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# THE AFTER-EFFECT OF LONG-TERM REDUCED TILLAGE SYSTEMS ON THE BIODIVERSITY OF WEEDS IN SPRING CROPS

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Abstract

A strictly controlled field experiment on traditional and reduced tillage systems as well as herbicide treatment was conducted at the Agricultural Experimental Station of Uhrusk in the years 2007-2011. In the last year of the experiment, the effect of different tillage systems on the level of weed infestation and biodiversity of weeds was determined in all the plots for the crop of common spring wheat *Triticum aestivum* L., spring durum wheat *Triticum durum* Desf., and oat *Avena sativa* L. at two growth stages: tillering (23/24 on BBCH scale) and dough stage (83/85). A higher number and higher air-dry weight of weeds were determined at tillering than at the dough stage. Long-term reduced tillage increased the number of weeds per 1m$^2$ at the tillering stage, contrary to herbicide treatment. At the dough stage, a higher number of weeds was observed in the herbicide treatment and reduced tillage plots compared to traditional tillage. The air-dry weight of weeds at the tillering and dough stages of cereals was significantly higher in the case of herbicide treatment than under the traditional and reduced tillage systems. Weed communities in spring wheat, durum wheat and oat included mostly annual weeds. A higher number of weed species was determined in the plot with long-term herbicide treatment than in the plots with reduced and traditional tillage systems.

**Key words:** spring wheat, durum wheat, oat, plough tillage, ploughless tillage, herbicide treatment, number of weeds, air-dry weight of weeds, weed species composition

## INTRODUCTION

Weeds (segetal plants) constitute a constant element accompanying arable crops. Their presence is associated with the diaspore bank in the soil (Wesołowski and Woźniak, 2001; Sekutowski and Rola, 2006; Feledyn-Szewczyk and Duer, 2007), agricultural practices used (Fykse and Waernhus, 1999; Kraska and Pałys, 2006; Gruber and Claupein, 2009; Knezevic et al. 2009), and habitat conditions (Jastrzębska et al. 2010; Woźniak, 2011). Tillage practices, and especially their number as well as the method and time of their performance (Knezevic et al. 2009; Pilipavicius et al. 2009; Brandsaeter et al. 2011), coupled with chemical (Fykse and Waernhus, 1999) and mechanical (Lundkvist, 2009) weed control, constitute factors determining the level of weed infestation (the number and mass of weeds) and weed biodiversity. The traditional (plough) tillage system, in relation to ploughless tillage, considerably increases energy consumption of tillage and therefore increases the cost of crop production (Bujak et al. 2010); however, in ecological farming, traditional tillage is an indispensable procedure to eliminate perennial weeds (Gruber and Claupein, 2009). A research conducted by Brandsaeter et al. (2011) demonstrated that ploughing to a depth of 25 cm (by 50%) reduced considerably more effectively weed infestation (the number and biomass of weeds) than that to 15 cm. However, a greater advantage of deep tillage, in comparison to shallow tillage, was the effective eradication of *Cirsium arvense* (L.) Scop., i.e. by 90%. When evaluating the herbicidal effectiveness of harrowing of spring crops and pea, Lundkvist (2009) stated that in the case of *Sinapis arvensis* L. and *Galeopsis* spp. the most effective was harrowing before their emergence. On the other hand, late-emerging weeds were most effectively reduced by harrowing before sprouting and one or two harrowings after sprouting.

Opinions concerning the effect of ploughless tillage systems on the level of weed infestation vary. A research done by Małecka et al. (2006) demonstrated considerably greater weed infestation (the number and weight of weeds) of winter crops under traditional (plough) tillage than in the reduced tillage system and direct sowing. In a study by Faltyn and Kordas (2009) spring crops were also considerably less weedy in direct drilling than under conditions of traditional and reduced tillage systems. In turn, in a research by Kraska and Pałys (2006) higher biomass was developed by weeds in the spring barley crop sown under reduced tillage than in the traditional system. Also, in a study by Woźniak (2011), reduced tillage significantly increased the air-dry weight of weeds in a spring wheat crop in relation to traditional tillage. Still, the tillage systems compared did not differentiate the number of weeds per 1m$^2$.

The aim of the study reported herein was to determine the effect of long-term reductions in tillage systems on weed infestation (the number and air-dry weight of weeds) and biodiversity of weeds in crops of spring wheat, durum wheat, and oat.

