THE IMPACT OF HERBICIDES AND THEIR MIXTURES ON THE CONTENT OF POLYPHENOLS IN EDIBLE POTATO TUBERS

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Abstract. The aim of the study was to determine the influence of applied herbicides and their mixtures on the polyphenol content in tubers of three edible potato varieties. The field experiment was conducted in the years of 2008-2010 in the Agricultural Experimental Station Zawady (52°03'N and 22°33'E) belonging to the University of Natural Sciences and Humanities in Siedlce, Poland. The experiment was established as two-factor in the split-plot system in three repetitions. The studied factors included: I – three varieties: Cekin, Satina and Tajfun. II – five ways of care: 1. mechanical care – control object, 2. mechanical-chemical care - mechanical care + Command 480 EC (chlomazon 480 g·l), 3. mechanical-chemical care - mechanical care + Command 480 EC (chlomazon 480 g·l) + Dispersion Afalon 450 SC (linuron 450 g·l), 4. mechanical-chemical care - mechanical care + Stomp 400 SC (pendimethalin 400 g· l), 5. mechanical-chemical care - mechanical care + Stomp 400 SC (pendimethalin 400 g· l) + Dispersion Afalon 450 SC (linuron 450 g·l). Polyphenols were determined in a fresh mass of potato tubers using the Swain and Hillis method using the Folin-Ciocalteu reagent. The results of the research were statistically analysed using the analysis of variance. The conducted own studies showed that the polyphenol content in potato tubers was on the level from 155.8 to 162.5 mg·kg^{-1} of fresh weight and depended significantly on the variety cultivated. Also the herbicides and their mixtures used in the experiment had a significant influence on the concentration of polyphenols in tubers, causing them to increase (from 2.2 to 6.0 mg·kg^{-1} of fresh weight) in relation to the control object that was cultivated only mechanically. In addition, meteorological conditions significantly modified the accumulation of polyphenols. Their smallest (on average-50.5 mg·kg^{-1}) content in potato tubers was obtained in 2009 with the smallest sum of precipitation in the examined three-year period and the average air temperature of 15.1 °C.
Keywords: *potato, phenols, methods of care, variety, antioxidants*

Introduction

For many years, it was believed that polyphenols are anti-nutritious substances, however, currently the importance of this group of compounds as active food components is significantly increasing, due to the recent studies on their pro-health effects on the human body (Gumul et al., 2005).

Polyphenols occur in various plant species, have a diversified structure, molecular weight, physical, biological and chemical properties and have a multidirectional effect on food, on the one hand, they shape the taste and colour, and on the other, they show

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antioxidant activity, stabilizing fats and other labile food components (Jaszka et al., 2010; Perla et al., 2012; Rytel et al., 2014).

Polyphenols are one of the largest groups of antioxidants. They include over 8000 identified substances and are considered the most numerous antioxidants in our diet (Ross and Kasum, 2002; Manach et al., 2004).

The studies of many authors (Chun et al., 2005; Mattila and Hellström, 2007; Navarre et al., 2009; Ezekiel et al., 2013) show that potatoes are the most important source of polyphenols, after apples and oranges, which contain on average - 160 $mg \cdot kg^{-1}$ of fresh weight.

Many studies show that the chemical composition of potato tubers is modified by genotype, agrotechnical measures and atmospheric conditions during the growing season. Therefore, the purpose of these studies was to determine the effect of the herbicides used and their mixtures on the polyphenol content in tubers of three edible potato varieties.

Material and methods

The field experiment was conducted in the years of 2008-2010 in the Agricultural Experimental Station Zawady (52°03'N and 22°33'E) belonging to the University of Natural Sciences and Humanities in Siedlce, Poland. The experiment was established as two-factor in the split-plot system in three repetitions.

The studied factors included:

I – three varieties: Cekin, Satina and Tajfun.

