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EFFICACY OF HERBICIDES IN POTATO CROP

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ABSTRACT
The experiment was conducted on slightly acidic soil classified as very good rye complex. The aim of the study was to assess the impact of plant–care procedures with the use of herbicides and their mixtures on the number and weed species composition in the field of three edible potato cultivars: Satina, Tajfun and Cekin. The weed infestation was determined at two dates: before the row closure and before tuber harvest. The most effective in decrease of weed infestation, before the row closure as well as before the harvesting of the tubers, appeared to be variations in which herbicides mixtures were used: Command 480 EC 0.2 $l \cdot ha^{-1}$ + Dispersive Afalon 450 SC 1.0 $l \cdot ha^{-1}$ and Stomp 400 SC 3.5 $l \cdot ha^{-1}$ + Dispersive Afalon 450 SC 1.0 $l \cdot ha^{-1}$. According to the conducted researches, the potato cultivars did not have significant effect on weed infestation marked at the beginning and at the end of vegetation.

Keywords: herbicides, potato, weed control methods.

INTRODUCTION

The number of weed species occurring in arable crops in Poland ranges from 300 to 400 [Sobótka 1999], and on potato plantations shapes from 29 to 55 [Nowacki and Podolska 2005]. According to Rola [2002], 50% of potato cropping in Poland are weedy to a medium and large extent and the reappearance of weeds plays an important role. Among all pests, weeds are characterized by the highest potential ability to lowering yields, on average from 10 to 50% [Praczyk and Skrzypczak 2011]. However, according to Wesołowski and Kacuga [1989], lowering yields caused by weed infestation may run into 70%, because of pests – 18%, and diseases – on average 6%.

The weed infestation of potato plantation enforces the need of looking for different weed control methods [Pytlarz-Kozicka 2002]. Using herbicides and their mixtures ensures high effectiveness of weed control which contributes to potato tuber yield increase [Guttieri and Eberlein 1997; Hashim et al. 2003]. Herbicides form a permanent element of the cultivation of crops technology. They guarantee almost complete removing of most of the weed species which occur in the potato canopy. What is more, they also reduce the development of many diseases by the destruction of the source of infection [Giebel et al. 1992]. The application of chemical methods of maintenance, in comparison with mechanical ones, may reduce weed infestation up to 99% [Zarzecka and Gugała 2004].

According to Pruszyński [2000], in the next ten, twenty years, the basis for protection of plants and reduction of losses caused by pests, including weeds, will be use of chemical plant protection products. Therefore, an attempt was made in this study to specify the impact of weed control methods as well as use of herbicides and their mixtures on the number and species composition in the canopy of three edible potato cultivars.

MATERIAL AND METHODS

The field researches were conducted in the years 2008–2010, at the Zawady Agricultural Experimental Station belonging to the University of

Natural Sciences and Humanities in Siedlce. The experiment was set up according to the split-splot design in three replications. The experimental factors were as follows:

1) **I factor** – five weed control methods:
- mechanical weed control – control object, until emergence – earthing up 3–4 times and earthing-up with harrowing (earthing-up once, once or twice earthing-up connected with harrowing + earthing-up once), and earthing-up twice after emergence,
- mechanical and chemical control, until emergence earthing-up and two or three times with harrowing and Command 480 EC about 7 days before emergence, at a dose of 0.2 $l \cdot ha^{-1}$,
- mechanical and chemical control, earthing–up with harrowing until emergence and spraying with a mixture of herbicides Command 480 EC 0.2 $l \cdot ha^{-1}$ + Dispersive Afalon 450 SC 1.0 $l \cdot ha^{-1}$ about 7 days before emergence,
- mechanical and chemical control, earthing–up with harrowing until emergence and herbicide Stomp 400 SC 3.5 $l \cdot ha^{-1}$ about 7 days before emergence,
- mechanical and chemical control, earthing–up with harrowing before emergence and spraying with a mixture of herbicides Stomp 400 SC 3.5 $l \cdot ha^{-1}$ + Dispersive Afalon 450 SC 1.0 $l \cdot ha^{-1}$ about 7 days before emergence,

2) **II factor** – three potato cultivars: Satina, Tajfun, Cekin.

