ACTA AGROBOTANICA
Vol. 61 (2): 221–228
2008

THE EFFECT OF TILLAGE SIMPLIFICATIONS AND MINERAL FERTILISATION LEVEL ON THE NUMBER AND DISTRIBUTION OF WEED SEEDS IN SOIL

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Received: 11.03.2008

Summary

In the present paper, results of a study on the effect of a reduction in the number of ploughings in a crop rotation on the seed weed bank in the soil are presented. The study was carried out in the second and fourth year of a crop rotation (potato– spring wheat– pea– winter wheat). A reduction in the number of ploughings to three in the crop rotation decreased weed infestation of the plough layer, whereas when only one ploughing was made there was clearly more weed diaspores in the soil than after plough tillage. In the first period of the study, the mineral fertilisation level did not differentiate the weed seed bank in the soil, whereas after the end of the rotation its significant increase was noted as a result of more intensive fertilisation. In all the experimental treatments, diaspores of *Chenopodium album, Viola arvensis, Galinsoga sp.* and *Apera spica-venti* occurred in greatest numbers.

Key words: crop rotation, tillage, weeds, weed seed bank

INTRODUCTION

In connection with the need to limit production costs in agriculture, different simplifications in soil tillage are used. They consist most frequently in reducing the depth and frequency of ploughings, replacing them by other less energy-consuming treatments, including direct sowing. Radecki, 1986; Dzienia and Sosnowski, 1991; (Gawrońska-Kulesza, 1997; Malicki et al. 1997; Kordas, 1999). The use of such simplifications may however lead to an increase in weed infestation of a crop canopy and accumulation of weed diaspores in the soil (Dwořak, 1987; Papay et al. 1994; Skrzypczak et al. 1995); Feldman et al. 1996; Witkowski, 1998; Dorado et al. 1999; Dzienia et al. 2003. Nevertheless, studies conducted so far do not give a full and unequivocal answer to the question how different plough tillage simplifications affect possible weed infestation of soil. Therefore, this study was conducted; its aim was to determine the condition and level of weed infestation of the cultivated soil layer under the influence of a reduced number of ploughings in a four-field crop rotation system and with differentiated mineral fertilisation levels.

MATERIALS AND METHODS

The field experiment was carried out in the years 1998–2002 at the Czesławice Experimental Farm, belonging to the University of Natural Sciences in Lublin. The field experiment was set up in a split-block design, with four replications, on grey-brown podzolic soil formed from loess with the granulometric composition of clayey silt (36% of fine particles). The soil in the experiment was characterised by a slightly acid reaction (pH in 1 mol KCl×dm^{-3} – 6.5-6.6), humus content of 16.3g×kg^{-1} of soil and a high abundance of available phosphorus, potassium and magnesium.

The field studies covered the first rotation of the four-field crop rotation beginning with the following crop sequencing of all the plants: potato-spring wheat-pea – winter wheat. For each plant, three tillage methods and two mineral fertilisation levels were used:

I. Tillage methods

A – traditional (7 ploughings per rotation),

B – reduced (3 ploughings per rotation),

C – reduced (1 ploughing per rotation);

II. Mineral fertilisation levels

a. 167.5 kg NPK and b. 251.2 kg NPK on an annual average basis per rotation.

Ploughings were replaced mainly by soil cultivating or disking. A detailed list of measures performed in particular tillage treatments is shown in Table 1.

The following herbicides were applied in particular crop plants: in potato – Dispersion Afalon 450SC

2L×ha^{-1} (450 g of linuron in 1L of the herbicide); in spring wheat – Puma Uniwersal 069 EW -1L×ha^{-1} (69 g of fenoxaprop-P-ethyl with a 75g addition of mefenpyr-diethyl in 1L of the herbicide) and Aminopielik D 450SL^{-3} L×ha^{-1} (417.5 g 2.4D, 32.5 g of dicamba in the form of dimethylamine salts in 1L of the herbicide); in pea – Stomp 330EC 4 L×ha^{-1} (330g of pendimethalin in 1L of the herbicide); in winter wheat - Puma Uniwersal 069 EW – 1.2 L×ha^{-1} (69g of fenoxaprop-P-ethyl with a 75g addition of mefenpyr-diethyl in 1L of the herbicide) and Aminopielik D 450SL – 3 L×ha^{-1} (417.5 g 2.4D, 32.5 g of dicamba in the form of dimethylamine salts in 1L of the herbicide).

