EFFECTS OF LONG-TERM REDUCED TILLAGE ON WEED INFESTATION OF PEA (*Pisum sativum* L.)

¹Andrzej Woźniak, ²Myroslawa Soroka

¹Department of Herbology and Plant Cultivation Techniques, University of Life Sciences in Lublin, Poland
e-mail: andrzej.wozniak@up.lublin.pl

²Department of Botany, Ukrainian National Forestry University, 79057 Lviv

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Abstract

The study evaluated weed infestation of pea (*Pisum sativum* L.) cultivated under conditions of conventional (CT), reduced (RT) and herbicide tillage (HT). It demonstrated the highest weed density per m² in plots with the herbicide (HT) and reduced (RT) systems and significantly lower weed infestation in plots cultivated in the conventional system (CT). In addition, more weeds occurred at the third leaf stage (13/14 in BBCH scale) than at the pod development stage (73/74 BBCH) of pea. The highest biomass was produced by weeds in the herbicide system (HT), a lower one – in the reduced system (RT), and the lowest one – in the conventional system (CT). The air-dry weight of weeds depended also on pea development stage. At the pod development stage (73/74 BBCH), the air-dry weight of weeds was significantly higher than at the third leaf stage (13/14 BBCH). The tillage system was also observed to influence the species composition of weeds. This trait was also affected by the period of weed infestation assessment. At the third leaf stage of pea (13/14 BBCH), there occurred 26 weed species, including 24 annual ones. The most abundant species included: *Chenopodium album* L., *Stellaria media* (L.) Vill., *Capsella bursa-pastoris* (L.) Med., *Matricaria inodora* L., *Thlaspi arvense* L., and *Fallopia convolvulus* (L.) A. Löve. At the pod development stage (73/74 BBCH), the pea crop was colonized by 24 weed species, including 3 perennial ones. At this stage the predominant species included: *Avena fatua* L., *Amaranthus retroflexus* L., *Papaver rhoeas* L., *Echinochloa crus-galli* (L.) P.B., *Matricaria inodora* L., and *Galeopsis tetrahit* L.

Key words: *Pisum sativum* L., tillage system, weeds number, air-dry weight of weeds, species composition

[1–3]. Weed density and biomass in a crop and species composition of weeds depend on the number of tillage operations and on the method and period of their application [4–6]. The opinions on the impact of no-till system on the extent of weed infestation are much diversified [7]. Davis *et al.* [8] and Peigné *et al.* [9] report that ploughless tillage increases weed infestation and resultantly decreases crop yield. In contrast, Tiesca *et al.* [10] demonstrate that the ploughing system increases weed infestation, whereas the no-till system reduces it as no weed diaspores emerge from the deeper layers of soil. According to Tørresen and Skuterud [11], ploughless tillage increases the diaspore bank in the topsoil from where seeds germinate, thus increasing weed infestation of the after-crop [12–14]. In turn, the investigations by Małacka *et al.* [15] and by Faltyn and Kordas [16] showed increased weed infestation of cereals under the conventional (ploughing) system, compared to the reduced system and direct seeding. In contrast, Kraska and Pałys [17] reported higher weed biomass in barley sown under ploughless tillage conditions than that for plough tillage. Also in a study by Woźniak [3,18], the reduced and herbicide tillage systems increased weed infestation in the plots compared to the conventional system.

The aim of this study was to determine the effect of long-term reduced tillage on the number and air-dry weight of weeds and on their species composition in a pea crop at the third true leaf (13/14 in BBCH scale) and pod development (73/74 BBCH) stages of pea.

INTRODUCTION

Weed infestation of crops results from the co-effects of agronomic practices and the soil seed bank

MATERIALS AND METHODS

A field experiment assessed the effect of three tillage methods, used over a period of 7 years (2007–

2013), on weed infestation of pea in 2013 at the Uhrusk Experimental Station (51°18'12"N, 23°36'50"E). The experiment was established in a randomized complete block design (8 m x 75 m) in three replications. It evaluated weed infestation of pea (*Pisum sativum* L.) sown under three tillage systems: a) conventional tillage (CT); b) reduced tillage (RT); and c) herbicide tillage (HT). The conventional tillage (CT) system included shallow ploughing and harrowing after harvest of the previous crop (spring wheat) and ploughing in the autumn. Reduced tillage only involved the use of a cultivator in the autumn, whereas herbicide tillage was limited to treatment with the herbicide Roundup 360 SL (a.s. glyphosate) – 4 l ha⁻¹. In the springtime, the tillage system including a cultivator, a string roller and a harrow was used in all plots.

