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EFFECTS OF THE TILLAGE TECHNOLOGY AND THE FORECROP ON WEEDS IN STANDS OF WINTER WHEAT

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Abstract

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The semipilot-scale field experiment was established in the cadastre of the village Letkovice in the South Moravian Region (Czech Republic). The study area was situated in a warm climatic region T2. Winter wheat was cultivated in two variants of tillage, viz. conventional tillage (CT) and minimum tillage (MT) and after three different forecrops (fodder beet, late potatoes, and broad (faba) bean). Weed infestation of wheat stands was evaluated in spring seasons of 2007 and 2008, always before the application of herbicides. Numbers of weed specimens and their species were defined by means of a calculation method. Recorded data were processed by means of multidimensional analyses of ecological data, viz. Data Correspondence Analysis (DCA) and Redundancy Analysis (RDA). Within the study period, altogether 22 weed species were identified in all variants with different tillage technologies and different forecrops. In the MT variant, the degree of winter wheat stand infestation with weeds was lower. As far as the forecrops were concerned, the most and the least intensive degrees of infestation were recorded on plots with faba bean and late potatoes, respectively.

Keywords: weeds, methods of tillage, forecrop, winter wheat

INTRODUCTION

Reduced and soil-protecting technologies of tillage are widely used above all in North and South Americas. As compared with conventional methods of tillage, these technologies reduce soil erosion, improve water balance and increase yields, especially in dry and erosion-endangered regions (Triplett & Dick, 2008).

In recent years, the interest in reduced tillage methods have been increasing also in Italy. The main reason of this trend are efforts to reduce production costs. However, reduced methods of tillage require an introduction of certain changes into the agricultural practice and this concerns above all in the field of weed control and killing (Moyer *et al*., 1994).

It is well known that the basic methods of plant production (e.g. tillage and crop rotation) very often determine both the diversity and intensity of weed infestation (Ulber *et al*., 2009). Recent studies performed by Gonzalez-Andujar *et al.* (2011) demonstrated the importance of long-term experiments studying effects of growing methods on the abundance and composition of weed populations. It can be said the these methods function as a certain filter that creates specific conditions for the existence of weeds also in shorter time intervals (Ryan *et al*., 2010).

MATERIAL AND METHODS

The experiment was established in the cadastre of the village Letkovice in the South Moravian Region (Czech Republic). This village is situated in the Boskovická brázda furrow around the confluence of rivers Jihlava and Oslava in the altitude of about 195 meters above sea level in the maize-growing region. The soil type was classified as brown soil on loess and/or loessial soil. As far as the soil texture was concerned, medium soils with predominating dust fraction were the most frequent in this territory.

The study area is situated in the climate subregion T2 (with long, very warm and dry summer, very short transition period of mild spring and dry to very dry winter; the duration of snow cover is usually very short). The long-term average of annual sum of precipitation is 550 mm. The highest and the lowest sums of precipitations occur in summer (June–August) and in the second half of winter (February–March), respectively. The average annual temperature is about 9 °C.

Winter wheat was grown using two variants of tillage and three different forecrops. The semipilot-scale field experiment consisted of altogether six plots of the size 50 m × 36 m. Individual variants were separated by 10 m wide bands of strips of land.

Tillage variants:

Variant 1 – conventional tillage (CT): In this variant, the first operation after the harvest of the forecrop was a shallow breaking with the breaker Agrozet Roudnice (with 9 blades) to the depth of about 0.10–0.12 m. Thereafter the plot was ploughed with the plough RABE&WERK 4 x 35 to the depth of 0.20–0.24 m. The last operation (i.e. sowing) was performed using a combined drilling machine Pneusej ACCORD.

Variant 2 – minimum tillage (MT): After the harvest, the post-harvest residues were ploughed-in with the breaker Agrozet Roudnice (9 blades) to the depth of about 0.10–0.15 m. Immediately prior to sowing, the breaking was repeated and the plot was sown using a combined drilling machine Pneusej ACCORD.

Forecrop variants:

Variant A (fodder beet): This forecrop was cultivated in wide rows (0.75 m) and manured with dung; roots and tops were harvested in the half of September.

Variant B (late potatoes): This forecrop was cultivated in ridges and manured with dung; tubers were harvested to the end of August.