## MATERIALS AND METHODS

A strictly controlled field experiment was conducted in the years 2007-2011 at the Agricultural Experimental Station of Uhrusk (51°18'12"N, 23°36'50"E) belonging to the University of Life Sciences in Lublin. The experiment was established on mixed rendzina soil with light, slightly sandy loam, in a randomized split-plot design, in 3 replicates on 24 m$^2$ plots. The experiment evaluated weed infestation of crops of common spring wheat *Triticum aestivum* L., spring durum wheat *Triticum durum* Desf., and oat *Avena sativa* L. in plots after 5-year-long reduced tillage, i.e. ploughless tillage and herbicide treatment, and after traditional plough tillage. In the plough tillage system, tillage involved shallow ploughing (harrowing) done after the harvest of the forecrop (pea) and autumn ploughing. Ploughless tillage only involved post-harvest treatment, whereas herbicide treatment was reduced to the application of Roundup 360 SL (active substance – glyphosate) – 4 l × ha$^{-1}$. In all plots, spring tillage treatments involved the use of a tillage assembly consisting of a cultivator, cage roller, and harrow. Weed control was limited to a single harrowing of crops at the tillering stage.

In the last year of the study (2011), weed infestation of spring crops was evaluated with the botanical-gravimetric method in all the plots at two growth stages – tillering (23/24 in BBCH scale) (before the harrowing of crops) and dough stage (83/85 BBCH scale) (Adamczewski and Matysiak, 2002). This method consisted in determining the species composition of weeds and their number as well as air-dry weight per 1m$^2$ of the plot. The sampling area was randomly selected (twice) using a frame of 1 m × 0.5 m in size. The determination of air-dry matter of weeds consisted in collecting all weeds from within the frame, removing their root systems, and placing the weeds in a well-aired and dry place until a constant weight was reached.

## RESULTS

Weed infestation, expressed by the number and air-dry weight of weeds per 1 m$^2$, was found to depend on the crop species, growth stage and tillage system applied. As shown in the data presented in Table 1, the number of weeds per 1 m$^2$ evaluated at the tillering stage was higher by 26.5% than at the dough stage. This was due to over 3 times higher weed infestation of oats at the tillering stage than at the dough stage. Additionally, the number of weeds per 1 m$^2$ in the oat crop at the tillering stage was almost 2 times higher than in durum wheat and 5 times higher than in spring wheat. This characteristic was different in the case of the dough stage of the crops. Over this period, the highest number of weeds was observed in durum wheat, on average 90.6 plants per 1 m$^2$, while this number was lower by 53.2 plants × m$^{-2}$ in spring wheat and by 50.7 plants × m$^{-2}$ in oat. The number of weeds in crops was also differentiated by tillage reductions. At the tillering stage, the lowest number of weeds was found in the plots where herbicide treatment was used, on average 68.0 plants per 1 m$^2$, while a higher number in the plots with ploughless tillage (by 14.1 plants × m$^{-2}$). A higher number of weeds was recorded in the ploughed plots than in the herbicide treated plots; however, this difference was not statistically confirmed. This trait was different at the dough stage of the crops, when the lowest number of weeds was recorded in the plots under plough tillage (29.9 per 1 m$^2$), whereas more than twice as many in the no-till and herbicide treated plots. When evaluating the number of weeds in the plots with spring wheat at the tillering stage, it can be observed that long-term ploughless tillage significantly reduced weed density per 1 m$^2$ in relation to plough tillage and herbicide treatment (by 14.7-18.6 plants × m$^{-2}$). Also, at the dough stage, the number of weeds in the plots with ploughless tillage was more than twice smaller in relation to herbicide treatment. When analyzing weed infestation of durum wheat at the tillering stage, a considerably higher number of weeds per 1 m$^2$ was observed in the plots cultivated using herbicide treatment than in those under plough and ploughless tillage. In the case of the dough stage of durum wheat, a higher number of weeds (by 63.7-76.0 plants × m$^{-2}$) was recorded in the plots under the conditions of long-term ploughless and herbicide treatment than in those in which plough tillage was used. In turn, herbicide treatment decreased the number of weeds in the oat crop by 42.0-79.2 plants × m$^{-2}$ in relation to plough and ploughless tillage. At the dough stage of oat, a higher number of weeds (by 31.7-44.0 plants × m$^{-2}$) was determined in the no-tillage and herbicide treated plots than under plough tillage.

