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BIODIVERSITY OF WEEDS IN PEA CULTIVATED IN VARIOUS TILLAGE SYSTEM

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ABSTRACT

Weed communities were evaluated in crops of pea sown in 3 tillage systems: a) conventional (CT), b) reduced (RT) and c) herbicide (HT). The CT system included shallow ploughing after the harvest of the previous crop and pre-winter ploughing in the autumn. The RT system was minimized to field cultivation, whereas the HT system – to treatment with Roundup 360 SL herbicide (a.s. glyphosate). Spring tillage consisted in field harrowing (in CT system) or cultivation (in RT and HT systems) and the use of a cultivating set (including a cultivator and a string roller). Weed community in pea crop was constituted by plants representing the following syntaxonomic classes: *Stellarietea mediae* R.Tx., Lohm. et Prsg, 1950, *Artemisietea vulgaris* Lohm., Prsg. et R.Tx. 1950, *Molinio-Arrhenatheretea* R.Tx.1937, and *Agropyretea intermedio-repentis* (Oberd. et al. 1967) Müller et Görs 1969. The highest species diversity of weeds occurred in the RT system, whereas the lowest one in the HT system.

Key words: Tillage system; syntaxonomy; weed species; *Pisum sativum*.

INTRODUCTION

The most significant sources of weed infestation of crops include weed spores deposited in soil (Cardina et al., 2002; Tørresen and Skuterud, 2002) and agricultural practices applied (Gruber and Claupein, 2009; Woźniak and Soroka, 2014; Woźniak et al., 2014). Investigations by Lundkvist (2009) and Brandsaeter et al. (2011) demonstrated that the number and weight of weeds as well as their species diversity depend on the method and period of cultivating measures applied. Opinions on the extent of crops infestation with weeds in various tillage systems are conflicting (Lahmar, 2010). According to Davis et al. (2005), Peigné et al. (2007) as well as Woźniak and Kwiatkowski (2013), the no-till method increases weed infestation, which results in crop reduction (Han et al., 2013; Woźniak, 2013). As reported by Tørresen and Skuterud (2002), the plough-less tillage contributes to a growing spore bank in the topsoil, from where the spores germinate and, thus, increase weed infestation (Cardina et al., 2002; Chauhan et al., 2006; Mohler et al., 2006). Also in a research by Woźniak (2012) the no-till system contributed to increased number and weight of weeds in pea compared to the ploughing system. In contrast, Tuesca et al. (2001) demonstrated increased weed infestations on plots with ploughing system and a reduced number and weight of weeds in the no-till system.

This study was aimed at evaluating the effect of tillage systems on biodiversity of weeds occurring in pea crop.

MATERIAL AND METHODS

An exact field experiment with pea sown in different tillage systems was conducted in the years 2007-2013 at the Experimental Station Uhrusk (51°18'12"N, 23°36'50"E) (University of Life Sciences in Lublin). The experiment was established with the method of completely randomised blocks (8 m x 75 m) in three replications. Three tillage systems were evaluated: a) conventional (CT), b) reduced (RT), and c) herbicide (HT), according to the scheme presented in Table 1. The experiment was established on soil with

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granulometric composition of light poorly-sandy loam, classified as Rendzic Phaeozem by the IUSS Working Group WRB (2006). This soil is rich in available forms of phosphorus (137 mg P kg^{-1}) and potassium (203 mg K kg^{-1}), and has a slightly alkaline pH value (pH_{KCl} =7.2). The total nitrogen (N) content in the soil is at 1.03 g kg^{-1} and that of organic carbon (C-organic) is at 7.60 g kg^{-1}.

According to the Agro-meteorological Station in Uhrusk, at the study area, the annual total precipitation accounts for 578 mm, whereas the mean air temperature for 7.5ºC (data of the years 1963 to 2010). In the period since sowing till harvest (since March till August), the sum of precipitation reaches 351 mm whereas air temperature reaches 12.6°C on average.

Table 1. Scheme of soil tillage

Tillage system	Soil tillage		
	After-harvest	Autumn	Spring
CT*	Shallow ploughing (10-12 cm), harrowing	autumn ploughing (25-30 cm)	harrowing, set for pre-sowing tillage (10-12 cm)
RT	Cultivating (2-fold) (10-15 cm)	no ploughing	cultivating (10-15 cm), set for pre-sowing tillage (10-12 cm)
HT	Glyphosate 360 g L^{-1} (4 L ha^{-1})		

*CT – conventional tillage; RT – reduced tillage; HT – herbicide tillage.