The experiment was established on chalk rendzina with the granulometric composition of light, poor, sandy loam, classified as Rendzic Phaeozem by the IUSS Working Group WRB [19]. This soil is rich in available forms of phosphorus (214 mg P kg⁻¹) and potassium (237 mg K kg⁻¹), and has a slightly alkaline pH value (pH_{KCl}=7.2). The total nitrogen (N) content in the soil is 1.03 g N kg⁻¹, whereas that of organic carbon (C-organic) – 7.60 g kg⁻¹.

Pea (*Pisum sativum* L.), cv. 'Tarchalska', was sown in the first decade of April, at the rate of 100 seeds per m² at a row spacing of 20 cm. 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: first before sprouting and then at the third leaf stage of pea (13/14 in BBCH scale) [20].

In the last year of the study (2013), pea plant density after sprouting and weed infestation of the pea crop were evaluated in all plots. Plant density was determined per m² of each plot at the leaf development stage (10/11 BBCH). Weed infestation was examined

using the botanical-gravimetric method at two developmental stages, i.e.: the third true leaf (13/14 BBCH) (before harrowing of crops) and pod development (73/74 BBCH). Weed infestation assessment consisted in the determination of the species composition of weeds as well as of the number and air-dry weight of weeds per m² of each plot. This area was determined at random (twice) using a 1 m x 0.5 m frame. The determination of air-dry weight of weeds consisted in the collection of all weeds from the frame, removing their root system and placing them on openwork shelves in an airy and dry place until constant weight was reached.

The results were elaborated analyzed using analysis of variance and the differences observed were estimated with Tukey's test at a significance level of $p < 0.05$.

RESULTS

The highest weed density per m² was determined in the plots with the herbicide (HT) and reduced (RT) tillage systems, whereas significantly lower weed density – by 47.6–48.7% – was found under the conventional system (CT) – Table 1. Weed density per m² was also observed to depend on the pea developmental stage. More weeds were recorded at the third leaf stage (13/14 BBCH) than at the pod development stage (73/74 BBCH). At the first time of weed infestation assessment (stage 13/14 BBCH), a significantly higher number of weeds occurred in the plots cultivated under the reduced (RT) and herbicide (HT) systems in relation to the conventional one (CT). The differences between the CT system and the RT and HT plots reached 57.1 and 53.1%, respectively. In turn, at the pod development stage (73/74 BBCH) the highest weed density was determined in the herbicide and reduced tillage systems, whereas a significantly lower one for conventional tillage.

Table 1
Number of weeds per m² in the pea crop

Growth stage (GS) in BBCH scale	Tillage systems (TS)			Mean
	conventional (CT)	reduced (RT)	herbicide (HT)	
13/14	38.1	88.9	81.2	69.4
73/74	40.1	60.3	71.2	57.2
Mean	39.1	74.6	76.2	-
LSD _{0.05} for TS – 12.1; GS – 8.3; TS x GS – 19.3				

The analysis of the other weed infestation parameter, i.e. air-dry weight of weeds, demonstrated that the highest biomass of weeds was produced under the herbicide system, it was lower in the case of re-

duced tillage (RT) and lowest for the conventional system (CT). The difference between the highest weight of weeds in the HT plots and the lowest weed weight in the CT plots reached 67.5% (Table 2). The air-dry

weight of weeds was also influenced by the pea development stage. At stage 73/74 (in BBCH scale), the weed weight was higher by 53.9% than at stage 13/14 (BBCH). On the first evaluation date, i.e. at the third leaf stage (13/14 BBCH), the air-dry weight of weeds was higher in the plots cultivated in the HT and RT systems, compared to the CT plots. In turn, at the pod development stage (73/74 BBCH), significant differ-

ences occurred between all plots, by the highest biomass was produced by weeds in the HT system, lower one – in RT, and the lowest one – in the CT system. The higher weed infestation and the higher weed biomass observed in the plots with the herbicide (HT) and reduced (RT) systems, compared to the CT plots, could be due to significantly poorer emergence of pea in the plots with ploughless tillage (HT and RT) (Table 3).

