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The effect of herbicides on the content of glycoalkaloids in the leaves and tubers of potato

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ABSTRACT

The aim of the studies was to determine the effect of the used herbicides and their mixtures on the level of glycoalkaloids (TGA) in the leaves and tubers of three edible potato cultivars. The studied factors were: I – three cultivars: Cekin, Satina and Tajfun. II – five ways of care: 1. mechanical care – the control object and four objects using herbicides Command 480 EC, Afalon Dispersion 450 SC and Stomp 400 SC. The content of glycoalkaloids both in the leaves and in the tubers of the edible potato significantly depended on the genotype. The highest content of TGA characterised the cv. Cekin – 623.5 mg/kg and 67.21 mg/kg of fresh weight (FW), respectively, while the smallest was found in cv. Satina – 339.3 mg/kg and 33.60 mg/kg of FW, respectively. Herbicides used in the experiment caused the increase of the content of glycoalkaloids compared to the tubers from the control object. However, a significantly higher concentration of TGA was stated after using the mixture of herbicides Command 480 EC + Afalon Dispersion 450 SC and Stomp 400 SC + Afalon Dispersion 450 SC.

Keywords: anti-nutrition substance; weed control methods; *Solanum tuberosum* L.

In addition to the components which determine the nutritional and dietary values of the potato, its tubers also contain anti-nutritional substances, one of them are glycoalkaloids (TGA), which are toxic steroid glycosides that naturally occur in the whole family of Solanaceae (Zgórska et al. 2006, Leszczyński 2012, Sołtys 2013). Glycoalkaloids, which can be found in leaves, stems, flowers, tubers and sprouts, play a role in the resistance of the plants to the bacterial and fungal diseases and pests, however, in the excessive amount they impair the taste of tubers and the concentration over 200 mg/kg of fresh weight (FW) has a toxic effect on the human body (Friedman et al. 1997, Mensinga et al. 2005). According to many authors (Percival and Dixon 1996, Badowski and Urbanek-Karłowska 1999, Zgórska and Sowa-Niedziałkowska 2005, Hamouz et al. 2014), the content of glycoalkaloids depends primarily on the cultivar and weather conditions prevailing during the growing season, while the opinions on the impact of pesticides on the TGA level in the potato tubers are divided (Hamouz et al. 2004, Zarzecka and Gugała 2007, Wierzbicka 2011).

Therefore, the aim of the studies was to determine the effect of the used herbicides and their mixtures on the level of glycoalkaloids in the leaves and tubers of three cultivars of the edible potato.

MATERIAL AND METHODS

The field experiment was conducted in the years of 2008–2010 in the Agricultural Experimental Station Zawady (52°03'N, 22°33'E) belonging to the University of Natural Sciences and Humanities in Siedlce, Poland. The experiment was established as two-factor in the split-plot system in three repetitions. The studied factors included: I – three cultivars: Cekin, Satina and Tajfun. II – five weed control methods: (1) mechanical care – control object; (2) mechanical-chemical care, i.e., until the emergence hilling combined with harrowing, and about 7 days before the emergence the herbicide Command 480 EC 0.2 L/ha; (3) mechanical-chemical care, i.e. until the emergence hilling combined with harrowing, and about 7 days before the emergence spraying with a mixture of herbicides Command 480 EC

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0.2 L/ha + Afalon Dispersion 450 SC 1.0 L/ha; (4) mechanical-chemical care, i.e., until the emergence hilling combined with hailing, and about 7 days before the emergence herbicide Stomp 400 SC 3.5 L/ha; (5) mechanical-chemical care, i.e., until the emergence hilling combined with hailing, and about 7 days before the emergence spraying with a mixture of herbicides Stomp 400 SC 3.5 L/ha + Afalon Dispersion 450 SC 1.0 L/ha.

