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The effect of herbicides and their mixtures and weather conditions on the content of vitamin C in edible potato tubers

Wpływ herbicydów i ich mieszanin na zawartość witaminy C
w bulwach ziemniaka jadalnego

Summary. The aim of the research was to determine the effect of the herbicides and their mixtures and weather conditions on the content of vitamin C in tubers of three edible potato cultivars. A field experiment was conducted from 2008 to 2010 at the Zawady Experimental Farm (52°03'N and 22°33'E) belonging to Siedlce University of Natural Sciences and Humanities. The experiment was established as a two-factorial split-plot arrangement with three replicates. The experimental factors included: I – three edible potato cultivars: 'Cekin', 'Satina' and 'Tajfun'; II – five weed control methods: 1. mechanical weed control only – control, 2. mechanical and chemical control – mechanical control + Command 480 EC (clomazone 480 g·dm^{-3}), 3. mechanical and chemical control – mechanical control + Command 480 EC (clomazone 480 g·dm^{-3}) + Dispersion Afalon 450 SC (linuron 450 g·dm^{-3}), 4. mechanical and chemical control – mechanical control + Stomp 400 SC (pendimethalin 400 g·dm^{-3}), 5. mechanical and chemical control – mechanical control + Stomp 400 SC (pendimethalin 400 g·dm^{-3}) + Dispersion Afalon 450 SC (linuron 450 g·dm^{-3}). Research results were statistically analysed using analysis of variance. The research demonstrated that vitamin C content in potato tubers ranged from 207.5 to 215.8 mg·kg^{-1} fresh matter and was significantly affected by cultivars. The examined herbicides and their mixtures significantly affected the potato tuber content of vitamin C, which increased from 3.3 to 10.4 mg·kg^{-1}, on average, compared with control where only mechanical control had been used. The effect of care methods on the content of vitamin C was dependent on the genetic factor. In the 'Santina' and 'Tajfun' cultivars, the highest content was obtained due to the care with herbicides Stomp 400 SC and Dispersion Afalon 450 SC, while in the 'Cekin' cultivar, it was the same on all objects regardless of the care used. Moreover, meteorological conditions significantly influenced the vitamin C accumulation. The lowest vitamin C content was recorded in the final study year, when the highest annual rainfall sum was accompanied by the air temperature averaging 15.6°C.

Key words: ascorbic acid, *Solanum tuberosum* L., genotype, mechanical-chemical care

INTRODUCTION

According to many authors, potatoes are a natural source of antioxidants, and display antioxidative activity [Lachman et al. 2000, Nara et al. 2006]. Potato tubers intended for direct consumption (except for dry matter and starch) for processing into food products should contain appropriate concentration of total sugars, reducing sugars and vitamin [Sądej et al. 2004].

Mazid et al. [2010] as well as Janda et al. [2015] emphasise the fact that, due to antioxidative properties, ascorbic acid protects cells of the body against oxidative stress.

Leszczyński [2012] claims that 200 g potatoes provide the human body with about 50% vitamin C it needs daily. The concentration of ascorbic acid in tuber fresh matter ranges from 140.0 to 300.0 $mg \cdot kg^{-1}$ and is one of major qualitative characteristics taken into account when evaluating table potato cultivars. The quality of tubers is affected by the chemical composition, which is differentiated by the impact of the genetic factor, environmental conditions and agrotechnical measures. According to Correia et al. [2010], and Kołodziejczyk [2013] these factors affect the metabolism of the plant, causing the chemical composition of tubers to shape.

An application of herbicides to control weeds in potato reduces the negative influence of weeds, but it can also affect changes in tuber chemical composition, including vitamin C. The aim of the research was to determine the effect of the herbicides and their mixtures and the weather conditions on the content of vitamin C in tubers of three edible potato cultivars.

MATERIALS AND METHODS

A field experiment was conducted from 2008 to 2010 at the Zawady Experimental Farm (52º03'N and 22º33'E) belonging to Siedlce University of Natural Sciences and Humanities. The experiment was set up as a two-factorial split-plot arrangement with three replicates.

