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The effect of foliar fertilization on darkening of tuber flesh of selected potato cultivars

Wpływ nawożenia dolistnego na ciemnienie miąższu bulw wybranych odmian ziemniaka

Summary. The aim of the study was to determine the effect of foliar fertilizers with the content of macro- and microelements used in the form of chelates on darkening of the tuber flesh of selected potato cultivars. The research was based on a 3-year (2013–2015) field experiment carried out in Haczów (49°40'N, 21°54'E) on brown, slightly acidic soil. The experiment was based on the method of randomized sub-blocks, where the first order factor was foliar fertilization: Fortis Zn Mn + Fortis Aminotop (A), Fortis B Mo + Ferti Agro (B), Fortis Zn Mn + Fortis B Mo (C) and a standard object without foliar fertilization (0). Second-order factor included four edible potato cultivars of all earliness classes (‘Viviana’, ‘Vineta’, ‘Agnes’, ‘Jelly’). Significant differences in tuber darkening due to foliar application were observed only for tubers 24 h after cooking. The application of Fortis B Mo + Ferti Agro and Fortis Duotop Zn Mn + Fortis Aminotop fertilizers reduced the darkening of the apical part tuber to the greatest extent. Genetic factor differentiated the most the value of all examined traits. The cultivars tested showed varied response to foliar fertilizers.

Key words: potato, foliar fertilization, flesh darkening

INTRODUCTION

Foliar fertilization is an alternative way to provide plants with the lacking macro- and micronutrients and the most effective way to supply plants with trace elements. It consists in sprinkling the leaves with a dilute solution of mineral salts or with chelate with the addition of a surface tension lowering agent [Mousavi et al. 2007, Villa et al. 2011, Singh et al. 2013, Trawczyński 2015]. Foliar fertilization allows the correction of poor nutritional status of plants [Fageria et al. 2009, Singh et al. 2013, Noaema 2018]. The most important function that foliar nutrition performs is intervention in supplementing the deficiency of ingredients during the growing season, caused by various reasons, including intensive plant development, drought, agrotechnical errors, etc. In the opinion of Szewczuk and Sugier [2009], plants absorb nutrients best during their intensive growth and development. The rate of absorption of chemicals applied to the leaves decreases with age of plants. Older leaves are not able to transfer nutrients after ripening [Sawicka and Krochmal-Marczak 2009]. Potatoes intended for direct consumption as well as for processing should have a slight darkening of cooked tuber flesh [Wang-Pruski and Nowak 2004, Zgórska 2012]. The increase in darkening intensity of cooked tubers under the influence of fertilization should prompt potato producers to limit its size or rationally divide doses of fertilizers, especially nitrogen. Hence, the purpose of the research was to determine the effect of foliar fertilizers with the content of macro- and microelements used in the form of chelates on darkening of the tuber flesh of the examined potato cultivars.

MATERIAL AND METHODS

The research was based on a 3-year field experiment carried out in Haczów (49°40'N, 21°54'E), on brown, slightly acidic soil. The experiment applied the method of randomized sub-blocks, in a dependent, split-plot system, where the first order factors were foliar fertilizers: Fortis Zn Mn + Fortis Aminotop (A), Fortis B Mo + Ferti Agro (B), Fortis Zn Mn + Fortis B Mo (C) and a standard object (0) without foliar fertilization, while the second order factors were potato cultivars from different classes of earliness (‘Viviana’ – very early, ‘Vineta’ – early, ‘Agnes’ – medium early and ‘Jelly’ – medium late). Characteristics of applied foliar fertilizers have been presented in Table 1.

In autumn, manure fertilization was applied for the entire fertilization at a dose of 25 $t \cdot ha^{-1}$ and phosphorus-potassium fertilization in the amount of 44 kg P and 124 kg $K \cdot ha^{-1}$. In spring, nitrogen fertilization was applied in a single dose, in an amount of 80 kg $N \cdot ha^{-1}$ – in the form of urea. Seedling material in C/A class was planted at the end of April, at a spacing of 70 × 38 cm. Foliar fertilizers were used from the end of May (phase BBCH 29). Depending on the combination of fertilizers used, they were applied at the beginning and the end of June and beginning, mid and end of July.

