DOI: 10.21005/AAPZ2016.38.2.08

FOLIA POMERANAE UNIVERSITATIS TECHNOLOGIAE STETINENSIS
Folia Pomer. Univ. Technol. Stetin., Agric., Aliment., Pisc., Zootech. 2016, 326(38)2, 89–96

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GLYCOALKALOID CONTENT IN THE TUBERS OF POTATO MANURED WITH UNDERSOWN CATCH CROPS IN THE INTEGRATED AND ORGANIC PRODUCTION SYSTEM

ZAWARTOŚĆ GLIKOALKALOIDÓW W BULWACH ZIEMNIAKA NAWOŻONEGO WSIEWKAMI MIĘDZYPLONOWYMI W INTEGROWANYM I EKOLOGICZNYM SYSTEMIE PRODUKCJI

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Streszczenie. W pracy przedstawiono wyniki badań prowadzonych w latach 2006–2009 w celu określenia wpływu biomasy wsiewek międzyplonowych, przyoranych jesienią i pozostawionych do wiosny w formie mulczu, na zawartość glikoalkaloidów w bulwach ziemniaka uprawianego w integrowanym i ekologicznym systemie produkcji. Przeprowadzono eksperyment, aby sprawdzić następujące dwa czynniki – 1. nawożenie wsiewką międzyplonową: kontrola (bez nawożenia wsiewką międzyplonową), obornik, nostrzyk biały, nostrzyk biały + rajgras holenderski (życica westerwoldzka), rajgras holenderski, nostrzyk biały – mulcz, nostrzyk biały + rajgras holenderski – mulcz, rajgras holenderski – mulcz; 2. systemy produkcji – integrowany i ekologiczny. Zawartość glikoalkaloidów w bulwach ziemniaka określono metodą Bergera. Najniższą zawartość glikoalkaloidów określono w bulwach ziemniaka nawożonego nostrzykiem białym oraz mieszanką nostrzyka białego z rajgrasem holenderskim, niezależnie od formy ich stosowania, a także rajgrasem holenderskim pozostawionym do wiosny w formie mulczu. Bulwy ziemniaka, uprawianego w integrowanym systemie produkcji, charakteryzowały się niższą zawartością glikoalkalodiów niż bulwy ziemniaka uprawianego w ekologicznym systemie produkcji.

Key words: glycoalkaloid content, potato, manuring with undersown catch crop, mulch, production system.
Słowa kluczowe: zawartość glikoalkaloidów, ziemniak, nawożenie wsiewką międzyplonową, mulcz, system produkcji.

INTRODUCTION

Glycoalkaloids (TGA) are natural toxic substances occurring in potato tubers as chaconine (around 60%) and solanine (around 40%). The total glycoalkaloid content in potato tubers usually does not exceed the safe level of 200 mg and ranges between 10 and 150 mg $\cdot$ kg^{-1} fresh matter (Percival and Dixon 1997; Mazurczyk and Lis 2000). TGA amount changes as it is affected by the genotype, growing conditions in a given year as well as fertiliser types and rates (Hlywka et al. 1994; Głuska 2002; Hellenäs et al. 2005). Studies by Mondy and

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Munsh (1990) as well as Płaza (2004) have demonstrated that potato manured with the biomass of catch crops contained less glycoalkaloids. Haslovǎ et al. (2005) have found that the production system significantly affects glycoalkaloid content in potato tubers, too. However, literature seems to lack works on the subject so the need arises to conduct this type of research. The present work is an attempt to fill this gap. Its aim was to determine the effect of the biomass of undersown catch crops, either autumn-incorporated or left on the soil surface as mulch for spring incorporation, on the tuber content of glycoalkaloids in the integrated and organic production system.

Manuring with undersown catch crops was assumed to enable tracking differences in the potato tuber content of alkaloids and select the combination of manuring with undersown catch crop which, when followed by potato, will contribute to the greatest decline in the potato tuber content of alkaloids.