The experimental factors were as follows:

I – three table potato cultivars: 'Cekin', 'Satina' and 'Tajfun',

II – five weed control methods:

– mechanical weed control which served as control, to the emergence ditching two or three times combined with harrowing, one time ditching after the emergence and before densing the inter-rows.

– mechanical and chemical control, i.e., until the emergence hilling combined with harrowing, and about 7 days before the emergence the herbicide Command 480 EC (clomazone 480 $g \cdot dm^{-3}$) at the rate of 0.2 $dm^3 \cdot ha^{-1}$,

– mechanical and chemical control, i.e. until the emergence hilling combined with harrowing, and about 7 days before the emergence spraying with a mixture of the herbicides Command 480 EC (clomazone 480 $g \cdot dm^{-3}$) at the rate of 0.2 $dm^3 \cdot ha^{-1}$ + Dispersion Afalon 450 SC (linuron 450 $g \cdot dm^{-3}$) at the rate of 1.0 $dm^3 \cdot ha^{-1}$,

– mechanical and chemical control, i.e., until the emergence hilling combined with hailing, and, about 7 days before the emergence, the herbicide Stomp 400 SC (pendimethalin 400 $g \cdot dm^{-3}$) at the rate of 3.5 $dm^3 \cdot ha^{-1}$,

– mechanical and chemical control, i.e., until the emergence hilling combined with hailing, and, about 7 days before the emergence, spraying with a mixture of the herbicides Stomp 400 SC (pendimethalin 400 g·dm^{-3}) at the rate of 3.5 dm^3·ha^{-1} + Dispersion Afalon 450 SC (linuron 450 g·dm^{-3}) at the rate of 1.0 dm^3·ha^{-1}.

Soil and weather conditions

The field experiment was established on soil represents the department – autogenous soils, order – brown-ground soils, type – Luvisols made of light clay sands and strong loamy sands, quality class IVa and IVb classified as a rye very good complex of agricultural suitability. The soil was characterised by a slightly acid reaction, and had a very high phosphorus content, high potassium content and average magnesium content. The winter triticale was the forecrop in all the research years. Farmyard manure was applied at the rate of 25 t·ha^{-1}, and the rates of mineral fertiliser were as follows: 100 kg N · ha^{-1}, 100 kg P_2O_5 · ha^{-1} and 150 kg K_2O · ha^{-1}.

The individual study years were characterised by changeable weather conditions (Tab. 1). The highest rainfall was recorded in the 2010 growing season (459.7 mm) when the average air temperature was by 0.9°C higher compared with the long-term

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

Years	Month						
	IV	V	VI	VII	VIII	IX	IV-IX
Rainfall (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
Long-term 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
Long-term average (1987–2000)	7.8	12.5	17.2	19.2	18.5	13.1	14.7
Sielianinov'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

* The value of the Sielianinov's coefficient [Skowera 2014]: extremely dry $k \leq 0.4$, very dry $0.4 < k \leq 0.7$, dry $0.7 < k \leq 1.0$, rather dry $1.0 < k \leq 1.3$, optimal $1.3 < k \leq 1.6$, rather humid $1.6 < k \leq 2.0$, humid $2.0 < k \leq 2.5$, very humid $2.5 < k \leq 3.0$, extremely humid $k > 3.0$

mean. The year 2009 received the lowest rainfall (354.4 mm) and had the average temperature by 0.4°C higher than the long-term mean. The rainfall in the 2008 growing season was at the level of 371.4 mm and the average air temperature was close to the long-term mean (14.9°C). Based on the calculated Sielianinov hydrothermal coefficient, the first year of the study was optimal (K = 1.39). May was the most humid month in this season (K = 2.18). The second year of research was quite dry (K = 1.28). April was extremely dry, May was moderately humid, June was extremely humid, July and September quite dry, while in August there were optimal atmospheric conditions. In the last year of research, the coefficient value was the highest and amounted to K = 1.61. It was a moderately humid year.