Table 1.
Number of weeds per 1 $m^2$ in the spring cereal crop

| Cereal species | Growth stage in BBCH scale | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 23/24 | | | | 83/85 | | | |
| | Tillage system | | | | | | | |
| | a* | b | c | mean | a | b | c | mean |
| Spring wheat | 33.6 | 15.0 | 29.7 | 26.0 | 31.0 | 24.2 | 57.0 | 37.4 |
| Durum wheat | 68.5 | 61.5 | 83.8 | 71.3 | 44.0 | 120.0 | 107.7 | 90.6 |
| Oats | 132.5 | 169.7 | 90.5 | 130.9 | 14.7 | 46.4 | 58.7 | 39.9 |
| Mean | 78.2 | 82.1 | 68.0 | 76.1 | 29.9 | 63.5 | 74.5 | 55.9 |
| LSD (p=0.05) | | | | | | | | |
| Between cereal species | | | | 13.9 | | | | 13.1 |
| Between tillage systems | | | | 13.9 | | | | 13.2 |
| Cereal species x tillage system | | | | 17.0 | | | | 15.3 |
| Cereal species x growth stage | | | | 16.3 | | | | - |
| Between growth stages of cereal crops | | | | 15.1 | | | | - |

*a – plough tillage ; b – ploughless tillage; c – herbicide treatment

In comparing the air-dry weight of weeds in the crops it can be stated that, similarly to the number of weeds per 1 $m^2$, it was 29.1% higher at the tillering stage compared to the dough stage (Table 2). Evaluation of the air-dry weight of weeds at tillering showed that weeds in durum spring wheat and oat had a higher weight than in spring wheat (by 33.5-38.4%). At the dough stage of the crops, weeds in durum wheat showed the highest weight (51.3 g × $m^{-2}$), while it was considerably lower in oat (by 82.4%) and spring wheat (by 79.5%). When comparing the tillage systems, it can be observed that in the period of tillering a significantly higher weight was developed by weeds in the plots under the conditions of long-term herbicide treatment (76.0 g × $m^{-2}$), while it was considerably lower under the ploughless (by 85.6%) and plough (by 83%) tillage systems. Also, at the dough stage of spring wheat, the highest weight of weeds was determined in the herbicide treated plot (49.0 g × $m^{-2}$) and a significantly lower weight in the one with plough (by 86.3%) and ploughless (69.2%) tillage. At the tillering stage of spring wheat, weeds in the plots with herbicide treatment showed the highest weight, whereas weed weight was lower by 80.5-81.3% in the remaining plots. Similarly, durum wheat and oat developed a higher weight under the conditions of herbicide treatment, while it was significantly lower under ploughless and plough tillage. This difference in the durum wheat crop accounted for 87.7-88.2%, whilst in the oat crop for 79.1-85.3%. Also, at the dough stage of spring wheat, the plot with long-term herbicide treatment was found to have the highest weed weight, whereas it was lower for plough and ploughless tillage. In the durum wheat crop, the highest weed weight was also recorded in the herbicide treated plots (120 g × $m^{-2}$), a lower one (28.4 g × $m^{-2}$) under ploughless tillage, whereas the lowest one under plough tillage (5.5 g × $m^{-2}$). In the case of oat, weed weight in all the plots was similar and ranged between 7.5 and 10.0 g × $m^{-2}$. A comparison of weed weight in the crops of spring wheat and oat demonstrated that it was higher at tillering than at the dough stage, while in durum wheat, on the contrary, at the dough stage.

Table 2.
Air-dry weight of weeds in g × $m^{-2}$ in the spring cereal crop

| Cereal species | Growth stage in BBCH scale | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 23/24 | | | | 83/85 | | | |
| | Tillage system | | | | | | | |
| | a* | b | c | mean | a | b | c | mean |
| Spring wheat | 10.2 | 9.8 | 52.5 | 24.2 | 7.0 | 7.5 | 17.0 | 10.5 |
| Durum wheat | 11.7 | 11.2 | 95.1 | 39.3 | 5.5 | 28.4 | 120.0 | 51.3 |
| Oats | 16.8 | 11.8 | 80.6 | 36.4 | 7.5 | 9.5 | 10.0 | 9.0 |
| Mean | 12.9 | 10.9 | 76.0 | 33.3 | 6.7 | 15.1 | 49.0 | 23.6 |
| LSD (p=0.05) | | | | | | | | |
| Between cereal species | | | | 7.5 | | | | 6.6 |
| Between tillage systems | | | | 7.5 | | | | 6.6 |
| Cereal species x tillage system | | | | 9.8 | | | | 7.6 |
| Cereal species x growth stage | | | | 8.2 | | | | - |
| Between growth stages of cereal crops | | | | 8.8 | | | | - |