The field experiment was established on soil classified to the department – autogenous soils, order – brown-ground soils, type – Luvisols made of light clay sands and strong loamy sands, the gradin class of IVa and IVb in terms of agricultural suitability classified as a very good rye complex. This soil was characterised by a slightly acid reaction, very high abundance of phosphorus, high abundance of potassium and the average wealth of magnesium. A potato was grown in the position after winter cereals. The experiment used the permanent organic fertilization with manure 25 t/ha and the mineral one in quantities: 100 kg N/ha, 44.0 kg P/ha and 124.5 kg K/ha. Protection treatments against diseases and pests were used where appropriate, in accordance with the recommendations of the plant protection. Samples of potato leaves (10 leaves) for chemical analyses were collected during flowering. Samples of potato tubers (50 tubers) were collected from plots during harvest and stored at the temperature of 10–12°C. Chemical analyses were performed in a fresh material in three repetitions. The content of glycoalkaloids in the leaves and tubers was marked with the Bergers method (Bergers 1980). The results were developed statistically by the analysis of variance. The significance of the variability sources was tested with the *F*-test of Fischer-Snedecor, and the assessment of the significance of differences at the significance level $P = 0.05$ between the comparable averages, using the multiple Tukey intervals (Trętowski and Wójcik 1991). Particular growing seasons during the studies were characterised by variable weather conditions (Table 1). The highest number of rainfall was noted in the growing season in 2010 – 459.7 mm and the average air temperature was higher by 0.9°C compared to the long-term average. The smallest amount of rainfall – 354.4 mm was noted in 2009, the average temperature was higher by 0.4°C. The growing season 2008 was characterised by the rainfall at the level of 371.4 mm and the air temperature did not deviate from the norm of the long-term one and was 14.9°C. According to the calculated hydrothermal coefficient of Sielianinow, the growing seasons of 2008, 2009 and 2010 were characterised by the lack of drought, however, the alternating months occurred with extreme conditions, from severe drought to the lack of drought.

RESULTS AND DISCUSSION

The content of glycoalkaloids in potato leaves (Table 2). Statistical calculations have shown a

Table 1. Characteristics of weather conditions in the years 2008–2010 (Zawady Meteorological Station, Poland)

		Month						
		IV.	V.	VI.	VII.	VIII.	IX.	IV.–IX.
Rainfall (mm)	2008	28.2	85.6	49.0	69.8	75.4	63.4	371.4
	2009	8.1	68.9	145.2	26.4	80.9	24.9	354.4
	2010	10.7	93.2	62.6	77.0	106.3	109.9	459.7
	multi-year sum (1987–2000)	38.6	44.1	52.4	49.8	43.0	47.3	275.2
Air temperature (°C)	2008	9.1	12.7	17.4	18.4	18.5	12.2	14.7
	2009	10.3	12.9	15.7	19.4	17.7	14.6	15.1
	2010	8.9	14.0	17.4	21.6	19.8	11.8	15.6
	multi-year mean (1987–2000)	7.8	12.5	17.2	19.2	18.5	13.1	14.7
Sielianinow's hydrothermic coefficient*	2008	1.04	2.18	0.94	1.25	1.36	1.73	1.39
	2009	0.26	1.72	3.08	0.44	1.48	0.57	1.28
	2010	0.40	2.14	1.20	1.15	1.74	3.10	1.61

*Coefficient value (Bac et al. 1998); < 0.5 strong drought; 0.51–0.69 mild; 0.70–0.99 weak pure drought; ≥ 1 fault drought

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Table 2. Total glycoalkaloid contents in potato leaves and tubers (mg/kg fresh matter)

	Weed control method	Cultivar			Year			Mean
		Cekin	Satina	Tajfun	2008	2009	2010	
Leaves	control object	612.7	327.8	342.2	413.8	438.9	430.0	427.6
	Command 480 EC 0.2 L/ha	622.0	337.8	350.3	426.8	447.8	435.6	436.7
	Command 480 EC 0.2 L/ha + Afalon Dispersion 450 SC 1.0 L/ha	632.8	352.0	361.0	445.4	453.3	447.0	448.6
	Stomp 3.5 L/ha	620.5	333.6	345.6	423.0	442.2	434.5	433.2
	Stomp 3.5 L/ha + Afalon Dispersion 450 SC 1.0 L/ha	630.0	345.5	352.3	432.3	450.2	445.0	442.5
	mean	623.5	339.3	350.3	428.3	446.5	438.4	–
Tubers	Control object	65.67	32.22	34.11	44.89	44.00	43.11	44.00
	Command 480 EC 0.2 L/ha	66.78	33.39	35.37	45.87	45.11	44.56	45.18
	Command 480 EC 0.2 L/ha + Dispersion Afalon 450 SC 1.0 L/ha	68.44	34.20	36.45	47.42	46.33	45.33	46.36
	Stomp 3.5 L/ha	67.06	33.95	35.50	46.45	45.56	44.50	45.50
	Stomp 3.5 L/ha + Dispersion Afalon 450 SC 1.0 L/ha	68.11	34.24	36.21	47.68	45.78	45.11	46.19
	mean	67.21	33.60	35.53	46.46	45.35	44.52	–

