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Weed infestation and potato yielding under the conditions of diversified tillage operations

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Abstract: A three-year field experiment was conducted in the years 2002-2004 at the Experimental Farm at Zawady owned by the University of Podlasie to evaluate an effect of soil tillage and weed control methods including herbicides and their mixtures on weed infestation and yielding of edible potato cv. Wiking. It was found that soil tillage methods significantly differentiated the potato tuber total yield, weed number determined at the onset and the end of vegetation and weed air dry matter before closing of potato rows. Compared with the control treatment where weeds were mechanically controlled, increased weed control intensity (including herbicides) significantly reduced weed infestation, which was followed by significantly increased tuber total yield by 2.17 to 5.56 t ha^{-1} and the share of commercial fraction of tubers yield in the total yield excluding variant 5 in which a single herbicide, (that is Barox 460 SL) was applied.

Keywords: potato, weed infestation, soil tillage methods, weed control methods

INTRODUCTION

Potato is a plant which requires fine and carefully tilled soil to grow well. It is estimated that conventional pre-plant soil tillage is associated with 25-40% energy inputs associated with the production of this plant [1]. Economic considerations frequently make farmers to apply soil tillage simplifications and abandon or limit some tillage operations. However, researchers' opinions on this issue are

not uniform. Most authors think that application of simplifications in soil tillage results in worse physical properties of the soil [2], increased weed infestation [2, 3] and decreased potato tuber yield [4, 5]. Negative effects of reduced soil tillage can be reduced by applying well-selected herbicides. Grant and Epstein [5] and Klikocka [1] proved that non-plough soil tillage preceding potato planting and combined with chemical weed control beneficially influenced on soil structure and limited erosion. Other authors showed that herbicides and herbicide mixtures reduced weed infestation compared with mechanical weed control. As a result, total and marketable yields of potato tubers increased [6-9].

The objective of the studies was to determine an effect of two soil tillage methods, that is conventional and simplified and mechanical-chemical weed control including herbicides and their mixtures on weed infestation and potato yielding.

MATERIALS and METHODS

A field experiment was conducted at the University of Podlasie Experimental Farm at Zawady over the years 2002-2004. It was set up on a soil belonging to the rye very good complex, pH being slightly acid. The experiment was laid out as a randomised sub-block design in three replications and it included the following factors:

I. two soil tillage methods – conventional (traditional) (skimming + fall ploughing + harrowing + cultivating + harrowing) and simplified (skimming + cultivating),
II. seven weed control methods including an application of herbicides:
    1. control treatment – mechanical weed control prior to and following potato emergence,
    2. Plateen 41.5 WG (metribuzin + flufenacet) 2.0 kg ha^{-1},
    3. Plateen 41.5 WG (metribuzin + flufenacet) 2.0 kg ha^{-1} + Fusilade Forte 150 EC (fluazifop-P-butyl) 2.5 l/ha (mixture),
    4. Plateen 41.5 WG (metribuzin + flufenacet) 1.6 kg ha^{-1} + Fusilade Forte 150 EC (fluazifop-P-butyl) 2.0 l/ha + adjuvant Atpolan 80 EC 1.5 l ha^{-1} (mixture),
    5. Barox 460 SL (bentazone + MCPA) 3.0 l ha^{-1},
    6. Barox 460 SL (bentazone + MCPA) 3.0 l ha^{-1} + Fusilade Forte 150 EC (fluazifop-P-butyl) 2.5 l ha^{-1} (mixture),
    7. Barox 460 SL (bentazone + MCPA) 2.4 l ha^{-1} + Fusilade Forte 150 EC (fluazifop-P-butyl) 2.0 l ha^{-1} + adjuvant Atpolan 80 EC 1.5 l/ha (mixture).