The tubers were harvested during technical maturity, at the end of August (very early and early cultivars) and in the mid of September (medium early and medium late cultivars). The assessment of darkening of raw and cooked tubers was carried out on 10 randomly selected tubers from each plot. To assess the degree of darkening of potato tuber flesh, a 9° color scale was used, in which 9 – unchanged color, and 1 – the strongest darkening. Evaluation for raw tubers was made 10 min and 4 h after cutting the tubers, and for cooked tubers – 10 min and 24 h after cooking [Roztropowicz 1999]. Obtained test results were subjected to analysis of variance (ANOVA) and multiple t-Tukey tests, at $p = 0.05$ significance level.

Table 1. Characteristics of applied foliar fertilizers

Fertilizer name	Fertilizer composition	Application
Ferti Agro	nitrogen – 10%, phosphorus – 45%, potassium – 5%, boron – 0.05%, copper – 0.1%, iron – 0.05%, manganese – 0.1%, zinc – 0.4%, magnesium – 2%, sulphur – 8.0%, molybdenum – 0.01%, amino acids, vitamins	3 kg·ha^{-1}, four times every 7 days, starting from the development phase of the lateral shoots
Fortis Aminotop	9% organic nitrogen, amino acid, soluble, aspartic acid – 0.46%, glutamic acid – 3.50%, serine – 0.21%, histidine – 0.04%, glycine – 4.16%, threonine – 0.04%, alanine – 1,71%, arginine – 0.11%, tyrosine – 0.47%, valine – 0.09%, methionine – 0.06%, phenylalanine – 0.24%, isoleucine – 0.28%, leucine – 0.29%, lysine – 0.23%, hydroxypoline – 0.77%, proline – 1.36%	2–3 dm^3·ha^{-1}, four times, from the moment when the plant reaches the height of 15–20 cm, every 10–15 days
Fortis B Mo	boron – 11%, molybdenum – 0.37%.	1–1.5 dm^3·ha^{-1}, twice: the first dose in a period from formation of shoots to shortening of rows, the second dose – during the formation of tubers and inflorescences.
Fortis Duotop Zn Mn	zinc – 7.1%, manganese – 5.1%, copper – 0.033%, boron – 0.024%, molybdenum – 0.003%, magnesium – 0.2%	2–3 dm^3·ha^{-1}, twice: in the phase of 10–15 cm plant growth and 15 days later

Meteorological conditions in the years of research varied. The year 2013 was characterized by dry summer, but very wet in September, excess rainfall was recorded in 2014, while 2015 was marked by a significant rainfall shortage during the potato growing season. The year 2013 was characterized by very dry July and August, during the period of maximum tuber yield accumulation. The average temperature in the third decade of April, when the potatoes were planted, was high, at 15°C. Relatively high temperatures in the last decade of April and May favored rapid potato growth. The distribution of temperatures in the vegetation period in 2014 favored the potato development. Average temperatures showed a slight deviation from the multi-year average. In 2015, the months of June and July were dry, and August – extremely dry. However, May was a very wet month, and in September precipitation exceeded the long-term standard. In August, the average air temperature was 2.2°C higher than the multi-year average, which had an impact not only on the size, but also on the quality of yield (Fig 1).

Fertility of studied soil in available phosphorus and potassium was average, in magnesium – very high, and in copper, manganese, iron and zinc – also average. Humus content in the arable layer was high and averaged 2.66%. The soil was slightly acidic (Tab. 2).

