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Biostimulants improve the content of polyphenols in the potato tubers

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Abstract: Research was conducted to determine the content of total polyphenols (TP) in table potato tubers obtained in a three-year field experiment arranged as a split-plot design with three replicates. The first experimental factor included two potato cultivars: Oberon and Malaga, the second one being an application of the following biostimulants: PlonoStart, Aminoplant, Agro-Sorb Folium and the herbicide Avatar 293 ZC (clomazone + metribuzin). The polyphenol content of potato tubers was determined in the fresh tuber mass by the spectrophotometric method with the Folin-Ciocalteu reagent. The tuber content of polyphenols was affected by cultivars and test biostimulants. Cv. Malaga accumulated more polyphenols than cv. Oberon. Biostimulants + herbicide significantly increased the accumulation of polyphenolic compounds compared with tubers cultivated in the control unit, which were not treated with the test products.

Keywords: *Solanum tuberosum* L.; bioactive substances; growth regulators; nutrition; bioactive compound; human diet

In recent years, a marked increase in the interest in and application of raw materials and plant products in nutrition and prophylaxis of numerous medical conditions has been observed. Such plants include potatoes, the world's fourth most important staple food. In nutritional terms, potato is a rich source of carbohydrates, protein, minerals and vitamins; also, it is available all year round (Leszczyński 2012, Akyol et al. 2016). The crop contains valuable bioactive compounds desirable in the human diet (Mishra et al. 2020, Franková et al. 2022). The most important bioactive compounds include vitamin C, polyphenols, carotenoids and anthocyanins. Polyphenols are the largest group, chlorogenic acid being the most abundant representative. Polyphenols act in a variety of ways. They have antioxidant, antiviral and anti-inflammatory properties, which may be preventative or therapeutic with respect to cardiovascular diseases, neurodegenerative disorders, cancer and obesity (Ezekiel et al. 2013, Cory et al. 2018); also, they affect the sensory properties of raw materials and foodstuffs (Sadowska et al. 2011). In the plant, they act as protective agents against bacteria, fungi, viruses and insects, as well as UV radiation (Akyol et al. 2016).

Polyphenolic content in potato tubers is affected by a variety of factors, including genetic properties, cultivar, climatic conditions, agrotechnological

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operations, storage conditions (Keutgen et al. 2019, Orsák et al. 2019, Zarzecka et al. 2019) and applied biostimulants which reduce stress and enhance plant growth and development (Głosek-Sobieraj et al. 2019b, Mystkowska et al. 2020). Taking into account high potato consumption (88.0, 83.4 and 32.3 kg per capita in Poland, Europe and the world, respectively), tubers may be an important source of desirable food components all over the world (Dzwonkowski 2021, FAOSTAT 2021). Thus, everyday potato consumption provides a substantial amount of polyphenols in the diet; it is the third largest quantity after oranges and apples (Tian et al. 2016).

In the available literature, there is a paucity of work on the effect of biostimulants on the potato content of bioactive compounds. Hence, the research reported here aimed at the determination of the polyphenolic content in the tubers of potatoes whose cultivation included an application of biostimulants and a herbicide.

MATERIAL AND METHODS

Chemical analyses were conducted of two table potato cultivars obtained in a 3-year, two-factor field experiment (factor I – cultivars, factor II – treatments with biostimulants and one herbicide) carried out at the Siedlce University of Natural Sciences and Humanities Experimental Farm (52°03'N and 22°33'E). The characterisation of the test potato cultivars is presented in Table 1, and the test biostimulants and herbicides are described in Table 2. Soil conditions, agrotechnological practices, dates and rates of the products have been presented in the previous work (Zarzecka et al. 2022). In each study year (2018, 2019 and 2020), potato harvest was performed at the stage of full physiological maturity. Prior to harvest, tuber samples were collected from ten randomly selected potato plants in each plot (excluding plants growing at the front and the back of the plot). Next, 50 tubers were taken from each sample for chemical analyses and stored at 10–14 °C. The chemical analyses were performed of fresh material in three replicates 4–6 days after tuber harvest.

