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Effect of tillage systems on weed infestation of durum wheat

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Abstract

Weed infestation of durum wheat was determined in the systems of conventional tillage (CT), reduced tillage (RT) and herbicide tillage (HT). Cultivations measures performed after the harvest of the previous crop included shallow ploughing (at a depth of 10-12 cm) and pre-winter ploughing (25-30 cm) in the CT system; only field cultivation (10-15 cm) in the RT system; and spraying with glyphosate (Roundup 360 SL) in the HT system. In the springtime, a tillage set consisting of a cultivator, a string roller and a harrow (10-12 cm) was applied on all plots. It was demonstrated that wheat cultivation in the RT and HT systems was increasing the number and weight of weeds, compared to the CT system. The highest number of weeds occurred at the middle level of wheat crop, whereas the highest air-dry weight was produced by the weeds at the upper and middle crop levels. In the HT system, weed community was constituted exclusively by short-term species, whereas in CT and RT systems – by short-term and perennial species.

Keywords: Weed infestation indices; Level distribution of weeds; Tillage systems.

Introduction

The system of tillage has a substantial effect upon weed infestation of crops (Tuesca et al., 2001; Lahmar, 2010; Hernández Plaza et al., 2011; Woźniak et al., 2015). Investigations conducted by Davis et al. (2005), Mohler et al. (2006) as well as Pekrun and Claupein (2006) demonstrate that the no-tillage system may increase the percentage of weeds maturing on the stubble-field, which by fallowing down increase the seed bank in soil (Cardina et al., 2002; Chauhan et al., 2006; Nichols et al., 2015). As reported by Woźniak (2007), almost 30% of the weed seed bank occurs on soil surface from where – under favorable conditions – the seeds germinate and thereby infest the crops. In turn, a small contribution of perennial weeds in the infestation of arable fields results from the standard application of glyphosate after the harvest of cereals, especially in the system of direct sowing (Puricelli and Tuesca, 2005; Johal and Huber, 2009). In contrast, no use of glyphosate in the no-tillage system leads to an increased number of perennial weeds, particularly *Cirsium arvense, Elymus repens* and *Convolvulus arvensis* (Woźniak and Soroka, 2015a).

The tillage system should be consistent with habitat and technical conditions of a farm (Gruber et al., 2012). Studies conducted by Morris et al. (2010) and Woźniak et al. (2015) show that in the areas with moderate precipitation better production effects are achieved by using the conventional tillage, whereas in the areas with low sums of precipitation – by applying the no-tillage system (López-Bellido et al., 1996). Investigations carried out by De Vita et al. (2007) proved that in the areas with precipitation below 300 mm in the vegetative season, better production effects were obtained from direct sowing, whereas in these with precipitation over 300 mm – by applying the conventional tillage system. It is due to lesser water evaporation from soil and to its greater availability for plants than in the conventional system. As reported by Farooq et al. (2011), the best solutions in such conditions include conservative tillage and crop rotation.

This study was aimed at evaluating weed infestation of durum wheat crop in the conventional, reduced and herbicide tillage systems.

Materials and Methods

A strict field experiment was established in 2007 at the Experimental Station Uhrusk (51°18'10" N, 23°36'44" E), but results presented in this manuscript originate from the years 2013-2015. The experiment was established on soil classified by the IUSS Working Group WRB (2015) as Rendzic Phaeozem. In terms of fraction composition, the soil contained 24.3% of silty fraction and 13.2% of dust fraction. It had an alkaline pH value (pH_{KCL}=7.20) and a high content of the available forms of phosphorus (130.1 mg P kg^{-1} d.m.) and potassium (318.5 mg K kg^{-1} d.m.). The content of total nitrogen in the soil was at 1.00 g N kg^{-1} d.m., that of nitrogen in the saltpetre form ($N\text{-}NO_3$) at 31.0 mg kg^{-1} d.m. and that of ammonia nitrogen ($N\text{-}NH_4$) at 1.19 mg kg^{-1} d.m. The content of organic C in the soil reached 6.40 g kg^{-1} d.m. On the study area, the annual sum of precipitation accounted for over 620 mm, whereas average air temperature for 8.2 °C. Since sowing till harvest (since March to August), the average sum of precipitation reached 390 mm, whereas average air temperature was at 13.2 °C (according to the Meteorological Station at the Experimental Station Uhrusk).