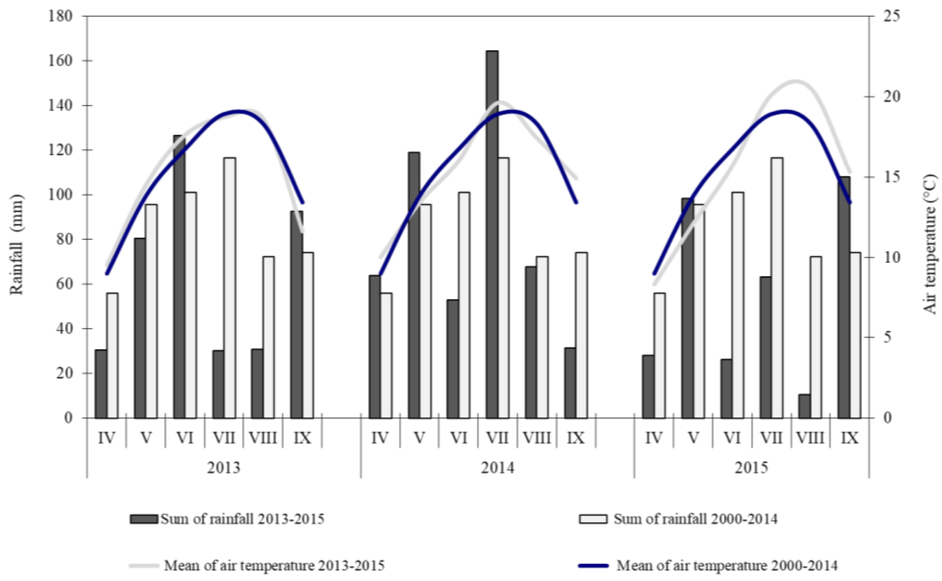

Fig. 1. Rainfall and air temperature in the potato vegetation season in the years 2013–2015, against the average annual rainfalls and air temperature in the years 2000–2014, according to data of the Hydrographic and Meteorological Station IMGW-PIB in Krosno

Table 2. Physical and chemical properties of soil in Haczów (2013–2015)

Years	Content of assimilable macronutrients ($mg \cdot kg^{-1}$ of soil)			$CaCO_3$ ($g \cdot kg^{-1}$)	Humus ($g \cdot kg^{-1}$)	pH (KCl)	Micronutrients content ($mg \cdot kg^{-1}$ of soil)			
	P	K	Mg				Cu	Mn	Zn	Fe
2013	55.0	166.0	197.0	0.2	27.1	5.66	5.6	175	14.3	1591
2014	52.0	166.0	195.0	0.2	25.5	5.70	5.9	174	14.5	1575
2015	55.0	168.0	199.0	0.1	27.2	5.70	5.3	175	14.4	1589
Mean	54.0	167.0	197.0	0.2	26.6	5.69	5.6	174.8	14.4	1585.0

RESULTS

Darkening of raw tuber flesh assessed 10 min after cutting was 8.87° on a 9° scale, and 4 h after cutting, the pulp darkened by about 1.1° (Tab. 3).

The application of foliar fertilizers in the case of evaluation of tuber flesh darkening 10 min after cutting, did not have any significant impact on the value of this feature, and the assessment made 4 h after sectioning showed that there is an increased darkening of raw tuber flesh originating from objects, on which foliar preparations Fortis Duotop Zn Mn + Fortis B Mo were applied. Other objects with foliar fertilization did not differ significantly from the standard one and were in the same homogeneous group due to the value of this trait (Tab. 3).

Table 3. Darkening of raw potato tubers flesh (scale 9°)

Experimental factors		The darkening of the raw tuber flesh	
		after 10 min	after 4 h
Fertlization*	0	8.88a	7.78a
	A	8.88a	7.78a
	B	8.87a	7.76a
	C	8.86a	7.59b
	HSD $_{0.05}$	ns **	0.04
Cultivars	‘Agnes’	8.82b	7.80b
	‘Jelly’	9.00a	8.58a
	‘Viviana’	8.83b	6.82d
	‘Vineta’	8.84b	7.71c
	HSD $_{0.05}$	0.03	0.04
Years	2013	8.85b	7.66c
	2014	8.86b	7.71b
	2015	8.91a	7.81a
	HSD $_{0.05}$	0.02	0.03
Mean		8.87	7.73
RSD (%)		0.50	0.85

* 0 – Standard object without foliar fertilization; A – Fortis Duotop Zn Mn + Fortis Aminotop; B – Fortis B Mo + Ferti Agro; C – Fortis Duotop Zn Mn + Fortis B Mo; ** not significant at $p_{0.05}$; RSD – coefficient of variation; HSD – the smallest significant differences in the average

Cultivars proved to be the most determining factor in darkening of raw tuber flesh. The lightest flesh, 10 min after cutting, was characterized by a medium late ‘Jelly’ cv. The other cultivars had significantly darker flesh than ‘Jelly’ cv. and were homogeneous in this trait. After 4 h from cutting, darkening of the flesh of individual cultivars was more diverse. The brightest flesh stood out from the ‘Jelly’ cultivar, followed by ‘Agnes’ and ‘Vineta’, while the darkest flesh was from ‘Viviana’ (Tab. 3).