Soil samples collected using a cylinder with a diameter of 7.8 cm from three soil layers, notably: 0-5 cm, 5-15 cm and 15-30 cm, after the harvesting of particular plants, were the object of detailed examination. The soil samples for each treatment were a mixed sample from the replications of each tillage method for particular plants of the crop rotation. In order to separate weed seeds from soil solid particles, the samples were washed with water on sieves with 0.25 mm mesh. They were then dried at a temperature of 40°C and weed fruits and seeds were picked out manually (using forceps) from them. In this study, only properly developed and filled weed fruits and seeds, hence presumably able to germinate, were taken into consideration. Species names of weed seeds followed M i r e k et al. [1995].

RESULTS AND DISCUSSION

The study conducted in the years 2000 and 2002 (in the second and fourth year of the crop rotation) showed that the applied tillage simplifications and mineral fertilisation level had no significant effect on the species composition of weed seeds in the 0-30 cm soil layer (Tab. 2 and 3). The determinations made after the end of the rotation only demonstrated substantial impoverishment of the species composition of weed diaspores (Tab. 3). From among previously noted species, seeds of *Fallopia convolvulus, Sonchus asper, Vicia tetrasperma, Thlaspi arvense, Myosotis arvensis* and *Polygonum persicaria* were not found, and caryopses of *Avena fatua,* which had not been previously noted, were determined. In both years of the study, irrespective of the tillage method, slightly more weed species were noted in the intensively fertilised treatments. A significant decrease in the number of weed diaspores in the soil in 2002 compared to 2000 is also worth noting.

The applied tillage modifications significantly differentiated the seed weed bank in the soil (Tab. 4). In both years of the study, the smallest number of weed seeds, both the total number and the number of dominant species' seeds, was found after the number of ploughings was reduced to 3 in the crop rotation (B), it was significantly larger after typical tillage (A – 7 ploughings in the crop rotation), and the largest one when only one ploughing was made in the crop rotation (C).

More intensive fertilisation increased significantly the total weed seed bank and the number of dominant species' seeds only in 2002, thus, after the end of the crop rotation (Tab. 4). In the present study, no significant interaction was found between the tillage system and the fertilisation level with respect to the weed seed bank in the soil.

Also, the applied tillage simplifications and mineral fertilisation level had no significant impact on the distribution of weed seeds in the analysed soil layers. Only the smallest number of diaspores in the surface layer was noted most frequently, and its increase together with the increase of the depth.

The species composition of weeds in particular experimental treatments was similar. In 2000 only 8 species from the weed species found occurred in all the tillage and fertilisation treatments. But in 2002 as many as 12 species were common out of 18 species found. The dominant species were as follows: *Chenopodium album*, *Viola arvensis*, *Apera spica-venti* and *Galinsoga sp*. *Chenopodium album* seeds occurred in greatest numbers among them. They accounted for 60% of the total number of all identified diaspores.

To sum up the obtained results, it should be stressed that the introduced simplifications did not have an unequivocal effect on the weed seed bank in the soil, since it was found that a reduction in the number of ploughings to three in the crop rotation decreased the seed bank, and it was the application of only one ploughing which clearly increased this trait compared to typical tillage (7 ploughings in the crop rotation). Such findings are only partially consistent with the results of W i t k o w s k i (1998), C a r d i n y et al. (1991), F e l d m a n a et al. (1992), P a p a y et al. (1994), C o u s e n s and M o s s (1990) as well as W e s o ł o w s k i and B u j a k (2006) in whose studies the application of tillage simplifications, mainly direct sowing, resulted in an increase in the weed seed bank. In turn, W r z e s i ń s k a et al. (2004) as well as O p i c (1996) noted a decrease in the weed seed bank under the influence of no-plough tillage or the application of direct sowing. But D w o ř a k (1987) reports that a decrease in tillage depth in crop sequencing did not result in an increase of potential weed infestation.

In our study, no great difference was found in the number of weed diaspores in the analysed soil layers. But W r z e s i ń s k a et al. (2004), O p i c (1996), O r z e c h et al. (2006), Z a w i e j a et al. (2000), D o r a d o et al. (1999), U n g e r et al. (1999) noted

Table 1
Tillage treatments.