Total polyphenols (TP) in tubers were determined spectrophotometrically using the Folin-Ciocalteu reagent (Mystkowska et al. 2020). A 20 g sample of fresh tubers was homogenised with 35 mL of 80% methanol. The diluted extract (0.5 mL) was poured into a 50 mL volumetric flask and mixed with 7 mL distilled water. After that, the Folin-Ciocalteu reagent (0.5 mL) was added to the mixture, which was then thoroughly stirred. After 3 min, 1 mL of Na_2CO_3 solution was added. After sitting for 1 h at room temperature, absorbency was measured (against a blind sample) using a spectrophotometer at the wavelength of 725 nm. The results were expressed in gallic acid equivalents (in g/kg fresh weight (FW)). The spectrophotometer UV-1800 Shimadzu (Kyoto, Japan) was used for the study.

The study results were statistically analysed using variance analysis. The significance of sources of variation was checked by means of the *F* Fisher-Snedecor test, and the significance of differences was tested using Tukey's test at the $P \leq 0.05$ (Trętowski and Wójcik 1991).

Temperatures and precipitation intensity varied in the study years (Figure 1, Table 3). Classification of study years according to precipitation and thermal conditions was based on values of the hydrothermal

Table 1. Factor I – Description of potato cultivars (Nowacki 2021)

Characteristic of features	Cultivar	
	Oberon	Malaga
Maturity time	medium early	medium early
Tuber shape	round oval	round oval
Skin colour	red	yellow
Flesh colour	light yellow	light yellow
Cooking type*	AB	B–BC
Vitamin C (mg/kg FM)	235.0	188.0
Nitrates mg (NO_3/kg FM)	low – below 100	low – below 100

*Cooking type: A – potatoes salad; B – potatoes versatile usable; AB – potatoes salad for versatile use; BC – potatoes versatile to floury flesh; C – potatoes with floury flesh; C – potatoes floury flesh; D – potatoes very floury flesh (European Association for Potato Research cooking type scale); FM – fresh matter

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Table 2. Factors II – Description of objects in the field experiment

No.		Object	Characteristic	Producer
1	C	control	mechanical weeding only	
2	A	Avatar 293 ZC	herbicide – clomazone + metribuzin	
3	A + P	Avatar 293 ZC + PlonoStart**	herbicide – clomazone + metribuzin and biostimulant contains: N_{tot} – 16.4%, K – 0.62%, Mg – 0.01%, Ca – 0.05%, S – 941 mg/kg, actinomycetes, lactic acid bacteria	Bogdan, Skarszewy, Poland
4	A + AM	Avatar 293 ZC + Aminoplant**	herbicide – clomazone + metribuzin and biostimulant contains: N_{tot} – 9.48%, N_{org} – 9.2%, N-NH_4 – 0.88%, organic matter – 87.7%, C_{org} – 25%, free amino acids – 11.57%	WUXAL®, AGLUKON GmbH & Co. KG, Düsseldorf, Germany
5	A + ASF	Avatar 293 ZC + Agro-Sorb Folium**	herbicide – clomazone + metribuzin and biostimulant contains: N_{tot} – 2.2%, Mn – 0.05%, Zn – 0.09%, B – 0.02%, total amino acids – 13.11%, free amino acids – 10.66%	VP AGRO, Ltd., Prague, Czech Republic

**The chemical composition of biostimulants is given according to the Institute of Soil Science and Plant Cultivation (IUNG) Puławy (2022). N_{tot} – total nitrogen; N_{org} – organic nitrogen; C_{org} – organic carbon

coefficient determined by Skowera et al. (2014). The year 2018 was dry (precipitation sum was 295.7 mm) and dry (the average temperature in the growing season was 17.6 °C), whereas 2019 was very dry (precipitation was 192.6 mm). The last study year (2020) was characterised by optimum precipitation

