JOURNAL OF PLANT PROTECTION RESEARCH
Vol. 45, No. 2 (2005)

CHANGES IN THE NUMBER OF WEED SEEDS IN SOIL UNDER DIFFERENT TILLAGE SYSTEMS OF WINTER WHEAT

Wiesław Wojciechowski[1], *Józef Sowiński*[2]

Agricultural University, Norwida 25, 50-375 Wrocław, Poland
[1]Department of Soil and Plant Management
e-mail: wojciech@ekonom.ar.wroc.pl
[2]Crop Production Department
e-mail: sowinski@ekonom.ar.wroc.pl

Accepted: August 16, 2005

Abstract: The aim of performed research was to evaluate weed seedbank in soil under the influence of four different winter wheat tillage systems. Winter wheat was grown in the following cultivation systems: A – monoculture with direct drilling into white clover mulch; B – monoculture with direct drilling into wheat stubble; C – monoculture with conventional tillage; D – crop rotation with conventional tillage. It was shown that pre-sowing wheat tillage had a more considerable effect on weed species and weed seedbank in soil than type of crop rotation. The least seedbank was observed when plough system was replaced by direct drilling. In the soil layer of 0–20 cm, under wheat no-plough tillage, 20.3% less weed diaspores was found compared to monoculture with plough tillage and by 40.1% less than in crop rotation. The plough tillage increased amount of weed diaspores in the whole plough layer, while direct drilling increased it only in 0–1 cm of soil layer. After direct drilling of wheat into stubble (B) the number of weed diaspores in 1 dcm^3 of soil in 0–1 cm layer was over twofold higher than in direct sowing in mulch (A), and threefold higher than in crop rotation (D) and almost six times higher than in wheat monoculture with conventional tillage (C).
Dominating weed species in the soil over the types of wheat cultivation systems were: *Chenopodium album* L., *Amaranthus retroflexus* L., *Apera spica-venti* L., *Lamium purpureum* L., and *Viola arvensis* Murr.

Key words: winter wheat, monoculture, crop rotation, weed seedbank, direct drilling, conventional tillage, weed diaspore

INTRODUCTION

Tillage and crop rotation are considered to be among the most important factors affecting weed infestation dynamics. Introducing pre-sowing tillage simplifications, apart from many advantages such as low energy use, soil protection against

erosion or slowing down mineralization of organic components, may at the same time enhance some dangers including increased weed infestation (Bräutigam and Tebrügge 1997; Dzienia and Dojss 1999). Reducing crop diversity in rotation (monoculture included) also often increases weed infestation of canopy and soil (Zawiślak and Grejner 1984; Adamiak 1992; Liebman and Dyck 1993). There are, however, different opinions about the effect of tillage simplification on weed seedbank accumulation in soil, which depends on other conditions. Wilson et al. (1985) correlates a high diversity and number of weed seeds in soil with cultivation background on given field. Ball (1992) claims that number of weed diaspores, after introducing monoculture, will not necessarily increase, but it may even decrease, and depending on conditions, among others, crop rotation and tillage system are properly correlated. Benoit et al. (1992) and Barberi et al. (1998b) point out that the lack of homogenous results in that matter is connected with crop cultivation systems, but also with seedbank features, i.e. its viability. Thus it is necessary to investigate more thoroughly changes in weed diaspores accumulation in soil resulting from correlation between typical simplifications in crop tillage technologies. This will allow to predict canopy weed infestation in the year of cultivation and this may become an important element of weed control strategy in the following years.

The aim of the present research was to evaluate weed seedbank in soil and its species diversity under different wheat tillage systems, both in the pre-sowing tillage and simplifications in the crop rotation.

