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Research Article

CONTENT AND UPTAKE OF SELECTED TRACE ELEMENTS BY WEEDS IN POTATO TO CULTIVATION UNDER DIFFERENT CONDITIONS OF SOIL TILLAGE AND WEED CONTROL METHODS

Krystyna Zarzecka[1], Marek Gugała[1], Alicja Baranowska[2]

[1] Chair of Plant Cultivation, University of Natural Sciences and Humanities in Siedlce, B. Prusa 14, 08-110 Siedlce, Poland, e-mail: kzarzecka@uph.edu.pl

[2] Pope John Paul II State School of Higher Education in Biala Podlaska, Sidorska 95/97, 21-500 Biala Podlaska, Poland

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ABSTRACT
The study utilized data from a field experiment carried out at the Experimental Station in Zawady owned by the University of Natural Sciences and Humanities in Siedlce in the years 2005–2007. The experimental factors included two soil tillage systems and seven weed control methods in potato. Iron, copper and zinc in weeds were determined with the AAS method. The trace element content in weed dry matter before row closure of potato depended significantly on soil tillage methods (excluding Cu), weed control methods and weather conditions, and, prior to tuber harvest, on soil tillage and weather conditions during the growing season. The uptake of Fe, Cu, and Zn by weeds from the area of 1 hectare depended on the experimental factors, weed biomass and weed chemical composition.

Keywords: weeds, trace elements, content, uptake, potato.

INTRODUCTION

Potato yield losses resulting from weed infestation are estimated at 20–80% [Hashim 2003; Jaiswal, Lal 1996; Knezevic et al. 1995]. According to many authors [Boligłowa, Gleń 2003; Boydston, Vaughin 2002; Dorado, Lopez-Fando 2006] an application of soil tillage simplifications increases weed infestation, reduces potato tuber yield and reduces its quality. Negative effects of simplified soil tillage may be alleviated by an application of accurately chosen herbicides. An application of herbicides and their mixtures in potato cultivation reduces weed infestation by 40 to 99%, compared with mechanical operations [Gugała et al. 2013; Guttieri, Eberlein 1997; Mišovic et al. 1997; Shah et al. 2003; Zarzecka et al. 1999]. When weed infestation is moderate (1.5 t dry matter of weeds) use of nutrients reaches the level of 150 kg NPK. Also, the uptake of macroelements is significant. Under average conditions this amount of nutrients is sufficient to produce over 10 tonnes of potato tubers [Domańska 1980]. Increased weed infestation is followed by an increased uptake of nutrients by weeds, and a reduced uptake by the crop plant [Lehoczky et al. 2003; Żurawski, Sienkiewicz 1981]. The existing literature on the subject of microelement content in segetal weeds is quite abundant whereas the literature pertaining to the microelement content is much scarcer. Also, research on an impact of plant protection agents, being the second most important industrial production means, on accumulation of microelements in weeds is lacking [Czuba, Wróbel 1983; Lozowicka, Konecki 2011].

The research aimed at determining, under various conditions of soil tillage, the content and uptake of selected trace elements by weeds which occur in the cultivation of potato including different herbicides.

MATERIALS AND METHODS

The research included a field experiment conducted over the years 2005–2007 at the Experimental Farm in Zawady. The soil of the experimental site was the rye very good complex with a pH of 5.6 to 6.5 (1 mol KCl dm^3), organic matter content of 11.3 to 11.5 g kg^{-1}, and Fe, Cu and Zn contents determined in the tilled layer, amounting to, respectively: 755–1300, 3.8–6.2 and 8.4–11.0 mg kg^{-1}. The experiment was designed as randomised sub-blocks, and it included two factors:

a) factor I included two methods of soil tillage:
   - conventional (reversing ploughing, winter ploughing, harrowing, cultivating, harrowing),
   - simplified (reversing ploughing, cultivating);

