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Short Communication

The Effect of Herbicides and Soil Tillage Systems on the Content of Polyphenols in Potato Tubers

Krystyna Zarzecka*, Marek Gugała

Department of Plant Cultivation, Faculty of Life Sciences, University of Podlasie in Siedlce, Prusa 14, 08-110 Siedlce, Poland

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Abstract

A three-year field experiment was conducted in 2002-04 to evaluate the effects of soil tillage and weed control methods (including herbicides and their mixtures) on the content of polyphenols in edible potato tubers, cv. Wiking. The results obtained indicated that the content of polyphenols in non-peeled and peeled tubers depend on the methods of soil tillage and weeding, as well as on the years of cultivation. The content of polyphenols in the tubers subjected to the initial treatment (peeling) decreased to 7.2-14.9%, compared to the level of polyphenols before peeling.

Keywords: potato, polyphenols, soil tillage systems, herbicides

Introduction

Plant-derived food, including the potato, is a rich source of biologically active substances, both nutritive and anti-feeding ones [1-3]. Among bioactive substances, antioxidants play an important role in protecting the organism against lifestyle diseases such as cardiovascular disease, cancer, and diabetes [4-6]. Compounds with antioxidative activity mainly include vitamin C, carotenoids, and polyphenols [7-10]. Antioxidants as a prevention factor have recently become a major topic of interest for many research centers. Moreover, the potato is described as an edible, healthy plant.

Potatoes are grown in nearly 150 countries, and are the world's single most important tuber crop with a vital role in the global food system. It is the worlds 4th major food crop after rice, wheat, and maize [11]. Potato tubers are a basic component of everyday diet of Poles because it is consumed at a rate of of 120 kg per capita per year [12, 13].

Potato consumption worldwide and in Europe is 34 and 96 kg per capita, respectively [11]. Also in the USA, potato consumption is high and averages 63 kg per capita. Of 34 fruits and vegetables, potatoes are the third source of antioxidants [14]. In an era of agriculture chemicalization and due to the arising assumption that plant protection chemicals may cause changes in chemical composition, studies have been undertaken to examine the impact of pesticides on the component content of plant material.

The purpose of our study was to determine polyphenol content in the tubers of edible potatoes cultivated under conditions of an application of herbicides and their mixtures to control weeds.

Material

Plant Material

Analyses were performed on potato tubers cv. Wiking harvested in 2002-04 during a field experiment set up at the experimental farm of the University of Podlasie, Siedlce. The soil of the experimental site belongs to a very good rye complex. The experiment was designed as randomized sub-blocks with three replicates. The following factors were examined:

*e-mail: kzarzecka@ap.siedlce.pl

Table 1. Weather conditions during potato vegetation, 2002-04.

Years	Months						Mean value
	April	May	June	July	August	September	
Precipitation (mm)							Sum
2002	12.9	51.3	61.1	99.6	66.5	18.7	310.1
2003	13.6	37.2	26.6	26.1	4.7	24.3	132.5
2004	35.9	97.0	52.8	49.0	66.7	19.5	320.9
Mean of many years (1981-95)	52.3	50.0	68.2	45.7	66.8	60.7	343.7
Temperature (ºC)							Average
2002	9.0	17.0	17.2	21.0	20.2	12.9	16.2
2003	7.1	15.6	18.4	20.0	18.5	13.5	15.5
2004	8.0	11.6	15.4	17.5	18.9	13.0	14.1
Mean of many years (1981-95)	7.7	10.0	16.1	19.3	18.0	13.0	14.0
Sielianinow's hydrothermic coefficients*							IV-IX
2002	1.5	1.0	1.2	1.5	2.1	1.5	1.1
2003	0.6	0.8	0.5	0.4	0.1	0.6	0.4
2004	1.5	2.7	1.1	0.9	1.1	0.5	1.2

*below 0.5 strong mild drought
0.51-0.69 mild drought
0.70-0.99 weak mild drought
≥1 fault mild drought