Weed infestation was evaluated in crops of durum wheat (*Triticum durum* Desf.) sown in three tillage systems: 1) conventional (CT), 2) reduced (RT) and 3) herbicide (HT). The experiment was established in three replications in the system of randomized blocks (8 m × 75 m). After the harvest of the previous crop (ie. peas), shallow ploughing (at a depth of 10-12 cm), harrowing and pre-winter ploughing (25-30 cm) were performed in the CT system. In the RT system, ploughing was replaced by double cultivation (10-15 cm), whereas in the HT system the only cultivation measure included application of glyphosate (Roundup 360 SL in a dose of 4 L ha^{-1}). In the springtime, a tillage set consisting of a cultivator, a string roller and a harrow (10-12 cm) was applied on all plots.

Durum wheat variety Duromax, classified in the Common Catalogue of Varieties of Agricultural Plant Species (European Union, 2012), was sown in each year of the study between the 1^{st} and the 10^{th} of April in the amount of 500 seeds m^{-2}. Fertilization with phosphorus (34 kg ha^{-1} P) and potassium (83 kg ha^{-1} K) was applied in the spring before wheat sowing. Fertilization with nitrogen (120 kg ha^{-1} N) was applied in the following terms: 1) before sowing – 50 kg ha^{-1}; 2) at the tillering stage (23-24 in BBCH scale) (Lancashire et al., 1991) – 30 kg ha^{-1}; 3) at the shooting stage (34-35 BBCH) – 20 kg ha^{-1}; and 4) at the ear formation stage (52-53 BBCH) – 20 kg ha^{-1}.

Wheat crops were protected against fungal diseases using: 1) flusilazole + carbendazim (Alert 375 SC) 1.0 L ha^{-1} (32-33 BBCH) and 2) propiconazol + fenpropidin (Tilt Plus 400 EC) 1.0 L ha^{-1} (53-54 BBCH). In turn, mecoprop + MCPA + dicamba (Chwastox Trio 540 SL) 1.5 L ha^{-1} (23-24 BBCH) was applied for after-sprouting weed control.

Weed infestation was evaluated with the botanical-gravimetric method at the waxy maturity stage of wheat (83-85 BBCH). This method consists in determining the number of weeds m^{-2}, air-dry weight produced by weeds and species composition of weeds. These determinations were conducted twice at each plot using a frame (1 m × 0.5 m). The collected weeds were divided in terms of their height: 1) weeds of the upper level – higher than durum wheat; 2) weeds of the middle level – reaching the full height of wheat; 3) weeds of the low level – reaching half the full height of wheat; 4) weeds of the ground level – reaching ten or so cm in height. Thus prepared samples were placed on openwork shelves in a ventilated and dry room until complete drying. In addition, the following indices were determined in the study: 1) Shannon–Wiener diversity index (*H'*) and 2) Simpson dominance index (*c*) according to the formulas:

1) $H' = -\Sigma\ (\frac{ni}{N})\ \log\ (\frac{ni}{N})$; 2) $c = \Sigma\ (\frac{ni}{N})^2$, where: *ni* – number of each species, *N* – total number of all species.

Study results were subjected to the statistical analysis using the analysis of variance (ANOVA) and the significance of differences was evaluated with the Tukey's HSD test, $P<0.05$.

Results and Discussion

Weed infestation of durum wheat was significantly affected by tillage systems. More weeds per m^{-2} and a higher air-dry weight of weeds were determined in the RT and HT systems than in the CT system (Table 1). Also other studies (Gruber et al., 2012; Santín-Montanyá et al., 2013; Woźniak et al., 2015) demonstrated greater weed infestation of crops in the no-tillage than in the conventional tillage system. In contrast, as reported by Mas and Verdu (2003), weed infestation was to little extent influenced by tillage system, but most of all by the year of the study and type of crop. In our experiment, high variability was observed in the number of weeds (from 61.7% to 108%) and in their weight (72.2% to 96.4%) in all tillage systems, which undoubtedly resulted from the various course of hydrothermal conditions in the analyzed years of the study. Also for this reason, only average values of these parameters were considered in this work because results of the statistical analysis for particular years of the experiment would be burdened with a high error. The tillage systems affected the number of weed species at particular plots. A significantly higher number of weed species occurred on RT than on HT plots. As reported by Puricelli and Tuesca (2005) and by Chikowo et al. (2009), it is due to a higher number of treatments with glyphosate and other herbicides applied in the no-tillage system than in the conventional one, as well as to the lack of weed diaspores drawn out onto soil surface by cultivating equipment (Chauhan et al., 2006). Other investigations demonstrated that the extent of weed infestation was also affected by plant succession in the crop rotation (Eyrea et al., 2011; Woźniak and Soroka, 2015b). As shown by Woźniak et al. (2015), a similar system of tillage after different previous-crops may either increase or decrease weed infestation. The tillage system influenced also values of Shannon–Wiener diversity index and Simpson dominance index (Table 1). The RT and HT plots were characterized by greater diversity of weed species and no predominance of any of the species, compared to the CT plots. It is due to a high contribution of species spreading with wind, especially these of the upper and the middle level (Table 2). In the compared tillage systems, the highest number of weeds was determined at the middle level of wheat crop, whereas the greatest weight was produced by weeds of the upper and the middle level.