b) factor II included weed control methods:
   - control treatment – mechanical weeding prior to and after potato stand establishment,
   - Plateen 41,5 WG (metribuzin + flufenacet) 2.0 kg ha^{-1},
   - Plateen 41,5 WG (metribuzin + flufenacet) 2.0 kg ha^{-1} + Fusilade Forte 150 EC (fluazyfop-P-butyl) 2.5 dm^3 ha^{-1} (mixture),
   - Plateen 41,5 WG (metribuzin + flufenacet) 1.6 kg ha^{-1} + Fusilade Forte 150 EC (fluazyfop-P-butyl) 2.0 dm ha^{-1} + adjuvant Atpolan 80 EC 1.5 dm^3 ha^{-1} (mixture),
   - Barox 460 SL (bentazone + MCPA) 3.0 dm^3 ha^{-1},
   - Barox 460 SL (bentazone + MCPA) 3.0 dm^3 ha^{-1} + Fusilade Forte 150 EC (fluazyfop-P-butyl) 2.5 dm^3 ha^{-1} (mixture),
   - Barox 460 SL (bentazone + MCPA) 2.4 dm^3 ha^{-1} + Fusilade Forte 150 EC (fluazyfop-P-butyl) 2.0 dm^3 ha^{-1} + adjuvant Atpolan 80 EC 1.5 dm^3 ha^{-1} (mixture).

The experimental site received a mineral and organic fertilizer application of 90 kg N, 32.9 kg P, 112.1 kg K, and 25.0 t ha^{-1} farmyard manure, respectively. Botanic and weight analyses of weeds were made twice – before and after row closure. Weeds from the area of 1 m^2 were collected on each plot and, after drying, their air dry weight was determined. Iron, copper and zinc contents were determined in weed air dry matter by the method of atomic absorption spectrophotometry (AAS). Digestion of weeds (1.0 g samples) was performed using a mixture of HNO_3 (7 ml) + H_2O_2 (1 ml). It was mineralized in a laboratory microwave oven Ethos plus. Distilled water was added to the sample and it was mixed. The sample was diluted to 50 ml with distilled water. Element concentration were expressed on a dry weight in mg kg^{-1}. An uptake of elements from an area of 1 ha was calculated on the basis of weed dry weight and weed chemical composition. The results obtained were statistically analysed with the analysis of variance and the significance of differences was determined using Tukey test at the significance level of $p=0.05$. Weather conditions over the growing seasons of studies varied. The year 2007 was most favourable as far as rainfall and temperature were concerned. In contrast, the season of the year 2006 was the least favourable due to a heavy drought that took place then.

RESULTS AND DISCUSSION

The average three-year air dry weight of weeds was the highest in the mechanically-cultivated control treatment (Table 1). The herbicides applied reduced the weed weight at the start of vegetation and prior to tuber harvest by 40.1 to 80.3%, and 33.2 to 61.9%, respectively. The works of other authors [Mišovic et al. Shah et al., 2003; Zarzecka et al. 1999; Mirabelli et al. 2005] support this finding.

Mineral composition and nutrient uptake of weeds are a function of at least several factors. They include: stage of weed growth, soil fertility of the site, the length of time of competition between plants, application of fertilizers and herbicides, and thermal and moisture conditions throughout the growing period [Johansen et al. 2005; Ali et al. 2006; Baćmaga et al. 2007; Królak 2003; Kirchmann et al. 2005].

Table 1. Weed control of air dry matter of weeds (2005–2007)

Weed control methods	Weed control [%]	
	before row closing	before tubers harvest
1.	0 (23.7 g m^2)	0 (98.9 g m^2)
2.	55.7	36.9
3.	75.9	48.7
4.	80.3	61.9
5.	40.1	33.2
6.	55.8	42.1
7.	59.5	50.0
Mean	61.2	45.5

* Explanation as in materials and methods.

The analysis of the results obtained in the present work showed that iron, copper and zinc contents in weeds sampled at the beginning of vegetation significantly depended on soil tillage methods, cultivation methods and growing conditions over the years of study (Table 2). More Fe and Zn were accumulated by weeds sampled from the simplified tillage treatment than from the conventionally-tilled plots. An application of herbicides reduced the iron content and increased the copper and zinc contents compared with the mechanically-tilled control treatment. The differences in the contents of the elements between herbicide treatments were not statistically proven, which means that the effect of individual herbicides was not pronounced.