Table 2
Air-dry weight of weeds in $\text{g} \times \text{m}^{-2}$ in the pea crop

Growth stage (GS) in BBCH scale	Tillage systems (TS)			Mean
	conventional (CT)	reduced (RT)	herbicide (HT)	
13/14	14.9	53.1	65.9	44.6
73/74	49.1	109.9	131.1	96.7
Mean	32.0	81.5	98.5	-
LSD _{0.05} for TS – 10.3; GS – 8.3; TS x GS – 17.1				

Table 3
Pea plant density per m^2 at the third leaf stage (10/11 in BBCH scale)

Tillage systems (TS)			Mean
conventional (CT)	reduced (RT)	herbicide (HT)	
81	56	51	63
LSD _{0.05} for TS – 14			

At the first time of weed infestation assessment, i.e. at the third leaf stage (13/14 BBCH), 26 weed species were recorded, including 24 annual ones (Table 4). In the CT plots, the analysis showed 19 species with the most abundant ones including: *Chenopodium album* L., *Stellaria media* (L.) Vill., *Capsella bursa-pastoris* (L.) Med., *Matricaria inodora* L., *Galinsoga parviflora* Cav., and *Avena fatua* L. In total, they constituted over 67% of the whole weed community. The plots with the RT system were infested by 19 annual species, quantitatively predominated by: *Chenopodium album* L., *Stellaria media* (L.) Vill., *Thlaspi arvense* L., *Matricaria inodora* L., *Avena fatua* L., and *Capsella bursa-pastoris* (L.) Med. As a result, the above species represented over 67% of the weed community. In the herbicide tillage (HT) system, the analysis revealed 19 weed species, including 2 perennial ones. Their most abundant representatives included: *Chenopodium album* L., *Stellaria media* (L.) Vill., *Capsella bursa-pastoris* (L.) Med., *Matricaria inodora* L., *Thlaspi arvense* L. and *Viola arvensis* Murr. In total, these species constituted 75% of the weed community.

On the second date of weed infestation analysis, i.e. at the pod development stage (stage 73/74 BBCH), the plots were colonized by 24 weed species, including 3 perennial ones (Table 5). In the CT plots, there occurred 18 species, including 2 perennial ones. They were predominated by: *Avena fatua* L., *Amaranthus retroflexus* L., *Echinochloa crus-galli* (L.) P.B., *Papaver rhoeas* L., *Galinsoga parviflora* Cav., and *Fallopia convolvulus* L. In total, these species constituted 77% of the weed community in this tillage system. The plots with reduced tillage were colonized by 23 weed species, including 3 perennial ones. The most abundant included: *Avena fatua* L., *Chenopodium album* L., *Amaranthus retroflexus* L., *Papaver rhoeas* L., *Galeopsis tetrahit* L., and *Matricaria inodora* L. They all represented 73% of the weed community. In turn, in the plots with herbicide tillage (HT) the analysis showed 17 weed species with the most abundant ones including: *Avena fatua* L., *Amaranthus retroflexus* L., *Papaver rhoeas* L., *Matricaria inodora* L., *Chenopodium album* L., and *Capsella bursa-pastoris* (L.) Med. The above species constituted more than 77% of the weed community.

Table 4
Species composition and number of weeds per m²
in the pea crop at the third leaf stage (13/14 in BBCH scale)