MATERIAL AND METHODS

The experiment was carried out in 1998–2001 in Research Station Pawłowice of Agricultural University Wroclaw, Poland. The experiment was located on brown earth soil, lessive type, typical subtype, from light loam on medium loam, representing good wheat complex, of IIIb quality evaluation class. Winter wheat (*Triticum aestivum* L.) var. "Kobra" was cultivated in four systems:

A Monoculture, direct drilling of wheat into white clover (*Trifolium repens* L.) mulch
B Monoculture, direct drilling of wheat into wheat stubble
C Monoculture, conventional tillage (plough tillage)
D Winter wheat-winter rape (*Brasica napus* L.) rotation, conventional tillage

In conventional tillage (C and D) after preceding crop harvest, ploughing at 18–22 cm depth was done as well as pre-sowing tillage, and wheat was sown using a conventional sowing drill machine. No-plough system (B) consisted of direct drilling of a tested crop into stubble. Before sowing, glyphosate herbicide was used at the dose of 6 l per ha (2.16 l i.a./ha) for weed control. In no-plough tillage with wheat sown in living mulch (A), before setting the experiment in spring of 1998, white clover was sown in spring wheat. In autumn of 1998, about 4 weeks before wheat sowing, dikwat was sprayed at the dose of 3 l/ha (0.6 kg i.a./ha) in order to limit clover competitiveness, in 1999 and 2000 instead dikwat, glyphosate was applied at a lower dose of 2 l per ha(0.72 kg i.a./ha). In both direct drilling tillage systems a sowing machine Vredo was used.

In each year of the experiment and in all tillage systems, 550 winter wheat grains and 100 seeds of winter rape (only in rotation system-D) were sown per 1 m^2.

The weed seeds content in soil was determined with a direct method. In the last experimental year, after harvest of winter wheat, for determining seedbank samples of soil were taken with a cylinder of 25 cm^2 cross section area. The evaluation was carried out in three soil layers: 0–1 cm; 1–10 cm and 10–20 cm. Soil samples were throughly washed with water on a 0.2 mm diameter sieve, and, the organic components of soil, including weed seeds, were removed with concentrated K_2CO_3. After drying the samples, whole seeds were picked up, counted and their seedbank was determined: number of weed species, amount of weed seedbank per ha, density of total weed seedbank and density of dominating weed seedbank. Density of seedbank was estimated in relation to the volume of soil samples taken with the cylinder, and expressed as number of seeds per 1 dcm^3. Totally, analysis was performed using 48 soil samples.

To determinine weed seed species of our seed collection weed seed guide book by Kulpa (1988) was used.

Data on density of weed seeds per dcm^3, number of weed species, seedbank size were subjected to analysis of variance and means were compared at the level of significance $\alpha=0.05$.

RESULTS

The factor shaping weed seedbank diversity in soil was rather winter wheat tillage method than crop rotation (Fig. 1). A considerable diversity in the amount of weed species was mainly observed in the soil surface layer of 0–1 cm. In this layer after conventional pre-sowing tillage, number of weed species was 4–5, both in wheat monoculture and in conventional crop rotation. The number of weed species

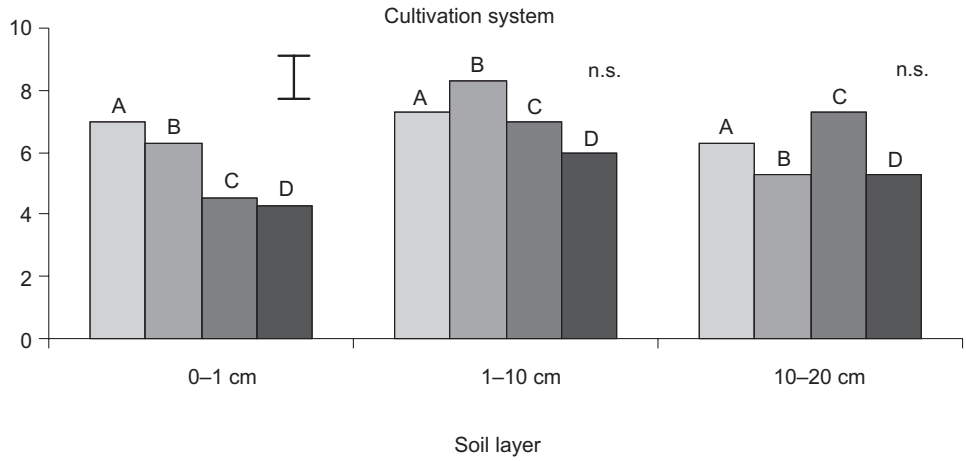

Fig. 1. Effect of cultivation method on number of weed species
A – Monoculture, direct drilling of wheat into white clover mulch
B – Monoculture, wheat direct drilling into stubble
C – Monoculture, conventional tillage
D – Winter wheat-winter rape rotation, conventional tillage
n.s. – not significant

(6–7) was higher when pre-sowing plough was replaced with wheat direct drilling both in drilling into stubble and white clover mulch. In deeper soil layers the differences in seedbank in particular tillage patterns were not so significant. However, in the 1–10 cm layer even a greater number of weed seeds was detected in direct drilling than in plough tillage.