Statistical analysis

Potato tuber samples (50 tubers) were collected from plots during harvest and stored at 10–12°C. Tubers from the harvest to the analysis for the content of vitamin C were stored for 7 days. Vitamin C content was determined by means of Tillman's method as modified by Pijanowski et al. [1964]. This method is based on the extraction of the sample with oxalic acid and titration of the resulting filtrate with 2,6-dichlorophenoloindophenol.

The research results were statistically analysed by means of analysis of variance. Significance of sources of variation was checked using the F test, and means were evaluated by Tukey's test at the significance level of p = 0.05 [Trętowski and Wójcik 1991].

Results and discussion

Based on our own studies, it was found that the content of vitamin C in potato tubers regardless of the weeding methods depended significantly on the genetic factor and was on average from 207.5 to 215.8 mg·kg^{-1} fresh matter (Tab. 2). The highest concentration of this vitamin was recorded for cv. Tajfun and the lowest for 'Cekin'. The diversity of vitamin C content in terms of the genetic factor was presented by Wierzbicka [2011]. According to the author, the most vitamin C among the eight tested cultivars was found in the 'Tajfun' tubers (254.0 mg·kg^{-1} of fresh weight). This finding corresponds to the values reported Wierzbicka [2011] who found the highest vitamin content for 'Tajfun'. Similarly, Hamouz et al. [2007] as well as Wichrowska and Pobereży [2008] claimed that vitamin C content in potato tubers was significantly affected by the genetic factor, and ranged from 158.5 to 201.0 mg·kg^{-1} fresh matter whereas the range reported by Barbaś and Sawicka [2015] was from 101.0 to 182.0 mg·kg^{-1} fresh matter, on average. Grudzińska and Zgórska [2011] reported that the minimum vitamin C content in tubers after harvest was 140.0 mg·kg^{-1}whereas the maximum value was 240.0 mg· kg^{-1}.

Herbicides and their mixtures applied in the experiment significantly influenced the concentration of vitamin C in table potato tubers, it being by 3.3-10.4 mg·kg^{-1} fresh matter higher compared with control units where only mechanical weed control had been used. (Tabs 2 and 3). The highest vitamin C content was found for treatment 5 where a mixture of Stomp 400 SC (pendimethalin 400 g·dm^{-3}) + Dispersion Afalon 450 SC (linuron 450 g·dm^{-3}) had been applied, and treatment 4 where mechanical weed control had been combined with an application of Stomp 400 SC (pendimethalin 400 g·dm^{-3}),

the respective average values being 216.6 and 213.9 mg·kg^{-1} fresh matter. Increasing the content of vitamin C in the tubers affected by herbicides was noted by Wichrowska and Pobereży [2008], the most positive effect being induced by the herbicide Azogard 50 WP. Sawicka and Kuś [2002] reported a significant increase in vitamin C content in potato tubers produced in an integrated versus organic production system. Contrasting results were obtained by Rytel et al. [2008] who claimed that, regardless of cultivar, organic potatoes had by around 20% higher vitamin C content compared with tubers of potato produced in the conventional and integrated farming system. Barbaś and Sawicka [2015] as well as Zarzecka et al. [2007] observed only a tendency for potatoes to accumulate more vitamin C when the herbicides Sencor 70 WG and Titus 25 WG had been applied after potato emergence. In turn, Laaniste et al. [1999] and Freitag et al. [2018] observed no increase in vitamin C due to an application of herbicides.

Table 2. Content of vitamine C in potato tubers depending on the cultivar and cultivars and weed control methods (mg·kg^{-1} fresh matter)

Experimental factors	Cultivars			Mean
	'Cekin'	'Satina'	'Tajfun'	
1. mechanical care – control object	203.2	204.4	210.9	206.2
2. mechanical care + Command 480 EC	206.9	208.8	212.9	209.5
3. mechanical care + Command 480 EC (chlomazon 480 g·dm^{-3}) + Dispersion Afalon 450 SC (linuron 450 g·dm^{-3})	208.8	211.8	214.4	211.7
4. mechanical care + Stomp 400 SC (pendimethalin 400 g·dm^{-3})	208.3	215.0	218.4	213.9
5. mechanical care + Stomp 400 SC (pendimethalin 400 g·dm^{-3}) + Dispersion Afalon 450 SC (linuron 450 g·dm^{-3})	210.0	217.4	222.1	216.6
Mean	207.5	211.5	215.8	–
$LSD_{0,05}$ for: cultivars – 2.0, weed control methods – 4.3, interaction: cultivars × weed control methods – 10.0				