*explanations as in Table 1

The weed species composition determined in the tillering stage of spring wheat included 11 annual species and one perennial species (Table 3). This trait was also found to depend on the tillage system. A higher number of weed species (9 species) was determined in the tilled plots than in the plots with herbicide treatment (7) and ploughless tillage (6). Under plough tillage, *Amaranthus retroflexus* L. and *Veronica persica* Poir. were predominant (59.5% of the number of weeds). *Lamium amplexicaule* L. and *Chenopodium album* L. were also quite numerous. In no-tillage, *Amaranthus retroflexus* L. constituted as much as 76.6% of the weed community. In the herbicide treatment plots, *Capsella bursa-pastoris* (L.) Med. (a species that was absent under plough and ploughless tillage) as well as *Papaver rhoeas* L. and *Veronica persica* Poir. were predominant quantitatively. Additionally, *Chenopodium album* L., *Galium aparine* L., *Anagallis arvensis* L., and a perennial species *Cirsium arvense* (L.) Scop. were also recorded. The spring wheat crop at the dough stage was characterized by considerably greater weed species diversity (23 species) than at the tillering stage (12 species). Annual weeds were predominant (21 species). It should also be noted that as many as 11 species were found in the plots only at the dough stage of wheat, whereas some of these were species of high thermal requirements: *Echinochloa crus-galli* (L.) P.B., *Euphorbia helioscopia* L., and *Solanum nigrum* L. In the plough tillage treatment, the most numerous were *Avena fatua* L. and *Amaranthus retroflexus* L. Also numerous were: *Euphorbia helioscopia* L., *Erodium cicutarium* (L.) L'Herit, *Capsella bursa-pastoris* (L.) Med., and *Consolida regalis* Gray. Under ploughless tillage, the following were predominant: *Geranium pusillum* L., *Amaranthus retroflexus* L., *Fumaria officinalis* L., *Avena fatua* L., *Veronica persica* Poir. as well as *Cirsium arvense* (L.) Scop. In the herbicide treated plots, the following species were the most abundant: *Amaranthus retroflexus* L., *Lapsana communis* L., and *Veronica persica* poir, followed by: *Solanum nigrum* L., *Papaver rhoeas* L., *Lamium amplexicaule* L., *Fallopia convolvulus* (L.) A. Löve, and *Sonchus asper* (L.) Hill.

Table 3.
Species composition and number of weeds per 1 $m^2$ in the spring wheat crop

| Species composition | Growth stage in BBCH scale | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 23/24 | | | | 83/85 | | | |
| | Tillage system | | | | | | | |
| | a* | b | c | mean | a | b | c | mean |
| I. Annual weeds | | | | | | | | |
| 1. *Amaranthus retroflexus* L. | 11.0 | 11.5 | - | 7.5 | 4.5 | 5.0 | 13.0 | 7.5 |
| 2. *Veronica persica* Poir. | 9.0 | - | 6.0 | 5.0 | 1.0 | 2.0 | 8.0 | 3.7 |
| 3. *Lamium amplexicaule* L. | 5.0 | 1.0 | - | 2.0 | 1.0 | - | 2.5 | 1.1 |
| 4. *Chenopodium album* L. | 4.0 | - | 2.5 | 2.2 | - | - | 1.0 | 0.3 |
| 5. *Galium aparine* L. | 1.0 | 1.0 | 1.0 | 1.0 | - | - | - | - |
| 6. *Consolida regalis* Gray | 1.0 | - | - | 0.3 | 1.5 | - | - | 0.5 |
| 7. *Fallopia convolvulus* (L.) A. Löve | 1.0 | - | - | 0.3 | - | - | 2.0 | 0.7 |
| 8. *Anagallis arvensis* L. | 0.8 | 0.8 | 1.0 | 0,9 | - | 1.0 | 1.0 | 0.7 |
| 9. *Avena fatua* L. | 0.8 | 0.5 | - | 0.4 | 13.0 | 2.0 | - | 5.0 |
| 10. *Capsella bursa-pastoris* (L.) Med. | - | - | 13.0 | 4.3 | 2.0 | - | - | 0.7 |
| 11. *Papaver rhoeas* L. | - | - | 6.0 | 2.0 | - | 1.0 | 3.0 | 1.3 |
| 12. *Echinochloa crus-galli* (L.)P.B. | - | - | - | - | 1.0 | - | - | 0.3 |
| 13. *Erodium cicutarium* (L.) L'Herit | - | - | - | - | 2.0 | - | - | 0.7 |
| 14. *Euphorbia helioscopia* L. | - | - | - | - | 3.0 | - | 0.2 | 1.1 |
| 15. *Fumaria officinalis* L. | - | - | - | - | 1.0 | 3.0 | 2.0 | 2.0 |
| 16. *Geranium pusillum* L. | - | - | - | - | 1.0 | 7.0 | - | 2.7 |
| 17. *Lapsana communis* L. | - | - | - | - | - | 1.0 | 12.5 | 4.5 |
| 18. *Solanum nigrum* L. | - | - | - | - | - | 1.0 | 4.0 | 1.7 |
| 19. *Sonchus asper* (L.)Hill | - | - | - | - | - | - | 2.0 | 0.7 |
| 20. *Stellaria media* (L.) Vill | - | - | - | - | - | - | 1.0 | 0.3 |
| 21. *Matricaria inodora* L. | - | - | - | - | - | - | 1.0 | 0.3 |
| 22. *Viola arvensis* Murr. | - | - | - | - | - | - | 0.8 | 0.2 |
| Number of annual weeds (I) | 33.6 | 14.8 | 29.5 | 25.9 | 31.0 | 23.0 | 54.0 | 36.0 |
| II. Perennial weeds | | | | | | | | |
| 1. *Cirsium arvense* (L.) Scop. | - | 0.2 | 0.2 | 0.1 | - | 1.2 | 2.0 | 1.1 |
| 2. *Taraxacum officinale* Web. | - | - | - | - | - | - | 1.0 | 0.3 |
| Number of perennial weeds (II) | - | 0.2 | 0.2 | 0.1 | - | 1.2 | 3.0 | 1.4 |
| Total I + II | 33.6 | 15.0 | 29.7 | 26.0 | 31.0 | 24.2 | 57.0 | 37.4 |
| Number of species | 9 | 6 | 7 | 12 | 11 | 10 | 17 | 23 |

