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Effect of soil conditioner (UG_{max}) application on the content of phenols and glycoalkaloids in potato tubers

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ABSTRACT

Gugała M., Zarzecka K., Sikorska A., Kapela K., Niewęgłowski M., Krasnodębska E. (2017): Effect of UG_{max} soil conditioner application on the content of phenols and glycoalkaloids in potato tubers. Plant Soil Environ., 63: 231–235.

The objective of the study was to determine the effect of the soil conditioner UG_{max} application on phenol and glycoalkaloid content in the tubers of two table potato cultivars. The following factors were examined: factor I – cultivars: Satina and Tajfun; factor II – five application methods of the soil conditioner UG_{max}: (1) control – no UG_{max} application; (2) 1.0 L/ha UG_{max} before planting; (3) 0.5 L/ha UG_{max} before planting + 0.25 L/ha at potato height of 10–15 cm + 0.25 L/ha in flower bud phase; (4) 1.0 L/ha UG_{max} before planting + 0.50 L/ha at potato height of 10–15 cm + in 0.50 L/ha in flower bud phase; (5) UG_{max} applied after emergence when plants were 10–15 cm high at the rate of 0.5 L/ha, and at the stage of flower buds at the rate of 0.5 L/ha. The highest concentration of phenols and glycoalkaloids was recorded in plots where UG_{max} was applied prior to potato planting at the rate of 1.0 L/ha, when plants were 10–15 cm high at the rate of 0.5 L/ha and at the stage of flower buds at the rate of 0.5 L/ha.

Keywords: *Solanum tuberosum*; phenolic compounds; polyphenol; tuberous crop; nutritional value

Phenolic compounds are the components that have stimulated particular interest in recent years. They are secondary metabolites with a very diverse structure, molecular weight, physical, biological and chemical properties, and they occur in all plant parts. Polyphenols have a multiple effect on food; on the one hand, they affect flavour and colour and, on the other, they show antioxidative activity by stabilising fats and other liable food components (Jeszka et al. 2010).

For many years, polyphenols were believed to be anti-nutritional substances but at present, their importance as active food components has increased markedly due to research conducted in recent years proving their positive effect on human health (Gumul et al. 2005).

Potato also contains undesirable substances, including glycoalkaloids, which affect the nutritional value of potato tubers (Pęksa et al. 2006, Rytel 2012).

Total glycoalkaloids (TGA) accumulation in tubers which exceeds 100 mg/kg affects potato tuber flavour, and when TGA exceeds 200 mg/kg fresh matter they are toxic to human body (Valkonen et al. 1996, Bejarano et al. 2000).

Modern agriculture relies not only on a wide range on pesticides, but also on a number of products classified as biostimulants or microbiological preparations whose influence on plants has not been fully recognised yet. Thus, the objective of the present study was to determine the effect of an application of the soil conditioner UG_{max} on phenol and glycoalkaloid content of two table potato cultivars.

MATERIAL AND METHODS

Study results were obtained from a field experiment conducted throughout the years 2008–2010

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at the Zawady Experimental Farm. The experiment was designed as a split-plot arrangement of plots in three repetitions. The following two factors were examined: factor I – two second early table potato cvs. Satina and Tajfun; factor II – five application methods of the soil conditioner UG_{max}: (1) control – no UG_{max} application; (2) UG_{max} applied prior to potato planting at the rate of 1.0 L/ha; (3) UG_{max} applied prior to planting at the rate of 0.5 L/ha, when plants were 10–15 cm high at the rate of 0.25 L/ha, and at the stage of flower buds at the rate of 0.25 L/ha; (4) UG_{max} applied prior to planting at the rate of 1.0 L/ha, when plants were 10–15 cm high at the rate of 0.5 L/ha, and at the stage of flower buds at the rate of 0.5 L/ha; (5) UG_{max} applied after emergence when plants were 10–15 cm high at the rate of 0.5 L/ha, and at the stage of flower buds at the rate of 0.5 L/ha.

The soil conditioner UG_{max} contains yeast, photosynthetic bacteria, lactic acid bacteria, *Pseudomonas genii*, *Azotobacter*, Actinobacteria as well as macro- and microelements (Kołodziejczyk 2014a,b).