MATERIALS AND METHODS

Field research was conducted in 2006–2009 at the Zawady Experimental Farm owned by Siedlce University of Natural Sciences and Humanities. The experimental soil was grey brown podzolic soil formed from very loamy sand with neutral pH, average available phosphorus, potassium and magnesium contents. Humus content amounted to 1.43%. An experiment was a split-block arrangement with 3 replicates. Two factors were examined: 1. manuring with undersown catch crop: control (no undersown catch crop), farmyard manure (30 t $\cdot$ ha^{-1}), white melilot (seeding rate 26 kg $\cdot$ ha^{-1}), white melilot + westerwolds ryegrass (13 + 10 kg $\cdot$ ha^{-1}), westerwolds ryegrass (seeding rate 20 kg $\cdot$ ha^{-1}), white melilot – mulch (seeding rate 26 kg $\cdot$ ha^{-1}), white melilot + westerwolds ryegrass – mulch (seeding rate 13 + 10 kg $\cdot$ ha^{-1}), westerwolds ryegrass – mulch (seeding rate 20 kg $\cdot$ ha^{-1}); 2. production system: integrated and organic. In autumn, the fresh matter yield of catch crop was determined together with roots to the depth of 30 cm of soil. In the integrated production system, the yield averaged across 3 years was: 27.9 t $\cdot$ ha^{-1} for white melilot, 34.2 t $\cdot$ ha^{-1} for white melilot + westerwolds ryegrass and 35.7 t $\cdot$ ha^{-1} for westerwolds ryegrass.

The respective values in the organic production system were as follows: 23.2, 26.5 and 27.9 t $\cdot$ ha^{-1}. The following amounts of microelements were introduced (per 1 ha) to the soil with the biomass of undersown catch crops: white melilot – 159.6 kg N, 33.6 kg P and 115.2 kg K, white melilot + westerwolds ryegrass – 158.0 kg N, 32.4 kg P and 118.4 kg K, westerwolds ryegrass – 120.3 kg N, 29.2 kg P and 110.5 kg K in the integrated system; white melilot – 152.8 kg N, 30.6 kg P and 112.3 kg K, white melilot + westerwolds ryegrass – 152.2 kg N, 29.5 kg P and 115.6 kg K in the organic system.

Spring triticale grown for grain was undersown with the catch crops. Table potato cv. Zeus was cultivated in the first year after manuring with the catch crops. It is a medium-late cultivar, suggested for organic cultivation. Potato tuber yields are given in the work by Płaza et al. (2013). In the integrated system of potato production, mineral fertilisers were applied to the whole experimental area at the following per 1 ha rates: 90 kg N, 36.9 kg P and 99.6 kg K. The rates were adjusted to soil availability and assumed yield level. In plots ploughed before winter, the mineral fertilisers were mixed with soil using a cultivator with a harrow attached to it whereas in mulch-covered units discing was followed by cultivator. In organic plots farmyard manure, applied at the rate of 30 t · ha^{-1} before spring triticale growing, replaced mineral fertilisation. Potatoes were planted in late April and harvested in mid-September. During harvest tubers for chemical analyses were sampled in each plot. Five potato tubers were sampled per plot for analysis. Glycoalkaloid content was determined by the Berger method. Results for each characteristic were analysed by ANOVA appropriate for the split--block design. When sources of variation were found to be significant, separation of means by the Tukey test followed. Statistical analysis was conducted in Ex. 1 7.0. using the authors' own algorithms (Trętowski and Wójcik 1991).

Study years had very changeable weather conditions (Table 1). Precipitation was the lowest and temperature was the highest in 2007 when slight drought occurred in April. The highest precipitation was recorded in 2008 when the average temperature was by 0.4°C lower than the long-term mean. The growing season in 2008, when precipitation was the highest, saw a slight drought in April only. In turn, in 2009 strong drought was recorded in April, July and September. The precipitation sum in 2009 was lower than in 2008 but higher than the long-term mean.