Meteorological conditions during the potato growing season also differentiated the darkening of tuber flesh. Ten min, as well as 4 h after cutting, the smallest darkening of the pulp was observed in 2015, which was favorable for the potato, while significantly larger in 2013, with extremely dry July and August, and wet June and September (Tab. 3).

In the case of darkening of the flesh assessed 4 h after cutting, significant interaction of cultivars and fertilization was found. The ‘Agnes’ cv. responded by an increase in tuber darkening due to the application of Fortis Duotop Zn Mn + Fortis Aminotop and Fortis Duotop Zn Mn + Fortis B Mo fertilizers (Fig. 2). In the ‘Jelly’ cv., an increase in tuber darkening was observed after the application of Fortis B Mo + Ferti Agro and Fortis Duotop Zn Mn + Fortis B Mo fertilizers. Raw tubers of ‘Viviana’ and ‘Vineta’ cultivars reacted by brightening the flesh to the application of Fortis Duotop Zn Mn + Fortis Aminotop and Fortis B Mo + Ferti Agro fertilizers. The application of Fortis Duotop Zn Mn + Fortis B Mo foliar fertilizers, in the case of the ‘Viviana’ cv., did not significantly affect the flesh darkening compared to the standard object, while in the ‘Vineta’ cv., it increased the degree of tuber flesh darkening (Fig. 2).

Regardless of the experimental factors, it was observed that the flesh of cooked tubers, both 10 min and 24 h after cooking, retained a lighter color in the apical part than in the stolon one. After 24 h, the pulp only slightly darkened, both in the apical and stolon areas (Tab. 4).

The application of foliar fertilizers did not differentiate between the darkening of the tuber flesh cooked after 10 min, both in the apical and in the stolon part. Significant differences caused by the use of foliar fertilization were observed only after 24 hfrom cooking. The application of Fortis B Mo + Ferti Agro and Fortis Duotop Zn Mn + Fortis Aminotop fertilizers reduced to the greatest extent the darkening of tubers in the apical part. In terms of this feature, these fertilizers proved to be homogeneous. Introduction of Fortis Duotop Zn Mn + Fortis B Mo fertilizers also contributed to reducing the darkening of the flesh of this part of tubers, but to significantly smaller extent than previous 2 applications. In the stolon part of the flesh, only the Fortis Duotop Zn Mn + Fortis Aminotop application limited the darkening of cooked tuber flesh compared to the standard combination. Other fertilizers applied on the potato plants were homogeneous due to the value of this trait (Tab. 4).

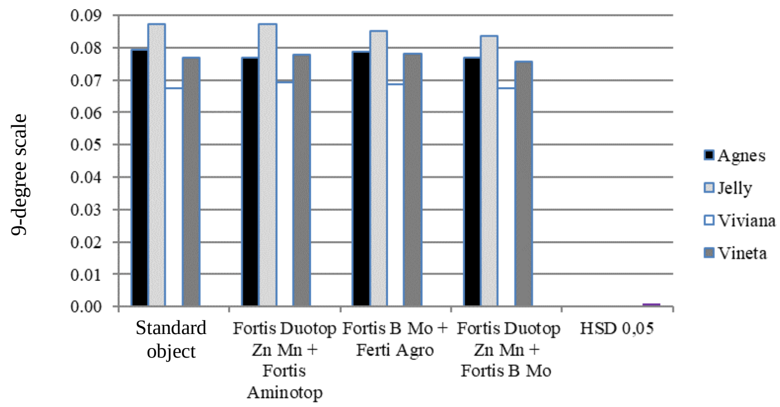

Fig. 2. Effect of fertilization and cultivars on the darkening of the raw tubers flesh after 4 h from the cut

Table 4. Darkening of the flesh of tubers boiled in the apical and the stolon part (scale 9°)

Experimental factors		Apical part		Stolon part	
		after 10 min	after 24 h	after 10 min	after 24 h
Fertilization	0	8.95a	8.68c	8.91a	8.61b
	A	8.97a	8.76a	8.93a	8.66a
	B	8.92a	8.77a	8.90a	8.63a.b
	C	8.96a	8.73b	8.91a	8.63a.b
	HSD 0.05	ns	0.03	ns	0.04
Cultivars Odmiany	'Agnes'	8.92c	8.57c	8.86c	8.53c
	'Jelly'	8.99a	8.84a	8.98a	8.81a
	'Viviana'	8.94b	8.83a	8.90b	8.63b
	'Vineta'	8.96b	8.70b	8.91b	8.56c
	HSD 0.05	0.02	0.03	0.03	0.04
Years Lata	2013	8.94a	8.72a	8.89a	8.60b
	2014	8.96a	8.74a	8.92a	8.65a
	2015	8.95a	8.74a	8.92a	8.65a
	HSD 0.05	ns	ns	ns	0.03
Mean Średnia		8.95	8.73	8.91	8.63
RSD (%)		0.37	0.48	0.47	0.70