Plant	A – traditional	B – reduced	C – reduced
Potato	summer/autumn: skimming (10-12 cm) + harrowing (2 times) + manure + fall ploughing (25-30 cm)	summer/autumn: cultivating (10-12 cm) + harrowing + manure + fall ploughing (25-30 cm)	summer/autumn: disking (10-12 cm) + harrowing + manure + fall ploughing (25-30 cm)
	spring: harrowing + cultivating (10-15 cm) + harrowing + planting		
Spring wheat	summer/autumn: fall ploughing (18-20 cm)	summer/autumn: cultivating (10-12 cm)	summer/autumn: harrowing (8- 10 cm)
	spring: harrowing + cultivating (10-15 cm) + harrowing + sowing + harrowing		
Pea	summer/autumn: skimming (10-12 cm) + harrowing (2 times) + manure + fall ploughing (18-20 cm)	summer/autumn: cultivating (10-12 cm) + harrowing + fall ploughing (shallow to 15 cm)	summer/autumn: disking (10-12 cm) + harrowing + subsoiling (35-40 cm)
	spring: harrowing + cultivating (10-15 cm) + harrowing + sowing + harrowing		
Winter wheat	summer/autumn: skimming (10-12 cm) + harrowing (2 times) + pre-sow ploughing (18-20 cm) + harrowing + sowing + harrowing	summer/autumn: without after-harvest cultivation – only hallow pre-sow ploughing (to 15 cm) + harrowing + sowing + harrowing	summer/autumn: disking (10-12 cm) + harrowing + cultivating (10-15 cm) + harrowing + sowing + harrowing
	spring: harrowing		

Table 2

Species composition, number and distribution of weed seeds in three soil layers in pcs×m^{-2} (mean for crop rotation in 2000).

Species composition	Fertilisation level																	
	a									b								
	Soil tillage method																	
	A			B			C			A			B			C		
	Soil layer in cm																	
	0–5	5–15	15–30	0–5	5–15	15–30	0–5	5–15	15–30	0–5	5–15	15–30	0–5	5–15	15–30	0–5	5–15	15–30
Chenopodium album L.	5156	13125	10781	6094	8594	10156	6875	15781	16875	7656	14062	16250	8125	10312	11250	9688	10938	17188
Matricaria maritima	2031	312	–	938	312	156	1094	156	–	156	–	156	156	156	–	1094	781	156
ssp. Inodora (L.) DOSTAL	1250	2812	781	1406	4062	1094	2031	1406	1094	7656	2344	2656	469	1406	1406	938	1094	2344
Viola arvensis MURRAY	1094	1719	1094	2188	625	156	1875	1250	1406	781	312	469	–	1719	469	2812	781	1094
Galinsoga sp. CAV.	781	156	938	1875	312	469	938	312	625	156	–	156	469	312	156	469	469	312
Stellaria media (L.) VILL	625	469	156	2188	1094	781	7969	3281	1250	312	156	938	1406	1094	312	4375	3281	781
Apera spica-venti (L.) BEAUV.	625	469	312	312	–	–	625	625	312	–	312	156	938	–	156	312	156	156
Galium aparine L.	469	–	156	938	312	–	–	312	156	–	–	312	156	–	–	1250	–	156
Capsella bursa-pastoris (L.) MEDIK	156	–	–	–	–	156	–	–	–	–	–	–	–	–	156	–	–	–
Fallopia convolvulus (L) A. LÖVE	156	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Galeopsis tetrahit L.	–	156	–	–	–	312	–	–	156	–	–	–	–	–	–	–	–	–
Lamium pupureum L.	–	156	–	–	–	–	–	–	156	–	–	–	–	–	–	–	–	–
Sonchus asper L.	–	–	312	–	156	–	156	–	–	–	156	469	–	–	–	156	–	156
Lamium amplexicaule L.	–	–	156	–	–	–	–	–	–	–	–	156	–	–	–	–	–	156
Vicia tetrasperma (L.) SCHREB.	–	–	–	312	625	469	781	938	156	–	156	–	156	–	–	–	–	625
Veronica persica POIR	–	–	–	312	625	312	–	312	–	156	–	–	–	156	–	–	–	–
Veronica arvensis L.	–	–	–	–	–	–	–	–	312	–	–	–	–	–	–	–	–	–
Thlaspi arvense L.	–	–	–	–	–	–	–	–	–	156	–	–	–	–	–	–	–	156
Myosotis arvensis (L) HILL.	–	–	–	–	–	–	–	–	–	781	156	156	–	156	–	–	–	156
Polygonum lapathifolium L.	–	–	–	–	–	–	–	–	–	469	–	–	–	–	–	–	–	–
Solanum nigrum L.	–	–	–	–	–	–	–	–	–	–	156	–	–	–	–	–	–	–
Polygonum persicaria L.	–	–	–	–	–	–	–	–	–	–	–	–	156	–	–	–	156	–
Echinochloa crus-galli (L.) P. BEAUV.	–	–	–	–	–	–	–	–	–	–	–	–	–	312	–	–	–	–
Polygonum aviculare L.	–	156	–	156	–	–	–	–	–	–	156	–	–	–	156	–	–	312
Rumex acetosella L.																		
Number of seeds	12343	19530	14686	16719	16717	14061	22344	24373	22498	18279	17966	21874	12031	15623	14061	21094	17656	23748
Number of species	10	10	9	11	10	10	9	10	12	10	10	11	9	9	8	9	8	14
Number of dominant species' seeds	8125	18125	12812	11876	14375	12187	18750	21718	20625	16405	16874	20313	10000	14531	13437	17813	16094	21407