In treatments 2-7 pre-emergence mechanical weed control was performed. Herbicides were applied just prior to potato emergence (treatments 2, 3, 4) and post-emergence to 10-15 cm of potato plant height (treatments 5, 6, 7). In the experiment, farmyard manure and mineral fertilizers were applied at the respective rates of 25 t/ha and 90 kg N, 90 kg P_2O_5, and 135 kg K_2O per hectare. Potato tubers of Wiking cultivar were planted in the third decade of April at the spacing of 67.5 x 37 cm.

Table 1. Characteristic of weather conditions of the period of potato vegetation in 2002-2004 (Zawady Meteorological Station)

Years	Months						April-September
	April	May	June	July	August	September	
Rainfalls (mm)							Sum
2002	12.9	51.3	61.1	99.6	66.5	18.7	310.1
2003	13.6	37.2	26.6	26.1	4.7	24.3	132.5
2004	35.9	97.0	52.8	49.0	66.7	19.5	320.9
Multi-year average (1981-1995)	52.3	50.0	68.2	45.7	66.8	60.7	343.7
Air temperature (°C)							Average
2002	9.0	17.0	17.2	21.0	20.2	12.9	16.2
2003	7.1	15.6	18.4	20.0	18.5	13.5	15.5
2004	8.0	11.6	15.4	17.5	18.9	13.0	14.1
Multi-year average (1981-1995)	7.7	10.0	16.1	19.3	18.0	13.0	14.0
Sielianinow's hydrothermic coefficients*							Average
2002	1.5	1.0	1.2	1.5	2.1	1.5	1.1
2003	0.6	0.8	0.5	0.4	0.1	0.6	0.4
2004	1.5	2.7	1.1	0.9	1.1	0.5	1.2

* below 0.5 strong mild drought
0.51 – 0.69 mild drought
0.70 – 0.99 weak mild drought
≥ 1 fault mild drought

Weed infestation was determined by the square frame and gravimetrical method before closing of potato rows and before tubers lifting . The number of weeds and their air dry matter per m^2 were determined. Just before lifting tubers were sampled by collecting them from 10 plants in each plot and grouped into the

following fractions: under 30, 30-40, 40-50, 50-60 and over 60 mm of diameter. Next, their weight share in the yield was calculated. The weight of tubers which diameter was over 40 mm was assumed to be the commercial fraction of tubers yield. The study results were statistically analysed by means of variance analysis and significance of differences between means was checked by Tukey test.

Weather conditions over the study years varied (Table 1). The year 2002 was most favourable for yield accumulation. Precipitation was close to the average sum for the multi-year period whereas temperature was higher than in the multiyear period. The growing season of 2003 was characterized by substantial rain shortages over the months of the crop plant growing whereas temperature was higher compared with the multi-year period. The year 2004 saw precipitation that was similar in amount to the multi-year period. However, the growing season of 2004 was the coldest compared with the previous years.

RESULTS and DISCUSSION

The number of weeds determined at the onset and towards the end of potato growth significantly depended on tillage methods, weed control methods and weather conditions in the study years (Table 2). Simplified tillage increased by 2.1 (before closing of potato rows) and 2.6 plant m^{-2} (before tubers lifting) number of weeds compared with conventional tillage. Also Derksen et al. [10] and Jabłoński and Bernat [3] found an increase in the number of weeds after reducing the number of tillage operations.

Mechanical-chemical weed control operations performed in treatments 2-7 significantly reduced the number of weeds at the dates of determination compared with the control treatment. As far as weed control, the best results were obtained after an application of the following herbicide mixtures: Plateen 41.5 WG + Fusilade Forte 150 EC + Atpolan 80 EC, Plateen 41.5 WG + Fusilade Forte 150 EC, and Barox 460 SL + Fusilade Forte 150 EC + Atpolan 80 EC. High weed control efficacy of two herbicides and their mixtures, equalling 40-99%, was also observed by Eberlein et al. [11], Guttieri and Eberlein [7] and Zarzecka [12].