I – two soil-tillage systems – conventional (skimming + fall plouwing + harrowing + cultivating + harrowing) and simplified (skimming + cultivating),
II –seven weed-control methods including an application of herbicides:
1. control object – mechanical weed control prior to and following potato emergence,
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 (fluazifop-P-butyl) 2.5 l/ha (mixture),
4. Plateen 41.5 WG (metribuzin + flufenacet) 1.6 kg/ha + Fusilade Forte 150 EC (fluazifop-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 (fluazifop-P-butyl) 2.5 l/ha (mixture),
7. Barox 460 SL (bentazone + MCPA) 2.4 l/ha + Fusilade Forte 150 EC (fluazifop-P-butyl) 2.0 l/ha + adjuvant Atpolan 80 EC 1.5 l/ha (mixture).

The area of one plot was 25 m^2 (7.4 m x 3.4 m), and the number of plants per plot was 100. Uniform mineral and organic fertilization were applied in the following amounts: 90 kg N, 32.9 kg P and 112.1 kg K, and 25.0 t/ha farmyard manure. Wiking tubers were planted in the third decade of April at spacing of 67.5 x 37 cm.

The Polyphenols

Chemical analyses of fresh material were carried out 4 days after tuber harvest. The content of polyphenols in peeled and non-peeled tubers was determined by a spectrophotometer with Folin-Ciocalteu's reagent [15]. 20 g of fresh potatoes were homogenized with 35 ml of 80% methanol. Appropriately diluted extract (0.5 ml) was added into a 50 ml volumetric flask and diluted with 7 ml distilled water. Folin-Ciocalteu reagent (0.5 ml) was added to the mixture and mixed. After 3 min, 1 ml Na_2CO_3 solution was added. After 1 hour of laboratory temperature absorbance on the spectrophotometer at wave length 725 nm was measured against blanks. Obtained results were expressed as gallic acid.

Weather Conditions

Weather conditions over the study years varied (Table 1). The year 2002 was most favourable for yield accumulation. Precipitation was close to the average sum for the multiyear period, whereas temperature was higher than in the multiyear period. The lowest content of polyphenols was found in tubers in 2002, when they were warm and moist, whereas the highest level was recorded in 2004, when precipitation and temperature were similar to the average multiyear period.

Table 2. Polyphenol content in non-peeled potato tubers in mg/kg of fresh matter.

Weed control methods	Tillage system soils		Mean value
	traditional	simplified	
1. Control object – mechanical weeding	172.2	173.0	172.6
2. Plateen 41.5 WG	173.5	174.7	174.1
3. Plateen 41.5 WG + Fusilade Forte 150 EC (mixture)	174.9	176.7	175.8
4. Plateen 41.5 WG + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	175.2	176.7	176.0
5. Barox 460 SL	175.4	175.5	175.5
6. Barox 460 SL + Fusilade Forte 150 EC (mixture)	176.9	177.3	177.1
7. Barox 460 SL + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	175.5	176.3	175.9
Mean value	174.8	175.7	175.3
$LSD_{0.05}$			
tillage system soil			0.1
weed control methods			0.3
interaction			n.s.

n.s. – not significant

Table 3. Polyphenol content in potato tubers after peeling in mg/kg of fresh matter.

Weed control methods	Tillage system soils		Mean value
	traditional	simplified	
1. Control object – mechanical weeding	153.0	154.8	153.9
2. Plateen 41,5 WG	153.4	155.4	154.4
3. Plateen 41,5 WG + Fusilade Forte 150 EC (mixture)	154.2	156.5	155.4
4. Plateen 41,5 WG + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	154.8	156.2	155.5
5. Barox 460 SL	156.0	156.2	156.1
6. Barox 460 SL + Fusilade Forte 150 EC (mixture)	157.5	158.1	157.8
7. Barox 460 SL + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	156.3	156.9	156.6
Mean value	155.0	156.3	155.7
$LSD_{0.05}$			
tillage system soil			0.1
weed control methods			0.2
interaction			0.2

Results of the study were statistically analyzed by means of variance analysis and the means were compared by Tukey test at the significance level of p=0.05.