A field experiment was conducted on soil classified in the division – autogenic soils, order – brown soils, type – grey-brown podzolic soils formed from light loamy sands and strong loamy sands, soil quality class IVa and IVb classified as very good rye complex, slightly acid. This soil was characterized by a high concentration in available phosphorous, high concentration in potassium and average concentration in magnesium.

Potato was cultivated in the field after winter cereals. Each year in autumn proceeding seeding the tubers, fertilizing with natural at a dose of 25 $t \cdot ha^{-1}$ of stable manure as well as mineral phosphorus and potassium fertilization in the amount P = 44.0 $kg \cdot ha^{-1}$ (P_2O_5 = 100 kg) i K = 124.5 $kg \cdot ha^{-1}$ (K_2O = 150 kg) were applied.

Each year in spring nitrogen fertilizers were applied at a dose of N 100 $kg \cdot ha^{-1}$. The potatoes were planted in the second and third ten-day period of April in row spacings 62.5×40 cm. In the experiment medium early varieties of edible potato were cultivated: Satin, Tajfun and Cekin. Plant protection treatments against diseases and pests were applied in accordance with the plant protection recommendations.

In order to compare efficiency of the weed control methods, species composition and the number of weeds per 1 m^2 were determined. The measurements were conducted on three randomly chosen plot areas marked out by a frame 33.4×150 cm (5010 cm^2).

The analysis of the field weed infestation was conducted at two dates: 2–3 weeks after application of herbicides (before row closure of the crop) and at the end of potato vegetation (1–2 weeks before tuber harvest). Names of weeds were given in accordance with Atlas of Weed Plants published by The Plant Protection Institute in Poznań [Praczyk 2015].

The results of the study were statistically analysed using analysis of variance. The significance of variability sources was tested by means of Fisher–Snedecor's test, and evaluation of the significance of differences at a significance level of p=0.05 between comparable means was performed using Tukey's multiple range test.

The weather conditions in the study years were changeable. According to hydrothermal Sielianinow's coefficient, analysed vegetation seasons were characterized by the absence of drought. The 2008 year was marked by favourable weather conditions, the rain was evenly distributed and temperatures were close to the average of multi-annual period. In 2009 the weather conditions in particular months were differential, ranged from strong drought in April and July, when Sielianinow's coefficient came to accordingly 0.26 and 0.44, to the absence of drought in June (3.08). However, in the 2010 growing season, strong drought was observed when hydrothermal Sielianinow's coefficient was 0.40 and temperatures were close to the long-term means (Table 1).

RESULTS AND DISCUSSION

The weed infestation of potato plantation marked at two dates, in the initial period of vegetation and before tuber harvest, made it possible to compare all weed control methods and pointing at the best option of reducing the fresh weight of weeds. The number of weeds marked at the initial period of potato vegetation and before tuber

Table 1. Rainfalls and air temperatures in 2008–2010 vegetation seasons at the Zawady Meteorological Station

Years	Months						Mean/Sum IV–IX
	IV	V	VI	VII	VIII	IX	
Rainfalls (mm)							
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
The average over the years 1987–2000	38.6	44.1	52.4	49.8	43.0	47.3	275.2
Temperature (°C)							
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
The average over the years 1987–2000	7.8	12.5	17.2	19.2	18.5	13.1	14.7
Sielianinov's hydrothermic coefficients							
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

Coefficient value [Bac at al. 1998]: < 0.5 – strong drought; 0.51–0.69 – semi drought; 0.70–0.99 – pure drought; ≥ 1 – fault drought.

harvest were significantly dependent on the weed control methods (Tables 2, 3).

The most effective in reducing weed infestation at both dates appeared to be variants: 3 – in which earthing-up with harrowing were used before emergence and spraying with a mixture of herbicides Command 480 EC 0.2 $l \cdot ha^{-1}$ + Dispersive Afalon 450 SC 1.0 $l \cdot ha^{-1}$ about 7 days before emergence; and variant 5. which means earthing-up with harrowing until emergences and spraying with mixture of herbicides Stomp 400 SC 3.5 $l \cdot ha^{-1}$ + Dispersive Afalon 450 SC 1.0 $l \cdot ha^{-1}$ (Tables 2, 4).

The results of the study are in compliance with reports of Eberlain et al. [1997], Kraska et al. [2006], Tomczak et al. [2007], Gugała and Zarzecka [2011] as well as Ciesielska and Wysmułek [2012]. These authors gained the highest percentage of destroying weeds by using combination of at least two herbicides or their mixtures, at two dates. The result of weed control with the mixtures of herbicides was also less dependent on the meteorological conditions in the years of research than after applying one preparation.

