leq 1.6$ – optimal; $1.6 < K \leq 2.0$ – relatively humid; $2.0 < K \leq 2.5$ – humid; $2.5 < K \leq 3.0$ – very humid; $K > 3.0$ extremely humid

https://doi.org/10.17221/103/2024-PSE

RESULTS AND DISCUSSION

The number of weeds determined before harvesting the tubers ranged from 7.45 to 25.23 per 1 m^2 and depended significantly on the cultivar, application of biostimulants and herbicide, and the humidity and thermal conditions during the study (Table 2). Among the cultivated cultivars, the cv. Malaga was more weeded, its plants dried out earlier, and the vegetation period ended earlier than the cv. Oberon. The influence of the cultivar on weed infestation is confirmed by research by Gugała et al. (2018) and Barbaś et al. (2020). The best herbicidal effect was obtained using the biostimulant Agro-Sorb Folium and herbicide Avatar 293 ZC (clomazone + metribuzin) (object 5) and the biostimulant PlonoStart and herbicide Avatar 293 ZC (clomazone + metribuzin) (object 3) compared to the control object (1). There were significant differences between objects 3 and 5 and object 2. The number of weeds was the highest in the very dry 2019. The humidity and thermal conditions prevailing in July, August and September 2019 favoured the occurrence and development of thermophilic weeds. Moreover, during this growing season, potatoes were harvested about 2 weeks later than in 2018 and 2020, which also created favourable conditions for weeds.

Statistical calculations confirmed that the number of tubers from one potato plant depended on the cultivar, the biostimulants and herbicide used, and weather conditions during the growing season (Table 2). The cv. Malaga produced more tubers than cv. Oberon. The significant effect of cultivar on the tuber number per plant was reported by the study of Sanli et al. (2013), Lemma et al. (2020) and Barbaś et al. (2024). The largest number of tubers was produced by the plant on the control plot, while the smallest number was produced on plots sprayed with the biostimulant Agro-Sorb Folium and herbicide Avatar 293 ZC. It was also found that in a very dry year, the number of tubers was the highest compared to the other years of the study, but the average weight of one tuber was the lowest, and there was a greater diminution of tubers. The share of small tubers in the yield structure in a very dry year was the high-

Table 2. Number of weeds and yield components of potato

Factor	Number of weeds per 1 m^2	Number of tubers from one potato plant	The average weight of one potato tuber (g)
Cultivar			
Oberon	11.8	9.9	93.0
Malaga	16.4	10.9	87.0
$HSD_{0.05}$	2.9	0.4	ns
Object			
Control object	25.2	11.1	73.4
Herbicide Avatar 293 ZC (clomazone + metribuzin)	16.2	10.7	83.3
Biostimulant PlonoStart and herbicide Avatar 293 ZC (clomazone + metribuzin)	9.9	10.2	95.4
Biostimulant Aminoplant and herbicide Avatar 293 ZC (clomazone + metribuzin)	11.8	10.4	89.7
Biostimulant Agro-Sorb Folium and herbicide Avatar 293 ZC (clomazone + metribuzin)	7.5	9.8	108.2
$HSD_{0.05}$	4.8	1.1	10.9
Year of study			
2018	9.7	8.0	97.0
2019	19.2	13.9	75.0
2020	13.4	9.4	98.0
$HSD_{0.05}$	4.4	0.6	9.9
Mean	14.1	10.4	90.0

HSD – honestly significant difference; ns – not significant

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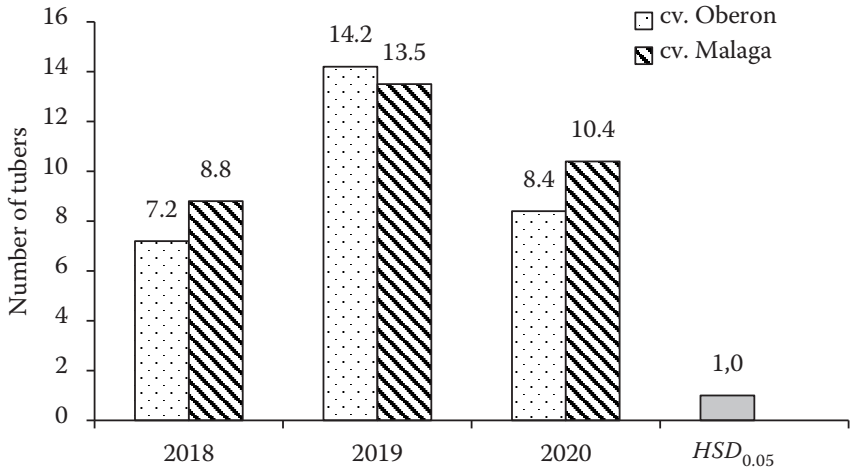

Figure 1. Effect of cultivar and years of study on the number of tubers from one potato plant. *HSD* – honestly significant difference

est (8.3%) compared to 2018 (2.9%) and 2020 (3.2%). Biostimulants used together with the herbicide also differentiated the mean tuber weight. The application biostimulants of PlonoStart, Aminoplant and Agro-Sorb Folium significantly increased the value of this trait compared to the average weight tube from the control object. However, the difference between the control object and the object sprayed only with the herbicide Avatar 293 ZC was not significant. The results indicate a beneficial effect of biostimulants on the average weight of one potato tuber. A similar reaction was noted by Kołodziejczyk and Gwóźdź (2022). Also, Karak et al. (2023) showed a favourable effect of biostimulant on average tuber weight compared to control tubers. Variance analysis revealed a significant interaction of cultivars with years of study on the number of tubers from one potato plant and average tuber weight (Figures 1 and 2). There was a differential response of cultivars to weather conditions during the study years. The Oberon cultivar produced the most tubers and the lowest tuber weight in the very dry year (2019), while the ąverage tuber weight of this cultivar was highest in the relatively dry year (2020).

