Changes in the content of glycoalkaloids in potato tubers according to soil tillage and weed control methods

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ABSTRACT

A field experiment was carried out in the fields of the Experimental Farm in Zawady owned by the University of Podlasie in Siedlce. An influence of soil tillage methods and herbicides application on the content of glycoalkaloids in edible potato tubers of the Viking cultivar was studied. The results obtained indicated that the content of glycoalkaloids in non-peeled tubers significantly depended on the method of soil tillage and weed control as well as on the research year, whereas in peeled tubers the content significantly depended only on the weather conditions in the growing season. The content of glycoalkaloids in the tubers subjected to the initial treatment (peeling) decreased to 46.81–55.3%, compared to the level of glycoalkaloids before peeling.

Keywords: potato; glycoalkaloids; soil tillage methods; herbicides

Glycoalkaloids are natural poisons found in plants of the *Solanaceae* family. α-Solanine and α-chaconine (Sanford et al. 1993, Cieślik 1997) are the main glycoalkaloids of potato tubers. They have a protective function (Osman 1983, Lachman et al. 2001, Smith et al. 2001); however, in the amount of more than 100 mg/kg of the tuber fresh matter they worsen the flavour (Maga 1980, Friedman and Dao 1992, Helenäs et al. 1995, Cieślik 1997). The level of 200 mg/kg is reported as harmful to human health (Nabrzyski and Ganowiak 1992, Friedman and McDonald 1997); thus it is advisable that edible potato tubers have a low (preferably less than 50 mg/kg) content of glycoalkaloids (Panovska et al. 1994, Frydecka-Mazurczyk and Zgórska 1997, Leszczyński 2000). The concentration of glycoalkaloids is mainly influenced by genetic (Maga 1980, Savage et al. 2000, Frydecka-Mazurczyk and Zgórska 2002, Nowacki 2002), environmental (Lachman et al. 2001, Frydecka-Mazurczyk and Zgórska 2002, Hamouz et al. 1999, 2004) and agrotechnological factors (Mazurczyk 1988, Żołnowski 2001, Zarzecka and Gugała 2003, Hamouz et al. 2005).

There has not been enough information available on the impact of cultivation operations and tillage methods on the potato chemical composition properties. Hence, the aim of the present work was to determine the impact of herbicides and soil tillage methods on the content of glycoalkaloids in potato tubers.

MATERIAL AND METHODS

Edible potato tubers of the Viking cultivar obtained from the field experiment constituted the research material. It was conducted in the years 2002–2004 in the fields of the Experimental Farm in Zawady owned by the University of Podlasie in Siedlce. The trial was situated on the soil originating from light clay sands and strong clay sands, and belonging to very good rye complex. It was set up in the randomised sub-blocks design in three replications. Two factors were studied in the experiment:

I. two methods of soil tillage – conventional and simplified,
II. seven methods of weed control including an application of herbicides (Table 1).

In the case of the treatments 2–7, mechanical weeding was carried out up to plant germination. Herbicides and their mixtures were applied just before the germination of potato plants (treatments 2, 3, 4) and after potato germination (treatments 5, 6, 7). Farmyard manure (25 t/ha) and mineral fertilization in the amounts of: 90 kg N, 90 kg

Table 1. Factors of the experiment

I. Tillage systems	1. traditional (skimming + fall ploughing + harrowing + cultivating + harrowing)
	2. simplified (skimming + cultivating)
II. Weed control methods	1. Control object – mechanical weeding until and after potato culture rising
	2. Plateen 41.5 WG (metribuzin + flufenacet) 2.0 kg/ha
	3. Plateen 41.5 WG (metribuzin + flufenacet) 2.0 kg/ha + Fusilade Forte 150 EC (fluazyfop-P-butyl) 2.5 l/ha (mixture)
	4. Plateen 41.5 WG (metribuzyn + flufenacet) 1.6 kg/ha + Fusilade Forte 150 EC (fluazyfop-P-butyl) 2.0 l/ha + adjuvant Atpolan 80 EC 1.5 l/ha (mixture)
	5. Barox 460 SL (bentazone + MCPA) 3.0 l/ha
	6. Barox 460 SL (bentazone + MCPA) 3.0 l/ha + Fusilade Forte 150 EC (fluazyfop-P -butyl) 2.5 l/ha (mixture)
	7. Barox 460 SL (bentazone + MCPA) 2.4 l/ha + Fusilade Forte 150 EC (fluazyfop-P -butyl) 2.0 l/ha + adjuvant Atpolan 80 EC 1.5 l/ha (mixture)

P_2O_5 and 135 kg K_2O per hectare were applied on a regular basis.