*explanations as in Table 1

At the tillering stage, the durum wheat crop was found to be colonized by 14 weed species, 13 of which were annual weeds (Table 4). In comparing the tillage systems, a higher number of weed species was observed in the herbicide treated plots (10 species) than in the plough (7) and ploughless (8) tillage systems. Under plough tillage, *Amaranthus retroflexus* L. was predominant and it constituted 53.4% of the total number of weeds. Also numerous were *Melandrium album* (Mill.) Garcke, *Veronica persica* Poir., and *Chenopodium album* L. Additionally, a perennial species of *Cirsium arvense* (L.) Scop. was recorded. *Amaranthus retroflexus* was also the most numerous under ploughless tillage (63.4% of the total number of weeds). Numerous were also *Chenopodium album* L., *Melandrium album* (Mill.) Garcke, *Veronica persica* Poir., and *Galium aparine* L. In the herbicide treated plots, the following weed species were predominant: *Capsella bursa-pastoris* (L.) Med. (37% of the total number of weeds), *Amaranthus retroflexus* L., *Chenopodium album* L., and *Galium aparine* L. At the dough stage, 16 species, including 2 perennials: *Echium vulgare* L. and *Bryonia alba* L., were recorded in the durum wheat crop. Additionally, a higher number of species was found in the herbicide treated plots (14 species) than in those with ploughless (8) and plough (7) tillage systems. Also at this growth stage of durum wheat, 7 species were recorded that had not been found at the tillering stage. In the plough tillage treatment, the most numerous were *Veronica persica* Poir. and *Amaranthus retroflexus* L. which accounted for as much as 68.2% of the total number of weeds. Also quite numerous were *Echinochloa crus-galli* (L.) P.B. and *Anagallis arvensis* L. Under ploughless tillage, the most abundant were *Echionochloa crus-galli* (L.) P.B., and *Amaranthus retroflexus* L. (76.7% of the number of weeds). Also numerous were the following: *Solanum nigrum* L.*,* *Galium aparine* L. and *Papaver rhoeas* L. In the herbicide treatment, *Echinochloa crus-galli* (L.) P.B. and *Amaranthus retroflexus* L. were predominant (64.1% of the total number of weeds). *Matricaria indora* L., *Solanum nigrum* L., and *Papaver rhoeas* L. were also numerous. Perennial species were represented by *Bryonia alba* L.