Variant C (faba bean): This forecrop was cultivated in rows 0.5 m wide and seeds were harvested in the second half of August.

No fungicides were used in stands of winter wheat and the weed control was performed using a post-emergence herbicide BIPLAY SX in the dose 30 g.ha^{-1}. For the supplementary foliar fertilisation the preparation DAM 390 was used in the dose of about 30 kg.ha^{-1}.

The monitoring and evaluation of the course of weed infestation took place in the spring of 2007 and 2008, respectively, always before the application of herbicides. Numbers of weed plants and their species were defined by means of a calculation method. In each forecrop and tillage variant, individual species were determined on the area of 1 sq.m in altogether ten replications. Evaluations were performed on the following dates: 26–28 April 2007 and 29 April–1 May 2008. Czech and Latin names of weed species were used in accordance with Kubát's *Key to the Flora of the Czech Republic* (2002).

Effects of different methods of tillage and of different forecrops on weed infestation of winter wheat stands were determined by means of the multidimensional analysis of ecological data and the selection of the optimum analyses was performed on the base of *lengths of gradients* as determined by means of Data Correspondence Analysis (DCA) and Redundancy Analysis (RDA). When testing the significance of results with the Monte-Carlo test, altogether 499 permutations were calculated. Obtained data were processed using the Canoco 4.0 software (Ter Braak, 1998).

RESULTS AND DISCUSSION

In the course of years under study, the total number of identified species was 22 in all experimental variants. Average values of weed infestation are presented in Tab. I.

According to the DCA, the length of gradient for data originating from points of study was 2.091 and this value was thereafter used for the RDA. The spatial distribution of individual weed species and of factor variants, as determined by means of RDA, is presented in following ordination diagrams. In case of the RDA, individual species are represented by different vectors (arrows); both the length and the direction of these arrows are of importance. Factor variants are expressed by means of points. The length and the direction of these vectors are important for the determination of relationships existing between individual weed species on the one hand and factor variants on the other. If a vector is directed to the point of a certain factor variant, the corresponding weed species occurs above all in the corresponding variant. The longer the vector, the higher the occurrence of the weed species. Species with very short vectors (and or vectors not directed to any factor symbol) are influenced more by factors that are not involved in the corresponding analysis.

The effect of the tillage method on individual weed species is presented in Fig. 1. RDA results are significant for all canonic axes at the significance level $\alpha = 0.002$. A graphical illustration of effects of different tillage methods on the occurrence of weeds is presented also in Fig. 1. Different colours express differences in the occurrence of individual species in individual experimental variants. The blue and the red colours represent the abundance of weed species in the CT and MT variants, respectively.

Effects of individual forecrops on individual weed species are presented in Fig. 2. Results of the RDA are significant at the significance level $\alpha = 0.002$ for all canonic axes. A graphical illustration of effects of different forecrops on the occurrence of weeds

I: *Average values of weed infestation in individual years of study an in individual variants*