In all wheat tillage systems, the dominating species in soil were: *Ch. album*, *A. retroflexus*, *A. spica-venti*, *L. purpureum* and *V. arvensis* (Fig. 2). A high percentage of *Ch. album* and *A. retroflexus* diaspores, over 60% and almost 10%, respectively, was favoured mainly by particularly high level of fertility and their persistence in soil. It must be emphasized that those species dominated in crop rotation. Wheat monoculture lowered the occurrence of the above mentioned weeds which was visible after eliminating deep ploughing from pre-sowing tillage pattern. On the other hand, *A. spica-venti*, *L. purpureum* and *V. arvensis* were typical for direct drilling. After this pre-sowing tillage significantly increased percentage of the above weed diaspores was recorded in total weed infestation. Winter wheat in crop rotation was most infested and seedbank size was significantly highest (Fig. 3).

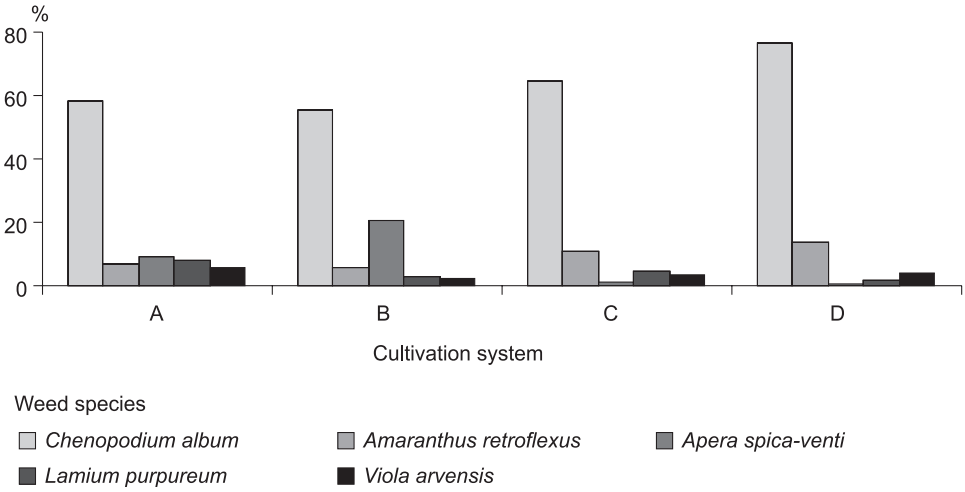

Fig. 2. Structure of dominating weed species diaspores in the soil (in %)

In winter wheat-winter rape rotation with conventional tillage, in the plough layer (0–20 cm), the number of weed diaspores was higher by 27.6% than in wheat monoculture with pre-sowing plough. However, pre-sowing tillage influenced more the number of weed diaspores than crop rotation did. The lowest seedbank was observed after eliminating plough before sowing and introducing direct drilling. In no-tillage, when wheat was sown into stubble or into mulch, the number of weed diaspores was lower in 0–20 cm soil layer, on average by 20.3% than in wheat monoculture with sowing after plough tillage and lower by 40.1% than in crop rotation. Similar correlations like in the whole plough layer, were recorded in 1–10 cm layer and 10–20 cm layer. The opposite results were obtained in 0–1 cm layer, where more weed diaspores were found after direct drilling than after pre-sowing