Table 4.
Species composition and number of weeds per 1 m$^2$ in the durum wheat crop

| Species composition | Growth stage in BBCH scale | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 23/24 | | | | 83/85 | | | |
| | Tillage system | | | | | | | |
| | a* | b | c | mean | a | b | c | mean |
| I. Annual weeds | | | | | | | | |
| 1. *Amaranthus retroflexus* L. | 35.0 | 39.0 | 19.0 | 31.0 | 10.0 | 41.0 | 31.0 | 27.3 |
| 2. *Melandrium album* (Mill.) Garcke | 8.0 | 3.0 | 1.0 | 4.0 | - | - | - | - |
| 3. *Veronica persica* Poir. | 8.0 | 3.0 | - | 3.7 | 20.0 | 1.0 | 2.0 | 7.7 |
| 4. *Chenopodium album* L. | 6.5 | 8.0 | 10.0 | 8.2 | - | - | - | - |
| 5. *Lamium amplexicaule* L. | 5.0 | 2.0 | 5.0 | 4.0 | - | - | - | - |
| 6. *Fallopia convolvulus* (L.)A. Löve | 3.0 | 2.5 | - | 1.8 | - | - | - | - |
| 7. *Gallium aparine* L. | - | 3.0 | 6.0 | 3.0 | - | 7.0 | 4.0 | 3.7 |
| 8. *Polygonum aviculare* L. | - | 1.0 | - | 0.3 | - | 1.0 | - | 0.3 |
| 9. *Capsella bursa-pastoris* (L.)Med. | - | - | 31.0 | 10.3 | - | - | - | - |
| 10. *Matricaria inodora* L. | - | - | 5.0 | 1.7 | - | - | 9.0 | 3.0 |
| 11. *Echinochloa crus-galli* (L.) P.B. | - | - | 3.0 | 1.0 | 8.0 | 51.0 | 38.0 | 32.4 |
| 12. *Erodium cicutarium* (L.) L'Herit | - | - | 3.0 | 1.0 | - | - | - | - |
| 13. *Papaver rhoeas* L. | - | - | 0.8 | 0.3 | - | 5.0 | 5.5 | 3.5 |
| 14. *Anagallis arvensis* L. | - | - | - | - | 3.0 | - | 1.0 | 1.3 |
| 15. *Stellaria media* (L.) Vill. | - | - | - | - | 1.0 | - | 3.0 | 1.3 |
| 16. *Viola arvensis* Murr. | - | - | - | - | 1.0 | - | 2.0 | 1.0 |
| 17. *Avena fatua* L. | - | - | - | - | 1.0 | - | 2.0 | 1.0 |
| 18. *Solanum nigrum* L. | - | - | - | - | - | 12.0 | 6.0 | 6.0 |
| 19. *Erigeron canadensis* L. | - | - | - | - | - | - | 2.0 | 0.7 |
| 20. *Apera spica-venti* (L.) P.B. | - | - | - | - | - | - | 1.0 | 0.3 |
| Number of annual weeds (I) | 65.5 | 61.5 | 83.8 | 70.3 | 44.0 | 118.0 | 106.5 | 89.4 |
| II. Perennial weeds | | | | | | | | |
| 1. *Cirsium arvense* (L.) Scop. | 3.0 | - | - | 1.0 | - | - | - | - |
| 2. *Echium vulgare* L. | - | - | - | - | - | 2.0 | - | 0.7 |
| 3. *Bryonia alba* L. | - | - | - | - | - | - | 1.2 | 0.4 |
| Number of perennial weeds (II) | 3.0 | - | - | 1.0 | - | 2.0 | 1.2 | 1.1 |
| Total I + II | 68.5 | 61.5 | 83.8 | 71.3 | 44.0 | 120.0 | 107.7 | 90.6 |
| Number of species | 7 | 8 | 10 | 14 | 7 | 8 | 14 | 16 |

