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THE EFFECT OF TILLAGE SYSTEMS ON SOIL SEEDBANK

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Abstract

The research was carried out in 2006–2008 in a static field experiment started in 1993 in the Research Field Station at Lipnik near Stargard Szczeciński, on Eutric Cambisol soil.

In soil samples taken from following layers: 0–10, 10–20, 20–30 cm of soil under ploughing, ploughless or direct drilling tillage systems, species composition and number of weed diaspores were evaluated. In the samples, in total there were diaspores of 17 weed species. *Chenopodium album* was the dominant weed species in all soil layers and tillage systems. The number of diaspores was significantly dependent on tillage system and soil layer. Irrespective of soil depth, the highest total number of diaspores (12251 pcs × m^{-2}) was in the treatment with the ploughing tillage system, while for the other treatments this number was significantly lower: by 14% for ploughless tillage and by 51% for the direct drilling treatment. Regardless of soil tillage system, the highest total number of diaspores (19936 pcs × m^{-2}) was in the top layer, while in the next layers this number was significantly lower (by 62 and 87%, respectively). The largest number of weed diaspores was in the top layer of soil after long application of the ploughless tillage system.

Key words: soil tillage systems, soil layers, weed species, number of weed diaspores.

INTRODUCTION

Weeds growing on arable land originate almost exclusively from seeds being an integral part of the soil seedbank (Bochenek, 1998). Their number and arrangement in a soil profile depends on many elements, both natural and agricultural (Jędruszczak et al. 2007; Małecka and Blecharczyk, 2000; Pawłowski and Wesołowski, 1980; Radecki and Ciesielska, 2000; Zawiślak, 1980). Modifications of ploughing tillage, such as reduced depth and frequency of ploughing, replacing tillage implements with some other ones, or even the elimination of soil tillage and replacing it with direct drilling, reduce soil cultivation costs, speed up seedbed preparation, protect soil environment, and increase productivity (Droese et al. 1986; Dzienia, 1995; Włodek et al. 1999). Such tillage reductions may cause changes in weed infestation of crops and in soil seedbank. The results of the research carried out by Bochenek, 2000; Cardina et al. 1991; Conn, 2006; Feldman et al. 1992; Kordas and Zawieja, 2003; Kręźel, 1991; Orzech et al. 2006; Radecki and Opic, 1995; Witkowski, 1998; Wojciechowski and Sowiński, 2005; Wrzesińska et al. 2003 and 2004; Zawieja and Kordas, 2003, have not given an unambiguous answer so far how tillage reductions affect the soil seed bank.

The aim of the study was to evaluate long-term application of three tillage systems (ploughing, ploughless and direct drilling) on species composition and number of weed diaspores in the plough layer of soil.

MATERIALS AND METHODS

The research was carried out in 2006–2008 in a static field experiment established in 1993 in the Research Field Station at Lipnik near Stargard Szczeciński, on Eutric Cambisol soil. The soil content was as follows: 11–13% clay, 1.3–1.5% humus, while its pH was 6.2 in 1mol KCl.

The experiment was established as a split-plot design, with two factors: I – soil tillage system (A – ploughing, B – ploughless, C – direst drilling); II – soil layer (a – 0–10 cm, b – 10–20 cm, c – 20–30 cm).

An estimation of seed diaspores was carried out after harvest of winter wheat – the last crop in the following crop rotation: sugar beet – winter wheat, faba bean – winter wheat. Soil cultivation treatments done prior to seeding of winter wheat are shown in Table 1. Soil samples for seed bank assessment were taken, using a 5 cm diameter cylinder, from given depths in four replications on every tillage treatment. To separate diaspores from solid soil, every sample was washed on a 0.11 mm mesh sieve and then dried. After that, undamaged and well-developed seeds and fruits of weed species were manually isolated and counted. For statistical analysis, the results were converted to a square meter basis. Analysis of variance was done using FR-ANALWAR 4.11 software, at a level of significance of 0.05.

