The effect of herbicide applications on the content of ascorbic acid and glycoalkaloids in potato tubers

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ABSTRACT

Field experiments were conducted at Zawady Experimental Station (University of Podlasie) in 1999–2001 to test the effect of herbicides (Sencor 70 WG, Basagran 600 SL) and their mixtures (Sencor 70 WG with Fusilade Super, Basagran 600 SL with Focus Ultra) on the content of ascorbic acid and glycoalkaloids in tubers of three potato cultivars. The application of herbicides to potato fields caused an increase in the content of ascorbic acid in comparison with the control. The statistical analysis showed a significant effect of potato cultivars on ascorbic acid and glycoalkaloid concentrations.

Keywords: potato; herbicides; varieties; ascorbic acid; glycoalkaloids

Herbicide applications to potato fields limit harmful effects of weeds. However, they can have some effects on changes in the chemical composition of potato tubers (Mężykowska and Mazurczyk 1979, Ceglarek and Księżak 1992, Leszczyński 2002).

From the aspect of consumption, ascorbic acid is one of the most important constituents of a potato tuber because table potatoes are the cheapest and commonest source of vitamin C (Wojdyła 1997, Leszczyński 2000).

Its content in tubers usually fluctuates between 100 and 300 mg/kg (Leszczyński 1994, 2000, Mazurczyk and Lis 2001) and mainly depends on the potato cultivar and weather conditions in the growing season (Zgórska and Frydecka-Mazurczyk 1985).

Glycoalkaloids are natural toxic constituents of potato tubers. It is likely that the main function of glycoalkaloids is to protect tubers from bacterial and fungal diseases as well as from pests – potato beetle, wireworms (Cieślik 1997, Lachman et al. 2001). Tubers of table potatoes should contain 10–100 mg/kg of glycoalkaloids (Cieślik 1997). The amount of glycoalkaloids above 120–140 mg/kg affects the taste of tubers (Wojdyła 1997) while the concentration exceeding 200 mg/kg can lead to poisoning (Ulman 1979, Maga 1980). The majority of Polish potato cultivars are characterised by low (below 50 mg/kg) and medium (from 50 to 100 mg/kg) concentration of glycoalkaloids, and their content mainly depends on cultivar, tuber ripeness, weather conditions in the growing season, mechanical damage as well as light access (Mazurczyk 1988, 1994).

The experiments describing the effects of herbicides on the chemical composition of potato tubers are not numerous. Therefore the aim of this research was to determine the effects of herbicides and the content of ascorbic acid and glycoalkaloids in tubers of three table potato cultivars.

MATERIAL AND METHODS

Field experiments were conducted at Zawady Experimental Station (University of Podlasie) in 1999–2001 on soils consisting of light and strong loamy sands. The experiment were performed by means of randomised subblocks in three replications. The characteristics of weather conditions in 1999–2001 are given in Table 1. The experimental scheme included:

Herbicide treatments:

1. control – mechanical weeding
2. Sencor 70 WG 0.5 kg/ha
3. Sencor 70 WG 0.5 kg/ha + Fusilade Super 1.5 l/ha (mixture)
4. Sencor 70 WG 0.4 kg/ha + Fusilade Super 2.0 l/ha + adjuvant Olbras 88 EC 1.5 l/ha (mixture)
5. Basagran 600 SL 2.5 l/ha
6. Basagran 600 SL 2.5 l/ha + Focus Ultra 1.5 l/ha (mixture)
7. Basagran 600 SL 2.0 l/ha + Focus Ultra 1.2 l/ha + adjuvant Olbras 88 EC 1.5 l/ha (mixture)

Ania, Baszta, Rywal potato cultivars were used.

On plots with treatments 2–7 mechanical weeding was performed before emergence while herbicides and their mixtures were applied after potato emergence. Organic fertilisation with manure (25 t/ha) and mineral fertilisation with N, P, K at the rates of 100, 100, 150 kg/ha were applied every year.

Chemical analyses were carried out in fresh material within 7–8 days after harvest. Ascorbic acid content was determined by Pijanowski's method (Drzazga 1981) and glycoalkaloid content by Berger's method (1980). The results of analyses were statistically evaluated by analysis of variance and tested by Tukey's test.

RESULTS AND DISCUSSION

The content of ascorbic acid in potato tubers ranged from 196.7 to 219.3 mg/kg and depended on weed control methods and years of cultivation to a great extent (Tables 2 and 3). Herbicides and their mixtures caused an increase in the content of ascorbic acid in comparison with the control.