Leaves: $HSD_{0.05}$ for: years – 7.3; cultivars – 7.3; weed control methods – 7.6; years × weed control methods = ns (no significant difference), cultivars × weed control methods = ns. Tubers: $HSD_{0.05}$ for: years – 1.77; cultivars – 1.77; weed control methods – 2.23; years × weed control methods = ns; cultivars × weed control methods = ns

significant effect of the cultivars grown in the experiment, the ways of care and the weather conditions prevailing in particular growing seasons on the level of glycoalkaloids in potato leaves. The most analysed component was accumulated by the cv. Cekin – on average 623.5 mg/kg in fresh weight of tubers, less by cv. Tajfun – on average 350.3 mg/kg, and the smallest by cv. Satina – on average 339.3 mg/kg. TGA content was almost ten times higher in the leaves than in the tubers of potatoes. While Uppal (1987) and Żołnowski (2001) stated even 40–50 times higher concentration of glycoalkaloids in the leaves in relation to the potato tubers. The analysis of variance showed a significant effect of the ways of potato cares on the level of the discussed component (TGA) in leaves. Herbicides and their mixtures used in the experiment caused the increase of the content of glycoalkaloids compared to the control object, cared only mechanically. The available literature lacks the information on the effect of herbicides on the accumulation of glycoalkaloids in the potato leaves. However, in the previous studies Zarzecka et al. (2013) proved that the insecticides used in the experiment had a significant effect on the concentration of glycoalkaloids in the leaves. Moreover, from the conducted studies it results that weather conditions in the years of studies significantly differentiated the content of glycoalkaloids, the largest amount of this component was accumulated by the leaves in the year with the smallest amount of rainfall during the whole growing season, however, in June the rainfall occurred at the level of 145.2 mm with the average temperature of the month lower by 1.5°C compared to the multi-year average.

The content of glycoalkaloids in potato tubers (Table 2). The content of glycoalkaloids in potato tubers depended greatly on the genotype. The largest TGA content was observed in the cv. Cekin – on average 67.21 mg/kg of FW (fresh weight), while the smallest one was in cv. Satina – on average 33.60 mg/kg of FW. The obtained results are fully supported by studies by Zgórska et al. (2006), Skrabule et al. (2010), Wierzbicka (2011), Hamouz et al. (2014), who confirmed the pivotal role of the genotype in the content of glycoalkaloids in potato tubers, moreover, these authors stated that none of the studied cultivars exceeded the value of 200 mg/kg of FW and reached the risk value for the human health. Herbicides used in the experiment caused the increase of the content of glycoalkaloids compared to the tubers of the control object, which was not chemically protected. However, a significantly higher TGA concentration was stated after the application of a mixture of herbicides Command

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480 EC in a dose of 0.2 L/ha + Afalon Dispersion 450 SC in a dose of 1.0 L/ha and Stomp 400 SC 3.5 L/ha + Afalon Dispersion 450 SC 1.0 L/ha. Also, in previous studies Zarzecka and Gugała (2007) stated the increase of the concentration of glycoalkaloids in potato tubers under the influence of herbicides, while; Hamouz et al. (2004, 2005) observed the tendency to accumulate a greater amount of this component in potatoes cultivated with the ecological method in comparison to the conventional one, while Wierzbicka (2011) and Zarzyńska (2013) did not state the significant impact on the applied cultivation technology on the content of glycoalkaloids in potato tubers. Also the climatic conditions prevailing in particular growing seasons had a significant impact on the content of glycoalkaloids in potato tubers, which was proved in the studies of Skrabul et al. (2010), Trawczyński and Wierzbicka (2011), Wierzbicka (2011), Zarzyńska (2013) and Hamouz et al. (2014).

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