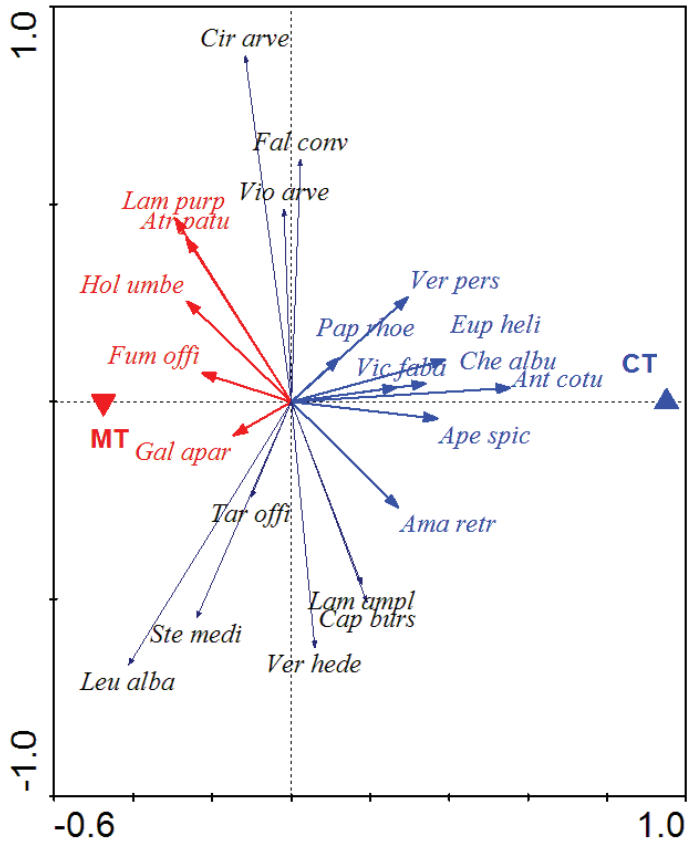
Weed species	Soil tillage		Forecrop			Year	
	MT	CT	Beta	Potato	Bean	2007	2008
Amaranthus retroflexus L.	0.73	1.65	0.65	0.80	1.65	1.63	0.43
Atriplex patula L.	0.58		1.00	0.15			0.77
Anthemis cotula L.		0.55			0.55	0.20	0.17
Apera spica-venti (L.)P.B.		0.55			0.55	0.30	0.07
Capsella bursa-pastoris (L.) MEDIK.	2.28	4.25	2.30	2.25	4.25	3.03	2.83
Cirsium arvense (L.) SCOP.	3.60	3.25	3.40	3.80	3.25	1.57	5.40
Euphorbia helioscopia L.		0.40			0.40		0.27
Fallopia convolvulus (L.) Á.LÖVE	1.78	2.30	1.20	2.35	2.30	0.53	3.37
Fumaria officinalis L.	1.55	1.00	2.15	0.95	1.00	0.83	1.90
Galium aparine L.	0.90	0.85	0.95	0.85	0.85	0.83	0.93
Holosteum umbellatum L.	0.65		0.15	1.15		0.10	0.77
Chenopodium album L.	0.10	0.90	0.15	0.05	0.90	0.17	0.57
Lamium amplexicaule L.	1.03	2.25	1.00	1.05	2.25	1.87	1.00
Lamium purpureum L.	0.90		1.25	0.55			1.20
Leucosinapis alba (L.) Spach	1.13		1.25	1.00		1.50	
Papaver rhoeas L.	0.33	0.60	0.55	0.10	0.60	0.37	0.47
Stellaria media (L.) VILL.	2.33	2.20	2.70	1.95	2.20	2.57	2.00
Taraxacum officinale WEB.	0.20	0.10	0.20	0.20	0.10	0.23	0.10
Veronica hederifolia L.	3.88	5.00	3.50	4.25	5.00	5.30	3.20
Veronica persica POIRET	0.20	1.10	0.30	0.10	1.10		1.00
Vicia faba L.		0.30			0.30	0.07	0.13
Viola arvensis MURRAY	1.40	1.40	1.60	1.20	1.40	0.77	2.03
Average number of weed specimens	23.53	28.65	24.30	22.75	28.65	21.87	28.60

is presented also in Fig. 2. Different colours express the abundance of weed species in individual variants.

The basic growing operations (e.g. methods of tillage and/or crop rotation) determine significantly the composition of weed population and numbers of weeds on fields (Ulber *et al.*, 2009). Many authors mentioned a general rule according to which the deeper and more frequent the processing of topsoil, the lower the degree of infestation (Boström, 1999) and also the more limited magnitude of the soil seedbank (Cardina *et al.*, 2002; Moonen & Bárberi, 2004; Légère *et al.*, 2011). In case of reduced (or minimum) soil processing technologies, the weed seedbank is concentrated near the soil surface, above all due to a shallower tillage (Moss, 1988; Cousens & Moss, 1990; Roger-Estrade *et al.*, 2001; Chauhan *et al.*, 2006; Mohler *et al.*, 2006). As indicated by some recent results (e.g. Gruber *et al.*, 2012), the conditions for seed germination are better and this resulted very often in a higher degree of weed infestation. However, our results indicated that in the MT variant, the degree of weed infestation was lower than in CT and this finding differred from data published by authors mentioned above. The explanation may be looked for in the composition of weed species spectrum. It seems that the conventional tillage technology is more favourable for the majority of identified weed species and that they have already adapted to it. The transition to the minimum tillage technology possibly induced dormancy and reduced the germination power of the majority of weed seeds.