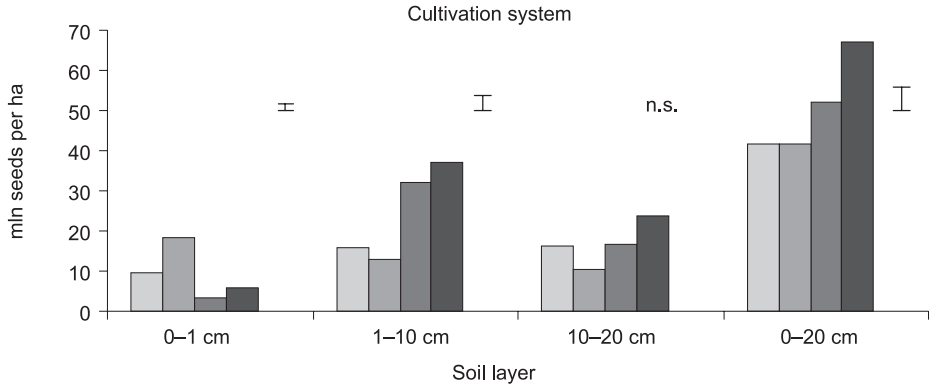

Fig. 3. Effect of cultivation system on seed bank size
A – Monoculture, direct drilling of wheat into white clover mulch
B – Monoculture, wheat direct drilling into stubble
C – Monoculture, conventional tillage
D – Winter wheat-winter rape rotation, conventional tillage
n.s. – not significant

plough tillage. Direct drilling in stubble turned out to be the most infesting. In those conditions seedbank was almost twofold higher than with wheat sowing into white clover mulch, and threefold higher than under pre-sowing tillage, and over fivefold higher than in crop rotation.

The horizontal weed seed accumulation in soil was significantly affected by pre-sowing tillage method (Fig. 4). After conventional tillage, both in crop rotation and monoculture, seedbank in deeper soil layers was higher than after direct drilling.

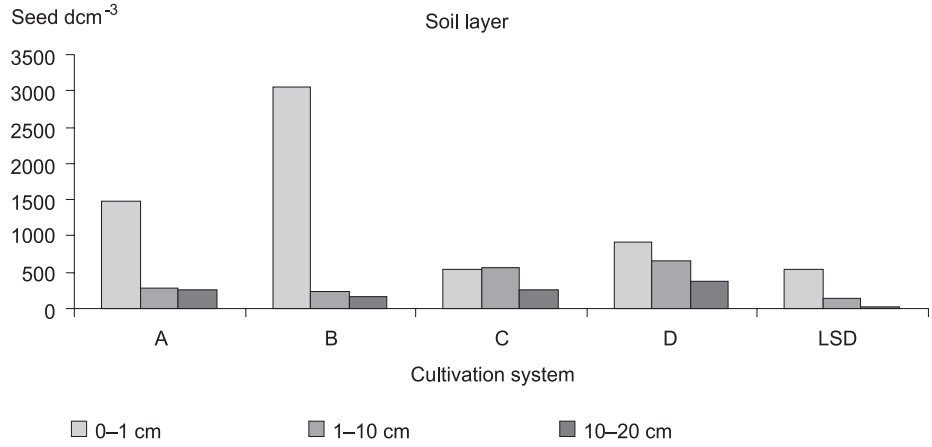

Fig. 4. Density of weed diaspores (weed seeds per dcm^3)
A – Monoculture, direct drilling of wheat into white clover mulch
B – Monoculture, wheat direct drilling into stubble
C – Monoculture, conventional tillage
D – Winter wheat-winter rape rotation, conventional tillage
LSD – Least Significant Difference

Table 1. Density of weed seeds per dcm^3 of soil in different soil layers

Soil layer	Cultivation system				Mean
	A	B	C	D	
			Chenopodium album		
0–1 cm	331b	1350a	76c	374b	533
LSD α=0.05			214		–
1–10 cm	191b	152b	403a	498a	311
LSD α=0.05			99		–
10–20 cm	179b	117b	148b	300a	186
LSD α=0.05			113		–
			Amaranthus retroflexus		
0–1 cm	38a	0b	102a	77a	54
LSD α=0.05			72		–
1–10 cm	23b	4b	78a	96a	50
LSD α=0.05			26		–
10–20 cm	20	24	19	53	29
LSD α=0.05			n.s.		–
			Lamium purpureum		
0–1 cm	15	25	26	26	92
LSD α=0.05			n.s.		–
1–10 cm	27	29	3	10	17
LSD α=0.05			n.s.		–
10–20 cm	24	8	8	8	12
LSD α=0.05			n.s.		–
			Apera spica-venti		
0–1 cm	536a	1274a	77b	26b	478
LSD α=0.05			182		–
1–10 cm	2	0	16	0	5
LSD α=0.05			n.s.		–
10–20 cm	3	0	8	8	5
LSD α=0.05			n.s.		–
			Viola arvensis		
0–1 cm	38	13	51	51	153
LSD α=0.05			n.s.		–
1–10 cm	11	15	5	28	15
LSD α=0.05			n.s.		–
10–20 cm	18	0	16	10	11
LSD α=0.05			n.s.		–

