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The effect of biostimulants and herbicides on glycoalkaloid accumulation in potato

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ABSTRACT

The objective of the study was to determine the effect of biostimulants and herbicides on the level of glycoalkaloids in leaves and tubers of three table potato cultivars. The following factors were examined: I – potato cultivars: Bartek, Gawin, Honorata; II – five weed control methods (application of biostimulants and herbicides: 1. mechanical weed control – control treatment and four herbicide or herbicide + biostimulant treatments (Harrier 295 ZC, Harrier 295 ZC + Kelpak SL, Sencor 70 WG, Sencor 70 WG + Asahi SL). The potato tuber content of glycoalkaloids was significantly affected by genotype. The highest total glycoalkaloid (TGA) content was determined in cv. Bartek tubers and the lowest in cv. Honorata tubers, on average 92.31 and 91.14 mg/kg fresh matter, respectively. Herbicides applied alone or in combination with biostimulants contributed to an increase in glycoalkaloids determined in both potato leaves and tubers, compared with the control. However, a significantly higher TGA content was found following the application of Harrier 295 ZC only.

Keywords: plant resistance; toxicity; weather conditions; tuberous crop; *Solanum tuberosum* L.

The presence of glycoalkaloids in potato leaves, stems and tubers is associated with plant resistance to bacterial and fungal diseases as well as pests (Wierzbicka 2014). However, when total glycoalkaloid (TGA) concentration exceeds 100 mg/kg fresh matter, it contributes to a decline in flavour, and when the accumulation exceeds 200 mg/kg fresh matter, TGA are toxic to humans (Valkonen et al. 1996, Bejarano et al. 2000). According to many authors (Percival and Dixon 1996, Wierzbicka 2011, Hamouz et al. 2014, Zarzecka et al. 2015), glycoalkaloid content is cultivar-specific but can also be affected by weather conditions during the growing season as well as cultivation methods applied. Modern agriculture, in addition to pesticides, also makes use of a number of substances called biostimulants which stimulate life processes and enhance plant resistance to stress conditions (Maciejewski et al. 2007). The objective of the study reported here was to determine the impact of an application of biostimulants and herbicides on glycoalkaloid levels in the leaves and tubers of three table potato tubers as there seems to be little research on this subject.

MATERIAL AND METHODS

The study results were obtained from a field experiment conducted in 2012–2014 in Wojnów, 52°12'59''N, 22°34'37''E. The experiment was a two-way split-plot arrangement with three replicates. The net area of the experiment was 843 m^2 (18.73 m^2 × 45 plots) and the gross area was 1612 m^2 (26 m × 62 m). When the experiment was set up, the plot area was 18.75 m^2 = 5.55 m × 3.375 m, that is 15 plants spaced every 37 cm × 5 rows spaced every 67.5 cm = 75 plants; the plot area at harvest was 15.0 m^2 = 5.55 m × 2.75 m, that is 15 plants spaced every 37 cm × 4 rows spaced every 67.5 cm = 60 plants. The factors were as follows: factor I – three intermediate table potato cultivars: Bartek, Gawin, Honorata; factor II – five methods of application of herbicides and biostimulants: 1. control – mechanical weed control prior to and after potato emergence; 2. mechanical and chemical weed control – one hilling prior to emergence and spraying with Harrier 295 ZC at a rate of 2.0 L/ha applied around 7–10 days after planting; 3. mechanical and chemical weed control – one hill-

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ing prior to emergence and spraying with Harrier 295 ZC at a rate of 2.0 L/ha applied around 7–10 days after planting + an application of the biostimulant Kelpak SL at the end of emergence and then again 14–28 days after the first spraying (each time the rate was 2.0 L/ha); 4. mechanical and chemical weed control – mechanical weed control prior to emergence, and the herbicide Sencor 70 WG at the rate of 1.0 kg/ha just before emergence; 5. mechanical and chemical weed control – mechanical weed control prior to emergence, Sencor 70 WG at 1.0 kg/ha just before emergence + the biostimulant Asahi SL at 1.0 L/ha towards the end of emergence, and Asahi SL at 1.0 L/ha applied 14–28 days after the first application.

