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EFFECT OF WEED CONTROL OPERATIONS AND TILLAGE SIMPLIFICATIONS ON IRON CONTENT AND UPTAKE WITH POTATO TUBER YIELD

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Abstract

Potato tubers obtained from a field experiment carried out in 2002-2004 were used for our analysis. The soil grain-size structure was that of light loamy sand. Two soil tillage systems were compared: conventional (ploughing + fall ploughing + harrowing + cultivating + harrowing) and simplified (reversing ploughing + cultivating). The second factor involved seven weeding methods such as application of the following herbicides: Plateen 41.5 WG, Plateen 41.5 WG + Fusilade Forte 150 EC, Plateen 41.5 WG + Fusilade Forte 150 EC + Atpolan 80 EC, Barox 460 SL, Barox 460 SL + Fusilade Forte 150 EC, Barox 460 SL + Fusilade Forte 150 EC + Atpolan 80 EC. Iron content and uptake with tuber yield significantly depended on the tillage practices and weeding methods as well as the weather conditions over the growing period. Conventionally tilled potato tubers had more iron, 65.80 $g \cdot kg^{-1}$ on average, than the tubers whose cultivation was based on simplified tillage, 64.82 $g \cdot kg^{-1}$ on average. The herbicides applied significantly increased the iron content and its uptake with tuber yield by an average 4.2 and 13.8%, respectively.

Key words: potato, iron, content, uptake.

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WPŁYW ZABIEGÓW PIELĘGNACYJNYCH I UPROSZCZENIA UPRAWY NA ZAWARTOŚĆ I POBRANIE ŻELAZA Z PLONEM BULW ZIEMNIAKA

Abstrakt

Pracę oparto na próbach bulw z doświadczenia polowego przeprowadzonego w latach 2002-2004 na glebie o składzie piasku gliniastego lekkiego. Porównywano dwa sposoby uprawy roli – tradycyjną (orka + orka przedzimowa + bronowanie + kultywatorowanie + + bronowanie) i uproszczoną (orka odwrotna + kultywatorowanie) i siedem sposobów pielęgnacji z udziałem herbicydów: Plateen 41,5 WG, Plateen 41,5 WG + Fusilade Forte 150 EC, Plateen 41,5 WG + Fusilade Forte 150 EC + Atpolan 80 EC, Barox 460 SL, Barox 460 SL + Fusilade Forte 150 EC, Barox 460 SL + Fusilade Forte 150 EC + Atpolan 80 EC. Zawartość żelaza i jego pobranie z plonem bulw zależały istotnie od sposobów uprawy i pielęgnacji oraz warunków pogodowych w okresie wegetacji. Więcej żelaza zawierały bulwy ziemniaka z uprawy tradycyjnej – średnio 65,80 $g \cdot kg^{-1}$ w porównaniu z uproszczoną – średnio 64,82 $g \cdot kg^{-1}$. Herbicydy zastosowane w pielęgnacji podwyższały istotnie zawartość żelaza – średnio o 4,2% i jego pobranie z plonem bulw – średnio o 13,8% w porównaniu z obiektem kontrolnym.

Słowa kluczowe: ziemniak, żelazo, zawartość, pobranie.

INTRODUCTION

Due to its low soil and climatic requirements as well as a significant role in crop rotation, potato is a valuable crop plant in Poland. Presently, it is mainly used for consumption purposes and the per capita consumption is as high as 129 kg per year (Dzwonkowski et al. 2006). The nutritional value of potato tubers is determined by their chemical composition, including macroelements and microelements, as well as a trace content of non-nutritive compounds (Lisińska 2006). Microelements represent the compounds that are necessary for human and animal metabolism, and the body has to be supplied with them along with food. Iron, being a component of many enzymes and taking part in processes of oxy-reduction and blood formation, is one of the more important microelements and its deficiency results in anaemia. The daily iron requirement of an adult person ranges from 10 to 15 mg (Czapska et al. 2000, Grajeta 2006). According to Gąsior (1996) eating 200-350 g potatoes containing an average of 150 mg $Fe \cdot kg^{-1}$ tuber d.m. can satisfy the daily iron requirement. Many authors believe that the iron content in tubers depends on soil and weather conditions, agronomic practice and cultivar properties. (Gąsior 1996, Prośba-Białczyk, Mydlarski 2000, Rudzińska-Mękal, Mikos-Bielak 2000). In the experiments by Mikos-Bielak et al. (1996), which included many cultivars representing different maturity groups, the iron content ranged from 9.5 to 23.9 $mg \cdot kg^{-1}$ tuber dry matter. In turn, Prośba-Białczyk and Mydlarski (2000), and Gąsior (1996) obtained the respective ranges of 29-74 $mg \cdot kg^{-1}$, and 37-241 $mg \cdot kg^{-1}$ tuber dry matter. There is a paucity of literature on the subject of an impact of plant

protection chemicals on microelement content in potato tubers. Thus, it has been attempted to determine the effect of weeding methods, including herbicide application, and soil tillage methods on the iron content in tubers and iron uptake with potato tuber yield.