In each year of the study, pea (*Pisum sativum* L.) of ‘Bohun’ or ‘Tarchalska’ cultivar was sown in the first decade of April, in the quantity of 100 seeds per 1 m^2 in row spacing of 20 cm. Pea was sown after spring wheat or spring triticale. Before sowing, the following doses of nitrogen, phosphorus and potassium were applied: 20 kg N ha^{-1}, 17.5 kg P ha^{-1} and 66.5 kg K ha^{-1}. Pea crops were harrowed twice: firstly – before sprouting, and secondly at the third pea leaf stage (13/14 in Zadoks scale) (Zadoks et al., 1974).

The phytosociological and syntaxonomic evaluation of weed communities was carried out according to the method of Braun-Blanquet (1964) in the whole vegetative season of pea. The constancy degree of weeds occurrence was evaluated using the following scale: V – permanent species that occur in 80-100% of the examined plots, IV – frequent species (60-80%), III – moderately frequent species (40-60%), II – not-frequent species (20-40%), and I – rare or sporadically occurring species (<20%). Results were collated in tables, according to the scheme adopted by Soroka (2008). Names of plant species were provided according to Flora Europea (1964-1980), whereas synonym names according to Tasenkevich (1998). Names and structure of syntaxons, and the syntaxonomic scheme were adopted after Matuszkiewicz (2001).

Results were analyzed statistically with the analysis of variance (ANOVA) method, and significance of differences between mean values was estimated with the Tukey’s HSD test, $P \leq 0.05$.

RESULTS AND DISCUSSION

The study demonstrated various effects of tillage systems on the formation of complexes of segetal weeds in pea crops (Table 2). In all tillage systems, the most abundant turned out to be short-term segetal and ruderal weeds belonging to the class *Stellarietea mediae* R.Tx., Lohm. et Prsg, 1950. Weeds species in this class were typical of two orders: *Centauretalia cyani* R.Tx. 1950 which encompasses species characteristic for cereals, and *Polygono-Chenopodietalia* (R.Tx. em Lohm. 1950) J.Tx. 1961 representing species typical of root crops (Matuszkiewicz, 2001). The compared orders had similar species composition; however the order *Polygono-Chenopodietalia* included weed species with higher degrees of constancy. The *Polygono-*

Chenopodion Siss. 1946 alliance is typical of weed communities occurring in root crops on fertile and well moistened soils, whereas the *Aperion spicae-venti* R.Tx. et J. Tx. 1960 alliance occurs in agrocenoses of cereals on rich loamy soils (Matuszkiewicz, 2001).

Table 2. Constancy degrees of diagnostic species from the class *Stellarietea mediae* R.Tx., Lohm. et Prsg, 1950 in weed community in pea crop

Species composition	Tillage systems		
	CT*	RT	HT
Ch.sp. Ass. *Apero spica-venti - Papaveretum rhoeadis* V.Sl.1987			
Papaver rhoeas L.	V	V	V
Apera spica-venti (L.) Beauv.	III	IV	II
Anagallis arvensis L.	II	III	II
Ch.sp. Ass. *Echinochloo-Setarietum* Krusem et Vlieg. (1939) 1940			
Echinochloa crus-galli (L.) Beauv.	IV	V	V
Raphanus raphanistrum L.	-	III	III
D. sp. Cl.: *a* - *Stellarietea mediae* R.Tx., Lohm. et Prsg, 1950; b - *Centauretalia cyani* R.Tx. 1950; c - *Aperion spicae-venti* R.Tx. et J. Tx. 1960, *Aphanenion arvensis* R.Tx. et J.Tx. 1960; d - *Caucalidion lappulae* R.Tx. 1950; e - *Polygono-Chenopodietalia* (R.Tx. em Lohm. 1950) J.Tx. 1961; f - *Polygono-Chenopodion* Siss. 1946			
a Stellaria media (L.) Vill.	V	V	V
a Viola arvensis Murray	IV	V	V
a Galeopsis tetrahit L.	III	III	-
a Consolida regalis S.F.Gray subsp. *regalis*	III	V	III
a Anthemis arvensis L.	III	III	III
a Centaurea cyanus L.	III	III	-
a Vicia hirsuta (L.) S.F.Gray	III	-	-
a Thlaspi arvense L.	II	III	-
a Lapsana communis L.	I	III	-
a Fallopia convolvulus (L.) Á.Löve	II	III	II
b Vicia sativa L.	III	III	-
b Vicia villosa Roth.	II	III	III
b Buglossoides arvensis (L.) I. M. Johnston	-	-	I
c Matricaria perforata Mérat	V	V	V
c Veronica hederifolia L. subsp. *hederifolia*	-	II	I
d Avena fatua L.	V	V	V
e Chenopodium album L.	III	V	V
e Capsella bursa-pastoris (L.) Medicus	III	V	III
e Setaria pumila (Poiret) Schultes	III	IV	III
e Solanum nigrum L.	III	IV	-
e Sonchus arvensis L. subsp. *arvensis*	-	II	-
e Atriplex patula L.	-	I	-
f Lamium purpureum L.	IV	V	V
f Galinsoga parviflora Cav.	IV	IV	IV
f Sonchus asper (L.) Hill	III	V	V
f Euphorbia helioscopia L.	III	IV	IV
f Veronica persica Poiret	IV	III	IV
f Sonchus oleraceus L.	III	III	III
f Lamium amplexicaule L.	II	II	-