Field studies were conducted in soils representing the following type of agricultural land: grey brown podzolic soil of ploughed fields belonging to agronomic category I, the order of brown soils, quality class IVb which represents the rye very good class of agricultural suitability. In 2012 and 2013, soil pH was slightly acidic (5.60) whereas in 2014 it was alkaline (7.35). The organic matter content ranged from 15.0–18.7 g/kg. The available phosphorus (P) content ranged from high to very high, available potassium (K) content ranged from average to very high, and available magnesium (Mg) content was high. Winter wheat crops preceded table potato in each study year. The same organic manuring and mineral fertilisation were applied: 25 t/ha farmyard manure as well as 100 kg/ha N, 44 kg P/ha and 125 kg K/ha. Samples of potato leaves (10 leaves) for chemical analyses were taken during the flowering stage. Potato tuber samples (50 tubers) were collected from the plots during harvest and stored at 10–12°C. Chemical analyses of fresh material were performed so as to obtain three replicates. Glycoalkaloid contents of potato leaves and tubers were determined following the Bergers' method (Bergers 1980). Results of the study were analysed by ANOVA. Significance of sources of variation was checked with the Fisher-Snedecor test and the significance of differences between means was tested using the multiple comparison Tukey's test at the significance level of $P = 0.05$. Statistical calculations were performed in Excel using own algorithm based on the mathematical model. Values of the Sielianinov's hydrothermal coefficient ($K = 0.95$) indicate that the year 2012 was slightly dry (Table 1). The precipitation sum amounted to 264.9 mm and was by 10.6 mm lower than the long-term mean whereas the average temperature over the growing season was 15.4°C and was by 0.7°C higher than the long-term mean. Precipitation was the highest in 2013 (441.3 mm). The average monthly air temperature in this year ranged from 7.4–19.0°C and the mean temperature in the growing season was 15.0°C. Based on the Sielianinov's hydrothermal coefficient ($K = 1.20$), there was no drought in the 2014 growing season;

Table 1. Characteristics of weather conditions in the years 2012–2014 (Zawady Meteorological Station, Poland)

Year	Month						
	IV	V	VI	VII	VIII	IX	IV–IX
Rainfall (mm)							sum
2012	29.9	53.4	76.2	43.0	51.0	11.4	264.9
2013	36.0	105.9	98.8	91.3	15.0	94.3	441.3
2014	45.0	92.7	55.4	10.0	105.7	26.3	335.1
Multiyear sum (1987–2000)	38.6	44.1	52.4	49.0	43.0	47.7	274.8
Air temperature (°C)							mean
2012	8.9	14.6	16.3	20.7	18.0	14.1	15.4
2013	7.4	15.3	18.0	19.0	18.8	11.7	15.0
2014	9.8	13.5	15.4	20.8	18.1	14.1	15.3
Multiyear mean (1987–2000)	7.8	12.5	17.2	19.2	18.5	13.1	14.7
Sielianinow's hydrothermic coefficients*							mean
2012	1.10	1.20	1.60	0.69	0.94	0.27	0.96
2013	1.60	2.30	1.80	1.60	0.30	2.70	1.71
2014	1.50	2.30	1.20	0.16	1.90	0.62	1.28

*Coefficient value (Bac et al. 1998); < 0.5 strong drought; 0.51–0.69 mild; 0.70–0.99 weak pure drought; ≥ 1.0 fault drought

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the precipitation sum was 335.1 mm and was by 60.3 mm higher compared with the precipitation sum averaged across 15 years. Average monthly air temperatures in 2014 ranged from 9.8–20.8°C.

RESULTS AND DISCUSSION

Glycoalkaloid content in potato leaves (Table 2). An analysis of the effect of cultivars studied on TGA content in potato leaves revealed no significant differences in the accumulation of this component in individual cultivars. Nevertheless, TGA content was the highest in cv. Bartek, on average 279.6 mg/kg tuber fresh matter, and the lowest in cv. Gawin, on average 276.8 mg/kg. Glycoalkaloid content was three times as high in potato leaves as it was in tubers. In their previous study, Zarzecka et al. (2015) found TGA content which was ten times higher in leaves than in tubers whereas Uppal (1987) and Żołnowski (2001) reported glycoalkaloid concentrations which were 40–50 times higher in leaves compared to potato tubers. Variance analysis demonstrated a significant effect of herbicide and biostimulant application methods on TGA levels in potato leaves. The herbicides applied alone or in combination with the biostimulants contributed to an increase in glycoalkaloid content, ranging from 5.5–10.3 mg/kg on average, compared with the control treatment where weeds were mechanically controlled. In addition, the glycoalkaloid content of potato leaves was slightly lower in units where combinations of herbicides and biostimulants were applied compared with herbicide-treated units. The available literature lacks information on the effect of biostimulants on accumulation of glycoalkaloids in potato leaves. However, in their earlier studies, Zarzecka et al. (2013, 2015) demonstrated that both insecticides and herbicides as well as their mixtures applied in the experiment significantly increased the level of glycoalkaloids in potato leaves. Weather conditions in the study years significantly influenced glycoalkaloid contents; it was the highest in 2012 when the lowest precipitation was recorded during the growing season and the average temperature was by 0.7°C higher than the long-term average, which had also been reported by Zarzecka et al. (2015).