MATERIAL AND METHODS

The studies was based on a field experiment carried out in 2002-2004 at the Zawady Experimental Farm on soil belonging to a very good rye complex. Selected soil chemical properties prior to the experiment are shown in Table 1. The experiment was in a randomized sub-block design with three replicates each year. The experimental factors were as follows: two soil tillage methods, conventional and simplified tillage, and seven methods of weed control consisting of herbicide application (Table 2).

Table 1

Chemical properties of the soil

Years	pH 1 mol KCl dm^3	Organic matter ($g \cdot kg^{-1}$)	Macroelements content ($mg \cdot 100\ g^{-1}$)			Microelements content ($mg \cdot kg^{-1}$)			
			P	K	Mg	Fe	Mn	Cu	Zn
2002	6.5	11.3	3.88	15.03	7.00	755.0	113.0	6.2	11.0
2003	6.4	11.3	4.30	10.22	15.70	962.0	108.0	4.2	8.4
2004	5.6	11.5	6.25	10.39	15.90	1300.0	120.0	3.8	10.7

Table 2

Experimental factors

Factor I – tillage system
1. Traditional (ploughing + fall ploughing + harrowing + cultivating + harrowing) 2. Simplified (second ploughing + cultivating)
Factor II – weed control methods
1. Control object (mechanical weeding before and after potato plants sprouting) 2. Plateen 41.5 WG 2.0 $kg \cdot ha^{-1}$ 3. Plateen 41.5 WG 2.0 kg ha^{-1} + Fusilade Forte 150 EC 2.5 $dm^3 \cdot ha^{-1}$ (mixture) 4. Plateen 41.5 WG 1.6 kg ha^{-1} + Fusilade Forte 150 EC 2.0 $dm^3 \cdot ha^{-1}$ + Atpolan 80 EC 1.5 $dm^3 \cdot ha^{-1}$ (mixture) 5. Barox 460 SL 3.0 $dm^3 \cdot ha^{-1}$ 6. Barox 460 SL 3.0 dm^3 ha^{-1} + Fusilade Forte 150 EC 2.5 $dm^3 \cdot ha^{-1}$ (mixture) 7. Barox 460 SL 2.4 dm^3 ha^{-1} + Fusilade Forte 150 EC 2.0 dm^3 ha^{-1} + Atpolan 80 EC 1.5 $dm^3 \cdot ha^{-1}$ (mixture)

Farmyard manure fertilization and mineral fertilization amounted to, respectively, 25.0 $t \cdot ha^{-1}$, and 90 kg N, 32.9 kg P and 112.1 kg $K \cdot ha^{-1}$. Iron content in the tubers of cultivar Wiking potato was determined by the atomic absorption spectrophotometry method (AAS). The results were subjected to the analysis of variance and conclusions were drawn on the basis of Tukey's test at the significance level of p=0.05. Precipitation sums and average air temperatures during the period of potato growth (April – September) were the following respective percentages of the multi-year mean: 112.7 and 110.2 for 2002, 48.3 and 105.4 in 2003, and 116.6 and 95.9 in 2004.

RESULTS AND DISCUSSION

Iron content in potato tubers. Iron content in the tubers of edible potato cv. Wiking averaged 65.36 $mg \cdot kg^{-1}$ d.m., and was significantly differentiated by the soil tillage systems, weed control methods and weather conditions in the study years (Table 3). Higher iron concentration was found in tubers of conventionally tilled potatoes, compared with the simplified tillage. ŻURAWSKI and SIENKIEWICZ (1981) proved that deeper tillage prior to the cultivation of root and tuber crops positively influenced yields of basic plants, as well as the content and uptake of nutrients. NOWAK et al. (2004) stress that potato, due to its poorly developed and shallow root system, takes up nutrients mainly from the plough layer of the soil, which should be well worked.

Table 3

Content of iron in potato tubers ($mg \cdot kg^{-1}$ d.m.)