Table 1. Characteristics of weather conditions during the potato vegetation in 1999–2001 (Zawady Meteorological Station)

Months	Deviations from long-term average 1981–1995 rainfalls (mm)			air temperature (°C)		
	1999	2000	2001	1999	2000	2001
April	+35.0	–4.8	+17.5	+2.2	+5.2	+1.0
May	–23.6	–25.4	–22.0	+2.9	+6.5	+5.5
June	+53.5	–50.8	–32.2	+4.4	+3.5	+1.0
July	–23.8	+110.2	+9.7	+2.5	–0.9	+4.5
August	+10.6	–23.2	–42.8	+0.7	+1.1	+1.4
September	–32.9	+0.4	+47.3	+3.1	–1.2	–0.9
April–September	+18.8	+6.0	–22.5	+2.7	+2.5	+2.3

Table 2. Content of ascorbic acid in potato tubers (mg/kg in fresh matter)

Weed control methods	Cultivars			Years			Average
	Ania	Baszta	Rywal	1999	2000	2001	
1. Control – mechanical weeding	205.2	203.0	207.6	215.0	201.5	199.4	205.3
2. Sencor 70 WG	209.6	206.7	208.9	218.2	204.2	202.8	208.4
3. Sencor 70 WG + Fusilade Super (mixture)	210.1	206.7	210.1	219.3	204.7	203.0	209.0
4. Sencor 70 WG + Fusilade Super + adjuvant Olbras 88 EC (mixture)	207.7	205.0	208.7	215.8	203.7	201.9	207.1
5. Basagran 600 SL	208.0	204.7	210.0	216.6	203.2	202.9	207.6
6. Basagran 600 SL + Focus Ultra (mixture)	208.9	206.1	210.9	217.7	204.2	203.9	208.6
7. Basagran 600 SL + Focus Ultra + adjuvant Olbras 88 EC (mixture)	207.5	203.2	208.7	216.0	202.5	200.9	206.5
Average	208.1	205.1	209.3	216.9	203.4	202.1	–

$LSD_{0.05}$ between: weed control methods = 3.1, cultivars = 1.6, years = 2.1; interaction: weed control methods × cultivars = 5.0, weed control methods × years = 7.2

A significantly higher concentration of ascorbic acid was determined after applications of such herbicides as Sencor 70 WG, Sencor 70 WG + Fusilade Super and Basagran 600 SL + Focus Ultra. The addition of the adjuvant Olbras 88 EC to herbicide mixtures did not increase ascorbic acid content in potato tubers very much. Some authors (Ceglarek and Księżak 1992, Wojdyła 1997, Zarzecka 1997, Zarzecka and Gąsiorowska 2000) reported positive effects of pesticides on the content of ascorbic acid. Mężykowska and Mazurczyk (1979) determined that Bladex (cyanazine), Sencor (metribuzin) and Patoran (metobromuron) reduced the content of this constituent in potato tubers while Hamouz et al. (1999b) did not find any significant influence of cultivation methods (ecological and conventional ones) on ascorbic acid concentration.

Table 3. Content of ascorbic acid in potato tubers (mg/kg in fresh matter) depending on cultivar

Years	Cultivars			Average
	Ania	Baszta	Rywal	
1999	216.4	216.2	218.2	216.9
2000	203.2	202.3	204.8	203.4
2001	204.8	196.7	204.8	202.1
Average	208.1	205.1	209.3	–

$LSD_{0.05}$ between: years = 2.1, cultivars = 1.6; interaction: years × cultivars = 2.7

A comparison of the cultivars showed the highest content of ascorbic acid in Rywal, somewhat lower in Ania and the lowest in Baszta. Many papers (Mężykowska and Mazurczyk 1979, Mazurczyk 1994, Hamouz et al. 1999b, Zarzecka and Gąsiorowska 2000) proved a significant effect of potato cultivar on this characteristic. The years when the experiments were conducted were also differentiated by the content of ascorbic acid. The highest concentration of this constituent was determined in 1999, the warmest but humid year at the same time, and potato maturity was delayed in comparison with the year 2001. Wyszkowski (1996) also observed that during a longer growing season the process of accumulation of ascorbic acid was also prolonged. The influence of weather conditions on the amount of vitamin C was also proved in experiments by Zgórska and Frydecka-Mazurczyk (1985), Mazurczyk (1994), Zarzecka (1997), and Mazurczyk and

Table 4. Content of glycoalkaloids in potato tubers (mg/kg in fresh matter)