* 0 – Standard object without foliar fertilization; A – Fortis Duotop Zn Mn + Fortis Aminotop; B – Fortis B Mo + Ferti Agro; C – Fortis Duotop Zn Mn + Fortis B Mo; ** not significant at $p_{0.05}$; RSD – coefficient of variation; HSD – the smallest significant differences in the average

Of all experimental factors, cultivars had the greatest impact on cooked tuber darkening. The smallest darkening of the flesh at the apical and stolon parts, in both terms of determination, was revealed by 'Jelly' cultivar. On the other hand, 'Agnes' showed the greatest tendency to darken the flesh. 'Viviana' and 'Jelly' turned out to be homogeneous in terms of darkening of the flesh in the stolon part 24 h after cooking, while 'Vineta' and 'Viviana' were homogeneous in terms of darkening of the apical and stolon flesh, 10 min after cooking. In the apical and stolon part of tubers assessed 24 h after cooking, the 'Viviana' cultivar was lighter in flesh than the 'Vineta' cultivar (Tab. 4).

Atmospheric factors significantly modified the darkening of the flesh only in the stolon part of tubers, assessed 24 h after cooking. Higher intensity of the flesh color was observed in 2013 in the conditions of dry but very wet September (Tab. 4).

DISCUSSION

In the opinion of many authors [Wang-Pruski and Nowak 2004, Sawicka et al. 2006, Grudzińska 2009, Zgórska and Grudzińska 2012, Keutgen et al. 2014], raw tuber flesh is subject to darkening due to the enzymatic oxidation of phenolic compounds, mainly chlorogenic acid and tyrosine, at the catalytic action of the diphenol oxidase enzyme. For cooked tubers, the flesh darkens due to Fe^{+2} binding to chlorogenic acid. This darkening can be inhibited by the presence of iron chelating compounds, e.g. citric acid, which forms colorless complexes with iron [Grudzińska 2009]. High nitrogen fertilization and excessively wide N:K ratio for a given cultivar causes that cooked tubers are darker [Wojdyła 1997]. High content of nitrogen and organic matter in the soil increases the concentration of chlorogenic acid in tubers and contributes to the increase in tuber darkening. According to Sawicka [2000], 100 kg of N·ha^{-1} is a safe amount of nitrogen due to the high quality of tubers. Wibowo et al. [2014] found that increasing doses of potassium fertilizers do not significantly affect the content of chlorogenic and ascorbic acid in potato tubers, while Hamouz et al. [2010] proved the existence of a negative relationship between the use of potassium fertilizers and content of chlorogenic acid. On the other hand, research by Wszelaczyńska [2004] shows that increasing doses of magnesium cause a decrease in the content of chlorogenic acid and an increase in the content of citric acid, and therefore contributing to the reduction of darkening of raw and cooked tubers. Wojdyła [2013] found no effect of increasing doses of nitrogen on darkening of raw tubers, but proved an increase in darkening of cooked tubers. The factor limiting the darkening of the flesh may be potato cultivation after pre-sowing. Płaza and Makarewicz [2014] found that honey clover plowed in autumn or left in the form of mulch until spring, and a mixture of the clover and Westerwold ryegrass, contribute to reducing darkening of the raw flesh.

Boligłowa [1995] did not find the effect of foliar fertilization on the characteristics of boiled potato tuber flesh, but foliar feeding of potato with Agrosol-K fertilizer had significant effect on darkening of raw tuber flesh. Wróbel [2012], using fertilizers YaraVita Ziemniak and Actisili, did not find their effect on darkening of raw tubers.