*CT – conventional tillage; RT – reduced tillage; HT – herbicide tillage.

The syntaxonomic analysis demonstrated the formation of very characteristic phytocenoses in pea crop. Weed species typical of root crops and cereals could be observed as well. The *Apero spica-venti - Papaveretum rhoeadis* V.Sl. 1987 association is specific to cereals, whereas *Echinochloa - Setarietum* Krusem et Vlieg (1939) 1940 – to root plants.

Weed species characteristic to both these associations occurred in our study, however, it may clearly be noticed that in pea crops the weeds with the higher degrees of consistency occurred in the association *Echinochloa - Setarietum*. The *Echinochloa crus-galli* (L.) Beauv. species being typical of this association contributed mainly to secondary weed infestation of root plants and rare crops of other plants. Such conditions in pea crop were evoked by RT and HT systems (Table 2). This was also confirmed in a study by Woźniak and Soroka (2014), where *Echinochloa crus-galli* occurred at significantly higher density in spring triticale crop in the reduced system and no-till system, compared to the conventional ploughing system. The following numbers of weed species with the V^th^ and IV^th^ constancy degree representing the class *Stellarietea mediae* were demonstrated in our study: 16 species in the reduced system (RT), 12 species in the herbicide system (HT) and 9 species in the conventional system (CT).

Representatives of other classes of phytocenoses included only few species, as they were unable to compete with highly-specialized weeds of the class *Stellarietea mediae* (Table 3).

Table 3. Constancy degrees of diagnostic species from other classes in weed community in pea crop

Species composition	Tillage systems		
	CT*	RT	HT
D. sp. Cl. *Artemisietea vulgaris* Lohm., Prsg. et R.Tx. 1950			
Cirsium arvense (L.) Scop.	II	V	-
D. sp. *S*Cl. *Artemisienea vulgaris* Pass. 1967			
Melandrium album (Mill.) Garcke	V	IV	-
D. sp. SCl. *Galio-Urticenea* Pass. 1967			
Galium aparine L.	V	V	V
D. sp. Cl. *Molinio-Arrhenatheretea* R.Tx.1937, Ord. *Plantaginetalia majoris* R.Tx. (1943) 1950, All. *Poligonion avicularis* Br.-Bl. 1931 ex Aich. 1933			
Poa annua L.	I	III	-
D. sp. Cl. *Agropyretea intermedio-repentis* (Oberd. et al. 1967) Müller et Görs 1969, Ord. *Agropyretalia intermedio-repentis* (Oberd. et al. 1967) Müller et Görs 1969, All. *Convolvulo-Agropyrion repentis* Görs 1966			
Elymus repens (L.) Gould	-	III	-
Convolvulus arvensis L.	-	III	-
Melampyrum arvense L.	I	I	-
Other species:			
Amaranthus retroflexus L.	IV	V	V
Brassica nigra (L.) Koch	II	IV	III
Veronica arvensis L.	-	II	-
Bryonia alba L.	I	-	-
Number of species, (The sum of Table 1 and Table 2)	37	42	27

*CT – conventional tillage, RT –reduced tillage, HT – herbicide tillage.