The soil of the experimental site is a Luvisol with the granulometric composition of sandy loam. The soil was slightly acidic and acidic (4.8–5.9 pH in 1 mol/L KCl), had a high to very high available phosphorus content, a low to high potassium content and a low to average magnesium content. In all the study years, potatoes were preceded by winter triticale. The same fertilisation rates were applied; in autumn, farmyard manure applied at the rate of 25 t/ha was accompanied by the following mineral fertiliser rates: 44.0 kg P/ha and 124.5 kg K/ha, nitrogen was applied at the rate of 100 kg N/ha in the spring. The soil conditioner UG_{max} was dissolved in 300 L water per 1 ha. Against the weeds, a mixture of Command 480 SC + Afalon Dyspersyjny 450 SC was applied. During vegetation, plant protection against potato beetles (Apacz 50 WG, Actara 25 WG) and potato blight (Ridomil Gold MZ 68 WG, Dithane 455 SC) was applied.

Potato tuber samples (50 tubers) were collected from plots during harvest and stored at the temperature of 10–12°C. Chemical analyses of fresh material were conducted. Polyphenols were determined in the fresh matter of potato tubers by means of the Swain and Hillis method using the Folin-Ciocalteu reagent (Swain and Hillis 1959). The content of glycoalkaloids in the tubers was marked with the Bergers method (Bergers 1980). The study results were statistically analysed using ANOVA. Significance of sources of variation was checked by the *F*-Fisher-Snedecor test and mean values were separated by the Tukey's test at the significance level of $P = 0.05$.

The climatic conditions during the experimental period varied (Table 1). In 2008, precipitation was favourably distributed and amounted to 371.4 mm and air temperature equalled the long-term mean. In 2009, precipitation exceeded the average long-term sum but it was unevenly distributed. The last study year, 2010, was the warmest and wettest, and the distribution of precipitation was favourable.

RESULTS AND DISCUSSION

The potato tuber content of phenols (Table 2). Statistical analysis confirmed a significant influ-

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

Year	Month						
	IV	V	VI	VII	VIII	IX	IV–IX
Rainfalls (mm)							sum
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
Multiyear sum (1987–2000)	38.6	44.1	52.4	49.0	43.0	47.7	275.2
Air temperature (°C)							mean
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
Multiyear mean (1987–2000)	7.8	12.5	17.2	19.2	18.5	13.1	14.7

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ence of experimental cultivars, UG_{max} application regime and weather conditions throughout the study years on phenol content in potato tubers (Table 2).

The cultivars accumulated different amounts of phenolic compounds. Cv. Satina accumulated a higher amount of phenols, 172.4 mg/kg on average, whereas the accumulation in cv. Tajfun tubers was significantly lower, 169.1 mg/kg on average. Studies by Cantos et al. (2002), Hamouz et al. (2010), Navarre et al. (2010) and Wierzbicka et al. (2015) confirmed this finding. According to these authors, the tuber content of phenols depends mainly on cultivar.

There is lack of literature data related to the effect of soil conditioner on phenol content in potato tubers. The study reported here demonstrated that the UG_{max} application regime had a significant effect on phenols. An increase in the concentration of phenols in soil conditioner-treated plots was noted compared with control. The average increase ranged from 1.1 to 6.8 mg/kg fresh mass. The highest concentration of phenols was recorded in the plots with the following treatment procedure: the soil conditioner was applied at the rate of 1.0 L/ha prior to potato planting, at the rate of 0.5 L/ha when plants were 10–15 cm high, and at the rate of 0.5 L/ha at the stage of flower buds. The above findings agree with a report by Wierzbicka et al. (2015) who demonstrated that tubers harvested from plots where microorganisms had been applied contained more phenolic acids compared with control tubers. Kraska (2002) reported an increase in the concentration of phenols in potato tubers following increased fertilisation and plant protection. The author observed that phenol compound content was significantly higher in no-till versus ploughed plots.

Meteorological conditions throughout the study years affected the accumulation of phenols. The highest phenol content in potato tubers was recorded in 2008 when precipitation sum was by 96.2 mm higher than the long-term mean, and the average air temperature amounted to 14.7°C. The influence of climatic conditions on phenol content was also reported by Kraska (2002), Hamouz et al. (2006) and Reddivari et al. (2007). No interaction of years with soil conditioner application regime, or cultivars with UG_{max} application regime was found.

Glycoalkaloid content in potato tubers (Table 3). Statistical analysis showed that there was a significant effect of cultivars examined in the experiment on the potato tuber content of glycoalkaloids. Glycoalkaloid content was higher in cv. Tajfun (34.8 mg/kg fresh mass on average) compared with cv. Satina (33.9 mg/kg, on average). The above findings are similar to those reported by Wierzbicka (2011), Valcarcel et al. (2014), Amer et al. (2014), Gugała et al. (2016) and Trawczyński (2016) who demonstrated that the glycoalkaloid content of potato tubers is mainly genotype-related.