The weather conditions in particular years of conducting the experiment had a significant impact on weed infestation of the plantation (Table 1). The highest number of weeds, before row closure as well as before tuber harvest, was found in 2008 which was characterized by even distribution of rainfall and temperatures (Tables 4, 5, 6). However, the lowest number of weed species was found in 2009 when severe rainfall deficiency occurred in April and July. A similar impact of the weather conditions on the weed infestation of potato was observed by Gruczek [2001], Zarzecka and Gugała [2004a, b] and Sawicka et al. [2011].

The analysis of the percentage share of weed species showed that at the beginning of the potato growing season the dominant taxons were as follows: *Agropyron repens* (L.) – average 19.8%, *Echinochloa crus-galli* (L.) – average 13.2%, *Viola arvensis* (Murr.) – average 12.1%, *Chenopodium album* (L.) – average 11.2% (Table 4). Also at the second date, before the tuber harvest, similar correlation appeared and the highest percentage share of these weed species have been seen: *Agropyron repens* (L.) – average 25.9% *Chenopodium album* (L.) – average 20.3%, *Echinochloa crus-galli* (L.) – average 14.7%, *Polygonum convolvulus* (L.) – average 11.2% (Table 5).

These taxons posed the greatest threat to growth, development and yielding of the potato. According to Kapeluszny [1980], few species characterized by eminent aggressiveness or abundant may decide about weed infestation of the field. While the abundance of species composition does not always prejudge the intensity of infestation.

Table 2. The species composition and the number of weeds per 1m^2 before potato row closure depending on weed control methods

Species	Weed control methods					Mean
	1*	2*	3*	4*	5*	
Chenopodium album (L.)	2.1	1.8	0.9	1.8	1.1	1.5
Thlaspi arvense (L.)	1.6	3.1	1.0	1.3	0.7	1.5
Erodium cicutarium (L.)	1.9	2.6	1.0	1.2	0.4	1.4
Anthemis arvensis (L.)	0.8	0.1	0.3	–	0.6	0.4
Viola arvensis (Murr.)	2.0	1.4	1.2	1.8	1.5	1,6
Polygonum convolvulus (L.)	2.1	1.3	0.9	1.7	1.7	1.5
Cirsium arvense (L.)	0.4	0.9	0.6	1.4	–	0.7
Galinsoga parviflora (Cav.)	1.0	0.1	0.2	0.7	0.7	0.5
Galium aparine (L.)	0.8	–	–	0.3	0.2	0.3
Total of dicotyledonous	**12.7**	**11.3**	**6.1**	**10.2**	**6.9**	**9.4**
Agropyron repens (L.)	4.2	4.2	1.6	3.0	3.7	3.3
Echinochloa crus-galli (L.)	6.1	0.9	1.3	2.0	1.9	2.4
Poa annua (L.)	0.2	0.4	1.4	0.3	–	0.5
Total of monocotyledonous	**10.5**	**5.5**	**4.3**	**5.3**	**5.6**	**6.2**
Other species	2.8	1.3	2.5	3.4	2.6	2.6
Total number of weeds	**26.0**	**18.1**	**12.9**	**18.9**	**15.1**	**18.2**
$NIR_{0,05}$ $LSD_{0,05}$ – between weed control methods						**2.4**

1* – Control object, 2* – Command 480 EC 0.2 dm^3·ha^{-1}, 3* – Command 480 EC 0.2 dm^3·ha^{-1} + Dispersive Afalon 450 SC 1.0 dm^3·ha^{-1}, 4* – Stomp 400 SC 3.5 dm^3·ha^{-1}, 5* – Stomp 400 SC 3.5 dm^3·ha^{-1} + Dispersive Afalon 450 SC 1.0 dm^3·ha^{-1}

Other species: *Veronica triphyllos* (L.), *Scleranthus annuus* (L.), *Taraxacum campylodes* (G. E. Haglund), *Melandrium album* (Mill.), *Symphytum officinale* (L.)