Glycoalkaloid content in potato tubers (Table 3). According to Nitithamyong et al. (1999) and Tajner-Czopek et al. (2008), glycoalkaloid content in potato tubers is affected by genetic and environmental factors as well as cultivation and storage conditions. Statistical calculations revealed a significant effect of cultivars examined in the study on the level of glycoalkaloids in table potato tubers. TGA content was the highest in cv. Bartek, on average 92.31 mg/kg fresh matter, and the lowest in cv. Honorata, on average 91.14 mg/kg fresh matter. The results of this study are similar to findings reported by Eltayeb et al. (2003), Hamouz et al. (2014) as well as Valcarcel et al. (2014) who stated that the genotype had a predominant effect on the glycoalkaloid content of potato tubers. Herbicides and biostimulants applied in the experiment contributed to a significant increase in the glycoalkaloid content of potato tubers compared with the control. The highest TGA concentration was found after the herbicide Harrier 295 ZC had been applied at 2.0 L/ha – on average 92.34 mg/kg fresh matter. Also in their previous study, Zarzecka et al. (2015) noted an increase in glycoalkaloid

Table 2. Total glycoalkaloid content in potato leaves (mg/kg fresh matter)

Methods of using biostimulants and herbicides	Cultivar			Year			Mean
	Bartek	Gawin	Honorata	2012	2013	2014	
1. Control object	275.30	271.20	269.60	322.90	215.90	277.20	272.00
2. Harrier 295 ZC 2.0 L/ha	282.40	279.00	277.70	333.00	222.60	283.50	279.70
3. Harrier 295 ZC 2.0 L/ha + Kelpak SL 2.0 L/ha	278.00	275.90	278.80	329.60	222.20	280.80	277.50
4. Sencor 70 WG 1.0 kg/ha	284.90	279.80	282.20	335.20	227.20	284.40	282.30
5. Sencor 70 WG 1.0 kg/ha + Asahi SL 1.0 L/ha	277.50	278.10	282.70	330.50	223.90	283.90	279.40
Mean	279.60	276.80	278.20	330.24	222.40	281.96	–

$LSD_{0.05}$ for: years – 2.9, cultivars – ns, weed control methods – 7.6, years × weed control methods – ns, cultivars × weed control methods – no significant difference

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Table 3. Total glycoalkaloid contents in potato tubers (mg/kg fresh matter)

Methods of using biostimulants and herbicides	Cultivar			Year			Mean
	Bartek	Gawin	Honorata	2012	2013	2014	
1. Control object	91.48	90.51	89.89	91.78	89.73	90.37	90.63
2. Harrier 295 ZC 2.0 L/ha	93.09	91.92	91.99	95.37	90.66	90.98	92.34
3. Harrier 295 ZC 2.0 L/ha + Kelpak SL 2.0 L/ha	92.64	91.50	91.31	94.30	90.55	90.61	91.82
4. Sencor 70 WG 1.0 kg/ha	92.38	91.35	91.30	93.90	90.57	90.57	91.68
5. Sencor 70 WG 1.0 kg/ha + Asahi SL 1.0 L/ha	91.96	91.23	91.20	93.43	90.41	90.54	91.46
Mean	92.31	91.30	91.14	93.76	90.38	90.61	–

$LSD_{0.05}$ for: years – 0.61; cultivars – 0.61; weed control methods – 0.62; years × weed control methods – 1.08; cultivars × weed control methods – no significant difference

content in potato tubers following the application of herbicides. By contrast, Hamouz et al. (2004, 2005) and Wierzbicka (2014) observed a tendency for increased TGA accumulation in the tubers of organic potatoes. Different glycoalkaloid contents were observed between units treated with herbicides + biostimulants and herbicide-treated plots. The application of combinations of herbicides and biostimulants resulted in a slight decrease in TGA compared the plots where weeds had been herbicide-controlled. There is no information in the available literature regarding the effect of biostimulants on the glycoalkaloid accumulation in potato tubers. However, there are many mentions in the literature confirming the fact that TGA in tubers increase due to stress conditions during the growing season; that is too low or too high temperature, prolonged cold or heat conditions, water shortage or excess and strong sunlight (Sinden et al. 1984, Bejarano et al. 2000, Hamouz et al. 2014). The present study demonstrated that the highest concentration of glycoalkaloids, on average 93.76 mg/kg fresh matter, was in 2012 when lowest precipitation in the growing season was accompanied by the highest average air temperature. By contrast, the lowest glycoalkaloids content, on average 90.38 mg/kg, was noted in the 2013 growing season when high precipitation and the lowest average air temperature were recorded. Similar results were reported by Morris and Petermann (1985). In the present study, an interaction was observed between the study years and weed control methods, which indicates that the weather conditions contributed to the effect of herbicides and biostimulants. To sum up, the glycoalkaloid content in potato leaves and tubers is significantly affected by genetic properties of the cultivars as well as weather conditions during the growing season. An application of herbicides contributed to an increase in TGA in both potato leaves and tubers. When herbicides were applied in combination with biostimulants, TGA slightly declined. The above findings indicate that this type of research should be continued.

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