Table 1. Weather conditions during the potato growing season recorded at the Zawady Meteorological Station
Tabela 1. Warunki pogodowe w okresie wegetacji ziemniaka zarejestrowane w Stacji Meteorologicznej Zawady

Years Lata	Month Miesiąc						Mean Średnia
	IV	V	VI	VII	VIII	IX	
Mean air temperature Średnia temperatura powietrza [°C]							
2007	8.6	14.6	18.2	18.9	18.9	13.1	15.4
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
1990–2005	8.2	14.2	17.6	19.7	19.1	12.9	15.3
Precipitation sum Suma opadów [mm]							
2007	21.2	59.1	59.0	70.2	31.1	67.6	308.2
2008	28.1	85.6	49.0	69.8	75.4	63.4	371.2
2009	8.1	68.9	145.2	26.4	80.9	24.9	354.4
1990–2005	37.4	47.1	48.1	65.5	43.5	47.3	288.9

RESULTS AND DISCUSSION

Statistical analysis revealed a significant effect of growing conditions, experimental factors studied and their interaction on glycoalkaloid content in potato tubers. The production system significantly affected the concentration of glycoalkaloids in potato tubers as well (Table 2). Their content was lower in tubers grown in the integrated versus organic production system, which agrees with findings reported by Sawicka and Kuś (2002) and Haslovă et al. (2005). The above relationship can be explained by the fact that organic potatoes produce lower yields of smaller tubers compared with the integrated or conventional production system. Small potato tubers (less than 50 g) have been confirmed to contain less glycoalkaloids compared with large tubers (Papathanasiou et al. 1999; Wroniak and Mazurczyk 2006;

Gregory 2008). It follows from the fact that small tubers contain more surface layer (the majority of glycoalkaloids are found in the skin and just below the skin), hence their glycoalkaloid content was higher than that of large tubers. In the experiment described here, there was found an interaction of the factors studied, which means that glycoalkaloids were the lowest in tubers of white melilot mulch-manured potato in the integrated production system. By contrast, it was the highest in control organic potatoes.

Table 2. Glycoalkaloid content in potato tubers depending on manuring with undersown catch crops and production system [mg · kg^{-1} f.m.]. Means across 2007–2009
Tabela 2. Zawartość glikoalkaloidów w bulwach ziemniaka w zależności od nawożenia wsiewką międzyplonową i systemu produkcji [mg · kg^{-1}]. Średnie z lat 2007–2009

Specification Wyszczególnienie	Production system System produkcji	
	intergrated integrowany	organic ekologiczny
Control Kontrola	72.8	76.4
Farmyard manure Nawożenie obornikiem	61.7	62.8
White melilit Nostrzyk biały	54.7	56.3
White melilot + westerwolds ryegrass Nostrzyk biały + rajgras holenderski	58.9	60.4
Westerwolds ryegrass Rajgras holenderski	61.3	62.5
White melilot – mulch Nostrzyk biały – mulcz	52.7	54.8
White melilot + westerwolds ryegrass – mulch Notrzyk biały + rajgras holenderski – mulcz	56.4	58.9
Westerwolds ryegrass – mulch Rajgras holenderski – mulcz	59.8	60.7
Mean Średnia	59.8	61.6
$LSD_{0.05}$ – $P_{0,05}$		
Production system System produkcji	0.5	
Interaction Interakcja	1.8	

Manuring with the biomass of undersown catch crops resulted in a decline in potato glycoalkaloids (Table 3). Also Mondy and Munsh (1990) as well as Płaza (2004) demonstrated that potatoes manured with the biomass of undersown catch crops contained less glycoalkaloids. In the study discussed here, a decline in alkaloids (by 22%, on average) was observed in plots manured with undersown catch crops compared with control potatoes. Also Mondy and Munsh (1990), Rogozińska (1995) as well as Smith (2007) reported that glycoalkaloids (solanine and chaconine) increased in potato tubers due to mineral fertilisation applied. In the present study, the lowest glycoalkaloid content was recorded in potato manured with autumn- and spring-incorporated white melilot. Glycoalkaloids were also lower, compared with farmyard manure, in potato tubers manured with a mixture of white melilot and westerwolds ryegrass, regardless of its incorporation time, and westerwolds ryegrass left on the soil surface as mulch for spring incorporation. It agrees with results of studies by Płaza (2004). According to Reust et al. (1999) cultivation of catch corps which have a favourable carbon-to-nitrogen ratio, contributes to the regeneration of soil habitat, increases humus content, amount of micro-organisms, enzymes and other biologically active compounds, which hinders an accumulation of harmful substances in potato tubers. Also Leszczyński (2002) has claimed that organic manures decrease potato tuber contents of harmful substances by enriching the soil with organic matter which inhibits the process of glycoalkaloid synthesis. In the present study, weather conditions during the growing season interacted with manuring with the biomass of undersown catch crops, which indicates that the concentration of glycoalkaloids was the lowest in potato manured with autumn- and spring-incorporated melilot in 2007 and spring-incorporated white melilot mulch in 2009. By contrast, the content was the highest in control tubers regardless of weather conditions during the growing season in all the study years.