*explanations as in Table 1

The oat crop at the tillering stage was colonized by 14 annual weed species and 1 perennial species (Table 5). A higher number of species was found in the herbicide treated plots (11 species) and a lower one in the ploughless (9) and plough (7) tillage systems. Under plough tillage, two species – *Amaranthus retroflexus* L. and *Veronica persica* Poir. – had the highest proportion in the number of weeds (94.3%). In the no-tillage plots, *Amaranthus retroflexus* L. and *Chenopodium album* L. were also predominant (73% of the number of weeds). Numerous were also *Veronica persica* Poir., *Capsella bursa-pastoris* (L.) Med. and *Echinochloa crus-galli* (L.) P.B. As a result of herbicide treatment, *Capsella bursa-pastoris* (L.) Med. and *Matricaria indora* L. were quantitatively predominant (48.6% of the number of weeds). Also numerous were: *Amaranthus retroflexus* L., *Chenopodium album* L., and *Stellaria media* (L.) Vill. At the dough stage, the oat crop was colonized by 15 weed species (14 annual ones). The lowest number of species was found under plough tillage (3 species), whereas a higher number in the no-till plots (8) and in the herbicide treated plots (10). In the plough tillage treatment, the following were predominant: *Capsella bursa-pastrois* (L.) Med., *Papaver rhoeas* L., and *Sonchus asper* (L.) Hill. Under ploughless tillage, *Capsella bursa-pastoris* (L.) Med. (56% of the total number of weeds) as well as *Lamium amplexicaule* L., *Papaver rhoeas* L., *Sonchus oleraceus* L., and *Sonchus asper* (L.) Hill. were predominant. Herbicide treatment resulted in the emergence of *Galium aparine* L., *Lamium amplexicaule* L., and *Veronica persica* Poir. (69% of the total number of weeds).

Table 5.
Species composition and number of weeds per 1 m$^2$ in the oat crop

| Species composition | Growth stage in BBCH scale | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 23/24 | | | | 83/85 | | | |
| | Tillage system | | | | | | | |
| | a* | b | c | mean | a | b | c | mean |
| I. Annual weeds | | | | | | | | |
| 1. *Amaranthus retroflexus* L. | 72.0 | 88.0 | 12.0 | 57.3 | - | - | - | - |
| 2. *Veronica persica* Poir | 53.0 | 13.0 | 5.0 | 23.7 | - | - | 11.0 | 3.7 |
| 3. *Galium aparine* L. | 3.0 | 4.5 | - | 2.5 | - | - | 17.5 | 5.8 |
| 4. *Capsella bursa-pastoris* (L.)Med. | 1.5 | 12.0 | 28.0 | 13.8 | 9.5 | 26.0 | - | 11.8 |
| 5. *Lamium amplexicaule* L. | 1.0 | 3.2 | 2.0 | 2.1 | - | 4.2 | 12.0 | 5.4 |
| 6. *Melandrium album* (Mill.) Garcke | 1.0 | - | - | 0.3 | - | - | - | - |
| 7. *Matricaria inodora* L. | 1.0 | - | 16.0 | 5.7 | - | - | - | - |
| 8. *Chenopodium album* L. | - | 36.0 | 7.0 | 14.3 | - | - | 1.0 | 0.3 |
| 9. *Echinochloa crus-galli* (L.)P.B. | - | 11.0 | 3.0 | 4.7 | - | - | - | - |
| 10. *Sonchus oleraceus* L. | - | 1.8 | - | 0.6 | - | 4.0 | 1.0 | 1.7 |
| 11. *Stellaria media* (L.) Vill. | - | - | 7.0 | 2.3 | - | 2.0 | - | 0.7 |
| 12. *Papaver rhoeas* L. | - | - | 4.5 | 1.5 | 4.0 | 4.2 | - | 2.7 |
| 13. *Sinapis arvensis* L. | - | - | 4.0 | 1.3 | - | 1.0 | - | 0.3 |
| 14. *Viola arvensis* Murr. | - | - | 2.0 | 0.7 | - | - | 2.5 | 0.8 |
| 15. *Sonchus asper* (L.) Hill. | - | - | - | - | 1.2 | 4.0 | 4.2 | 3.2 |
| 16. *Apera spica-venti* (L.) P.B. | - | - | - | - | - | - | 6.0 | 2.0 |
| 17. *Avena fatua* L. | - | - | - | - | - | - | 2.0 | 0.7 |
| 18. *Lapsana communis* L. | - | - | - | - | - | - | 1.5 | 0.5 |
| Number of annual weeds (I) | 132.5 | 169.5 | 90.5 | 130.8 | 14.7 | 45.4 | 58.7 | 39.6 |
| II. Perennial weeds | | | | | | | | |
| 1. *Cirsium arvense* (L.) Scop. | - | 0.2 | - | 0.1 | - | 1.0 | - | 0.3 |
| Number of perennial weeds (II) | - | 0.2 | - | 0.1 | - | 1.0 | - | 0.3 |
| Total I + II | 132.5 | 169.7 | 90.5 | 130.9 | 14.7 | 46.4 | 58.7 | 39.9 |
| Number of species | 7 | 9 | 11 | 15 | 3 | 8 | 10 | 15 |