The applied biostimulants and herbicides in the present study also affected yield structure (Figure 3). There was a higher share of commercial tubers > 35 mm and large tubers > 50 mm from objects with biostimulants compared to control plots. The best effects were obtained after the application of biostimulant Agro-Sorb Folium and herbicide Avatar 293 ZC (object 5) and biostimulant PlonoStart and herbicide Avatar 293 ZC (object 3). A higher share of commercial and large tubers after using the biostimulants GreenOK Universal-PRO, Asahi SL and biostimulant GreenOK Universal-PRO + herbicide Avatar 293 ZC was also obtained by Baranowska et al. (2019). Also, Kołodziejczyk and Gwóźdź (2022), using biostimulants Asahi SL, Tytanit and GA3, noted an improvement in the yield structure – an increase in the share of commercial and large tubers compared to the control object.

The correlation analysis showed a significant positive relationship between the number of weeds de-

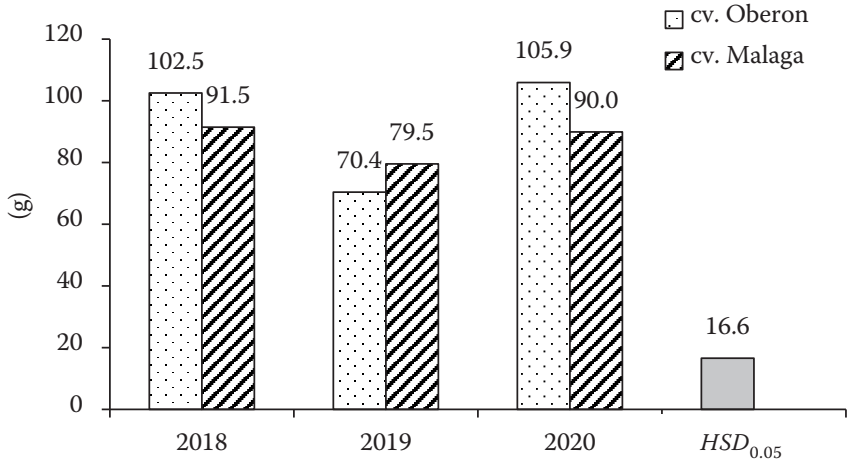

Figure 2. Effect of cultivar and years of study on the average weight of one potato tuber. *HSD* – honestly significant difference

https://doi.org/10.17221/103/2024-PSE

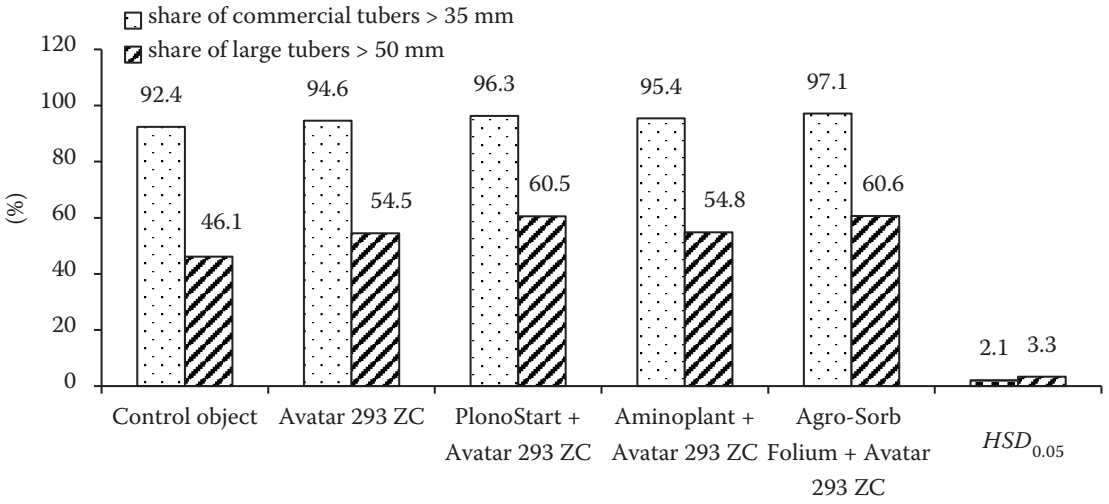

Figure 3. Share of commercial (> 35 mm) and large tubers (> 50 mm) depending on biostimulants and herbicide. *HSD* – honestly significant difference

Table 3. Significant values of linear correlation coefficients between the number of weeds and components of potato yield (means for cultivars and 3 study years)

Index	Number of tubers from one potato plant	The average weight of one potato tuber (g)	Share of commercial tubers > 35 mm	Share of large tubers > 50 mm
			(%)	
Number of weeds per 1 m^2 (before harvest)	+0.961	–0.959	–0.964	–0.979

termined at the end of the growing season and the number of tubers from one potato plant (r = +0.961), which indicates that the greater the number of weeds per unit area, the greater the number of tubers under the potato plant (Table 3). This also suggests that changes in one of these parameters go hand in hand with similar changes in the other. However, the correlation between the number of weeds per 1 m^2 and the average weight of one potato tuber, share of commercial tubers and share of large tubers was: r = –0.959, r = –0.964, r = –0.979, indicating a strong negative correlation between these yield parameters, respectively. Similar relationships and trends between weed infestation and yield and its parameters were observed by other authors (Barbaś and Sawicka 2020, Barbaś et al. 2024).

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Received: March 8, 2024
Accepted: May 24, 2024
Published online: June 27, 2024