Table 1. Indices of weed infestation of durum wheat crop in various tillage systems (average of the years 2013-2015).

Weed infestation indices	Tillage system		
	CT[a]	RT[b]	HT[c]
Number of weeds m^{-2}	45.3 [a*]	60.9 [b]	64.0 [b]
Coefficient of variation (CV%)	64.5	61.7	108.0
Air-dry weight of weeds g m^{-2}	34.7 [a]	46.0 [b]	49.8 [b]
Coefficient of variation (CV%)	72.2	81.4	96.4
Number of weed species	23 [ab]	27 [b]	21 [a]
Coefficient of variation (CV%)	13.0	14.8	14.3
Shannon–Wiener diversity index	0.47	0.57	0.57
Simpson dominance index	0.00	0.01	0.01

[a] Conventional tillage; [b] Reduced tillage; [c] Herbicide tillage.
[*] mean values in rows denoted with the same letters do not differ significantly, $P<0.05$.

Table 2. Level distribution of weeds in durum wheat crop in various tillage systems (average of the years 2013-2015).

Tillage systems	Crop level			
	UL[a]	ML[b]	LL[c]	GL[d]
	Number of weeds m^{-2}			
Conventional tillage	6.8 [e*]	22.2 [f]	6.3 [e]	10.0 [e]
Reduced tillage	14.3 [f]	26.5 [g]	2.8 [e]	17.3 [f]
Herbicide tillage	11.4 [f]	43.5 [g]	1.0 [e]	8.1 [f]
	Air-dry weight of weeds g m^{-2}			
Conventional tillage	12.5 [f]	15.3 [f]	2.3 [e]	4.6 [e]
Reduced tillage	22.0 [f]	6.9 [e]	2.0 [e]	5.1 [e]
Herbicide tillage	19.4 [f]	25.7 [f]	1.5 [e]	3.2 [e]
	Number of weed species			
Conventional tillage	4 [a]	9 [b]	6 [ab]	4 [a]
Reduced tillage	6 [a]	11 [b]	6 [a]	4 [a]
Herbicide tillage	3 [a]	10 [b]	4 [a]	4 [a]

[a] Upper level; [b] Middle level; [c] Lower level; [d] Ground level.
[*] mean values in rows denoted with the same letters do not differ significantly, $P<0.05$.

In the three-year study period, analyses revealed the presence of 29 weed species (Figures 1-4). Out of these, 16 species occurred on all plots. The highest number of species were representatives of the syntaxonomic class *Stellarietea mediae*, whereas the most numerous species included: *Stellaria media* (L.) Vill., *Consolida regalis* Gray, *Papaver rhoeas* L., *Avena fatua* L., *Apera spica-venti* (L.) P.B., *Anthemis arvensis* L., *Anagallis arvensis* L., *Galinsoga parviflora* Cav., *Capsella bursa-pastoris* (L.) Medicus and *Veronica persica* Poiret. In a study conducted by Woźniak and Soroka (2015b), 6 syntaxonomic classes were distinguished in cereals and the highest number of species belonged to the class *Stellarietea mediae* with the association *Apero spica-venti Papaveretum rhoeadis* typical of cereals and with species characteristic for root plants, mainly these of the order *Polygono-Chenopodietalia*.

Interesting seems to be the level distribution of weeds in wheat crops. In the CT and RT systems, mainly *A. fatua* and *P. rhoeas*, whereas in the HT system mainly *A. spica-venti* and *P. rhoeas* occurred at the upper level (Figure 1).

At the middle level of wheat grown in the CT system, the most abundant were *C. regalis*, *Fallopia convolvulus* (L.) A. Löve and *Amaranthus retroflexus* L.; in RT – *Chenopodium album* L., *Echinochloa crus galli* (L.) Beauv. and *A. retroflexus*, whereas in HT – *F. convolvulus*, *A. arvensis* and *E. crus-galli* (Figure 2).