Table 3. Glycoalkaloid content in potato tubers depending on manuring with undersown catch crops during the years 2007–2009 [mg · kg^{-1} f.m.]
Tabela 3. Zawartość glikoalkaloidów w bulwach ziemniaka w zależności od nawożenia wsiewką międzyplonową w latach 2007–2009 [mg · kg^{-1}]

Specificaion Wyszczególnienie	2007	2008	2009	Mean Średnia
Control Kontrola	74.1	75.4	74.4	74.6
Farmyard manure Nawożenie obornikiem	61.7	63.1	62.0	62.2
White melilit Nostrzyk biały	54.8	56.2	55.6	55.5
White melilot + westerwolds ryegrass Nostrzyk biały + rajgras holenderski	59.1	60.5	59.4	59.7
Westerwolds ryegrass Rajgras holenderski	61.4	62.7	61.7	61.9
White melilot – mulch Nostrzyk biały – mulcz	53.2	54.6	53.5	53.8
White melilot + westerwolds ryegrass – mulch Nostrzyk biały + rajgras holenderski – mulcz	57.1	58.5	57.4	57.7
Westerwolds ryegrass – mulch Rajgras holenderski – mulcz	59.7	61.1	60.0	60.3
Mean Średnia	60.1	61.5	60.5	–
$LSD_{0.05}$ – $P_{0,05}$				
Years Lata				0.6
Manuring with undersown catch crop Nawożenie wsiewką międzyplonową				1.7
Interaction Interakcja				1.9

The content was the highest in 2008 when precipitation was the highest during the potato growing season. Increased glycoalkaloids in potato tubers result from stress during their growth i.e. prolonged cold, rain and cloudy weather, extreme heat, drought or water excess and high solar radiation (Frydecka-Mazurczyk and Zgorska 2000). Diviš (2008) demonstrated that the highest level of glycoalkaloids was found in tubers harvested in the growing season with high temperature and insufficient water supply. The effect of weather on glycoalkaloids in tubers has also been confirmed by Hamouz et al. (1999) as well as Nowacki (2002). In the present study, a significantly lower concentration of glycoalkaloids was recorded in 2007 and 2009 when both precipitation and temperatures were favourably distributed and potato tuber yields were higher.

CONCLUSIONS

1. The concentration of glycoalkaloids was the lowest in the tubers of potato manured with either autumn- or spring-incorporated white melilot and a mixture of white melilot and westerwolds ryegrass as well as westerwolds ryegrass left on the soil surface as mulch for spring incorporation.
2. Tubers of potato cultivated in the integrated production system contained less glycoalkaloids compared with organic potatoes.
3. Thermal conditions and precipitation significantly affected glycoalkaloid content in potato tubers. The content was the lowest in 2007 and 2009 when both precipitation and temperatures were favourably distributed.

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Abstract. The paper presents results of studies carried out in 2006-2009 to determine the effect of the biomass of undersown catch crops, which were either autumn-incorporated or left on the soil surface as mulch for spring incorporation, on glycoalkaloid content in the tubers of potato grown in the integrated and organic production system. An experiment was conducted to examine the following two factors: 1. manuring with undersown catch crops: control (no undersown catch crop), farmyard manure, white melilot, white melilot + westerwolds ryegrass, westerwolds ryegrass, white melilot – mulch, white melilot + westerwolds ryegrass – mulch, westerwolds ryegrass – mulch; 2. production system: integrated and organic. Glycoalkaloid content was determined in potato tubers by means of the Bergers method. The lowest glycoalkaloid content was determined in potato tubers manured with white melilot and a mixture of white melilot and westerwolds ryegrass, either autumn- or spring-incorporated, as well as westerwolds ryegrass left on the soil surface as mulch for spring incorporation. Potato tubers grown in the integrated production system contained less glycoalkaloids compared with organic potato.