An interaction between cultivars and weed control methods is indicative of the fact that the cultivars differently responded to the examined herbicides. The 'Cekin' cultivar had the same content of vitamin C in potato tubers on all objects, regardless of the applied mechanical and mechanical-chemical care. In the 'Santina' cultivar, the same value of this feature as in the control object was noted after the application of mechanical care and the Command 480 EC herbicide (object 2) and mechanical care with the Command 480 EC and Dispersion Afalon herbicide (object 3). Insignificant differences were noted between objects 3, 4 and 5. In the 'Santina' and 'Tajfun' cultivars, the most significant increase in vitamin C compared to the control variant was found in object 5 where mechanical care was applied as well as a mixture of herbicides Stomp 400 SC and Dispersion Afalon 450 SC. The 'Tajfun' cultivar was characterized by the same content of vitamin C on objects 1–4.

Table 3. Content of vitamine C potato tubers depending on years of research and years and weed control methods (mg·kg^{-1} fresh matter)

Experimental factors	Years			Mean
	2008	2009	2010	
1. mechanical care – control object	220.1	213.6	184.9	206.2
2. mechanical care + Command 480 EC (chlomazon 480 g·dm^{-3})	225.7	216.3	186.6	209.5
3. mechanical care + Command 480 EC (chlomazon 480 g·dm^{-3}) + Dispersion Afalon 450 SC (linuron 450 g·dm^{-3})	230.7	217.1	187.2	211.7
4. mechanical care + Stomp 400 SC (pendimethalin 400 g·dm^{-3})	236.4	218,0	187.3	213.9
5. mechanical care + Stomp 400 SC (pendimethalin 400 g·dm^{-3}) + Dispersion Afalon 450 SC (linuron 450 g·dm^{-3})	241.4	220.1	188.3	216.6
Mean	230.8	217.0	187.6	–
$LSD_{0,05}$ for: years – 2.0, weed control methods – 4.3, interaction: years × weed control methods – ns				

ns – non-significant

The research reported here demonstrated that climatic conditions in the study years significantly affected vitamin C in table potato tubers (Tab. 3), which is consistent with earlier studies by Gugała et al. [2012] as well as other authors [Barbaś and Sawicka 2015, Trawczyński [2016]. They demonstrated that evenly distributed rainfall and air temperatures which are higher than the long-term mean favourably affects the concentration of vitamin C in potato tubers. In the present work, the lowest vitamin C content (187.6 mg·kg^{-1}) was determined in 2010 when the annual precipitation sum was the highest of all the study years and the air temperature averaged 15.6°C. By contrast, Wierzbicka [2011] recorded the highest vitamin C content in the year with the wettest growing season.

Statistical analysis demonstrated no interaction of study years with weed control methods.

CONCLUSIONS

1. Table potato cultivars contained different amounts of vitamin C in their tubers. The highest concentration of this vitamin was found in ‘Tajfun’, it being the lowest in ‘Cekin’.

2. The use of chemical plant protection influenced the content of vitamin C in potato tubers. The most significant increase in its concentration compared to the control variant occurred after the use of a mixture of herbicides Stomp 400 SC and Dispersion Afalon 450 SC.

3. The influence of care methods on the content of vitamin C was dependent on the genetic factor. In the 'Santina' and 'Tajfun' cultivar, the highest content was obtained in the care with herbicides Stomp 400 SC and Dispersion Afalon 450 SC, while in the 'Cekin' cultivar it was the same on all objects regardless of the applied care.

4. Vitamin C content in tubers was affected by weather conditions prevailing during the growing season of table potato. The lowest content of vitamin C was obtained in the last year of the study, which was moderately humid, and the highest in the first optimal growing season.