Table 1
Tillage systems

Tillage systems	Cultivation treatments
A – ploughing	ploughing – (25 cm), harrowing – light harrow
B – ploughless	spraying with the herbicide Roundup 360 SL (3 $dm^3 \times ha^{-1}$), tillage assembly (cultivator + roller packer)
C – direct drilling	spraying with the herbicide Roundup 360 SL (3 $dm^3 \times ha^{-1}$)

RESULTS

In total, diaspores of 18 species were identified in the soil of the experimental plots, all of them annual weeds (Table 2). Diaspores of 9 weed species were in every tillage treatment. A few weed species with a small number of diaspores were found in the soil after the particular soil tillage systems. Diaspores of *Fumaria officinalis* L., *Myosotis arvensis* (L.) Hill and *Lycopsis arvensis* L. were only found in the soil in the ploughed plots, whereas *Bromus sterilis* L. and *Sinapis arvensis* L. were only found after ploughless tillage and direct drilling. In the treatments with reduced soil tillage (ploughless tillage and direct drilling), seeds of *Thlaspi arvense* L. were noted. Seeds of *Agrostemma githago* L. were only recorded in the soil after ploughless tillage, while diaspores of *Veronica persica* Poir. and *Poa annua* L. only after direct drilling application. Weed species diversity of soil seedbank after ploughing tillage and direct drilling was the same (13), while in the no-tillage treatment this number was lower by 3 species.

Regardless of tillage system, similar numbers of diaspores were found in the top (0–10 cm) and deepest (20–30 cm) layers of soil, whereas in the middle layer (20–30 cm) about 3 and 4 species fewer. In every layer, there were diaspores of the same 9 species. Diaspores of *Agrostemma githago* L. and *Veronica persica* Poir. were found only in the top layer, while in the middle layer – seeds of *Fumaria officinalis* L., *Myosotis arvensis* (L.) Hill, *Lycopsis arvensis* L., and *Poa annua* L. Seeds of *Setaria viridis* (L.) P. Beauv. were found both in the top and middle layers, while in the top and deepest layers – diaspores of *Bromus sterilis* L. and *Sinapis arvensis* L. In spite of some variation in species, *Chenopodium album* L. was the dominant species in terms of number of seeds, regardless of both tillage system and soil layer. The percentage of seeds of this species in the total number of seeds in the soil for the particular tillage systems was as follows: 56% ploughing tillage, 65% on ploughless tillage, and 76% direct drilling. In the top and deepest soil layers, the percentage of common lambsquarters seeds was similar (66 and 64%, respectively), while in the middle layer – 57%. The next species with a distinctly higher number of seeds and fruits were *Viola arvensis* and *Fallopia convolvulus* (L.) Á. Löve.

Both the factors, tillage system and soil layer, significantly differentiated the number of weed diaspores (Table 3). The highest number of diaspores (12 251 pcs. $\times$ m^{-2}) was after ploughing tillage, while in the treatments with ploughless tillage and direct drilling there were significantly less seeds – by 14 and 15%, respectively.

Regardless of soil tillage, the highest number of weed seeds was found in the top layer – 19936 pcs. $\times$ m^{-2}), while in the deepest layer this number was significantly lower: in the middle layer by about 62%, whereas in the deepest one by about 87%, compared to the top layer.

The percentage of diaspores distributed in the soil layers was dependant on soil tillage systems (Fig. 1). The distribution of diaspores in the 0–30 cm soil layer was mostly the same in the plots where ploughing tillage or direct drilling was used. More than half of diaspores (56 and 63%, respectively) in the soil under these systems were distributed in the top layer (0–10 cm). In the middle layer (10–20 cm), it was 33 and 30%, while in the deepest one (20–30 cm) – 11 and 7%, respectively. Ploughless tillage caused up to 80% of seeds and fruits of weeds to be deposited in the top

layer, while the rest of diaspores were deposited in the deeper layers evenly. The results show that the impact of soil tillage systems is not unambiguous.

DISCUSSION

In the present study, weed species diversity in soil seedbank after ploughing tillage and direct drilling did not differ, whereas in the no-till plots the number of species was lower. This result did not confirm the results of Feldman et al. (1992) and Wrzesińska et al. (2004) who concluded that tillage that disturbs less the soil (cultivator or direct drilling) caused increased weed species diversity.