As compared with the MT variant, the average number of weed specimens on plots with the conventional tillage variant was higher by 5.13 individuals per square meter. However, in the variant with the conventional method of tillage, the average number of weed species per square meter was lower by 0.55 than in the MT variant. This result was corroborated also by results published by Mikulka (1999) who reported that the application of minimum tillage reduced the number of weed species on the one hand and increased the total number of weed specimens on the other. In the CT variant, the total number of weed species was higher by 0.55 than in the MT variant. These results corresponded with data published by Mikulka (1999) who reported that the minimum tillage technology reduced the species spectrum of weeds. Winkler (2008) published identical results.

The method of tillage influences the occurrence of individual species in different ways; many authors also wrote that they observed the existnce of interactions among tillage, year and crop (e.g. Gruber *et al.*, 2012; Pollard & Cussans, in a similar way 1976;



1: *Ordination diagram expressing the effect of tillage on weeds*
Note: Abbreviations used in the ordination diagram of tillage variants are as follows: CT – conventional tillage, MT – minimum tillage
Abbreviation of weed species: *Ama retr – Amaranthus retroflexus, Ant cotu – Anthemis cotula, Ape spic – Apera spica-venti, Atr patu – Atriplex patula, Cap burs – Capsella bursa-pastoris, Cir arve – Cirsium arvense, Eup heli – Euphorbia helioscopia, Fal conv – Fallopia convolvulus, Fum offi – Fumaria officinalis, Gal apar – Galium aparine, Hol umbe – Holosteum umbellatum, Che albu – Chenopodium album, Lam amp – Lamium amplexicaule, Lam purp – Lamium purpureum, Leu alba – Leucosinapis alba, Pap rhoe – Papaver rhoeas, Ste medi – Stellaria media, Tar offi – Taraxacum officinale, Ver hede – Veronica hederifolia, Ver pers – Veronica persica, Vic faba – Vicia faba, Vio arve – Viola arvensis.*

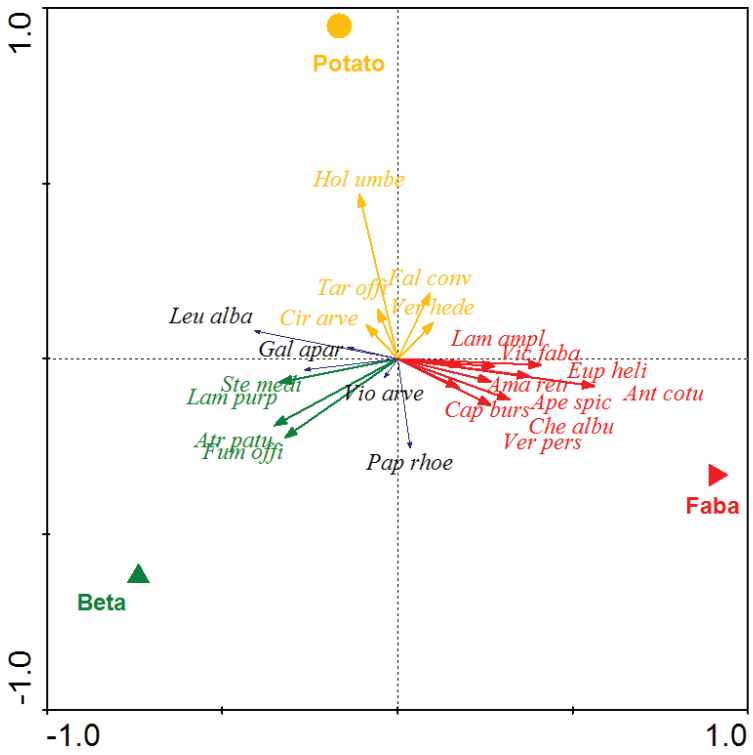
Tørresen & Skuterud, 2002). The reason why some annual species occur more frequently consists probably in the fact that in the reaction to a reduced depth of soil processing some species produce more seeds so that the number of specimens in the soil weed seedbank is gradually increasing (Schwerdtle, 1977; Froud-Williams *et al.*, 1983).