A – Monoculture, direct drilling of wheat into white clover mulch
B – Monoculture, wheat direct drilling into stubble
C – Monoculture, conventional tillage
D – Winter wheat-winter rape rotation, conventional tillage
n.s. – not significant
a, b, c – statistical group
LSD – Least Significant Difference

In 1–10 cm layer, eliminating plough from wheat pre-sowing tillage decreased diaspore accumulation over twofold on average when compared with plough tillage. Similarly, in 10–20 cm layers the number of diaspores per 1 dcm^3 of soil was higher in plough tillage than in wheat direct drilling, although these differences were statistically not significant. The opposite situation was noted in the upper soil layers. In the 0–1 cm layer a higher accumulation of weed diaspores was observed when plough for wheat was omitted. In wheat direct drilling into stubble the number of weed diaspores per 1 dcm^3 of soil was as high as 3045 seeds. It was over twice higher than in wheat direct drilling in white clover mulch and over three times higher than in crop rotation, and almost six times higher than seedbank in wheat monoculture with plough.

A considerable diversity in accumulation of dominating weed diaspores was observed in soil layers. Although diaspores of *Ch. album* and *A. retroflexus* were mainly accumulated in upper soil layers, their frequent occurrence was also noted in the whole plough layer, including the deepest layer of 10–20 cm. The diaspores of *L. purpureum, A. spica-venti* and *V. arvensis* were mostly accumulated close to the soil surface and were not common in deeper soil layers. The concentration of dominating weed seeds in soil also depended on pre-sowing tillage of winter wheat. It was confirmed as before, that wheat plough tillage, regardless crop rotation, enhanced a significant concentration of *Ch. album* diaspores (mainly in 1–10 cm and 10–20 cm layer) and of *A. retroflexus* diaspores (in the whole plough layer). Diaspores of other weeds occurred most frequently in crop direct drilling and were accumulated mainly in the upper soil layer (0–1 cm).

DISCUSSION

Liebman and Dyck (1993) found out that monoculture results were characterized by a lower weed species differentiation as compared to crop rotation. Ball (1992) also noted correlation between the number and structure of weed species in seedbank and crop species and crop rotation. The results of our investigations showed a small differentiation in the number of weed species in soil between wheat monoculture and crop rotation. This was observed that pre-sowing tillage of winter wheat considerably increased the number of weed seed species in soil. It was mostly observed in upper soil layer. Eliminating plough and direct drilling increased the number of weed species (twice on average). Cardina et al. (1991), Feldman et al. (1997) and Dorado et al. (1999) recorded the highest number of weed species in soil in no-plough tillage systems compared to tilled soil. It is claimed that an increased seedbank in no-plough tillage compared to plough or mouldboard tillage results from accumulating a higher content of plant residues on soil surface in tillage system. While mulch prevents from weed seeds germinating, it decreases their dispersion in soil profile and hinders activating of dormant weed diaspores (Feldman et al. 1994).

Ch. album, A. retroflexus, A. spica-venti, L. purpureum and *V. arvensis* were the species whose diaspores occurred most frequently in soil. This corresponds to the results obtained by Wilson et al. (1988), Ball (1992), Forcella et al. (1992) or Blecharczyk et al. (1996). In all wheat cultivation technologies, *Ch. album* and *A. retroflexus* were

the most common weed diaspores in soil. The highest number of weed diaspores related to root crops was noted mainly in crop rotation. These results are confirmed by research of Zawieja et al. (2000) and Wojciechowski and Zawieja (2001), who recorded threefold higher number of *A. retroflexus* seeds and fourfold higher number of *Ch. album* in soil in crop rotation (25% of root crop) compared to the number of these diaspores in monoculture. Blecharczyk et al. (1996) also noted that in the rotation unit: root crops – spring cereals, dominating taxons in soil were species typical for root crops. Barberi and Lo Cascio (2001) claims that the dominating weeds are *Amaranthus* spp., *Chenopodium* spp., *Veronica* spp., *A. retroflexus*, *Ch. album*, *Veronica.*, *Lolium muiltiflorum* and *Polygonum aviculare* L. regardless of crop rotation and pre-sowing tillage. However they point out, , that *Chenopodium* occurred mainly in wheat and faba bean crop rotation and was insignificant in wheat monoculture. The authors also recorded good environmental conditions for emerging of some weed species i.e. *Portulaca oleracea* L. after crop harvest. In monoculture with direct sowing of winter wheat, after harvest, *Ch. album* found ecological niches, emerged and grew very fast until seed ripening before herbicide Roundap treatment.