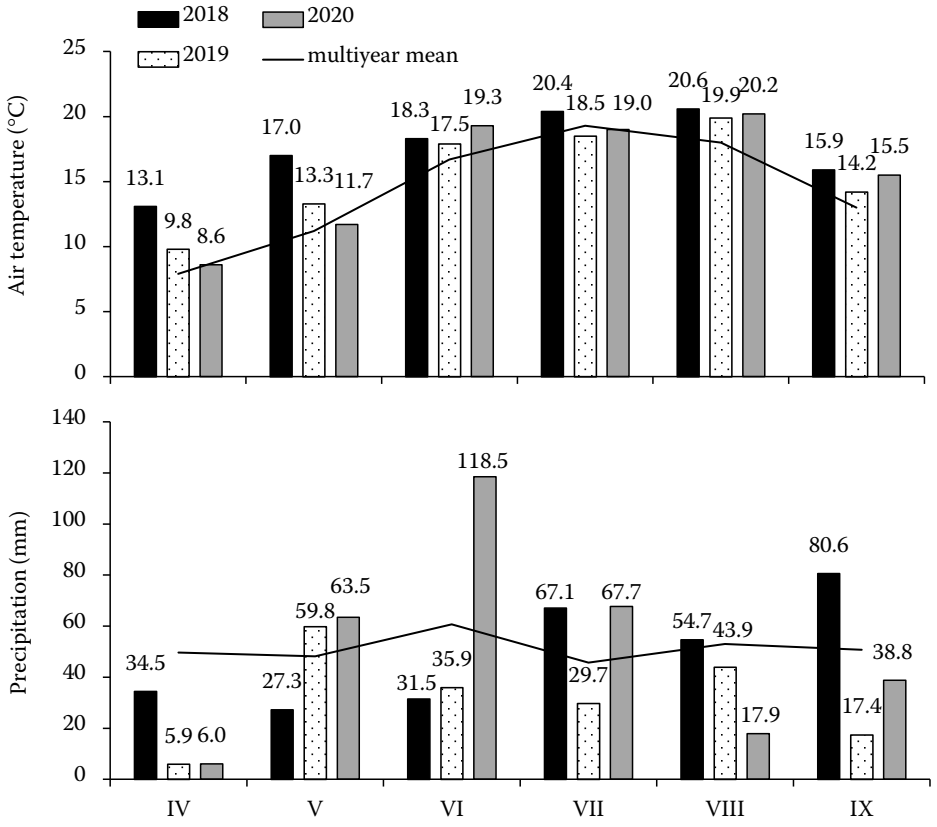

Figure 1. Mean air temperature and precipitation comparison with the mean multiyear 1980–2009

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Table 3. Air temperature and precipitation in years of study and multiyear

	Temperature (°C)	Precipitation (mm)
2018	17.6	295.7
2019	15.6	192.6
2020	15.7	312.4
1980–2009	14.4	307.9

(312.4 mm), which, however, was irregularly distributed throughout the growing season of the potato crop, the temperature being higher (excluding July) than the long-term mean.

RESULTS AND DISCUSSION

The conducted research and chemical analyses demonstrated that the tuber content of total polyphenols was significantly affected by potato cultivar, an application of herbicide and biostimulants, as well as moisture and thermal conditions. On average, it ranged from 155.7 to 188.9 mg/kg fresh weight (Tables 4–6). The obtained values are similar to those reported by other authors (Albishi et al. 2013, Głosek-Sobieraj et al. 2019b, Orsák et al. 2019, Mystkowska et al. 2020). In the present study, cv. Malaga accumulated more polyphenols than cv. Oberon (182.3 *vs.* 167.7 mg/kg, on average), the trend is observed in all the study years. Many researchers have reported varied polyphenol contents as affected by the genetic factor (Albishi et al. 2013, Wierzbicka et al. 2015, Orsák et al. 2019, Franková et al. 2022). Based on numerous studies, Rasheed et al. (2022) have demonstrated that phenolic content is much more affected by the genetic makeup of a cultivar than the environment.

The test biostimulants and herbicides significantly influenced the concentration of polyphenolic compounds in table potato tubers compared with untreated control (Table 4). The highest phenolic content was recorded in tubers harvested from units treated with the biostimulant Agro-Sorb Folium and the herbicide Avatar 293 ZC (clomazone + metribuzin). An increased accumulation of TP has also been confirmed in the tubers of potatoes grown in plots which were amended with the remaining biostimulants (Aminoplant and PlonoStart) or treated only with the herbicide Avatar 293 ZC. The obtained results show that high TP content was found using the combination A + ASF. Agro-Sorb Folium, in contrast with PlonoStart and Aminoplant, contains less nitrogen and free amino acids but contains Mn 0.05%, Zn 0.09%, and B 0.02%. Many antioxidant enzymes containing manganese (Mn) (superoxide dismutase, catalase, peroxidase, glutathione peroxidase) increase their activity at certain concentrations. Also, zinc (Zn) increases the activity of certain enzymes – peroxidase, oxidase and polyphenol oxidase. Boron (B) positively affects the activity of superoxide dismutase, while it decreases the activity of catalase, peroxidase or polyphenol oxidase depending on the boron concentration. The study shows that Agro-Sorb Folium (ASF) containing Mn + Zn + B in a certain ratio (0.05/0.09/0.02%, respectively) can be useful for increasing TP content in potato tubers.