Species composition	Tillage systems		
	CT*	RT	HT
I. Annual weeds			
<i>Chenopodium album</i> L.	8.9	24.1	19.8
<i>Stellaria media</i> (L.) Vill.	4.5	9.8	12.5
<i>Capsella bursa-pastoris</i> (L.) Med.	4.5	5.4	10.5
<i>Matricaria inodora</i> L.	2.8	6.5	7.2
<i>Galinsoga parviflora</i> Cav.	2.5	-	-
<i>Avena fatua</i> L.	2.5	6.5	-
<i>Thlaspi arvense</i> L.	2.2	7.5	6.8
<i>Fallopia convolvulus</i> (L.) A. Löve	1.8	3.9	4.2
<i>Galium aparine</i> L.	1.2	2.8	-
<i>Papaver rhoeas</i> L.	1.2	1.2	0.4
<i>Poa annua</i> L.	1.2	-	-
<i>Veronica persica</i> Poir.	0.8	4.9	3.9
<i>Anagallis arvensis</i> L.	0.8	0.8	0.9
<i>Amaranthus retroflexus</i> L.	0.8	7.5	-
<i>Lamium amplexicaule</i> L.	0.7	-	4.3
<i>Viola arvensis</i> Murr.	0.5	-	4.5
<i>Consolida regalis</i> Gray.	0.5	1.2	2.2
<i>Galeopsis tetrahit</i> L.	-	0.9	-
<i>Sonchus asper</i> (L.) Hill.	-	0.9	1.0
<i>Polygonum lapathifolium</i> L.	-	0.2	0.2
<i>Apera spica-venti</i> (L.) P.B.	-	2.5	1.2
<i>Vicia villosa</i> L.	-	2.1	0.2
<i>Echionochloa crus-galli</i> (L.) P.B.	-	0.2	-
<i>Centaurea cyanus</i> L.	-	-	0.4
Number of annual weeds (I)	37.4	88.9	80.2
II. Perennial weeds			
<i>Cirsium arvense</i> (L.) Scop.	0.5	-	0.8
<i>Convolvulus arvensis</i> L.	0.2	-	0.2
Number of perennial weeds (II)	0.7	-	1.0
Number of species	19	19	19

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

Table 5
Species composition and number of weeds per m² in the pea crop
at the pod development stage (73/74 in BBCH scale)

Species composition	Tillage systems		
	CT*	RT	HT
I. Annual weeds			
<i>Avena fatua</i> L.	8.2	12.2	13.8
<i>Amaranthus retroflexus</i> L.	6.2	8.9	12.2
<i>Echinochloa crus-galli</i> (L.) P.B.	5.2	2.8	4.8
<i>Papaver rhoeas</i> L.	4.4	5.2	10.5
<i>Galinsoga parviflora</i> Cav.	4.3	0.8	-
<i>Fallopia convolvulus</i> (L.) A. Löve	2.5	0.8	2.5
<i>Chenopodium album</i> L.	2.5	10.3	6.2
<i>Galeopsis tetrahit</i> L.	2.2	3.9	2.2
<i>Matricaria inodora</i> L.	1.2	3.9	6.5
<i>Sonchus asper</i> (L.) Hill	1.2	2.2	-
<i>Capsella bursa-pastoris</i> (L.) Med.	0.4	2.2	5.9
<i>Thlaspi arvense</i> L.	0.4	1.2	2.2
<i>Viola arvensis</i> Murr.	0.2	0.8	0.8
<i>Veronica persica</i> Poir.	0.2	0.8	-
<i>Vicia villosa</i> Roth	0.2	0.8	-
<i>Veronica hederifolia</i> L.	0.2	-	-
<i>Galium aparine</i> L.	-	0.8	0.9
<i>Lamium amplexicaule</i> L.	-	0.5	0.2
<i>Apera spica-venti</i> (L.) P.B.	-	0.2	1.5
<i>Vicia angustifolia</i> L.	-	0.2	0.2
<i>Anagallis arvensis</i> L.	-	0.2	0.4
Number of annual weeds (I)	39.5	58.7	70.8
II. Perennial weeds			
<i>Convolvulus arvensis</i> L.	0.4	0.2	-
<i>Cirsium arvense</i> (L.) Scop.	0.2	0.2	0.4
<i>Elymus repens</i> (L.) P.B.	-	1.2	-
Number of perennial weeds (II)	0.6	1.6	0.4
Number of species	18	23	17