Chemical analyses of fresh material were carried out during 4 days after tuber harvest. The content of glycoalkaloids in peeled and non-peeled tubers was determined by the Bergers method (Bergers 1980). The results of the studies are given in mg per 1 kg of tuber dry matter. They were statistically analysed using the analysis of variance, and the differences between means were determined by the Tukey test.

Weather conditions in the years 2002–2004 varied (Figure 1). The highest content of glycoalkaloids was found in tubers in the year 2003, which was warm and dry, whereas the lowest level was recorded in the year 2004, in which precipitation and temperature were similar to the average multi-year period.

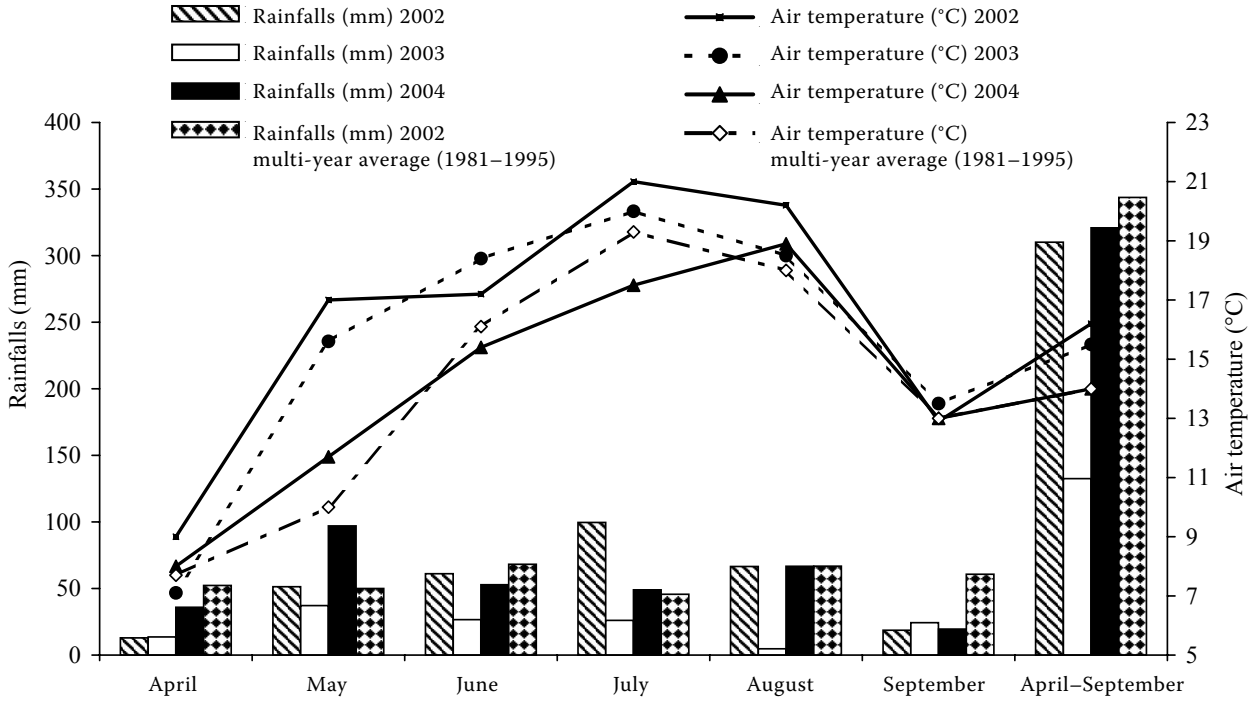

Figure 1. Characteristics of weather conditions in the potato vegetation period in 2002–2004 according to the Zawady Meteorological Station

Table 2. Content of glycoalkaloids in non-peeled potato tubers (mg/kg of fresh matter)

Weed control methods	Tillage systems		Year			Average
	traditional	simplified	2002	2003	2004	
1. Control object	35.84	36.70	36.10	37.03	35.74	36.27
2. Plateen 41.5 WG	36.72	37.06	37.08	37.26	36.34	36.89
3. Plateen 41.5 WG + Fusilade Forte 150 EC (mixture)	37.40	37.53	37.13	38.90	36.32	37.47
4. Plateen 41.5 WG + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	37.15	37.42	37.06	38.48	36.32	37.29
5. Barox 460 SL	36.92	37.54	36.81	38.55	36.34	37.23
6. Barox 460 SL + Fusilade Forte 150 EC (mixture)	37.59	37.73	37.51	39.03	36.44	37.66
7. Barox 460 SL + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	38.15	38.29	37.61	40.73	36.32	38.22
Average	37.11	37.47	37.04	38.57	36.26	37.29
Average for objects 2–7	37.32	37.60	37.20	38.83	36.33	37.46