II – five ways of care:

1. mechanical care – control object,
2. mechanical-chemical care, i.e., until the emergence hilling combined with harrowing, and about 7 days before the emergence the herbicide Command 480 EC (chlomazon 480 g·l) in a dose 0.2 $l \cdot ha^{-1}$,
3. mechanical-chemical care, i.e. until the emergence hilling combined with harrowing, and about 7 days before the emergence spraying with a mixture of herbicides Command 480 EC (chlomazon 480 g·l) in a dose 0.2 $l \cdot ha^{-1}$ + Dispersion Afalon 450 SC (linuron 450 g·l) in a dose 1.0 $l \cdot ha^{-1}$,
4. mechanical-chemical care, i.e., until the emergence hilling combined with hailing, and about 7 days before the emergence herbicide Stomp 400 SC (pendimethalin 400 g·l) in a dose 3.5 $l \cdot ha^{-1}$,
5. mechanical-chemical care, i.e., until the emergence hilling combined with hailing, and about 7 days before the emergence spraying with a mixture of herbicides Stomp 400 SC (pendimethalin 400 g·l) in a dose 3.5 $l \cdot ha^{-1}$ + Dispersion Afalon 450 SC (linuron 450 g·l) in a dose 1.0 $l \cdot ha^{-1}$.

The field experiment was established on soil classified to the department – autogenous soils, order – brown-ground soils, type – Luvisols made of light clay sands and strong loamy sands, the gradin class of IVa and IVb in terms of agricultural suitability classified as a very good rye complex. This soil was characterised by a slightly acid reaction, very high abundance of phosphorus, high abundance of potassium and the average wealth of magnesium. A potato was grown in the position after winter cereals. The experiment used the permanent organic fertilisation with manure 25 $t \cdot ha^{-1}$ and the mineral one in quantities: 100 $kg \cdot ha^{-1}$ N, 100 $kg \cdot ha^{-1}$ P_20_5 and 150 $kg \cdot ha^{-1}$ K_20.

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Samples of potato tubers (50 tubers) were taken from plots during harvest and stored at 10-12 °C. Polyphenols were determined in a fresh mass of potato tubers using the Swain and Hillis methods with the Folin-Ciocalteu reagent (Swain and Hillis, 1959). The results of the research were statistically analysed during the analysis of variance. The significance of the sources of variation was tested by the "F" Fischer-Snedecor test, and the significance assessment of differences at the level of significance of p = 0.05 between the compared averages, using the multiple Tukey intervals.

Particular growing seasons during the studies were characterised by variable weather conditions (*Table 1*). The highest amount of rainfall was noted in the growing season in 2010 – 459.7 mm and the average air temperature was higher by 0.9 °C compared to the long-term average. The smallest amount of rainfall – 354.4 mm was noted in 2009, the average temperature was higher by 0.4 °C. The growing season 2008 was characterised by the rainfall at the level of 371.4 mm and the air temperature did not differ significantly from the long-term average 14.9 °C. According to the calculated hydrothermal coefficient of Sielianinow, the growing seasons of 2008, 2009 and 2010 were characterised by the lack of drought, however, the alternating months occurred with extreme conditions, from severe drought to the lack of drought.

Table 1. *Characteristic of weather conditions in the years 2008-2010 (Zawady Meteorological Station)*

Years	Months						
	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	49.8	43.0	47.3	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
	Sielianinow's hydrothermic coefficients*						**Mean**
2008	1.04	2.18	0.94	1.25	1.36	1.73	1.39
2009	0.26	1.72	3.08	0.44	1.48	0.57	1.28
2010	0.40	2.14	1.20	1.15	1.74	3.10	1.61

*Value of coefficients Sielianinovs (Bac et al., 1998): <0.5 strong drought; 0.51-0.69 mild; 0.70-0.99 weak pure drought; ≥1 fault drought

Results and discussion

A study by many authors (Al-Saikhan et al., 1995; Reddivari et al., 2007a; Hamouz et al., 2013; Murniece et al., 2013) shows that the polyphenol content in potato tubers varies in a wide range from 53.0 to 1098.0 $mg \cdot kg^{-1}$ of fresh weight and depends on both the genotype, agrotechnical factors and climatic conditions.

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The conducted own studies showed that the polyphenol content in potato tubers was on the level from 155.8 to 162.5 $mg \cdot kg^{-1}$ of fresh weight and depended significantly on the cultivar (*Table 2*). The highest amount of the discussed component was accumulated by the Satina variety – an average of 162.5 $mg \cdot kg^{-1}$, significantly less in Tajfun – an average of 158.1 $mg \cdot kg^{-1}$, which was confirmed in the studies of Reddivari et al. (2007b), Hamouza et al. (2010); Wierzbicka et al. (2015) and in the earlier studies by Gugała et al. (2017). In their opinion, the content of phenolic compounds in tubers depends mainly on the variety.