A beneficial effect of biostimulants on the tuber content of polyphenols was also reported by other authors (Arafa et al. 2012, Głosek-Sobieraj et al. 2019b, Mystkowska et al. 2020). Moreover, Arafa et al. (2012) found a significant increase in total polyphenols following an application of biostimulants (SE 500 and HA 150) and effective microor-

Table 4. Content of total polyphenols in potato tubers (mg/kg fresh matter)

Object		Cultivar		Mean
		Oberon	Malaga	
1	C	161.3	173.7	167.5
2	A	166.7	178.7	172.7
3	A + P	170.0	182.7	176.2
4	A + AM	168.5	187.4	178.0
5	A + ASF	172.1	188.9	180.5
Mean		167.7	182.3	175.0

$HSD_{0.05}$ for: cultivars – 0.5; objects – 1.3; interaction cultivars × objects – 1.5

HSD – honestly significant difference

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Table 5. Content of total polyphenols in potato tubers depending on weather conditions (mg/kg fresh matter)

Object		2018	2019	2020	Mean
1	C	172.0	174.8	155.7	167.5
2	A	175.5	175.0	167.1	172.7
3	A + P	177.2	177.0	174.5	176.2
4	A + AM	177.8	177.5	178.7	178.0
5	A + ASF	177.8	177.5	186.0	180.5
Mean		176.1	176.5	172.4	175.0
$HSD_{0.05}$ for: objects – 1.3; years – 0.7; objects – 1.3; interaction objects × years – 2.3					

HSD – honestly significant difference

ganisms compared with potato plants sprayed with water. Głosek-Sobieraj et al. (2019b) have reported a positive influence of the biostimulants Asahi SL, Trefinder WP and Bio-Algen S-90 on chlorogenic acid content in white-fleshed cultivars (Irga and Satina). They have also noted that the number of compounds they determined was affected by weather conditions in the study years. Also, Mystkowska et al. (2020), who applied the biostimulants: Kelpak SL, Tytanit, GreenOk and BrunatneBio Złoto, found a significant increase in phenolic content compared with tubers harvested from water-sprayed control. Zarzecka et al. (2019) demonstrated increased TP in potato tubers harvested in units treated with a herbicide (either Harrier 295 ZC and Sencor 70 WG) or a herbicide + biostimulants (Kelpak SL and Asahi SL). However, the authors (2019) confirmed no significant effect of the products on the concentration of polyphenols in *Solanum tuberosum* leaves. In turn, Głosek-Sobieraj et al. (2019a) reported that the concentration of chlorogenic acids was higher in the petioles of potatoes treated with the biostimulant Trifender WP compared with untreated plants.

Climatic conditions throughout the growing seasons had a significant impact on total polyphenols in table potato tubers (Tables 5–6), which is concurrent with findings reported by other workers (Keutgen et al. 2019, Orsák et al. 2019). In the present work, on average, an accumulation of total polyphenols in tubers was the lowest in 2020 when precipitation was the highest an irregularly distributed. In the remaining seasons (2018 was dry and 2019 was very dry), PT contents were significantly higher and similar to each other, which was confirmed by research results reported by Mystkowska et al. (2020). Statistical analysis confirmed that there was an interaction between study years and experimental treatments, which indicated that the response of plants treated with test products varied under changeable weather conditions (Table 5). Tubers harvested in 2020 in experimental plots treated with the biostimulants Agro-Sorb Folium and the herbicide Avatar 293 ZC (treatment 5) had the highest PT content. During this growing season, the accumulation of phenols in potato tubers harvested in individual experimental plots was found to be the most diverse (ranging from 155.7 to 186.0 mg/kg) compared with 2018 and 2019, which, in turn, leads to the conclusion that it is important to undertake research into an accumulation of bioactive compounds following an application of biostimulants in various cultivars of potato grown under diverse environmental conditions.

Table 6. Content of total polyphenols in potato cultivars in the years of the study (mg/kg fresh weight)

Cultivar	2018	2019	2020	Mean
Oberon	166.8	167.8	168.6	167.7
Malaga	185.3	185.3	176.3	182.3
Mean	176.1	176.5	172.4	175.0
$HSD_{0.05}$ for: cultivars – 0.5; years – 0.7; interaction cultivars × years – ns				

HSD – honestly significant difference; ns – not significant

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