Results and Discussion

The content of polyphenols in the non-peeled potato Wiking tubers averaged 175.3 mg/kg and ranged from 165.0 to 181.7 mg/kg of fresh matter (Tables 2, 4). The content of polyphenols significantly depended on the soil tillage systems, weed control methods (including herbicide application), and year of potato cultivation. A higher content of polyphenols was recorded in the tubers obtained from the plots cultivated in a simplified way rather than conventionally. Kraska [16] observed increased polyphenol concentrations in tubers obtained from the cultivation in a simplified way – plowless.

Table 4. Polyphenol contents in potato tubers depending on weather conditions in the investigated years in mg/kg of fresh matter.

Years	Non-peeled potato	Peeled potato
2002	165.0	153.2
2003	179.1	159.2
2004	181.7	154.7
$LSD_{0.05}$	0.2	0.1

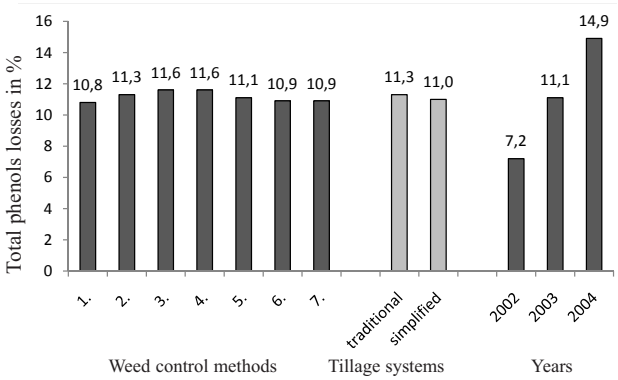

Fig. 1. The influence of peeling on polyphenols losses in potato tubers (non peeled potato 100%).

The herbicides and their mixtures applied in potato weed control increased polyphenol contents in comparison with the tubers of the control without herbicides. Significantly higher polyphenol concentrations were found following all herbicides and their mixtures. Kraska [16] found an increased content of polyphenols as influenced by herbicide, and Antonius et al. [17] as influenced by some insecticides, and Rudzińska and Mikos-Bielak [18] as affected by selected synthetic plant growth regulators. Hamouz et al. [19] observed a tendency to accumulate higher amounts of polyphenols in potatoes cultivated ecologically as compared to the conventional method.

Weather conditions over the research years significantly influenced the accumulation of polyphenols. The highest amounts accumulated in tubers in 2004, when precipitation and temperature were similar to the average multiyear conditions. The lowest polyphenols were determined in potatoes cultivated in 2002, when they were warm and moist. The impact of the weather conditions on the level of polyphenols was also found in the studies by Hamouz et al. [19], Kraska [16], Reyes et al. [9], and Zgórska [20]. The authors inferred that stressors such as cold, excess rain, high temperatures, and water deficiency during the growing period decreased the content of polyphenols in tubers.

The Wiking tubers subjected to peeling were characterized by a lower content of polyphenols ranging from 7.2 to 14.9%, compared to the potatoes before peeling (Fig. 1). Their amount in peeled tubers depended significantly on tillage systems, weed control methods, and weather conditions (Tables 3, 4). A similar effect of peeling on polyphenol content was observed by Mondy and Gosselin [21], Pirjo and Jarkko [22], and Reyes et al. [23]. Friedman [24] reported that phenolic compounds usually accumulated in potato peel and serve as a defense against pathogens.

The consumption of phenolic compounds in Poland is not well known yet. There are many products on the market that can supply them. The potential sources in our diet can be potatoes, *Brassica* vegetables, coffee, tea, apples, and beer [5].

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