The contents of the elements determined in older weeds (prior to tuber harvest) were lower than in younger weeds, and depended significantly on the tillage methods and weather conditions over the years of study. Also Parylak [1994] found that the contents of elements in weeds decreased as they matured. Fe, Cu and Zn concentrations in weeds were similar to the values obtained by other authors [Ali et al. 2006; Johansen et al. 2005; Kalny et al. 2007; Kirchmann et al. 2005].

Trace element uptake by weeds (at both dates of determination) was significantly affected by the experimental factors of the trial (Table 3). Higher uptake of elements was recorded in simplified tillage treatments. Herbicides reduced the volume of weed biomass prior to the crop plant harvest by 45.5%, on average. As a result, the uptake of the elements by weeds decreased almost twice (Fe – from 116.76 in the control treatment to 70.33 g ha^{-1} in herbicide treatments; Cu – from 12.558 to 7.570; Zn – from 34.820 to 21.538 g ha^{-1}). Kirchmann et al. [2005] and Trąba [2001] also found that uptake of elements by weeds from a one-hectare area depended on the concentration of the elements in weeds, and on their biomass.

In the studies discussed, a large effect of weather conditions on Fe, Cu and Zn contents and accumulation was found. Under favourable moisture conditions of the year 2004 (precipitation was higher than in the multi-year period, and the temperature was close to the average) the uptake of the elements was several times higher than in the year 2006 when a heavy drought took place, which was confirmed in the studies by Dziekanowski et al. [1992].

Some authors [Mirabelli et al. 2005; Ali et al. 2006; Trąba 2001] believe that chemical composition of weeds is influenced by the species which dominate in a weed community. In the research carried out the dominating were *Chenopodium album* and *Echinochloa crus-galli*, and the Fe, Cu and Zn contents were higher in white goosefoot than barnyard grass (Figure 1). Higher Cu and Zn

Table 2. Content of Fe, Cu and Zn of dry matter of weeds (mg kg^{-1})

Experimental factors		Harvest times of weeds					
		I*			II**		
		Fe	Cu	Zn	Fe	Cu	Zn
Tillage systems	1.	125.5	13.01	36.44	114.8	12.99	35.69
	2.	128.8	12.94	36.74	118.1	12.95	36.16
	$LSD_{0.05}$	0.7	n.s.	0.15	0.5	0.02	0.29
Weed control methods	1.	127.6	12.85	36.29	116.9	12.94	35.68
	2.	127.0	12.93	36.59	116.9	12.98	35.85
	3.	126.8	13.05	36.56	116.1	12.99	36.14
	4.	127.0	13.04	36.61	116.6	12.96	35.94
	5.	127.8	13.04	36.68	116.2	13.01	36.06
	6.	127.3	12.98	36.75	116.0	12.96	35.91
	7.	127.3	13.02	36.66	116.6	12.98	35.91
	$LSD_{0.05}$	0.6	0.47	0.19	n.s.	n.s.	n.s.
Years	2005	126.9	12.57	36.34	115.7	12.60	35.39
	2006	125.8	12.78	36.95	114.1	13.66	35.92
	2007	128.9	13.60	36.48	119.7	12.66	36.47
	$LSD_{0.05}$	1.1	0.34	0.24	0.8	0.03	0.44
Mean		127.2	12.98	36.59	116.5	12.97	35.93

* before row closing of potato, ** before tubers harvest
n.s. – non-significant differences

Table 3. Uptake of Fe, Cu and Zn by weeds (g ha^{-1})