The study years influenced the number and weight of weeds. The highest weed infestation was observed in 2004 when substantial precipitation during the growing period was recorded. A similar influence of atmospheric conditions on weed occurrence in potato was found by Zarzecka et al. [9].

Table 2. The number of weed per 1 m^2 depending on weed control methods and soil tillage

Weed control methods	Tillage systems soil		Years			Average
	traditional	simplified	2002	2003	2004	
Before closing of potato rows						
1. Control object	17.9	25.5	16.4	22.5	26.2	21.7
2. Plateen 41,5 WG	8.8	11.1	3.8	12.0	14.0	9.9
3. Plateen 41,5 WG + Fusilade Forte 150 EC (mixture)	8.4	10.2	3.0	11.5	13.5	9.3
4. Plateen 41,5 WG + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	7.0	9.2	3.0	11.2	10.2	8.1
5. Barox 460 SL	10.4	14.6	13.2	6.4	18.0	12.4
6. Barox 460 SL + Fusilade Forte 150 EC (mixture)	9.7	12.3	12.4	4.7	16.0	11.0
7. Barox 460 SL + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	8.9	9.9	10.5	5.9	11.9	9.4
Average	10.2	13.3	8.9	10.6	15.7	11.8
$LSD_{0.05}$: weed control methods = 3.8; tillage methods = 2.3; years = 3.5, Interaction: weed control methods x tillage methods = n.s.; weed control methods x years = 6.6; tillage methods x years = n.s.; n.s. = not significant						
Before tubers lifting						
1. Control object	15.0	21.0	12.0	18.5	23.5	18.0
2. Plateen 41,5 WG	10.3	12.8	8.4	10.4	16.0	11.6
3. Plateen 41,5 WG + Fusilade Forte 150 EC (mixture)	8.1	11.4	6.2	9.0	14.2	9.8
4. Plateen 41,5 WG + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	7.2	8.7	5.0	8.7	10.2	8.0
5. Barox 460 SL	10.9	12.9	8.8	10.7	16.2	11.9
6. Barox 460 SL + Fusilade Forte 150 EC (mixture)	10.4	12.3	8.0	10.0	16.2	11.4
7. Barox 460 SL + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	9.7	10.8	7.7	9.3	13.7	10.2
Average	10.2	12.8	8.0	10.9	15.7	11.5
$LSD_{0.05}$: weed control methods = 2.9; tillage methods = 2.1; years = 3.3, Interaction: weed control methods x tillage methods = n.s.; weed control methods x years = n.s.; tillage methods x years = n.s.; n.s. = not significant						

Table 3. Air-dry matter of weed depending on weed control methods and soil tillage in g m^{-2}

Weed control methods	Tillage systems soil		Years			Average
	traditional	simplified	2002	2003	2004	
Before closing of potato rows						
1. Control object	17.5	29.8	11.5	11.1	48.5	23.7
2. Plateen 41,5 WG	11.7	13.7	2.6	4.6	30.9	12.7
3. Plateen 41,5 WG + Fusilade Forte 150 EC (mixture)	4.1	6.9	1.9	2.7	12.0	5.5
4. Plateen 41,5 WG + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	3.0	5.3	1.7	2.1	8.7	4.1
5. Barox 460 SL	12.6	18.1	10.0	1.7	34.5	15.4
6. Barox 460 SL + Fusilade Forte 150 EC (mixture)	9.2	12.5	8.2	0.6	23.9	10.9
7. Barox 460 SL + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	7.8	11.6	7.8	0.6	20.9	9.8
Average	9.5	14.0	6.3	3.3	25.6	11.7
$LSD_{0.05}$: weed control methods = 4.6; tillage methods = 3.0; years = 4.6, Interaction: weed control methods x tillage methods = 4.3; weed control methods x years = 8.0; tillage methods x years = n.s.; n.s. = not significant						
Before tubers lifting						
1. Control object	91.9	105.8	55.3	42.3	199.0	98.9
2. Plateen 41,5 WG	62.9	73.4	40.4	18.5	145.7	68.2
3. Plateen 41,5 WG + Fusilade Forte 150 EC (mixture)	49.4	55.4	34.3	16.4	106.7	52.5
4. Plateen 41,5 WG + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	37.3	42.3	19.4	15.6	84.5	39.8
5. Barox 460 SL	64.7	82.0	51.5	12.7	155.9	73.4
6. Barox 460 SL + Fusilade Forte 150 EC (mixture)	60.5	69.9	46.0	8.5	141.2	65.2
7. Barox 460 SL + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	51.9	60.8	42.6	5.5	121.0	56.4
Average	59.8	69.9	41.4	17.1	136.3	64.9
$LSD_{0.05}$: weed control methods = 28.3; tillage methods = n.s.; years = 22.6, Interaction: weed control methods x tillage methods = n.s.; weed control methods x years = n.s.; tillage methods x years = n.s.; n.s. = not significant						