Weed control methods	Cultivars			Years			Average
	Ania	Baszta	Rywal	1999	2000	2001	
1. Control – mechanical weeding	33.5	29.4	71.4	44.4	45.1	44.7	44.8
2. Sencor 70 WG	35.6	31.7	72.9	47.0	48.0	45.3	46.7
3. Sencor 70 WG + Fusilade Super (mixture)	39.2	33.8	73.3	52.4	48.0	46.0	48.8
4. Sencor 70 WG + Fusilade Super + adjuvant Olbras 88 EC (mixture)	33.7	29.6	71.7	43.9	45.4	45.8	45.0
5. Basagran 600 SL	35.0	30.7	72.3	45.9	46.8	45.3	46.0
6. Basagran 600 SL + Focus Ultra (mixture)	36.8	32.6	72.9	49.8	46.9	45.3	47.4
7. Basagran 600 SL + Focus Ultra + adjuvant Olbras 88 EC (mixture)	33.3	29.7	71.6	43.7	45.6	45.3	44.9
Average	35.3	31.1	72.3	46.7	46.5	45.4	–

$LSD_{0.05}$ between: weed control methods = n.s., cultivars = 2.6, years = n.s.; interaction: weed control methods × cultivars = n.s., weed control methods × years = n.s.; n.s. = not significant

Lis (2001). In our experiments there were interactions between the treatments and potato cultivars, treatment 3 and years, and years and cultivars, that means the cultivars responded differently to herbicides and weather conditions during the growing season.

It can be stated from the results presented in Tables 4 and 5 that the glycoalkaloid content in potato tubers depended significantly only on cultivars. The highest amount of this constituent was accumulated in tubers of Rywal whereas Ania and Baszta contained significantly lower amounts. The effect of genetic characteristics on the level of glycoalkaloids was proved in experiments conducted by Mazurczyk (1988, 1994), Wojdyła (1997), Zrůst (1997), and Machnacki and Kołpak (1998). These authors also reported that drought and high temperatures as well as low temperatures and high amount of rainfalls in the growing season caused an increase in the glycoalkaloid content. The influence of weather conditions on the above-mentioned characteristic was not proved in our research because the growing seasons were neither dry nor excessively wet.

The applications of herbicides and their mixtures to potato fields did not cause any significant changes in glycoalkaloid content. However, their increased concentration in comparison with the control was observed.

Table 5. Content of glycoalkaloids in potato tubers (mg/kg in fresh matter) depending on cultivar

Years	Cultivars			Average
	Ania	Baszta	Rywal	
1999	38.7	28.3	73.2	46.7
2000	34.0	33.5	72.1	46.5
2001	33.2	31.5	71.5	45.4
Average	35.3	31.1	72.3	–

$LSD_{0.05}$ between: years = n.s., cultivars = 2.6;
interaction: years × cultivars = n.s.; n.s. = not significant

Mazurczyk (1988) also reported an increase in TGA under the effects of herbicides, but it was insignificant. Hamouz et al. (1999a) observed the tendency of potato tubers cultivated in an ecological way, compared to a conventional one, to accumulate larger amounts of glycoalkaloids. Wilson and Frank (1975) stated that a twofold increase in glycoalkaloids in potato tubers was derived from plants treated with pesticides. There is a prevailing opinion that the high glycoalkaloid content is connected with stress caused by drought, high temperatures or pesticides during vegetation (Leja 1987, Zrůst 1997). Sencor 70 WG (metribuzin) and Basagran 600 SL (bentazon) initially inhibit photosynthesis and transport of electrons in CO_2 reactions, which influences the metabolism of plants (LeBaron and Gressel 1982, Corbett 1994). The research findings by Zrůst (1997) showed that the increase in TGA content above the limit 200 mg/kg as a result of herbicide applications to control weeds and potato late blight should not cause any problems.

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ABSTRAKT

Vliv aplikace herbicidů na obsah kyseliny askorbové a glykoalkaloidů v hlízách brambor

Polní pokusy proběhly v letech 1999–2001 na pokusné zemědělské stanici Podlaské univerzity v Siedlcích. Byl sledován vliv herbicidů a jejich směsí na obsah kyseliny askorbové (vitaminu C) a glykoalkaloidů v hlízách tří odrůd brambor. Použití herbicidů při pěstování brambor zvýšilo obsah kyseliny askorbové v hlízách brambor ve srovnání s jejím obsahem v kontrolních variantách. Statistická analýza ukázala průkazný vliv odrůd na koncentraci kyseliny askorbové a glykoalkaloidů.

Klíčová slova: brambory; herbicidy; odrůdy; kyselina askorbová; glykoalkaloidy

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