Weed control methods	Tillage systems		Years			Mean
	traditional	simplified	2002	2003	2004	
1.*	63.45	62.68	63.88	64.16	61.17	63.07
2.	67.02	65.64	66.25	69.83	62.92	66.33
3.	67.75	65.36	66.89	67.33	65.47	66.56
4.	65.18	65.33	64.30	68.50	62.99	65.26
5.	66.09	65.87	64.59	70.83	62.53	65.98
6.	65.49	64.82	65.50	66.67	63.30	65.16
7.	65.62	64.72	64.84	67.33	63.35	65.17
Mean	65.80	64.92	65.18	67.81	63.10	65.36
Mean for 2-7	66.19	65.29	65.40	68.42	63.43	65.75
$LSD_{0.05}$ for:						
tillage systems						0.24
weed control methods						1.28
years						0.37
interaction:						
tillage systems x weed control methods						1.19
weed control methods x years						2.21

* designations as in Table 2

Herbicides applied in potato cultivation increased iron concentration in tubers by 4.2%, on average. The highest iron concentration was found in the tubers of potato sprayed with a mixture of Plateen 41.5 WG + Fusilad Forte 150 EC, and herbicide Plateen 41.5 WG – 66.33 and 66.56 $mg \cdot kg^{-1}$, respectively. Similar changes were observed by ZARZECKA (2004), a significant increase in iron concentration occurring only in two treatments where plant protection agents were applied as mixtures or as post-emergence chemicals sprayed twice. Increased iron concentration in tubers of some cultivars was also observed by RUDZIŃSKA-MĘKAL and MIKOS-BIELAK (2000), who applied the growth regulator Mival.

Analysis of the effect of weather conditions over the study years showed that tubers harvested in the warm and dry year 2003 were the highest in iron. Distinct differentiation in the iron content in the study years was also reflected in the works by BOLIGŁOWA (1996), GĄSIOR (1996), and ZARZECKA and GUGAŁA (2005).

The iron content in tubers was close to the literature values (RUDZIŃSKA-MĘKAL, MIKOS-BIELAK 2000, PROŚBA-BIAŁCZYK, MYDLARSKI 2000). KUCHARZEWSKI et al. (2002) believe that iron concentration below the average value, ranging from 21 to 58 $mg \cdot kg^{-1}$ d.m., is not harmful because plants take up the element in varying amounts (200-2500 g per 1 ha) and, in general, show a marked tolerance to high Fe concentration in tissues. Under the Regulation of the Ministry for Health of April 30, 2004, on permissible levels of food chemical and biological pollution, limiting copper, zinc, iron and manganese contents in potato tubers has been abandoned due to the present deficiencies of these elements in diets (WOJCIECHOWSKA-MAZUREK et al. 2003). However, the maximum threshold levels of lead, cadmium, mercury and arsenic are maintained (*Regulation* 2004). Also GEMBARZEWSKI (2000) in his studies on basic crops found a decreased uptake of Cu, Mn and Fe with potato tuber yield in the years 1966-1970.

Iron uptake with tuber yield. In the yield of tubers, averaging $31.4\ t \cdot ha^{-1}$, potatoes took up and accumulated an average of 532.6 g iron per 1 ha (Table 4). Cultivation operations performed in the experiment and moisture and thermal conditions in the study yields significantly affected the iron uptake with potato tuber yield. Conventionally-tilled potatoes took up over 8% more iron than the potatoes whose cultivation was based on simplified tillage. Moreover, the chemically-protected potatoes took up 9.6 to 21.0% more iron than the potatoes grown in the control treatment, where weeds were mechanically controlled. In addition, the present research has shown that iron uptake is to a large extent conditioned by the level of yields, which was reflected in the study years, which were different as far as the weather was concerned. The highest iron uptake was recorded in the wet and warm year 2002. The lowest uptake was found in 2003, when precipitation was twice as low as in the multi-year period.

Table 4

Uptake of iron with the yield of potato tubers ($g \cdot h^{-1}$)

Weed control methods	Tillage systems		Years			Mean
	traditional	simplified	2002	2003	2004	
1.*	494.0	458.8	626.6	399.7	402.9	476.4
2.	543.9	511.8	669.6	471.6	452.5	527.9
3.	571.9	532.3	707.0	452.2	497.1	552.1
4.	602.1	550.7	719.6	470.4	539.2	576.4
5.	541.6	502.7	620.7	497.1	448.7	522.2
6.	549.0	500.0	624.8	474.4	457.7	525.0
7.	576.2	520.8	650.1	509.7	485.7	548.5
Mean	554.1	511.1	659.8	466.5	471.7	532.6
Mean for 2-7	564.1	519.9	665.3	477.6	480.2	542.0
$LSD_{0.05}$ for:						
tillage systems						6.5
weed control methods						29.2
years						10.0
interaction:						
tillage systems x weed control methods						n.s.
weed control methods x years						50.5

* designations as in Table 2
n.s. – not significant

CONCLUSIONS

1. Simplifications of soil tillage created poorer conditions for iron accumulation in potato tubers compared with the conventional tillage.

2. When potatoes were cultivated using herbicide weed control, the iron content in their tubers was higher than in the tubers of potatoes whose cultivation included mechanical weed control.

3. Iron uptake with tuber yield was higher under the conditions of conventional than simplified tillage, and when intense chemical protection of crop was applied compared with mechanical control of weeds.

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