Many authors very often reported perennial species as typical weeds occurring in minimum tillage systems (Boström & Fogelfors, 1999; Locke *et al.*, 2002; Streit *et al.*, 2002; Tørresen & Skuterud, 2002). However, as mentioned by Gruber *et al.* (2012), their experimental results did not support this observation. In our experiment, the creeping thistle (*Cirsium arvense*) was the most frequent perennial weed species. Although it occurred more frequently in the MT variant, the statistical analysis did not corroborate the effect of tillage.

In the CT variant, the species ivy-leaved speedwell (*Veronica hederifolia*) was the most frequent weed species; as far as the forecrops were concerned, this weed species occurred most frequently after the faba bean. Species shepherd's purse (*Capsella bursa-pastoris*) and henbit (*Lamium amplexicaule*) responded to the tillage system and to the forecrop in a similar way. In the CT variant, the species black-bindweed (*Fallopia convolvulus*) was more frequent after faba bean and potatoes.

The highest occurrence of chickweed (*Stellaria media*) was observed after the fodder beet, probably due to the shedding of seeds in the fodder beet crop and the subsequent germination of produced seeds in the winter wheat stand. The difference between both variants of tillage was not too large. As far as this species was concerned, many authors wrote about its inconsistent response to tillage and mentioned that its occurrence was influenced markedly by the year and by the application of herbicides (Pollard & Cussans, 1976; Nielsen & Pinnerup, 1982).

It is probable that in systems of reduced soil processing a combination of weather, soil conditions and different crops influenced above all the abundance of field pansy (*Viola arvensis*). This effect was reported for example by Nielsen &



2: *Ordination diagram expressing the effect of different forecrops on weeds*
Note: Abbreviations used in the ordination diagram of forecrop variants are as follows: Faba – broad bean; Potato – late potatoes; Beta – fodder beet
Abbreviation of weed species: *Ama retr – Amaranthus retroflexus, Ant cotu – Anthemis cotula, Ape spic – Apera spica-venti, Atr patu – Atriplex patula, Cap burs – Capsella bursa-pastoris, Cir arve – Cirsium arvense, Eup heli – Euphorbia helioscopia, Fal conv – Fallopia convolvulus, Fum offi – Fumaria officinalis, Gal apar – Galium aparine, Hol umbe – Holosteum umbellatum, Che albu – Chenopodium album, Lam amp – Lamium amplexicaule, Lam purp – Lamium purpureum, Leu alba – Leucosinapis alba, Pap rhoe – Papaver rhoeas, Ste medi – Stellaria media, Tar offi – Taraxacum officinale, Ver pers – Veronica persica, Vic faba – Vicia faba, Vio arve – Viola arvensis*

Pinnerup (1982) and Froud-Williams *et al.* (1983). On the other hand, however, Andersen (1987) and Skuterud *et al.* (1996) wrote that the method of tillage did not show any effect on the abundance of this species. Results of our experiment enabled us to draw similar conclusions. However, Tørresen *et al.* (2003) observed that a combination of a relatively dry year with a thin cereal stand could created favourable conditions for the development of field pansy biomass and the occurrence of *V. arvensis* so that it may become a serious problem.

The occurrence of the common fumitore (*Fumaria officinalis*) was observed above all in the MT variant, especially after the forecrop fodder beet. According to Stach (1992), different methods of tillage change light, temperature, and moisture conditions and subsequently also the germination and development of many weed species. Due to this fact the strategy of weed control must be modified so that the species spectrum of the weed population can be changed as well as the economic importance of some weeds.

As mentioned by Nakamoto (2006) a disadvantage of some minimum tillage technologies consists in an increased occurrence of some both annual and perennial weeds and, subsequently, also an increase in the magnitude of their seedbank in the topsoil. These shortcomings become more and more obvious in the course of the period of use and for that reason they may restrain a permanent application of minimum tillage technologies without the application of herbicides.

CONCLUSION

When studying effects of different methods of tillage on weed infestation of winter wheat, it was observed that the abundance of weeds decreased above all in the variant with the minimum tillage. A reduced spectrum of weed species was observed just in this variant.
The effect of the forecrop on the intensity of weed infestation was also significant. The highest degree of weed infestation (both in numbers of individuals and in the total number of species) was recorded

after the forecrop broad bean. The lowest weed infestation of winter wheat stands was found out after the forecrop late potatoes.