In the experiment reported here, a significant effect of soil conditioner application regime on glycoalkaloid content was also confirmed; it was

Table 2. Content of phenols in potato tubers (mg/kg fresh mass)

Experimental factor	Cultivar		Year			Mean
	Satina	Tajfun	2008	2009	2010	
Control object – without UG_{max}	169.9	165.7	179.2	162.4	161.9	167.8
UG_{max} before planting 1.0 L/ha	172.0	169.1	184.0	164.3	163.4	170.6
UG_{max} before planting 0.5 L/ha + at potato height 10–15 cm 0.25 L/ha + in flower bud phase 0.25 L/ha	173.3	170.4	184.0	166.0	165.7	171.9
UG_{max} before planting 1.0 L/ha + at potato height 10–15 cm 0.50 L/ha + in flower bud phase 0.50 L/ha	175.5	171.4	185.5	166.3	168.7	173.5
UG_{max} at potato height 10–15 cm 0.50 L/ha + in flower bud phase 0.50 L/ha	171.3	169.0	183.7	163.9	163.0	170.2
Mean	172.4	169.1	183.2	164.6	164.5	–

$LSD_{0.05}$ for: years – 2.2, cultivars – 1.4, UG_{max} method – 1.9; interaction: years × UG_{max} method – ns, cultivars × UG_{max} method – ns

LSD – least significant difference; ns – not significant

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

Experimental factor	Cultivar		Year			Mean
	Satina	Tajfun	2008	2009	2010	
Control object – without UG_{max}	32.9	34.3	33.9	33.6	33.3	33.6
UG_{max} before planting 1.0 L/ha	33.7	34.8	34.2	34.5	34.0	34.2
UG_{max} before planting 0.5 L/ha + at potato height 10–15 cm 0.25 L/ha + in flower bud phase 0.25 L/ha	34.3	35.1	34.6	34.8	34.7	34.7
UG_{max} before planting 1.0 L/ha + at potato height 10–15 cm 0.50 L/ha + in flower bud phase 0.50 L/ha	34.9	35.4	35.0	35.0	35.5	35.2
UG_{max} at potato height 10–15 cm 0.50 L/ha + in flower bud phase 0.50 L/ha	33.9	34.6	34.1	34.5	34.2	34.2
Mean	33.9	34.8	34.3	34.5	34.3	–

$LSD_{0.05}$ for: years – ns, cultivars – 0.52, UG_{max} method – 0.89; interaction: years × UG_{max} method – ns, cultivars × UG_{max} method – ns

LSD – least significant difference; ns – not significant

the lowest in control tubers, 33.6 mg/kg on average, whereas it was significantly the highest in plots where soil conditioner had been applied at the following rates: 0.5 L/ha prior to potato planting, 0.25 L/ha when plants were 10–15 cm high, and 0.25 L/ha at the stage of flower buds, and also at the following rates: 1.0 L/ha prior to potato planting, 0.50 L/ha when plants were 10–15 cm high, and 0.50 L/ha at the stage of flower buds. On average, the potato tuber content of glycoalkaloids due to an application of soil conditioner ranged from 0.15 to 2.17 mg/kg. There is no available literature on the effect of soil conditioner on glycoalkaloid content. In their study, Gugała et al. (2016) observed a tendency for TGA to slightly decline in biostimulant-treated plots.

Weather conditions in individual study years had an insignificant influence on glycoalkaloid levels in potato tubers. Throughout the study period, glycoalkaloid content in potato tubers ranged from 34.3 to 34.5 mg/kg fresh mass in 2010 and 2009, respectively. It agrees with the findings of a previous study by Zarzecka and Gugała (2003) who reported no significant effect of atmospheric conditions in the study years on TGA accumulation in potato tubers. By contrast, Skrabule et al. (2010) and Wierzbicka (2011) argued that the level of glycoalkaloids was determined by weather conditions during the growing season.

No years × soil conditioner application regime interaction or cultivars × UG_{max} application regime interaction were found.

REFERENCES

Amer F.S., Reddivari L., Madiwale G.P., Stone M., Holm D.G., Vanamala J. (2014): Effect of genotype and storage on glycoalkaloid and acrylamide content and sensory attributes of potato chips. American Journal of Potato Research, 91: 632–641.

Bejarano L., Mignolet E., Devaux A., Espinola N., Carrasco E., Larondelle Y. (2000): Glycoalkaloids in potato tubers: The effect of variety and drought stress on the α-solanine and α-chaconine contents of potatoes. Journal of the Science of Food and Agriculture, 80: 2096–2100.