In the species composition of soil seedbank, diasporas of short-lived weeds prevail and only a few species are dominants. The results of our earlier research (Wrzesińska et al. 2003, 2004) as well as studies of other authors (Bujak and Frant, 2009; Idkowiak and Kordas, 2006; Małecka and Blecharczyk, 2000; Wojciechowski and Sowiński, 2005) also show that dicotyledonous species: *Chenopodium album* L, *Fallopia convolvulus* (L.) Á. Löve and *Viola arvensis* Murray, dominate in the seedbank.

The number of weed diaspores in the soil was dependant on soil tillage system. The highest number of diaspores was found after ploughing tillage was used, compared to ploughless tillage or direct drilling. This finding confirms earlier studies of Wrzesińska et al. (2003, 2004) as well as Wojciechowski and Sowiński (2005). Similarly, Bujak and Frant (2009) observed that the reduction of ploughing to three times in crop rotation leads to a decrease in seed bank supply. Other studies of Bochenek (2000), Conn (2006), Kordas and Zawieja (2003), Krężel (1991), Radecki and Opic (1995), Sekutowski (2009), Zawieja and Kordas (2003) show that the number of weed diaspores increases when soil tillage is reduced to direct drilling.

The distribution of diaspores in the deeper layers of soil observed in the present study is in accordance with numerous literature data (Orzech et al. 2006; Radecki and Opic, 1995; Wrzesińska et al. 2003 and 2004). But the finding of Bujak and Frant (2009) shows an opposite relationship in changes in the distribution of weed diaspores; the lowest number of diaspores was in the top layer (0–5 cm), while in the next layers (5–15 cm and 15–30 cm) it was higher by 46 and 29.5%, respectively.

The percentage distribution of weed diaspores in the soil layers was dependent on soil tillage system. Direct drilling affected it mostly the same as the ploughing tillage system. Earlier studies of Wrzesińska et al. (2003, 2004) show that such spatial distribution of weed seeds and fruits observed in the soil layers after ploughing was also found in the soil where ploughless tillage was used. In the opinion of Cardina et al. (1991), Dorado et al. (1999), Feldman et al. (1992), Radecki and Opic (1995), and Unger et al. (1999), under no-till or zero tillage seeds are accumulated mostly in the top layer of soil. However, Dorado et al. (1999) found in the case of ploughing tillage that diaspores were almost evenly distributed, but Pawłowski and Pomykalska (1980) observed that, regardless of ploughing depth, the spatial distribution of weed diaspores decreased in every deeper layer of soil.

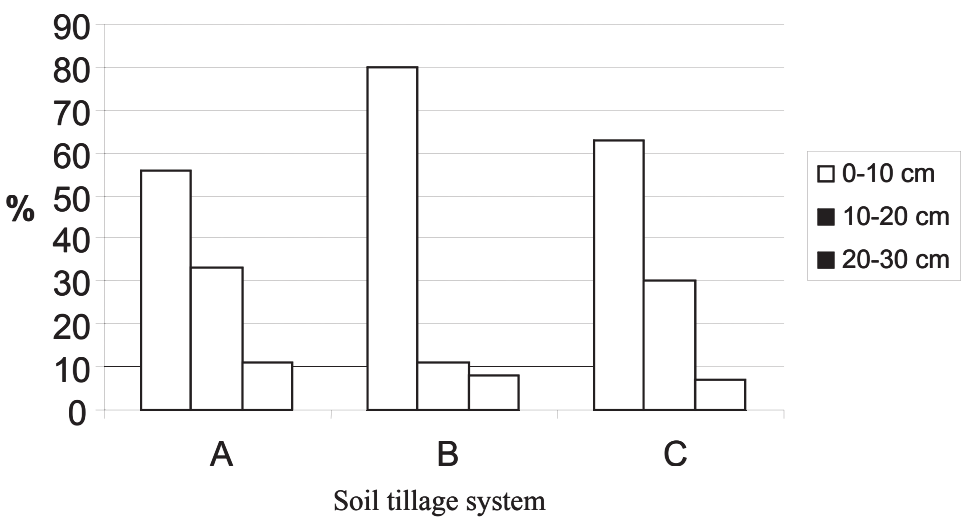

Fig. 1. Effect of tillage systems on weed seed distribution in the respective soil layers (%).