The highest occurrence of the species *Veronica hederifolia* was recorded in the CT variant and after the forecrop faba bean. Species *Capsella bursa-pastoris* and *Lamium amplexicaule* showed a similar response to the tillage technology and the forecrop. In the CT variant, an increased occurrence of the species *Fallopia convolvulus* was recorded as well. An increased occurrence of this species was observed also after forecrops faba bean and late potatoes. The highest abundance of *Stellaria media* was recorded after the forecrop fodder beet. The difference between both variants of tillage was not too large. The method of tillage did not influence the occurrence of the species *Viola arvensis* but the effect of the year on this species was more pronounced. The species *Fumaria officinalis* occurred above all in the MT variant. As far as different forecrops were concerned, the highest abundance of this species was recorded after the forecrop fodder beet.

In some species, a marked effect of the year was observed, probably due to their different response to weather conditions.

It can be therefore concluded that a good understanding of effects of different systems of tillage on the existence and development of weed associations may play a decisive role in the efficiency and organisation of methods of weed control (Swanton *et al*., 1993).

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REFERENCES

ANDERSEN, A. 1987. Effects of direct drilling and ploughing on weed populations. *Tidsskr. Planteavl,* 91: 243–254.

BOSTRÖM, U. 1999. Type and time of autumn tillage with and without herbicides at reduced rates in southern Sweden: 1. Yields and weed quantity. *Soil & Tillage Research*, 50: 271–281.

BOSTRÖM, U., FOGELFORS, H. 1999. Type and time of autumn tillage with and without herbicides at reduced rates in southern Sweden: 2. Weed flora and diversity. *Soil & Tillage Research*, 50: 283–293.

CARDINA, J., HERMS, C. P., DOOHAN, D. J. 2002. Crop rotation and tillage system effects on weed seedbanks. *Weed Science,* 50: 448–460.

COUSENS, R., MOSS, S. R. 1990. A model of the effects of cultivation on the vertical distribution of weed seeds within the soil. *Weed Research,* 30: 61–70.

FROUD-WILLIAMS, R. J., DRENNAN, D. S. H., CHANCELLOR, R. J. 1983. Influence of cultivation regime on weed floras of arable cropping systems. *J. Appl. Ecol*., 20: 187–197.

GONZALEZ-ANDUJAR, J. L., HERNANDEZ PLAZA, E., KOZAK, M., NAVARRETE, L. 2011. Tillage system did not affect weed diversity in a 23-year experiment in Mediterranean dry land. *Agriculture, Ecosystems & Environment,* 140: 102–105.

GRUBER, S., PEKRUN, C., MÖHRING, J., CLAUPEIN, W. 2012. Long-term yield and weed response to conservation and stubble tillage in SW Germany. *Soil & Tillage Research,* 121: 49–56.

CHAUHAN, B. S., GILL, G. S., PRESTON, C. 2006. Tillage system effects on weed ecology, herbicide activity and persistence: a review. *Australian Journal of Experimental Agriculture,* 46: 1557–1570.

KUBÁT, K. 2002. *Klíč ke květeně České republiky* [*Key to the Flora of the Czech Republic*]. Praha: Academia.

LÉGÈRE, A., STEVENSON, F. C., BENOIT, D. L. 2011. The selective memory of weed seedbanks after 18 years of conservation tillage. *Weed Science,* 59: 98–106.

LOCKE, M. A., REDDY, K. N., ZABLOTOWICZ, R. M. 2002. Weed management in conservation crop production systems. *Weed Biology and Management,* 2: 123–132.

MIKULKA, J. 1999. *Plevelné rostliny polí, luk a zahrad* [*Weeds of fields, meadows and gardens*]. Praha: Farmář-Zemědělské listy.

MOHLER, C. L., FRISCH, J. C., MCCULLOCH, C. E. 2006. Vertical movement of weed seed surrogates by tillage implements and natural processes. *Soil & Tillage Research,* 86: 110–122.

MOONEN, A. C., BÁRBERI, P. 2004. Size and composition of the weed seedbank after 7 years of different cover-crop-maize management systems. *Weed Research,* 44: 163–177.

MOSS, S. R. 1988. Influence of cultivations on the vertical distribution of weed seeds in the soil. In: *Proceedings of the VIIIth International Symposium on the Biology, Ecology and Systematics of Weeds*. Dijon, 71–80.