The class *Artemisietea vulgaris* Lohm., Prsg. et R.Tx. 1950 is constituted by nitrophilic communities of ruderal vegetation (Matuszkiewicz, 2001), e.g. communities of nitrophilic mesophytes on fertile substratum. In our study, this class was represented by only one species – *Cirsium arvense* (L.) Scop. The sub-class *Artemisienea vulgaris* Pass. 1967 covers anthropogenic phytocenoses with many species that constitute successive stages of the overgrowing of ruderal communities. The only representative of the typical species was *Melandrium album*. The sub-class *Galio-Urticenea* Pass. 1967 forms semi-natural ecotonic phytocenoses on fresh and moist soils, sometimes located in shaded places. In the primary landscape, they occurred alongside banks of watercourses and edges of forests (Matuszkiewicz, 2001). As a consequence of anthropogenic activity, however, their spreading attained a various character. The *Galium aparine* L. species confirmed in our study is a typical representative of these habitats. The semi natural phytocenoses of the class *Molinio-Arrhenatheretea* R.Tx.1937, order *Plantaginetalia majoris* R.Tx. (1943) 1950 and alliance *Poligonion avicularis* Br.-Bl. 1931 ex Aich. 1933, merge nitrophilic communities of low plants in treaded places. They were represented by only one of the characteristic species (*Poa annua* L.). Rocky substratum facilitates the occurrence of species belonging to the class *Agropyretea intermedio - repentis* (Oberd. et 1967) Müller et Görs 1969, order *Agropyretalia intermedio-repentis* (Oberd. et al., 1967) Müller et Görs 1969, alliance *Convolvulo-Agropyrion repentis* Görs 1966. The rendzic soil occurring at the investigated area facilitated the prevalence of 3 species of this class (*Elymus repens* (L.) Gould, *Convolvulus arvensis* L. and *Melampyrum arvense* L.).

The analyzed tillage systems were found to induce changes in weed communities. Data presented in Tables 2 and 3 show that weed species with the highest constancy degrees occurred in the reduced system (RT). Considering the species from the class *Stellarietea mediae***,** in the RT system the highest constancy degrees were noted for the species specific to root crops - *Chenopodium album* L., *Capsella bursa-pastoris* (L.) Medicus, *Setaria pumila* (Poiret) Schultes, *Solanum nigrum* L., *Lamium purpureum* L., *Galinsoga parviflora* Cav., *Sonchus asper* (L.) Hill, and *Euphorbia helioscopia* L. Species of the other classes also quickly responded to reduced measures in soil tillage – the highest degrees of constancy were reported in the case of ruderal weeds from the class *Artemisietea vulgaris* that occurred at moderately intensive agrotechnical measures. This study demonstrates that a weed community was formed in pea crop that contained species characteristic to root plants and cereals, however with a distinct preponderance of weeds specific to root crops. The composition of such communities includes weed species of the class *Stellarietea mediae* that are typical of root crops as well as diagnostic species of other classes of phytocenoses. This may be due to weed seeds introduction to soil with manure and to plant succession in crop rotation. In this case, the syntaxonomic diagnostics of communities is based, to a larger extent, on quantitative indicators of species, including constancy degrees.

The tillage systems were also observed to influence the number of weed species colonizing pea crop (Table 3). Regardless of study year, the highest number of weed species occurred in the RT system (42 species), whereas the lowest number – in the HT system (27 species). The majority of these were short-term species, though the RT system facilitated also the presence of perennial weeds (*Cirsium arvense, Elymus repens* and *Convolvulus arvensis*). In the CT system, the perennial species were represented only by *Cirsium arvense*, whereas no perennial species were found in the HT system. It may by hypothesized that this could result from the use of herbicides (a.s. glyphosate) in this system that ensured effective weed control. In turn, in the RT system the basic tool in tillage was a cultivator that was effective in dissemination of asexually-reproducing weeds on this plot. For this reason, a higher number of weed species was recorded each year in the RT system than in the HT and CT systems (Table 4).

Table 4. Number of weed species in pea

Years	Tillage systems		
	CT*	RT	HT
2007	18 ab**	21 a	15 b
2008	22 b	31 a	18 c
2009	23 b	35 a	23 b
2010	21 b	27 a	21 b
2011	21 b	27 a	19 c
2012	16 c	28 a	19 b
2013	18 b	28 a	19 b

* CT – conventional tillage; RT – reduced tillage; HT – herbicide tillage.

** means followed by the same letters in the same rows do not differ significantly, P≤0.05.

In summary, it ought to be concluded that the tillage systems were determining the formation of specific agrocenoses of pea. The substitution of mechanical treatments with chemical ones facilitated increased species diversity of weeds and, consequently, the compensation of species tolerant to the applied herbicides.

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