Tendency to darken the flesh of both raw and cooked tubers was determined by genetic characteristics of cultivars, which is confirmed by studies of many authors [Sawicka 1991, Boligłowa 1995, Wang-Pruski and Nowak 2004, Sawicka et al. 2006, Zgórska and Grudzińska 2012, Kołodziejczyk 2014]. Such relationship was not confirmed by Wojdyła's study [2013]. Żołnowski [2013], assessing the darkening of raw tubers after 10 min and cooked tubers, did not show any significant effect of the cultivar on this trait. He showed variation differences in tuber flesh assessment after 4 h. Zgórska and Grudzińska [2012] assessing tuber darkening of 19 cultivars have shown that the limit value of edible potato tuber darkening is 5.0° on a 9° scale. The enzymatic and non-enzymatic darkening, according to Sawicka [1991, 2000], Sawicka et al. [2006], Zgórska [2012], Kamiński [2015], is influenced by genetic and genetic-environmental factors. According to research by Sawicka [1991] carried out on 34 potato cultivars belonging to different classes of earliness, the variability of darkening of cooked tuber flesh is determined by the genotype in 28–48%, and in the case of raw tubers – in 11–39%. In turn, Wang-Pruski and Nowak [2004] examining the share of genetic and environmental traits in the total ACD variability, obtained results showing that genetic and environmental traits accounted for more than 80% of the total variance. Keutgen et al. [2014] prove significant dependence of the darkening process of raw tubers after 10 min on the content of ascorbic acid, in cooked tubers evaluated after 10 min also between the content of ascorbic acid and total polyphenolic compounds, which confirms their effect on darkening of the flesh.

The tendency of potato tubers to darken the raw tuber flesh depends not only on the genotype, but also on atmospheric conditions during potato vegetation [Sawicka 1991, Sawicka et al. 2006, Wojdyła 2013, Kołodziejczyk et al. 2013]. Own research confirms this thesis. Sawicka [1991] estimated that darkening of raw tubers after cutting and after 1 hour was 9.8% and 35.0%, respectively depending on environmental conditions. Results of Kołodziejczyk's research [2013] prove that weather conditions determined this feature in 9.5% – in the case of raw tuber darkening after 1 hour and in 16.4% – in the case of raw tuber darkening after 4 h.

Stability of darkening of cooked tuber flesh, compared to other potato quality characteristics, was very high. This was confirmed by the results of Sawicka's research [1991]. According to it, the repeatability of darkening of cooked tuber flesh is very high and ranges from 0.59 in the case of darkening of cooked tuber flesh in the stolon part, to 1.00 in the apical part. Higher stability of tuber flesh darkening was usually observed in the apical part than the stolon one, which is probably due to higher content of citric acid in the apical part, which in turn is genetically conditioned [Kamiński 2015].

In the experiment, environmental conditions modified the darkening of cooked tuber flesh. Sawicka [1991], on the other hand, showed only a significant effect of this factor in the case of the stolon part of tubers assessed 10 min and 2 h after cutting, and the impact of years in shaping this feature was determined to be 9.6% on average. The interaction of cultivars and years generally modified the darkening of cooked tubers to a greater extent than years or phenotypic variability. Sawicka et al. [2006] and Krochmal-Marczak et al. [2016] found that sunny, dry weather favors darkening of raw tubers, while moderate rainfall and average air temperature favors the preservation of the light color of cooked tuber flesh. According to Wang-Pruski and Nowak [2004], physiologically immature tubers darker more than mature tubers, and the stolon end of the tuber more than the apical part. Sawicka et al. [2006], Wang-Pruski and Nowak [2004] and Noaema [2018] explain this phenomenon by changes in the distribution of chlorogenic and citric acids during the plant growth.

CONCLUSIONS

1. Effect of foliar fertilization was observed only in boiled tubers, 24 h after cooking. The application of Fortis B Mo + Ferti Agro and Fortis Duotop Zn Mn + Fortis Aminotop fertilizers reduced the darkening of the tuber flesh in the apical part to the greatest extent.

2. The 'Agnes', 'Viviana' and 'Vineta' cultivars, after applying foliar fertilizers during the growing season, showed greater susceptibility to enzymatic darkening of the flesh of raw tubers after 4 h.

3. The 'Jelly' cultivar showed the lowest tendency to darken the flesh of raw and cooked tubers.

4. Meteorological conditions during the research years also differentiated the darkening of raw and cooked tubers, but only in the stolon part. Atmospheric factors significantly modified darkening of the flesh only in the stolon portion of cooked tubers assessed 24 h after cooking.