MOYER, J. R., ROMAN, E. S., LINDWALL, C. W., BLACKSHAW, R. E. 1994. Weed management in conservation tillage systems for wheat production in North and South America. *Crop Protect*., 13: 243–259.

NAKAMOTO, T., YAMAGISHI, J., MIURA, F. 2006. Effect of reduced tillage on weeds and soil organisms in winter wheat and summer maize cropping on Humic Andosols in Central Japan. *Soil & Tillage Research* 85: 94–106.

NIELSEN, H. J., PINNERUP, S. P. 1982. Reduceret jordbehandling og ukrudt. In: *Ogräs och ogräsbekämpning, 23:e svenska ogräskonferensen, Del 2.*

Rapporter, 27–29 January 1982. Uppsala, Sweden, 381–395.

POLLARD, F., CUSSANS, G. W. 1976. The influence of tillage on the weed flora of four sites sown to successive crops of spring barley. In: *Proceedings British Crop Protection Conference–Weeds.* 15–18 November 1976. Brighton, England, Vol. 3: 1019–1028.

ROGER-ESTRADE, J., COLBACH, N., LETERME, P., RICHARD, G., CANEILL, J. 2001. Modelling vertical and lateral weed seed movements during mouldboard ploughing with a skim-coulter. *Soil & Tillage Research,* 63: 35–49.

RYAN, M. R., SMITH R. G. MIRSKY, S. B., MORTENSEN, D. A., SEIDEL, R. 2010. Management filters and species traits: weed community assembly in long-term organic and conventional systems. *Weed Science,* 58: 265–277.

SCHWERDTLE, F. 1977. Der Einfluss des Direkts. averfahrens auf die Verunkrautung. *Z. Pfl. Krankh. Pfl. Schutz, Sonderheft,* 8: 155–163.

SKUTERUD, R., SEMB, K., SAUR, J., MYGLAND, S. 1996. Impact of reduced tillage on the weed flora in spring cereals. *Norwegian J. Agri. Sci.,* 10: 519–532.

STACH, J. 1992. Zpracováni půdy ve vztahu k rozvoji plevelů [Effects of tillage on the development of weeds]. *Rostlinná výroba*, 38(7): 589–593.

STREIT, B., RIEGER, S. B., STAMP, P., RICHNER, W. 2002. The effect of tillage intensity and time of herbicide application on weed communities and populations in maize in central Europe. *Agriculture, Ecosystems & Environment,* 92: 211–224.

SWANTON, C. J., CLEMENTS, D. R., DERKSEN, D. A. 1993. Weed succession under conservation tillage: a hierarchical framework for research and management. *Weed Technol.,* 7: 286–297.

TER BRAAK, C. J. F. 1998. *CANOCO – A FORTRAN program for canonical community ordination by [partial] [detrended] [canonical] correspondence analysis (version 4.0.).* Report LWA-88-02. Wageningen: Agricultural Mathematics Group.

TØRRESEN, K. S., SKUTERUD, R., TANDSÆTHER, H. J., HAGEMO, M. B. 2003. Long-term experiments with reduced tillage in spring cereals. I. Effects on weed flora, weed seedbank and grain yield. *Crop Protection*, 22: 185–200.

TØRRESEN, K. S., SKUTERUD, R. 2002. Plant protection in spring cereal production with reduced tillage. IV. Changes in the weed flora and weed seedbank. *Crop Prot.,* 21: 179–193.

TRIPLETT, G. B., DICK, W. A. 2008. No-tillage crop production: a revolution in agriculture! *Agronomy Journal,* 100: 153–165.

ULBER, L., STEINMANN, H. H., KLIMEK, S., ISSELSTEIN, J. 2009. An on-farm approach to investigate the impact of diversified crop rotations on weed species richness and composition in winter wheat. *Weed Research,* 49: 534–543.

WINKLER, J. 2008. Vliv odlišného zpracování půdy na zaplevelení jarního ječmene v podmínkách srážkově sušší oblasti České republiky [Effects of different methods of tillage on weed infestation of sprin barley under conditions of drier regions of the Czech Republic]. *Acta Univ. Agric. Silvic. Mendelianae Brun.*, LVI(5): 235–242.

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