Experimental Factors		Harvest times of weeds					
		I*			II**		
		Fe	Cu	Zn	Fe	Cu	Zn
Tillage systems	1.	11.8	1.3	3.4	68.6	7.6	21.5
	2.	18.3	1.8	5.1	85.3	8.9	25.3
	$LSD_{0.05}$	2.2	0.2	0.6	7.6	0.8	n.s.
Weed control methods	1.	30.2	4.0	8.6	116.8	12.6	34.8
	2.	16.1	1.6	4.4	81.2	8.7	24.6
	3.	7.1	0.7	2.0	61.8	6.8	19.2
	4.	5.3	0.5	1.5	47.3	5.1	14.43
	5.	19.9	2.0	5.6	87.3	9.4	26.7
	6.	14.0	1.4	3.9	77.4	8.3	23.9
	7.	12.6	1.3	3.5	66.9	7.2	20.5
	$LSD_{0.05}$	3.4	0.4	0.9	15.8	1.7	1.3
Years	2005	7.9	0.8	2.3	47.8	5.3	14.7
	2006	4.1	0.4	1.1	19.5	2.3	6.1
	2007	33.1	3.4	9.3	163.6	17.2	49.5
	$LSD_{0.05}$	3.4	0.4	0.9	11.7	1.2	3.7
Mean		15.0	1.5	4.2	77.0	8.3	23.4

* before row closing of potato, ** before tubers harvest
n.s. – non-significant differences

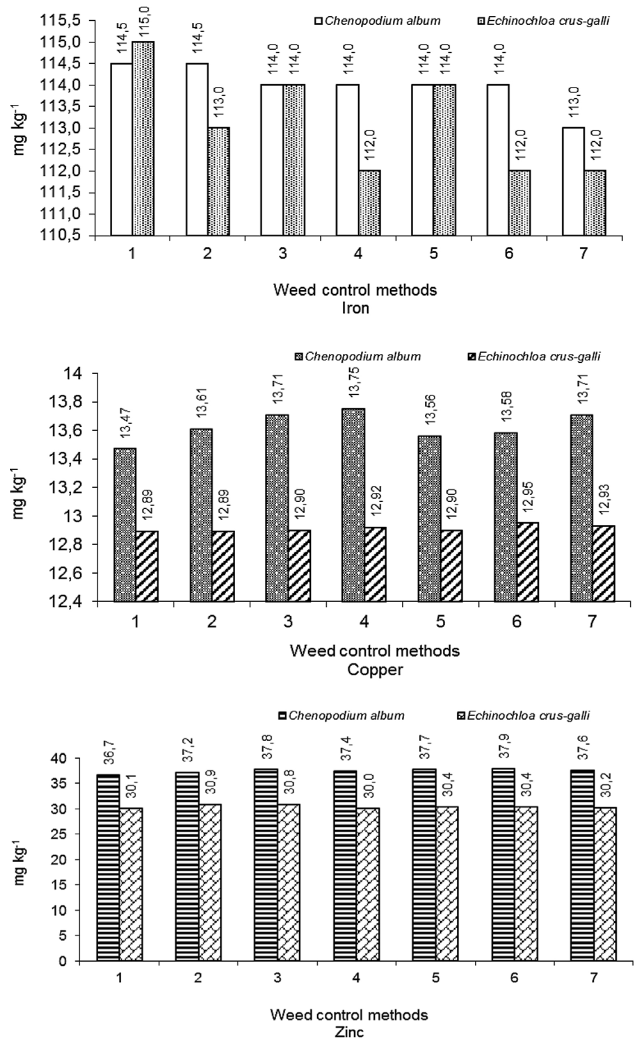

Figure 1. Content of iron, copper and zinc in *Chenopodium album* and *Echinochloa crus-galli* before tubers of potato harvest (mg kg^{-1})

concentrations in dicotyledonous weeds than in monocotyledonous weeds were recorded by other workers [Czuba, Wróbel 1983].

CONCLUSIONS

1. Iron, copper and zinc contents in weed dry weight at the beginning of vegetation and prior to potato harvest depended, respectively, on tillage methods (excluding Cu), weed control, and growth conditions, and on tillage methods and whether conditions over the research years.
2. Herbicides significantly reduced Fe content and increased Cu and Zn contents in young weeds, which indicates that plant protection agents influenced the chemical composition of segetal vegetation.
3. The amount of trace element uptake from a one-hectare area depended on experimental factors, weed biomass and weed chemical composition.

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