Table 2
Species diversity and number of weed diaspores in the soil in dependence on soil tillage system and depth of soil layers [pcs.×m-2]

Weed species	Tillage system			Soil layer in cm		
	A*	B	C	0-10	10-20	21-30
Chenopodium album L.	6 819	6 860	5 531	13 237	4 281	1 692
Viola arvensis Murray	2 752	1 045	1 156	3 215	1 486	252
Fallopia convolvulus (L.) Á. Löve	1 988	1 772	107	2 061	1 297	509
Echinochloa crus-galli (L.) P.Beauv.	342	560	141	710	197	136
Setaria viridis (L.) P. Beauv.	204	188	127	456	63	-
Lamium amplexicaule L.	71	37	59	74	89	4
Stellaria media (L.) Vill.	37	68	48	93	41	19
Sinapis arvensis L.	11	-	23	19	-	15
Fumaria officinalis L.	7	-	-	-	-	7
Veronica hederifolia L.	6	6	30	8	30	4
Lycopsis arvensis L.	6	-	-	-	-	6
Bromus sterilis L.	4	-	11	11	-	4
Myosotis arvensis (L.) Hill	4	-	-	-	-	4
Thlaspi arvense L.	-	22	41	37	19	7
Agrostemma githago L.	-	4	-	4	-	-
Veronica persica Poir.	-	-	11	11	-	-
Poa annua L.	-	-	4	-	-	4
Total	12 251	10 562	7 289	19 936	7 503	2 663
Number of species	13	10	13	13	9	14

A – ploughing; B – ploughless; C – direct drilling

Table 3
Number of weed diaspores in the soil in dependence on soil tillage systems and depth of soil layer [pcs.×m-2]

Tillage system	Soil layer in cm			Mean
	0 – 10	11– 20	21– 30	
A – ploughing	20 533	12 277	3 944	12 251
B – ploughless	25 478	3 619	2 589	10 562
C – direct drilling	13 800	6 613	1 455	7 289
Mean	19 937	7 503	2 663	
LSD 0.05 for: tillage systems – 945 soil layer – 4 644 interaction: tillage system × soil layer – 2 049				

CONCLUSIONS

1. The elimination of ploughing and the application of direct drilling do not cause changes in weed species dominance in soil seedbank.
2. Ploughing tillage favours the accumulation of weed seeds and fruits in soil, whereas ploughless tillage and direct drilling significantly decrease it.
3. The largest amount of weed diaspores accumulate in the top layer of soil (0–10 cm), whereas down the soil profile the number of diaspores significantly decreases.
4. In the top layer, the highest number of seeds and fruits of weeds were after long-term application of the ploughless tillage system.

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Wpływ systemów uprawy roli na zapas diaspor chwastów w glebie

Streszczenie

Badania przeprowadzono w latach 2006–2008 w statycznym doświadczeniu polowym, założonym w 1993 roku w RZD Lipnik kolo Stargardu Szczecińskiego na glebie kompleksu żytniego dobrego. W próbach glebowych pobranych z trzech warstw gleby (0–10, 10–20, 20–30 cm) po różnych systemach uprawy roli (płużny, bezpłużny, siew bezpośredni) określono skład gatunkowy i liczebność diaspor chwastów. W badanych warstwach gleby oznaczono ogółem diaspory 17 gatunków chwastów. Na wszystkich obiektach uprawowych oraz w każdej warstwie gleby dominowały nasiona *Chenopodium album*. Liczebność diaspor w glebie istotnie zależała zarówno od zastosowanych systemów uprawy roli, jak i głębokości pobierania prób. Niezależnie od głębokości pobierania prób glebowych, najwięcej diaspor chwastów ogółem (12 251 szt. × m^{-2}) stwierdzono na obiektach z uprawą płużną, natomiast na pozostałych obiektach istotnie mniej: po uprawie bezpłużnej o 14%, a po siewie bezpośrednim o 51%. Niezależnie od zastosowanych systemów uprawy roli najwięcej diaspor (19 936 szt. × m^{-2}) oznaczono w wierzchniej warstwie gleby a istotnie mniej w każdej następnej warstwie (odpowiednio o 62 i 87%). W wierzchniej warstwie gleby najwięcej nasion i owoców chwastów stwierdzono po wieloletnim stosowaniu uprawy bezpłużnej.