*explanations as in Table 1

## DISCUSSION

Weed infestation of spring crops expressed by the number of weeds and their air-dry weight was considerably higher at the tillering stage than at the dough stage. This was mainly due to a higher level of weed infestation of the oat crop compared to the spring wheat and durum wheat crops. A significantly high number of weeds in oat was recorded in the plots under several--year-long ploughless (169.7 plants × m$^{-2}$) and plough (132.5 plants per 1 m$^2$) tillage. In the herbicide treated plots, weed infestation was considerably lower. This probably results from the fact that post-harvest treatment applied in these plots involved only the use of herbicides (Roundup 360 SL), whereas in the other plots a plough and a harrow (plough tillage) or a cultivator (ploughless tillage) were used. As Weber and Hryńczuk (2005) state these tools destroy emerging weeds but, at the same time, they facilitate the sprouting of seeds extracted from lower layers of the soil. According to Wrzesińska et al. (2003) and Dzienia and Dojss (1999), ploughless tillage results in the majority of weed seeds being found in topsoil, whereas herbicides in the direct drilling system effectively decrease the number of weeds in the soil. The harrowing of crops (after the evaluation of weed infestation) and the competitiveness of oat against weeds contributed to a considerable reduction in the number and weight of weeds at the dough stage. In comparing weed weight, it can be stated that in both periods of evaluation it was higher on the herbicide treated plot than in the plots using the plough and ploughless systems. Additionally, at the dough stage, the highest weight was developed by weeds in the durum wheat crop, which was due to poorer crop content in relation to spring wheat and oat, and thus to lower competitiveness against weeds.

Long-term reduced tillage systems also affected the biodiversity of weeds. In the compared crops and tillage systems, short-lived weed species were predominant. According to the opinion of many authors, long-term tillage reductions resulted in an increased number of perennial weeds (Buhler et al. 1994; Dzienia and Dojss, 1999). As claimed by Weber and Hryńczuk (2005), reduced tillage resulted in a greater diversity of the weed species composition than traditional (plough) tillage and direct drilling. In the present study, weeds in the crops were characterized by greater biodiversity at the dough stage than at the tillering stage. Also, a higher number of weed species was found in the plots with long-term herbicide treatment than in those in which the plough and ploughless systems were used.

## CONCLUSIONS

1. Weeds were found to have a higher number and higher air-dry weight per 1 $m^2$ at the tillering stage of the crops than at the dough stage.
2. At the tillering stage, the highest number of weeds and air-dry weight of weeds per $m^2$ were observed in oat, while at the dough stage – in durum wheat.
3. Long-term tillage reductions resulted in an increased number of weeds and higher air-dry weight of weeds per 1 $m^2$ in spring cereal crops in relation to plough tillage.
4. The weed community in the crops was characterized by greater biodiversity at the dough stage than in the tillering phase. Additionally, a higher number of weed species was recorded after long-term herbicide treatment than under the plough and ploughless systems.

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## Następczy wpływ wieloletnich uproszczeń w uprawie roli na bioróżnorodność chwastów w zbożach jarych

### Streszczenie

Ścisłe doświadczenie polowe z tradycyjną uprawą roli, uproszczoną i herbicydową prowadzono w latach 2007-2011 w Gospodarstwie Doświadczalnym Uhrusk. W ostatnim roku badań we wszystkich obiektach doświadczenia określono wpływ zróżnicowanej uprawy roli na stan zachwaszczenia i bioróżnorodność chwastów w łanie pszenicy zwyczajnej jarej *Triticum aestivum* L., pszenicy twardej jarej *Triticum durum* Desf., i owsa siewnego *Avena sativa* L. w dwóch fazach rozwojowych: krzewienia (23/24 w skali BBCH) i dojrzałości woskowej (83/85). Wykazano większą liczbę i powietrznie suchą masę chwastów w fazie krzewienia zbóż niż w fazie dojrzałości woskowej. Wieloletnia bezorkowa uprawa roli zwiększała w fazie krzewienia zbóż liczbę chwastów na 1 m$^2$ w stosunku do uprawy herbicydowej. W fazie dojrzałości woskowej więcej chwastów wystąpiło w stanowisku po uprawie herbicydowej i bezorkowej niż płużnej. Powietrznie sucha masa chwastów w fazie krzewienia i dojrzałości woskowej zbóż była istotnie większa w warunkach uprawy herbicydowej niż płużnej i bezorkowej. Zbiorowisko chwastów w pszenicy jarej, pszenicy twardej i owsie siewnym stanowiły głównie chwasty krótkotrwałe. Więcej gatunków chwastów stwierdzono na stanowisku po wieloletniej uprawie herbicydowej niż płużnej i bezorkowej.