Air dry matter of weeds determined before closing of potato rows was significantly affected by the experimental factors and study years. After

termination of potato growth a similar effect was exerted by weed control methods and weather conditions during the experiment (Table 3). Compared with conventional tillage, simplified tillage increased air dry matter of weeds whereas the differences in weed infestation were small prior to tuber lifting. Lack of an influence of reductions in potato cultivation operations on the characteristics discussed was also found by Klikocka [1]. In contrast, Jabłoński and Bernat [3] observed an increase in the number of weed species as well as number and fresh matter of weeds per 1 m^2.

Table 4. Potato total yield of tubers in t ha^{-1}

Weed control methods	Tillage systems soil		Years			Average
	traditional	simplified	2002	2003	2004	
1. Control treatment	29.75	27.12	36.34	22.20	26.79	28.44
2. Plateen 41,5 WG	32.06	29.71	39.17	23.73	29.77	30.89
3. Plateen 41,5 WG + Fusilade Forte 150 EC (mixture)	34.06	31.56	42.04	24.39	31.70	32.71
4. Plateen 41,5 WG + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	35.72	32.28	42.25	24.74	35.02	34.00
5. Barox 460 SL	32.14	29.10	36.96	25.40	29.47	30.61
6. Barox 460 SL + Fusilade Forte 150 EC (mixture)	32.98	29.61	37.13	25.79	30.97	31.29
7. Barox 460 SL + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	33.85	30.27	37.33	27.36	31.49	32.06
Average	32.94	29.92	38.75	24.80	30.74	31.43
$LSD_{0.05}$ between: weed control methods = 2.22; tillage systems = 0.71; years = 1.14, Interaction: weed control methods x tillage methods = 2.90; weed control methods x years = 3.85; tillage systems x years = 1.23						

An analysis of an effect of weed control methods on air dry matter of weeds determined before lifting indicated significant differences between the control treatment and the remaining weed control methods, excluding variant 5 in which a single herbicide, that is Barox 460 SL (Table 3) was applied. The lowest average dry matter value was recorded in treatments sprayed with a mixture of Plateen 41.5 WG + Fusilade Forte 150 EC (treatment 3) and the same mixture but applied at rates lower by 20% and including an addition of adjuvant Atpolan 80 EC (treatment 4). It was by 2-2.5 times lower than for the control treatment. According to many authors, higher effectiveness in reducing weed matter is assured when applying two herbicides or their mixtures. Eberlain et al. [11] applied metribuzin and rimsulfuron and obtained a 77-98% reduction in weed

matter. In the study by Gruczek [6] who used metribuzin and bentazon, and Wilson et al. [13] who applied metribuzin, sulfentrazone and flumioxazin, the percentage of dicotyledonous weed mass destruction was over 90%.

Soil tillage methods significantly affected potato total yield and impacted the share of the commercial fraction of tubers in the total yield (Table 4, Figure 1). In comparison with conventional plough-based tillage, the reductions in tillage decreased total yield of tubers by 9.2%. In their studies Boligłowa and Gleń [4] obtained, respectively, a 11.4 and 6.9% reduction in tuber yield after eliminating some tillage operations. Moreover, the authors observed a more negative yield structure.