REFERENCES

Barbaś P., Sawicka B., 2015. The content of vitamin C in potato tubers depending on different methods of potato production. Biul. IHAR, 278, 39–48.

Correia M., Barroso A., Barroso M., Soares D., Oliveira M.B., Delerue-Matos C., 2010. Contribution of different vegetable types to exogenous nitrate and nitrite exposure. Food Chem. 120, 960–966.

Freitag S., Verrall S.R., Pont S.D.A., McRae D., Sungurtas J.A., Palau R., Hawes C., Alexander C.J., Allwood J.W., Foito A., Stewart D., Shepherd L.V.T., 2018. Impact of conventional and integrated management systems on the water-soluble vitamin content in potatoes, field beans, and cereals. J. Agric. Food Chem. 66(4), 831–841, DOI: 10.1021/acs.jafc.7b03509

Grudzińska M., Zgórska K., 2011. Zmiany zawartości witaminy C (kwasu L-askorbinowego) i związków fenolowych w czasie przechowywania bulw ziemniaka. Zesz. Probl. Post. Nauk Rol. 566, 61–68.

Gugała M., Zarzecka K., Dołęga H., Baranowska A., 2012. Effectiveness of herbicides in potato cultivation. Annales UMCS, sec. E, Agricultura, 67(4), 45–51.

Hamouz K., Lachman J., Dvořák P., Dušková O., Čížek M., 2007. Effect of conditions of locality, variety and fertilization on the content of ascorbic acid in potato tubers. Plant Soil Environ. 53(6), 252–257.

Janda K., Kasprzak M., Wolska J., 2015. Vitamin C – structure, properties, occurrence and functions. Pom. J. Life Sci. 61(4), 419–425.

Kołodziejczyk M., 2013. Fenotypowa zmienność plonowania, składu chemicznego oraz wybranych cech jakości bulw średnio późnych i późnych odmian ziemniaka jadalnego. Acta Agrophys. 20(3), 411–422.

Laaniste P., Joudu J., Lohmus A., Jeremejev V., 1999. Mechanical and chemical weed control influence to the potato weediness, yield and quality. Trans. Estonian Agric. Univ. 203, 106–110.

Lachman J., Hamouz K., Orsák M., Pivec V., 2000. Potato tubers as a significant source of antioxidants in human nutrition. Rostl. Výr. 46, 231–236.

Leszczyński W., 2012. Nutrition value of potato and potato products (Review of literature). Biul. IHAR 266, 5–20.

Mazid M., Ali B., Hayat S., Ahmad A., 2010. The effect of 4-chloroindole-3-acetic acid on some growth parameters in mung bean under cadmium stress. Turk. J. Biol. 34, 9–13.

Nara K., Miyoshi T., Honma T., Koga H., 2006. Antioxidative activity of bound-form phenolics in potato peel. Biosci. Biotech. Biochem. 70, 1489–1491.

Pijanowski E., Mrożewski S., Horubała A., 1964. Technologia produktów owocowych i warzywnych [Technology of fruit and vegetable products]. PZWiL, Warszawa, 1–634.

Rytel E., Lisińska G., Kozicka-Pytlarz M., 2008. Wpływ sposobu uprawy na jakość konsumpcyjną ziemniaka [The effect of cultivation methods on the quality of potato]. Zesz. Probl. Post. Nauk Rol. 530, 259–269.

Sawicka B., Kuś J., 2002. Variability chemical composition of potato tubers using ecological and integrated production system. Zesz. Probl. Post. Nauk Rol. 489, 273–282.

Sądej W., Przekwas K., Bartoszewicz J., 2004. Zmienność plonu i składu chemicznego bulw ziemniaka w warunkach zróżnicowanego wieloletniego nawożenia. Annales UMCS, sec. E, Agricultura 59(1), 83–92.

Skowera B., 2014. Zmiany warunków hydrotermicznych na obszarze Polski (1971−2010). Fragm. Agron. 31(2), 74–87.