Bergers W.W.A. (1980): A rapid quantitative assay for solanidine glycoalkaloids in potatoes and industrial potato protein. Potato Research, 23: 105–110.

Cantos E., Tudela J.A., Gil M.I., Espín J.C. (2002): Phenolic compounds and related enzymes are not rate-limiting in browning development of fresh-cut potatoes. Journal of Agricultural and Food Chemistry, 50: 3015–3023.

Gugała M., Zarzecka K., Dołęga H., Niewęgłowski M., Sikorska A. (2016): The effect of biostimulants and herbicides on glycoalkaloid accumulation in potato. Plant, Soil and Environment, 62: 256–260.

Gumul D., Korus J., Achremowicz B. (2005): The effect of processing operations on the antioxidant activity of plant raw materials. Food. Science. Technology. Quality, 4: 41–48. (In Polish)

Hamouz K., Lachman J., Dvořák P., Jůzl M., Pivec V. (2006): The effect of site conditions, variety and ferlilization on the content of polyphenols in potato tubers. Plant, Soil and Environment, 52: 407–412.

Hamouz K., Lachman J., Hajtamánková K., Pazderů K., Čižek M., Dvořák P. (2010): Effect of natural and growing conditions on the content of phenolics in potatoes with diferent flesh colour. Plant, Soil and Environment, 56: 368–374.

doi: 10.17221/196/2017-PSE

Jeszka M., Flaczyk E., Kobus-Cisowska J., Dziedzic K. (2010): Phenolics – Characteristic and significance in food technology. Nauka Przyroda Technologia, 4: 1–13. (In Polish)

Kołodziejczyk M. (2014a): Effectiveness of nitrogen fertilization and application of microbial preparations in potato cultivation. Turkish Journal of Agriculture and Forestry, 38: 299–310.

Kołodziejczyk M. (2014b): Effect of nitrogen fertilization and microbial preparations on potato yielding. Plant, Soil and Environment, 60: 379–386.

Kraska P. (2002): Effect of growing methods, fertilization levels and protection on selected potato qualities. Zeszyty Problemowe Postępów Nauk Rolniczych, 489: 229–237. (In Polish)

Navarre D.A., Shakya R., Holden J., Kumar S. (2010): The effect of different cooking methods on phenolics and vitamin C in develomentally young potato tubers. American Journal of Potato Research, 87: 350–359.

Pęksa A., Gołubowska G., Aniołowski K., Lisińska G., Rytel E. (2006): Changes of glycoalkaloids and nitrate contents in potatoes during chip processing. Food Chemistry, 97: 151–156.

Reddivari L., Hale A.L., Miller J.C. (2007): Determination of phenolic content, composition and their contribution to antioxidant activity in specialty potato selections. American Journal of Potato Research, 84: 275.

Rytel E. (2012): Changes in glycoalkaloid and nitrate content in potatoes during dehydrated dice processing. Food Control, 25: 349–354.

Skrabule I., Grauda D., Mikelsone A., Vasariete A. (2010): Adaptation of glycoalkaloids detection method for evaluation of Latvian potato genetic resources. Agronomy Research, 8 (special issue III): 705–710.

Swain T., Hillis W.E. (1959): The phenolic constituens of *Prunus domestica*. I. – The quantitative analysis of phenolic constituents. Journal of the Science of Food and Agriculture, 10: 63–68.

Trawczyński C. (2016): The influence of cultivars and weather conditions of vegetation period on the content of some nutritional and anti-nutritional components in potato tubers. Acta Agrophysica, 23: 119–128.

Valcarcel J., Reilly K., Gaffney M., O'Brien N. (2014): Effect of genotype and environment on the glycoalkaloid content of rare, heritage, and commercial potato varieties. Journal of Food Science, 79: 1039–1048.

Valkonen J.P.T., Keskitalo M., Vasara T., Pietilä L., Raman K.V. (1996): Potato glycoalkaloids: A burden or a blessing? Critical Reviews in Plant Sciences, 15: 1–20.

Wierzbicka A. (2011): Some quality characteristics of potato tubers grown in the ecological system depending on irrigation. Journal of Research and Applications in Agricultural Engineering, 56: 203–207. (In Polish)

Wierzbicka A., Hallmann E., Grudzińska M. (2015): Polyphenol content of potatoes depending on the variety and effective microorganisms. Fragmenta Agronomica, 32: 81–88. (In Polish)

Zarzecka K., Gugała M. (2003): The effect of herbicide applications on the content of ascorbic acid and glycoalkaloids in potato tubers. Plant, Soil and Environment, 49: 237–240.

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