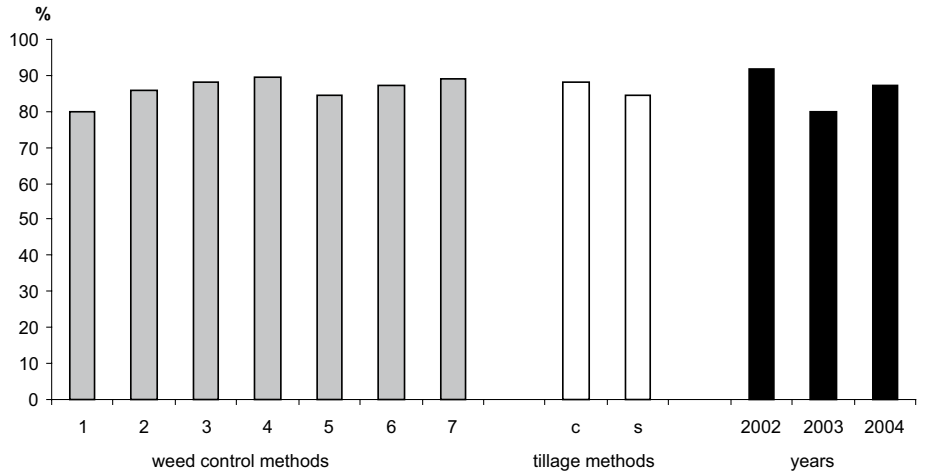

Figure 1. Percentage of the commercial fraction of tubers yield in the potato total yield depending on weed control methods, tillage methods and years.

Weed control methods diversified weed infestation which in turn affected potato yields (Table 4). In the treatments where weeds were controlled by means of herbicides or their mixtures yields were by 2.17 to 5.56 t ha^{-1} higher compared with the control treatment. The highest yields were harvested in treatments 3 and 4 where weeds in potato plots were controlled by means of herbicide mixtures. Increased total and commercial yields of potato tubers following an application of herbicides or herbicide mixtures were observed by Ciuberkis et al. [14], Guttieri and Eberlein [7], Renner [15], Shah et al. [13] and Zarzecka [12]. In the present studies a higher commercial fraction of tubers yield share in the total yield in treatments where mechanical-chemical weed control was applied, compared with

the control treatment were also found (Table 5, Figure 1). A similar response was observed by Gruczek [6] and Zarzecka and Gugała [16].

Table 5. Share of the commercial fraction of tubers yield in the potato total yield in %

Weed control methods	Tillage systems soil		Average
	traditional	simplified	
1. Control treatment	83.50	76.40	79.95
2. Plateen 41,5 WG	87.37	84.28	85.83
3. Plateen 41,5 WG + Fusilade Forte 150 EC (mixture)	89.08	87.36	88.22
4. Plateen 41,5 WG + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	90.43	88.76	89.59
5. Barox 460 SL	86.57	82.16	84.37
6. Barox 460 SL + Fusilade Forte 150 EC (mixture)	88.66	86.22	87.44
7. Barox 460 SL + Fusilade Forte 150 EC + adjuvant Atpolan 80 EC (mixture)	90.28	87.68	88.98
Average	87.98	84.69	86.34

According to Adamczewski and Praczyk [17], weed control operations should not only protect crops but also reduce production of weed seeds, thus limiting weed threat to crops cultivated in the following years.

CONCLUSIONS

1. Simplifications of soil tillage increased weed infestation compared with the conventional tillage.
2. Herbicides and their mixtures significantly reduced the number and air dry matter of weeds in potato compared with the mechanical weeding.
3. Potato total yield of tubers was higher under the conditions of conventional than simplified tillage, and when intense chemical protection of crop was applied compared with the mechanical control of weeds.

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