Trawczyński C., 2016. Wpływ odmiany i warunków pogodowych okresu wegetacji na zawartość wybranych składników odżywczych i antyżywieniowych w bulwach ziemniaka [The influence of cultivars and weather conditions of vegetation period on the content of some nutritional and anti-nutritional components in potato tubers]. Acta Agrophys. 23(1), 119–128.

Trętowski J., Wójcik R., 1991. Metodyka doświadczeń rolniczych [Methodology of agricultural experiments]. Wyższa Szkoła Rolniczo-Pedagogiczna, Siedlce, 1–500.

Wichrowska D., Poberężny J., 2008. Wpływ wybranych czynników na zawartość witaminy C w bulwach ziemniaka [The effect of chosen factors on vitamin C content in potato tubers]. Ekol. Techn. 16(2), 60–63.

Wierzbicka A., 2011. Some quality characteristics of potato tubers grown in the ecological system depending on irrigation. J. Res. Appl in Agri. Eng. 56(4), 203–207.

Zarzecka K., Gugała M., Mystkowska I., 2007. Zawartość kwasu askorbinowego w bulwach ziemniaka odmiany jadalnej Wiking w zależności od sposobów uprawy roli i herbicydów [The ascorbic acid content in table cultivar Wiking of potato tubers depending on soil tillage systems and herbicides]. Żywn. Nauka Technol. Jakość 2(51), 112–119.

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Streszczenie. Celem badań było określenie wpływu stosowanych herbicydów i ich mieszanin na zawartość witaminy C w bulwach trzech odmian ziemniaka jadalnego. Badania polowe zrealizowano w latach 2008–2010 w Rolniczej Stacji Doświadczalnej – Zawady (52°03'N. 22°33'E) należącej do Uniwersytetu Przyrodniczo-Humanistycznego w Siedlcach. Doświadczenie polowe założono w układzie losowych podbloków (split-plot) w trzech powtórzeniach. Badanymi czynnikami były: I – trzy odmiany ziemniaka: 'Cekin', 'Satina' and 'Tajfun'; II – pięć sposobów pielęgnacji: 1. pielęgnacja mechaniczna – obiekt kontrolny, 2. mechaniczno-chemiczna pielęgnacja – pielegnacja mechaniczna + Command 480 EC (chlomazon 480 g·dm^{-3}), 3. mechaniczno-chemiczna pielęgnacja – pielegnacja mechaniczna + Command 480 EC (chlomazon 480 g·dm^{-3}) + Dispersion Afalon 450 SC (linuron 450 g·dm^{-3}), 4. mechaniczno-chemiczna pielęgnacja – pielegnacja mechaniczna + Stomp 400 SC (pendimethalin 400 g·dm^{-3}), 5. mechaniczno-chemiczna pielęgnacja – pielegnacja mechaniczna + Stomp 400 SC (pendimethalin 400 g·dm^{-3}) + Dispersion Afalon 450 SC (linuron 450 g·dm^{-3}). Wyniki badań opracowano statystycznie za pomocą analizy wariancji. Przeprowadzone badania własne wykazały, że zawartość witaminy C w bulwach ziemniaka kształtowała się na poziomie od 207.5 do 215.8 mg·kg^{-1} świeżej masy i zależała istotnie od uprawianej odmiany. Stosowane w doświadczeniu herbicydy i ich mieszaniny istotnie wpłynęły na koncentrację witaminy C w bulwach, powodując ich zwiększenie średnio od 3.3 do 10.4 mg·kg^{-1} świeżej masy w stosunku do obiektu kontrolnego pielęgnowanego wyłącznie mechanicznie. Ponadto warunki meteorologiczne w istotny sposób modyfikowały akumulację witaminy C. Najmniejszą (średnio 186.9 mg·kg^{-1}) zawartość witaminy C otrzymano w ostatnim roku badań wyróżniającym się największą roczną sumą opadów w badanym trzyleciu i średnią temperaturą powietrza wynoszącą 15.6°C.

Słowa kluczowe: witamina C, ziemniak, odmiana, sposoby pielęgnacji

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