REFERENCES

Boligłowa E., 1995. Wpływ dolistnego dokarmiania na plonowanie i jakość bulw ziemniaka. Rozpr. Habil. 41, Wyd. WSRP w Siedlcach, pp. 79.

Fageria N.K., Filho B.M.P., Moreira A., Guimarăes C.M., 2009. Foliar fertilization of crop plants. J. Plant Nutr. 32, 1044–1064.

Grudzińska M., 2009. Czynniki wpływające na ciemnienie miąższu bulw surowych i po ugotowaniu. Ziemn. Pol. 4, 33–36.

Hamouz K., Lachman J., Hejtmankowa P., Pazderu M., Cizek M., Dvorak P., 2010. Effect of natural and growing conditions on the content of phenolics in potatoes with different flesh color. Plant Soil Environ. 56(8), 368–374.

Kamiński P., 2015. Ocena stabilności plonu i właściwości kulinarnych bulw ziemniaka odpornego na *Phytophthora infestans*. PhD Thesis, IHAR-PIB, Radzików, pp. 194.

Keutgen A., Pobereżny J., Wszelaczyńska E., Murawska B., Spychaj-Fabisiak E., 2014. Wpływ przechowywania na procesy ciemnienia bulw ziemniaka (*Solanum tuberosum* L.) i ich właściwości prozdrowotne. Inż. Apar. Chem. 2, 86–88.

Kołodziejczyk M. 2014. Wpływ warunków opadowo-termicznych na plonowanie średnio późnych i późnych odmian ziemniaka jadalnego. Annales UMCS, sec. E, Agricultura, 68(3), 1–10.

Kołodziejczyk M., Szmigiel A., Kulig B., Oleksy A., Lepiarczyk A. 2013. Ocena plonowania, składu chemicznego i jakości bulw wybranych odmian ziemniaka skrobiowego. Inż. Roln. 3(146), 123–130.

Krochmal-Marczak B., Sawicka B., Kiełtyka-Dadasiewicz A., Bienia B., 2016. Wpływ przechowywania oraz warunków meteorologicznych na jakość miąższu bulw ziemniaka uprawianego w systemie ekologicznym. Fragm. Agron. 33(2), 44–54.

Mousavi S.R. Galavi M., Ahmadvand G., 2007. Effect of zinc and manganese foliar application on yield, quality and enrichment on potato (*Solanum tuberosum* L.). Asian J. Plant Sci. 6, 1256–1260.

Noaema A.H., 2018. The effectiveness of foliar fertilization of several cultivars of potato (*Solanum tuberosum* L.) under conditions of the South-Eastern Poland. PhD Thesis, UP Lublin, 211 pp.

Płaza A., Makarewicz A. 2014. Wartość konsumpcyjna ziemniaków nawożonych wsiewkami międzyplonowymi w integrowanym i ekologicznym systemie produkcji. Ziemn. Pol. 4, 15–17.

Roztropowicz S. (red.), 1999. Metodyka obserwacji, pomiarów i pobierania prób w agrotechnicznych doświadczeniach z ziemniakiem. IHAR, oddz. Jadwisin, pp. 50.

Sawicka B., 1991. Studia nad zmiennością wybranych cech oraz degeneracją różnych odmian ziemniaka w rejonie bialskopodlaskim. Rozpr. Nauk. AR w Lublinie, 141. pp. 78.

Sawicka B., 2000. Wpływ technologii produkcji na jakość bulw ziemniaka. Pam. Puł. 120, 411–414.

Sawicka B., Krochmal-Marczak B., 2009. Wpływ stosowania nawozu dolistnego Insol 7 i bioregulatora Asahi SL na zdrowotność bulw kilku odmian ziemniaka. Annales UMCS, sec. E, Agricultura 64(2), 29–38.

Sawicka B., Kuś J., Barbaś P., 2006. Ciemnienie miąższu bulw ziemniaka w warunkach ekologicznego i integrowanego systemu uprawy. Pam. Puł. 142, 445–457.

Singh J., Singh M., Jain A., Bhardwaj S., Singh A., Singh D.K., Bhushan B., Dubey S.K., 2013. An introduction of plant nutrients and foliar fertilization: a review. In: Precision farming: a new approach. Daya Publishing Company, New Delhi, 252–320.