Table 3

Species composition, number and distribution of weed seeds in three soil layers in pcs·m-2 (mean for crop rotation in 2002).

Species	Fertilisation level																	
	a									b								
	Soil tillage method																	
	A			B			C			A			B			C		
	Soil layer in cm																	
	0–5	5–15	15–30	0–5	5–15	15–30	0–5	5–15	15–30	0–5	5–15	15–30	0–5	5–15	15–30	0–5	5–15	15–30
Chenopodium album L.	2969	3906	5312	2344	3594	3594	5000	5625	6875	4688	6406	5312	2812	4531	6406	7188	5781	7969
Viola arvensis MURRAY	938	625	781	312	312	469	938	312	312	312	625	469	–	625	625	312	781	1094
Echinochloa crus-galli (L.) P. BEAUV.	781	312	–	–	156	–	156	–	–	–	–	312	–	156	156	–	156	–
Solanum nigrum L.	156	–	156	469	–	–	312	–	–	–	–	–	156	–	–	312	–	156
Lamium amplexicaule L.	156	–	–	–	–	–	–	–	–	–	156	156	156	156	–	156	156	156
Stellaria media (L.) VILL	–	312	312	469	312	–	–	469	625	312	–	312	312	312	625	312	469	469
Apera spica-venti (L.) BEAUV.	–	312	156	1406	469	312	2812	469	312	469	–	156	938	625	–	4375	1406	469
*Galinsoga sp.*CAV.	–	156	625	1094	1056	156	312	312	469	–	625	1250	312	469	312	156	469	469
Galium aparine L.	–	156	156	–	–	–	156	–	312	–	156	156	312	–	–	–	–	–
Lamium pupureum L.	–	156	–	–	–	–	–	–	156	–	–	–	156	–	156	–	–	–
Avena fatua L.	–	–	–	156	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Matricaria maritima ssp. indora (L.) DOSTAL	–	–	–	–	–	–	312	–	–	469	156	156	156	156	–	469	156	–
Veronica persica POIR	–	–	–	–	–	–	–	–	156	–	–	–	–	156	–	–	156	–
Polygonum aviculare L.	–	156	—	–	–	–	–	–	312	156	–	–	–	–	156	–	–	156
Polygonum lapathifolium L.	–	–	–	–	–	–	–	–	–	156	–	156	–	–	–	156	–	–
Galeopsis tetrahit L.	–	–	–	–	–	–	–	–	–	–	–	–	156	—	–	156	–	156
Veronica arvensis L.	–	–	–	–	–	–	–	–	–	–	–	—	–	156	–	–	–	–
Capsella bursa-pastoris (L.) MEDIK	–	–	–	–	–	–	–	–	–	–	–	–	–	–	312	–	–	156
Number of seeds	5000	6091	7498	6250	4999	4531	9998	7187	9529	6562	8124	8435	5466	7342	8748	13529	9530	11250
Number of species	5	9	7	7	6	4	8	5	9	7	6	10	10	10	8	10	9	10
Number of dominant species' seeds	3907	4999	6874	5156	4531	4531	9062	6718	7968	5469	7656	7187	4062	6250	7343	12031	8437	10001

Table 4
Number of weed seeds in 0-30 cm soil layer in pcs×m^{-2} (mean per crop rotation).