No significant effect of crop rotation on weed seedbank in soil was recorded, but, it was observed that the number of weed seeds in the whole plough layer was increased by over 25% in soil from crop rotation compared to the monoculture. Barberi and Lo Cascio (2001) did not prove any important effect of crop rotation on weed seed accumulation in soil, either.

Barberi et al. (1998a) claim that small differences in weed diaspores number in soil under crop rotation may result from so called seed buffering which results from long-lasting persistence of some weed seeds in soil. In this way a typical seed bank for a given area is formed regardless the applied measures i.e. tillage, crop rotations and weed control (Barberi et al. 1998b), but Blecharczyk et al. (1996) are of a different opinion. They recorded a considerably higher number of weed seeds in soil in monoculture than in crop rotation. They also showed that after 15 years of crop rotation special experiments, the number of weeds in crop rotation tended to decrease more than in monoculture.

However, a more significant effect on the number of weeds and their accumulation in soil was observed with the pre-sowing tillage than in crop rotation. In wheat no-plouhg tillage system, in 0–20 cm layer, the number of weed diaspores was on average lower by 30.2% than in monoculture system with conventional tillage, and by 40.1% lower than in crop rotation. Similar correlations were observed in 1–10 cm and 10–20 cm layers. However, opposite results were obtained in 0–1 cm layer. In this layer, it was direct drilling that increased weed bank, and not drilling in plough tillage. Feldman et al. (1997) and Barberi and Lo Cascio (2001) found out that the deeper is the sampled soil level, the lower is the number of weed species and their seeds, which is especially visible in reduced tillage.

CONCLUSIONS

Pre-sowing tillage of winter wheat influenced more seedbank diversity than crop rotation type did. Replacing plough by direct drilling of tested crop increased both number of weed species and weed diaspores in soil. The most common species

were: *Ch. album*, *A. retroflexus*, *A. spica-venti*, *L. purpureum* and *V. arvensis*. Weeds that dominated the experimental fields are also the most common in many crops. Diaspores of *Ch. album* and *A. retroflexus* occurred most frequently in the whole plough layer, and a high concentration of these species was caused by winter wheat plough tillage. Diaspores of other weeds were most common in crop direct drilling system and were mostly accumulated in the upper soil layer (0–1cm).

REFERENCES

Adamiak E. 1992. Weed infestation of cereals grown in specialized cereal rotations and monocultures. Acta Acad. Agricult. Tech. Olst. Agricultura 55: 115–128.

Ball D.A. 1992. Weed seedbank response to tillage, herbicide, and crop rotation sequence. Weed Sci., 40: 654–669.

Barberi P., Lo Cascio B. 2001. Long-term tillage and crop rotation effects on weed seedbank size and composition. Weed Res., 41: 325–340.

Barberi P., Cozzani A., Macchia M., Bonari E. 1998a. Size and composition of the weed seedbank under different management systems for continuous maize cropping. Weed Res., 38: 319–334.

Barberi P., Macchia M., Cozzani A., Bonari E. 1998b. Structure of weed seedbank communities under different management systems for continuous maize crop. Aspects of Applied Biology 51: 289–296.

Benoit D.L., Derkens D.A., Panneton B. 1992. Innovative approaches to seedbank studies. Weed Sci., 40: 660–669.

Blecharczyk A., Skrzypczak G., Pudełko J. 1996. Weed seedbank response to continuous cropping and fertilization. Second International Weed Control Congres, Copenhagen: 247–252.

Bräutigam V., Tebrügge F. 1997. Influence of long-termed no-tillage on soilborne plant pathogens and on weeds. Experience with the applicability of no-tillage crop production in the West-European countries. Proc. the EC-Workshop-III: 17–29.