Table 3. The species composition and the number of weeds per 1m^2 before potato tubers harvest depending on weed control methods

Species	Weed control methods					Mean
	1*	2*	3*	4*	5*	
Chenopodium album (L.)	4.3	1.5	1.8	2.6	1.2	2.3
Thlaspi arvense (L.)	–	–	–	–	–	–
Erodium cicutarium (L.)	1.1	1.1	2.3	1.6	1.2	1.5
Anthemis arvensis (L.)	–	–	–	–	–	–
Viola arvensis (Murr.)	1.3	1.1	1.0	1.2	0.5	1.0
Polygonum convolvulus (L.)	3.0	0.9	0.8	1.3	1.2	1.4
Cirsium arvense (L.)	1.4	2.9	1.0	0.4	0.7	1.3
Galinsoga parviflora (Cav.)	–	–	–	0.2	0.3	0.1
Galium aparine (L.)	0.2	–	–	–	0.3	0.1
Total of dicotyledonous	**11.3**	**7.5**	**6.9**	**7.3**	**5.4**	**7.7**
Agropyron repens (L.)	4.2	3.7	1.2	5.3	3.4	3.6
Echinochloa crus-galli (L.)	4.3	2.0	0.5	1.8	2.2	2.2
Poa annua (L.)	0.1	–	0.1	0.4	0.1	0.1
Total of monocotyledonous	**8.6**	**5.7**	**1.8**	**7.5**	**5.7**	**5.9**
Other species	1.1	0.6	0.1	1.1	0.9	0.7
Total number of weeds	**21.2**	**13.8**	**8.8**	**15.9**	**12.0**	**14.3**
$NIR_{0,05}$ $LSD_{0,05}$ between weed control methods						**2.7**

1* – Control object, 2* – Command 480 EC 0.2 dm^3·ha^{-1}, 3* – Command 480 EC 0.2 dm^3·ha^{-1} + Dispersive Afalon 450 SC 1.0 dm^3·ha^{-1}, 4* – Stomp 400 SC 3.5 dm^3·ha^{-1}, 5* – Stomp 400 SC 3.5 dm^3·ha^{-1} + Dispersive Afalon 450 SC 1.0 dm^3·ha^{-1}

Other species: *Taraxacum campylodes* (G.E.Haglund), *Melandrium album* (Mill.), *Plantago lanceolata* (L.)

Table 4. The species composition and the number of weeds per 1m^2 before potato row closure in the years 2008–2010

Species	Years			Mean	Percentage of species
	2008	2009	2010		
Chenopodium album (L.)	3.0	1.9	1.2	2.0	11.2
Thlaspi arvense (L.)	2.9	0.2	0.5	1.2	6.6
Erodium cicutarium (L.)	1.6	–	2.3	1.3	7.2
Anthemis arvensis (L.)	0.2	–	0.4	0.2	1.1
Viola arvensis (Murr.)	3.7	2.4	0.4	2.2	12.1
Polygonum convolvulus (L.)	3.7	1.1	0.3	1.7	9.3
Amaranthus retroflexus (L.)	0.9	–	–	0.3	1.6
Galinsoga parviflora (Cav.)	0.3	0.1	0.8	0.4	2.2
Capsella bursa pastoris (L.)	0.3	–	–	0.1	0.5
Polygonum persicaria (L)	–	0.3	–	0.1	0.5
Cirsium arvense (L.)	–	–	1.2	0.4	2.2
Galium aparine (L.)	–	–	0.3	0.1	0.5
Other species	**0.8**	**3.0**	**2.2**	**2.0**	**10.9**
Total of dicotyledonous	**17.4**	**9.0**	**9.6**	**12.0**	**65.9**
Agropyron repens (L.)	3.8	2.8	4.1	3.6	19.8
Echinochloa crus-galli (L.)	5.2	1.1	1.0	2.4	13.2
Poa annua (L.)	–	0.3	0.3	0.2	1.1
Total of monocotyledonous	**9.0**	**4.2**	**5.4**	**6.2**	**34.1**
Total number of weeds	26.4	13.2	15.0	18.2	–
Total number of species	**12.0**	**10.0**	**13.0**	**16.0**	–
$NIR_{0,05}$ $LSD_{0,05}$ for years					**1.9**

Other species: *Veronica triphyllos* (L.), *Scleranthus annuus* (L.), *Taraxacum campylodes* (G.E.Haglund), *Melandrium album* (Mill.), *Symphytum officinale* (L.)