Soil tillage method	Weed seeds 1. Total 2. Dominant species	Fertilisation level		Mean	Soil layer in cm		
		a	b		0-5	5-15	15-30
2000							
A	1	46559	58119	52339	15311	18748	18280
	2	39062	53592	46327	12265	17500	16562
B	1	47497	41715	44606	14375	16170	14061
	2	38438	37968	38203	10938	14453	12812
C	1	69215	62498	65856	21719	21014	23123
	2	61093	55314	58204	18282	18906	21016
Mean	1	54424	54111	54267	17135	18644	18488
	2	46198	48958	47578	13828	16953	16797
LSD (p=0.05) 1. total between: tillage methods – 3801; 2. dominant between: tillage methods – 4536							
2002							
A	1	18589	23121	20855	5781	7108	7966
	2	15780	20312	18046	4688	6328	7030
B	1	15780	21556	18668	5858	6170	6640
	2	14218	17655	15936	4609	5390	5937
C	1	26714	34372	30543	11795	8358	10390
	2	23748	30469	27108	10546	7578	8984
Mean	1	20361	26350	23355	7811	7212	8332
	2	17915	22812	20363	6614	6432	7317
LSD (p=0.05) 1. total between: tillage methods – 1900; fertilisation levels – 1267; 2. dominant between: tillage methods – 1831; fertilisation levels – 1222							

a significant increase in the number of weed seeds on the soil surface and a marked decrease in their number in the deeper layers under the influence of tillage simplifications, in particular the application of direct sowing.

The influence of the mineral fertilisation level was evident only in the second period of the study in which a significant increase in the seed bank in the soil was noted in the more intensively fertilised treatments. The absence of research in this area prevents a confrontation of results. The studies of K ę s i k (1980), B l e c h a r c z y k et al. (2000) as well as P a w ł o w s k i and W e s o ł o w s k i (1990) demonstrate that more intensive fertilisation is one of factors inhibiting weed infestation of a crop canopy.

When analysing the species composition of weed seeds in the soil, it should be stated that it is typical for loess-formed soils (W e s o ł o w s k i , 1986) and plants cultivated in a crop rotation system (K a p e l u s z n y and J ę d r u s z c z a k , 1992). The dominant species were *Chenopodium album*, *Viola arvensis, Apera spica-venti* and *Galinsoga sp*, which accounted for over 80% of the total bank of weed diaspores. Similarly, B o c h e n e k (1992), R a d e c k i and C i e s i e l s k a (2000) also report that only several weed species are always predominant in weed communities found in the soil. A substantial decrease in the seed weed bank in the soil and a reduction in their species composition noted after the end of the rotation, compared to the first period of the study, resulted from the application of intensive chemical protection of canopies of particular plants. It finds confirmation in earlier studies of D w o ř a k and K r e j c i r (1980), R o b e r t s (1981), A d a m i a k et al. (1988) who report that the introduction of herbicides in the protection of crop canopies significantly reduces the weed seed pool in the soil and impoverishes the species composition of the community.

CONCLUSIONS

1. A comparison of results of determinations from the end of the crop rotation and its beginning showed that a very large decrease in the number of weed diaspores in the soil occurred in all the experimental treatments.
2. A reduction in the number of ploughings to three in the crop rotation decreased weed infestation of the plough layer, whereas giving only one ploughing clearly increased the weed diaspore bank in the soil compared to typical tillage.

3. In the first period of the study, the mineral fertilisation level did not differentiate the weed seed bank in the soil. But there was its significant increase after the end of the rotation as a result of more intensive fertilisation.
4. Diaspores of *Chenopodium album*, *Viola arvensis*, *Galinsoga* sp. and *Apera spica-venti* occurred in greatest numbers in the examined loess soil layer.

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Wpływ uproszczeń uprawy roli i poziomu nawożenia mineralnego na liczbę i rozmieszczenie nasion chwastów w glebie

S t r e s z c z e n i e

W pracy przedstawiono wyniki badań nad wpływem ograniczenia liczby orek w rotacji płodozmianu oraz poziomu nawożenia mineralnego na kształtowanie się zapasu nasion chwastów w glebie. Badania przeprowadzono w drugim i czwartym roku rotacji płodozmianu (ziemniak – pszenica jara – groch siewny – pszenica ozima). Ograniczenie liczby orek do trzech w rotacji płodozmianu zmniejszało zachwaszczenie warstwy ornej, a po wykonaniu tylko jednej orki było wyraźnie więcej diaspor chwastów w glebie niż po uprawie płużnej. Poziom nawożenia mineralnego w pierwszym terminie badań nie różnicował zapasu nasion chwastów w glebie, zaś po zakończeniu rotacji odnotowano znaczny jego wzrost w wyniku intensywniejszego nawożenia. Na wszystkich obiektach doświadczenia najliczniej występowały diaspory: *Chenopodium album, Viola arvensis, Galinsoga sp.* i *Apera spica-venti.*