Species of the lower level included: *G. parviflora* and *C. bursa-pastoris* in the CT system; *Viola arvensis* Murray and *C. bursa-pastoris* in the RT system; as well as *C. bursa-pastoris* and *Lamium purpureum* L. in the HT system (Figure 3).

In turn, the most frequent species of the ground level included *S. media* and *Poa annua* L. in the CT and RT systems, as well as *V. persica, S. media* and *A. arvensis* in the HT system (Figure 4). The level distribution of weeds in a cereal crop determines the mode of their spreading and infesting the successive crops. Generally, it may be conluded that seeds of the weeds of the upper level spread with wind or during harvest, seeds of the weeds of the middle level are collected with the cereal crop during harvest or fall down before the harvest; whereas seeds of the weeds of the lower and ground levels mature on the stubble-filed, thereby increasing the seed bank in the soil.

In the HT system, weed community included exclusively the short-term species, whereas in the CT and RT systems it included both short-term and perennial weeds (*Convolvulus arvensis* L., *Sonchus arvensis* L., *Cirsium arvense* (L.) Scop. and *Elymus repens* (L.) Gould). As reported by Woźniak and Soroka (2015b), the presence of weeds typical of the root crops results from the application of manure. In turn, the lack of perennial weeds on HT plots is due to the use of glyphosate (Puricelli and Tuesca, 2005).

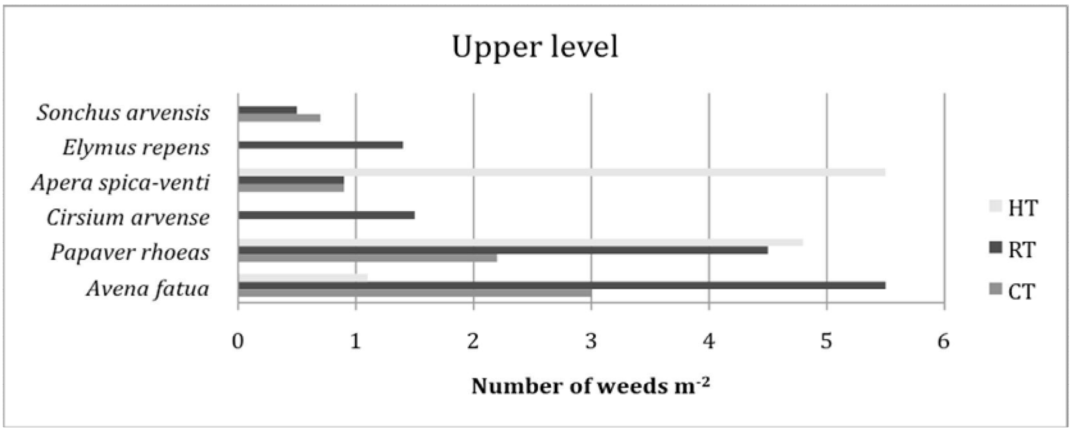

Figure 1. Species composition and the number of weed species present at the upper level of durum wheat crop; CT – Conventional tillage, RT – Reduced tillage, HT – Herbicide tillage (average of the years 2013-2015).

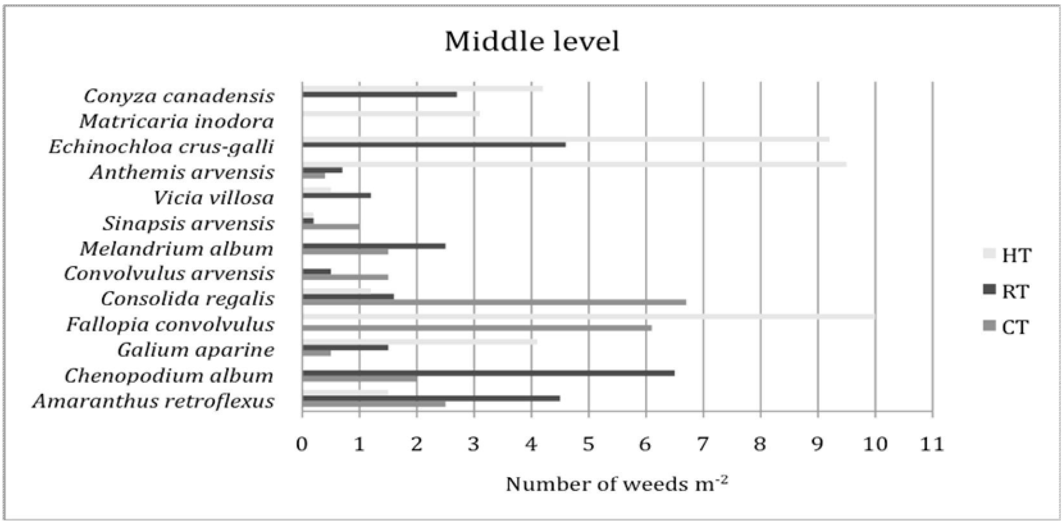

Figure 2. Species composition and the number of weed species present at the middle level of durum wheat crop; CT – Conventional tillage, RT – Reduced tillage, HT – Herbicide tillage (average of the years 2013-2015).