Cardina J., Regnier E., Harrison K. 1991. Long-term tillage effects on seedbanks in three Ohio soils. Weed Sci., 39:186–194.

Dorado J., Del Monte J.P., Lopez-Fando C. 1999. Weed seedbank response to crop rotation and tillage in semiarid agroecosystems. Weed Sci., 47: 67–73.

Dzienia S., Dojss D. 1999. Wpływ sposobów uprawy roli na zachwaszczenie i plonowanie pszenicy ozimej. Fol. Univ. Agric. Stetin. 195, Agricult., 74: 185–190.

Feldman S.R., Alzugaray C., Torres P.S., Lewis J.P. 1997. The effect of different tillage systems on the composition of the seedbank. Weed Res., 37: 71–76.

Feldman S.R., Vesprini J., Lewis P. 1994. Survival and establishment of *Corduus acabthoides* L. Weed Res., 34: 265–273.

Forcella F., Wilson R.G., Renner K.A., Dekker J., Harvey R.G., Alm D.A., Buhler D.D., Cardina J. 1992. Weed seedbank of the U.S. Corn belt: magnitude, variation, emergence, and application. Weed Sci., 40: 636–644.

Kulpa W. 1988. Nasionoznawstwo chwastów. PWRiL, Warszawa, 413 pp.

Liebman M., Dyck E. 1993. Crop rotation and intercropping strategies for weed management. Ecol. Appl., 3: 92–122.

Wilson R.G., Kerr E.D., Nelson L.A. 1985. Potential for using weed seed content in the soil to predict future weed problems. Weed Sci., 33: 171–175.

Wojciechowski W., Zawieja J. 2001. The influence of soil tillage on the number and vertical distribution of weed seeds in soil of the rye *Secale cereale* monoculture. Rost. Vyrob., 47 (9): 389–392.

Zawieja J., Wojciechowski W., Wacławowicz R. 2000. Wpływ zróżnicowanej uprawy roli na liczebność i pionowe rozmieszczenie diaspor chwastów w glebie w monokulturze pszenicy ozimej. Ann. UMCS sec. E, 55: 239–243.

Zawiślak K., Grejner M. 1984. Zbiorowiska chwastów w monokulturowej uprawie zbóż oraz efektywność ich zwalczania. Cz. I. Zboża ozime. Rocz. Nauk. Rol., ser. A, 106, 1: 149–168.

POLISH SUMMARY

ZMIANY BANKU NASION CHWASTÓW W GLEBIE POD WPŁYWEM RÓŻNYCH SPOSOBÓW UPRAWY PSZENICY OZIMEJ

Celem badań była ocena kształtowania się banku diaspor chwastów w glebie pod wpływem czterech zróżnicowanych systemów uprawy pszenicy ozimej: A. Monokultura z siewem bezpośrednim w mulcz z koniczyny białej; B. Monokultura z siewem bezpośrednim w ściernisko; C. Monokultura z uprawą tradycyjną (z orką siewną); D. Płodozmian z uprawą tradycyjną.

Czynnikiem, który bardziej wpłynął na różnorodność gatunków i liczebność diaspor chwastów w glebie był sposób uprawy przedsiewnej pszenicy, niż typ płodozmianu. Najmniej diaspor chwastów wykazano po zastąpieniu orki siewnej siewem bezpośrednim rośliny uprawnej. W bezorkowej uprawie pszenicy, w warstwie gleby 0–20 cm, stwierdzono średnio o 20,3% mniej diaspor chwastów niż w monokulturze z orką siewną oraz o 40,1% niż w płodozmianie. Wykonywanie orki pod pszenicę zwiększało koncentrację diaspor chwastów w całej warstwie ornej, natomiast siewu bezpośredniego w warstwie 0–1 cm. Po siewie bezpośrednim pszenicy w ściernisko ilość diaspor chwastów w 1 dcm^3 gleby warstwy 0–1 cm, była ponad dwukrotnie większa od określonej w siewie bezpośrednim w mulcz, ponad trzykrotnie niż w płodozmianie oraz blisko sześciokrotnie większa od wykazanej w monokulturze pszenicy z orką siewną.

Gatunkami dominującymi w glebie w każdym sposobie uprawy pszenicy ozimej były: *Chenopodium album, Amaranthus retroflexus, Apera spica-venti, Lamium purpureum* oraz *Viola arvensis*