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

DISCUSSION

Pea is characterized by a long period of sprouting and a low initial rate of growth and hence it is easily colonized by weeds. For this reason, it requires careful agronomic management, including an appropriate tillage system [10]. As reported by L a h m a r [7] and Wo ź n i a k [3], disparity may be observed

in opinions on the effect of ploughless tillage systems on yielding and weed infestation of crops. Generally, however, the no-till system is believed to increase weed infestation of cultivated crops [3,8,9,18]. Also our study demonstrated a significant increase in weed numbers and biomass in the reduced (RT) and herbicide (HT) system compared to the conventional system (CT). This increase may be explained by the

accumulation of freshly fallen seeds on the soil surface from where they germinate and thus increase weed infestation of the crop [11,14]. In the opinion of some authors [10,18], long-term reduced tillage contributes to increased weed infestation. In turn, the studies by Małecka *et al.* [15] and Faltyn and Kordas [16] demonstrate increased weed colonization of crops under conditions of the ploughing system, compared to reduced tillage and direct sowing. The extent of weed infestation was also observed to depend on the time of assessment. A higher weed density per m² occurred at the third leaf stage (13/14 BBCH) than at the pod development stage (73/74 BBCH). It may be explained by multiple seedlings of plants in this period, especially of *Chenopodium album* L., *Stellaria media* (L.) Vill. and *Capsella bursa-pastoris* (L.) Med. At the later time of assessment, the weed community was already predominated by fruiting weeds and seedlings grown from fallen seeds. It was reflected in a higher weight of weeds which in this period was higher than at the third leaf stage. A higher weed density at the third leaf stage (13/14 BBCH) was determined in the plots with reduced (RT) and herbicide (HT) tillage than in the plots with the conventional tillage system (CT). According to Cardina *et al.* [12] and other authors [13,14], the no-till system increases the bank of diaspores in the topsoil which germinate and thereby increase crop colonization by weeds. In our experiment, the increased weed infestation of the pea crop in the reduced (RT) and herbicide (HT) system also resulted from poorer pea sprouting than in the conventional system (CT) as well as from a significantly lower plant density. The tillage system was also observed to affect the species composition of weeds. This trait was also influenced by the pea development stage. At the third leaf stage (13/14 BBCH), the crop was colonized by 26 weed species, including 25 annual ones, whereas at the pod development stage (73/74 BBCH) the analysis revealed 24 weed species, including 3 perennial ones.

CONCLUSIONS

The highest weed density per m² occurred in the plots with the herbicide and reduced tillage systems, whereas significantly lower weed density was found in the conventional plots. In addition, more weeds occurred at the third leaf stage (13/14 in BBCH scale) of pea than at the pod development stage (73/74 BBCH).

The highest biomass was produced by weeds in the herbicide system, lower in the reduced and the lowest in the conventional system. Also, a higher air-dry weight of weeds was recorded at the pod development stage (73/74 BBCH) than at the third leaf stage (13/14 BBCH).

The tillage system affected the species composition of weeds. This trait was also influenced by the

time of weed infestation assessment. At the third leaf stage (13/14 BBCH), the plots were colonized by 26 weed species (including 24 annual ones), whereas at the pod development stage (73/74 BBCH) by 24 species of weeds (including 3 perennial ones).

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Authors' contributions

Concept of study: AW; field research and data collection: AW; data interpretation: AW, MS; writing of the manuscript, table: AW.

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Wpływ wieloletnich uproszczeń w uprawie roli na zachwaszczenie grochu siewnego (*Pisum sativum* L.)

Streszczenie

Oceniono zachwaszczenie grochu siewnego (*Pisum sativum* L.) wysiewanego w warunkach konwencjonalnej (CT), uproszczonej (RT) i herbicydowej (HT) uprawy roli. Wykazano, że największe zagęszczenie chwastów na m² wystąpiło na obiektach uprawy herbicydowej i uproszczonej, natomiast istotnie mniejsze w uprawie konwencjonalnej. Również większą biomasa wytworzyły chwasty w uprawie herbicydowej, mniejszą w uprawie uproszczonej, zaś najmniejszą w konwencjonalnej. Uprawa roli wpływała również na skład gatunkowy chwastów. Cecha ta zależała także od terminu oceny zachwaszczenia. W fazie trzeciego liścia grochu najliczniejszymi były: *Chenopodium album* L., *Stellaria media* (L.) Vill., *Capsella bursa-pastoris* (L.) Med., *Matricaria inodora* L., *Thlaspi arvense* L. i *Fallopia convolvulus* (L.) A. Löve. W fazie rozwoju strąków ilościowo dominowały: *Avena fatua* L., *Amaranthus retroflexus* L., *Papaver rhoeas* L., *Echinochloa crus-galli* (L.) P.B., *Matricaria inodora* L. i *Galeopsis tetrahit* L.

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