Table 2. *Content of polyphenols in potato tubers depending on the cultivar ($mg \cdot kg^{-1}$ fresh matter)*

Experimental factors	Cultivars			Mean
	Cekin	Satina	Tajfun	
1. Mechanical care – control object	152.5	160.3	153.2	155.3
2. Mechanical care + Command 480 EC (chlomazon 480 g·l)	154.7	161.2	156.4	157.5
3. Mechanical care + Command 480 EC (chlomazon 480 g·l) + Dispersion Afalon 450 SC (linuron 450 g·l)	156.8	164.2	160.2	160.3
4. Mechanical care + Stomp 400 SC (pendimethalin 400 g·l)	156.8	162.9	158.8	159.5
5. Mechanical care + Stomp 400 SC (pendimethalin 400 g·l) + Dispersion Afalon 450 SC (linuron 450 g·l)	158.3	163.8	161.9	161.3
Mean	155.9	162.5	158.1	-

$LSD_{0,05}$ - for: cultivars – 1.5; weed control methods – 2.1; interaction: cultivars x weed control methods - non-significant

The herbicides and their mixtures used in the experiment significantly influenced the concentration of polyphenols in tubers, causing them to increase (from 2.2 to 6.0 $mg \cdot kg^{-1}$ of fresh weight) in relation to the control object that was cultivated only mechanically (*Tables 2* and *3*). The highest concentration of the discussed component on average – 161.3 $mg \cdot kg^{-1}$ of fresh weight was noted on object 5, where the mixture of Stomp 400 SC (pendimethalin 400 g·l) + Dispersion Afalon 450 SC (linuron 450 g·l) herbicides was used and 3. (on average – 160.3 $mg \cdot kg^{-1}$ d.w.), sprayed with the mixture of Command 480 EC (chlomazon 480 g·l) + Dispersion Afalon 450 SC (linuron 450 g·l) herbicides. Also, in their earlier studies, Zarzecka and Gugała (2011) showed that under the influence of herbicides and their mixtures (Plateen 41.5, WG Plateen 41.5 WG + Fusilade Forte, Barox 400 SL, Barox 400 SL + Fusilade Forte), the discussed component increased. Similar changes were noted by Mickovski et al. (1984) using the Patoran herbicide with other preparations in tobacco cultivation. Hamouz et al. (2013) cultivating potatoes according to ecological and conventional methods obtained ambiguous results regarding the content of polyphenols. While Chauhan et al. (2013) after the application of the imidacloprid insecticide in potatoes noted a reduction in polyphenol content.

Meteorological conditions in the years of conducting the research significantly modified the accumulation of polyphenols (*Table 3*). It was found that their smallest (on average 150.5 $mg \cdot kg^{-1}$) content in potato tubers was obtained in 2009 with the smallest sum of precipitation in the examined three year period and the average air temperature of 15.1 °C. While the highest content, on average – 163.5 $mg \cdot kg^{-1}$ of fresh weight was obtained in the growing season of 2010, which was characterized by the highest rainfall

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and the highest air temperature. The influence of climatic conditions on this feature was also observed in own studied by Reddivari et al. (2007a, b), Zarzecka and Gugała (2011) and Hamouz et al. (2013).

Table 3. *Content of polyphenols in potato tubers depending on years of research [mg·kg^{-1} fresh matter]*

Experimental factors	Years			Mean
	2008	2009	2010	
1. Mechanical care – control object	159.0	147.6	159.4	155.3
2. Mechanical care + Command 480 EC (chlomazon 480 g·l)	161.2	148.6	162.6	157.5
3. Mechanical care + Command 480 EC (chlomazon 480 g·l) + Dispersion Afalon 450 SC (linuron 450 g·l)	164.3	150.4	166.6	160.3
4. Mechanical care + Stomp 400 SC (pendimethalin 400 g·l)	162.9	152.1	163.4	159.5
5. Mechanical care + Stomp 400 SC (pendimethalin 400 g·l) + Dispersion Afalon 450 SC (linuron 450 g·l)	164.4	153.7	165.9	161.3
Mean	162.4	150.5	163.5	-

$LSD_{0,05}$ - for: years – 1.5; weed control methods – 2.1; interaction: years x weed control methods - non-significant

No interaction was found between the years and methods of using herbicides and the varieties and ways of applying herbicides on the polyphenol content in potato tubers.

Conclusions

1. The cultivars accumulated a different amount of phenolic compounds in tubers. The Satina variety has accumulated the most of this component, while Tajfun the least.
2. The herbicides and their mixtures used in the study significantly increased the content of polyphenols in potato tubers.
3. The content of polyphenols in potato tubers depended on the weather conditions during the potato growing season.

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