$LSD_{0.05}$: weed control methods = 0.10; tillage systems = 0.30; years = 0.05
Interaction: weed control methods × tillage systems = n.s.; weed control methods × years = 0.18; tillage systems × years = n.s.; n.s. = not significant

RESULTS AND DISCUSSION

The content of glycoalkaloids in the non-peeled potato tubers of the Viking cultivar averaged 37.29 mg/kg and ranged from 35.74 to 40.73 mg/kg dry matter (Table 2). The experimental factors, i.e. soil tillage techniques, weed control methods including herbicide application, and year of potato cultivation, significantly influenced the accumulation of this component. A higher content of glycoalkaloids was recorded in the tubers obtained from the plots cultivated in a simplified way rather than conventionally. On the plots cultivated in a simplified way the harvested yields were lower with a higher share of small tubers. Cieślik (1997) and Leszczyński (2000) found that in small tubers (weighing less than 50 g) the content of glycoalkaloids was lower than in large tubers.

The herbicides applied in potato weed control increased the content of total glycoalkaloids when compared with the tubers harvested from the control treatment. A significantly higher concentration of glycoalkaloids was recorded after spraying with all the weed-killing chemicals. Mazurczyk (1988) and Zarzecka and Gugała (2003) found an increased content of glycoalkaloids as influenced by a herbicide application but the differences were not statistically significant. Hamouz et al. (2004) observed a tendency to accumulate higher amounts of glycoalkaloids on potatoes cultivated ecologically as compared to the conventional method.

Weather conditions over the research years significantly influenced the accumulation of glycoalkaloids; the highest amounts were accumulated in tubers in the growing period of 2003 when the highest temperatures and precipitation deficiencies were recorded. The lowest levels of glycoalkaloids were determined in potatoes cultivated in the year 2004 when the weather conditions were similar to the average multi-year conditions. An impact of the weather conditions on the level of glycoalkaloids was also found in the studies carried out by Friedman and McDonald (1997), Frydecka-Mazurczyk and Zgórska (1997, 2002), Hamouz et al. (1999), Żołnowski (2001) and Nowacki (2002). The authors inferred that stressors such as cold and excess of rain, high temperatures and water deficiency during the growing period stimulated an increase of the content of glycoalkaloids in tubers.

Table 3. Content of glycoalkaloids in peeled potato tubers (mg/kg of fresh matter)

Weed control methods	Tillage systems		Year			Average
	traditional	simplified	2002	2003	2004	
1. Control object	16.31	16.48	16.70	17.40	15.09	16.40
2. Plateen 41.5 WG	16.80	17.14	16.90	18.08	15.93	16.97
3. Plateen 41.5 WG + Fusilade Forte 150 EC (mixture)	17.08	17.53	17.08	18.72	16.12	17.31
4. Plateen 41.5 WG + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	16.83	17.18	16.80	18.13	16.09	17.01
5. Barox 460 SL	17.00	17.17	17.10	17.71	16.42	17.08
6. Barox 460 SL + Fusilade Forte 150 EC (mixture)	17.26	17.32	17.15	18.15	16.57	17.29
7. Barox 460 SL + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	17.80	17.97	17.05	20.37	16.25	17.89
Average	17.01	17.25	16.96	18.37	16.07	17.13
Average for objects 2–7	17.13	17.39	17.01	18.53	16.23	17.26

$LSD_{0.05}$: weed control methods = n.s.; tillage systems = n.s.; years = 0.10
Interaction: weed control methods × tillage systems = n.s.; weed control methods × years = n.s.; tillage systems × years = n.s.; n.s. = not significant

The potatoes of the Viking cultivar subjected to peeling were characterised by a lower content of glycoalkaloids ranging from 52.3 to 55.3%, compared to the tubers before peeling. Their amount in peeled tubers did not depend significantly on tillage and weed control methods (Table 3). Only weather conditions were proved to influence the content of the examined characteristic.

The lowest level of glycoalkaloids was recorded in the tubers of potatoes cultivated under optimal conditions, which were in the year 2004.

A high content of glycoalkaloids is undesirable in the potato tubers produced for direct consumption and the peeling process most efficiently reduces the content of this component (Cieślik 1998). Removal of the potato skin reduces the content of glycoalkaloids in tubers, depending on various factors, by 51.5 to 55.1% (Zrůst et al. 2000), 51.1 to 74.3% (Cieślik 1998) or even by 50–95% (Schwardt 1982, Valkonen et al. 1996).

Frydecka-Mazurczyk and Zgórska (2002) stress that all the registered cultivars should have a genetically conditioned low content of glycoalkaloids (preferably under 50 mg/kg); the probability of exceeding of the dangerous level (less than 200 mg/kg) is then relatively low.

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