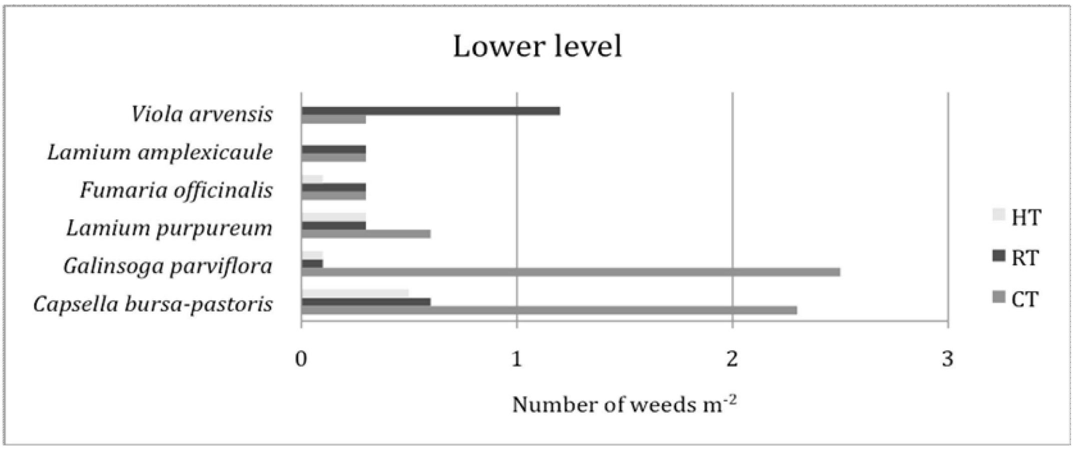

Figure 3. Species composition and the number of weed species present at the lower level of durum wheat crop; CT – Conventional tillage, RT – Reduced tillage, HT – Herbicide tillage (average of the years 2013-2015).

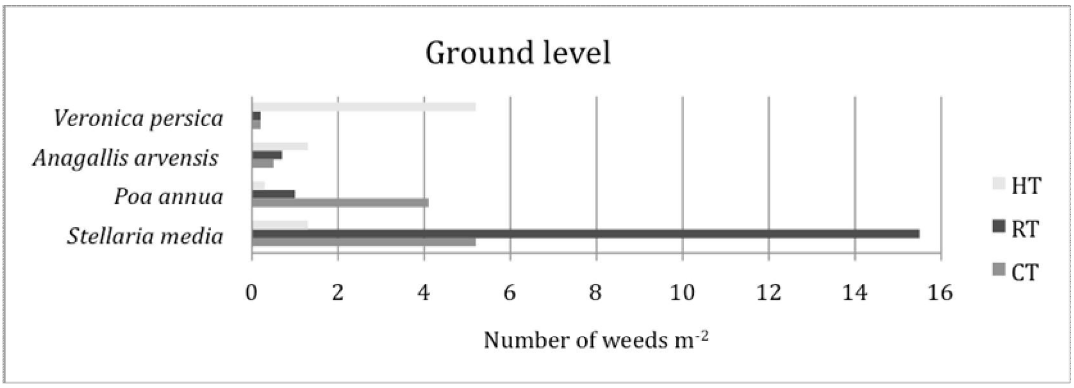

Figure 4. Species composition and the number of weed species present at the ground level of durum wheat crop; CT – Conventional tillage, RT – Reduced tillage, HT – Herbicide tillage (average of the years 2013-2015).

Conclusions

Durum wheat cultivation in the RT and HT systems caused an increase in both the number and weight of weeds compared to the CT system. The highest number of weeds was found at the middle level of wheat crop, whereas the highest air-dry weight was produced by weeds of the upper and the middle level. In the HT system, weed community included only short-term species – typical of cereals, whereas in the CT and RT systems it included both short-term and perennial species (*C. arvensis*, *C. arvense*, *E. repens, S. arvensis*).

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