Szewczuk C., Sugier D., 2009. Ogólna charakterystyka i podział nawozów dolistnych oferowanych na polskim rynku. Annales UMCS, sec. E, Agricultura 64(1), 29–36.

Trawczyński C., 2015. Kompleksowe odżywianie ziemniaka na bazie nawozów nowej generacji. Ziemn. Pol. 3, 14–18.

Villa M.R., Rodriguez L.E., Gomez J.M., 2011. Effect of edaphic and foliar management of manganese on the field of the Criolla Colombia cultivar. Agron. Colomb. 29(3), 447–454.

Wang-Pruski G., Nowak J., 2004. Potato after-cooking darkening. Am. J. Potato Res. 81(1), 7–16.

Wibowo C., Wijaya K., Sumartono G.H., Pawelzik E., 2014. Effect of Potassium Level on Quality traits of Indonesian Potato Tubers. Asia Pacific J. Sustain. Agric. Food Energy (APJSAFE) 2(1), 11–16.

Wojdyła T., 1997. Smakowitość bulw ziemniaka w zależności od zastosowanych fungicydów i nawożenia azotem. Fragm. Agronom. 4, 5–17.

Wojdyła T., 2013. Cechy konsumpcyjne bulw wybranych odmian ziemniaka po zbiorze i po przechowywaniu w zależności od nawożenia mineralnego. Wyd. Uczeln. Uniwersytetu Technologiczno-Przyrodniczego, Bydgoszcz, pp. 153.

Wróbel S., 2012. Wpływ nawożenia ziemniaka odmiany Jelly dolistnymi preparatami YaraVita Ziemniak oraz Actisil na plon i cechy jego jakości. Biul. IHAR 266, 295–306.

Wszelaczyńska E., 2004. Wpływ nawożenia magnezem na zawartość kwasów organicznych i ciemnienie miąższu bulw ziemniaka odmiany Mila. Acta Sci. Pol. Agricultura 3(1), 175–186.

Zgórska K., 2012. Ziemniak − surowiec do produkcji żywności wygodnej i minimalnie przetworzonej. In: J. Chotkowski (ed.), Produkcja i rynek ziemniaka. Wieś Jutra, Warszawa, 324–333.

Zgórska K., Grudzińska M., 2012. Zmiany wybranych cech jakości bulw ziemniaka w czasie przechowywania. Acta Agrophys. 19(1), 203–214.

Żołnowski A.C., 2013. Studia nad zmiennością plonowania i jakością ziemniaka jadalnego (*Solanum tuberosum* L.) w warunkach zróżnicowanego nawożenia mineralnego. Rozprawy i Monografie UWM Olsztyn. 191, pp. 259.

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Streszczenie. Celem badań było określenie wpływu nawozów dolistnych z zawartością makro- i mikroelementów stosowanych w formie chelatów na ciemnienie miąższu bulw wybranych jadalnych odmian ziemniaka. Badania oparto na 3-letnim (2013–2015) doświadczeniu polowym przeprowadzonym w Haczowie (49°40'N, 21°54'E), na glebie brunatnej, lekko kwaśnej. Eksperyment założono metodą losowanych podbloków, gdzie czynnikami I rzędu było nawożenie dolistne: Fortis Zn Mn + Fortis Aminotop (A), Fortis B Mo + Ferti Agro (B), Fortis Zn Mn + + Fortis B Mo (C) i obiekt standardowy, bez nawożenia dolistnego (0). Czynnikami II rzędu były 4 jadalne odmiany ziemniaka wszystkich klas wczesności (‘Viviana’, ‘Vineta’, ‘Agnes’, ‘Jelly’). Istotne różnice ciemnienia miąższu bulw wywołane stosowaniem nawożenia dolistnego obserwowano jedynie w przypadku bulw po 24 h od ugotowania. Aplikacja nawozów Fortis B Mo + + Ferti Agro oraz Fortis Duotop Zn Mn + Fortis Aminotop w największym stopniu ograniczały ciemnienie miąższu bulw części wierzchołkowej. Czynnik genetyczny różnicował w największym stopniu ciemnienie miąższu bulw surowych i po ugotowaniu. Badane odmiany wykazały zróżnicowaną reakcję na nawozy dolistne.

Słowa kluczowe: ziemniak, nawożenie dolistne, ciemnienie miąższu

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