Table 5. The species composition and the number of weeds per 1m^2 before potato tubers harvest in the years 2008–2010

Species	Years			Mean	Percentage of species
	2008	2009	2010		
Chenopodium album (L.)	3.7	2.7	2.2	2.9	20.3
Thlaspi arvense (L.)	–	–	–	–	–
Erodium cicutarium (L.)	1.0	–	1.7	0.9	6.3
Anthemis arvensis (L.)	–	–	–	–	–
Viola arvensis (Murr.)	1.0	2.4	0.3	1.2	8.4
Polygonum convolvulus (L.)	3.0	1.7	0.1	1.6	11.2
Amaranthus retroflexus (L.)	0.6	–	–	0.2	1.4
Galinsoga parviflora (Cav.)	–	–	0.3	0.1	0.7
Capsella bursa pastoris (L.)	0.3	–	–	0.1	0.7
Polygonum persicaria (L.)	–	0.3	–	0.1	0.7
Cirsium arvense (L.)	–	–	1.5	0.5	3.5
Galium aparine (L.)	–	–	0.3	0.1	0.7
Total of dicotyledonous	**9.6**	**7.1**	**6.4**	**7.7**	**53.9**
Agropyron repens (L.)	4.1	1.4	5.5	3.7	25.9
Echinochloa crus-galli (L.)	4.9	0.8	0.8	2.1	14.7
Poa annua (L.)	–	–	0.3	0.1	0.7
Total of monocotyledonous	**8.9**	**2.2**	**6.6**	**5.9**	**41.2**
Other species	**1.0**	**0.2**	**0.9**	**0.7**	**4.9**
Total number of weeds	**19.6**	**9.5**	**13.9**	**14.3**	–
Total number of species	**9.0**	**7.0**	**11.0**	**14.0**	–
$NIR_{0,05}$ $LSD_{0,05}$ dla; for: lat-years					**1.4**

Other species: *Equisetum arvense* (L.), *Lamium purpureum* (L.), *Matricaria chamomilla* (L.), *Taraxacum campylodes* (G. E. Haglund), *Melandrium album* (Mill.), *Plantago lanceolata* (L.)

Table 6. The number of weeds per 1m^2 harvest depending on weed control methods and years of the study

Cultivars	Years			Mean
	2008	2009	2010	
Before row closure				
1*	34.9	15.7	27.4	26.0
2*	27.2	12.9	14.0	18.1
3*	19.3	10.7	8.7	12.9
4*	27.4	15.9	13.4	18.9
5*	23.0	10.8	11.5	15.1
Mean	**26.4**	**13.2**	**15.0**	**18.2**
NIR $_{0,05}$ LSD $_{0,05}$ between years 1.9 between weed control methods 1.9 – in interaction between weed control methods x years 4.1				
Before tubers harvest				
1*	26.1	13.1	24.4	21.2
2*	20.0	9.1	12.4	13.8
3*	12.9	6.6	6.9	8.8
4*	22.0	10.6	15.2	15.9
5*	17.1	8.1	10.7	12.0
Mean	**19.6**	**9.5**	**13.9**	**14.3**
NIR $_{0,05}$ LSD $_{0,05}$ between years 1.4 between weed control methods 1.4 – in interaction between weed control methods x years 4.6				

1* – Control object, 2* – Command 480 EC 0.2 dm^3·ha^{-1}, 3* – Command 480 EC 0.2 dm^3·ha^{-1} + Dispersive Afalon 450 SC 1.0 dm^3·ha^{-1}, 4* – Stomp 400 SC 3.5 dm^3·ha^{-1}, 5* – Stomp 400 SC 3.5 dm^3·ha^{-1} + Dispersive Afalon 450 SC 1.0 dm^3·ha^{-1}

CONCLUSIONS

The most effective in decrease of weed infestation marked before row closure and potato tuber harvest were variations: 3 – in which mechanical weed control until emergence and sprying with mixture of herbicides Command 480 EC 0.2 l·ha^{-1} + Dispersive Afalon 450 SC 1.0 l·ha^{-1} were used as well as variant 5 – which means mechanical weed control until emergence and sprying with mixture of herbicides Stomp 400 SC 3.5 l·ha^{-1} + Dispersive Afalon 450 SC 1.0 l·ha^{-1} just before germination. The analysis of variances did not confirm the significant impact of potato cultivars on the number and weed species composition. The weather conditions in particular years of conducting the experiment significantly diversified weed infestation of potato plants.

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