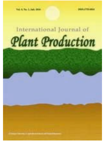

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Effects of a 3-year reduced tillage on the yield and quality of grain and weed infestation of spring triticale (*Triticosecale* Wittmack)

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Abstract

This study was aimed at analyzing the yield, grain quality and weed infestation of spring triticale sown in 3 tillage systems: a) conventional tillage (CT)-shallow ploughing and harrowing after harvest of the previous crop, ploughing in the autumn; b) reduced tillage (RT)-only cultivator after harvest of the previous crop, and c) no-tillage (NT)-only glyphosate (360 g L^{-1}) after harvest of the previous crop. Depth of tillage varied according to intended purpose with shallow ploughing at a depth of 10-12 cm, autumn ploughing at a depth of 25-30 cm and cultivator tillage at a depth of 10-15 cm. The yield of spring triticale of 'Legalo' cultivar sown in the CT was higher than grain yields from RT and NT systems. The lower productivity of triticale in the NT and RT systems, compared to the CT system, resulted from a reduced number of spikes as well as a lower weight and number of grains from spike. Grain of triticale harvested from CT plots was characterized by a higher content of starch and by lower contents of protein and crude fiber than the grain from the RT and NT systems. The RT and NT systems significantly increased the number and air-dry weight of weeds in triticale crop, compared to the CT system.

Keywords: Spring triticale; Grain quality; Grain yield; Weeds; Tillage systems.

Introduction

The necessity of reducing energy expenditures incurred on crop cultivation as well as the need for soil protection against degradation have contributed to the search for unconventional solutions in tillage systems (Lahmar, 2010; Morris et al., 2010). However, not all of these solutions are optimal and opinions on them are varied or even conflicting. The study by Gruber et al. (2012) demonstrated that each tillage system oughts to be adjusted to specific conditions of an individual farm. As reported by Morris et al. (2010), the cultivation aims at providing optimal growth conditions to plants, however solutions used in practice not always meet these expectations. According to Jones et al. (2006) and Knight (2004), crop yield in conventional and no-till systems depends on multiple factors that influence one another and are hardly predictable. Generally, however, lower yields are achieved in the no-till system than in the conventional one. As reported by Davis et al. (2005), Peigné et al. (2007) and Woźniak (2012) the ploughless tillage increases weed infestation and, consequently, contributes to yield decrease. According to Tørresen and Skuterud (2002), the no-till system increases the bank of diaspores in the topsoil, from where they germinate and thus increase infestation of the after-crop (Cardina, 2002; Chauhan et al., 2006; Mohler et al., 2006). Thompson and Grime (1983) report that seeds covered with mulch have lesser chance to sprout than these from the topsoil. This may be due to temperature fluctuations at the surface of mulch-covered soil and usually high fluctuations of temperature facilitate the sprouting process (Thompson and Grime, 1983). Locke et al. (2002) claims that the post-harvest residues remaining on soil surface in the ploughless systems inhibit seeds germination owing to shading.

The goal of this study was to evaluate the yield and quality of grain as well as weed infestation of spring triticale sown in different tillage systems.

Material and Methods

A field experiment with various tillage systems was carried out in the years 2009-2012 at the Experimental Station Uhrusk (51° 18' 12" N, 23° 36' 50" E) of the University of Life Sciences in Lublin, Poland. The experiment was established with the method of completely randomized blocks (8×75 m) in three replications and evaluated three tillage systems: a) conventional (CT), b) reduced (RT) and c) no-tillage (NT), according to the design presented in Table 1. The soil of the experimental area is Chalk Rendzina soil with texture of sandy loam, rich in available phosphorus and potassium and a slightly alkaline pH (Table 2). According to the classification by the IUSS Working Group WRB (2006), this soil was classified as Rendzic Phaeozem.

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)
NT	glyphosate 360 g L^{-1} (4 L ha^{-1})		

[*] CT-conventional tillage, RT-reduced tillage, NT-no-tillage.

Table 2. Physicochemical properties of soil (0-35 cm).

Traits	Value
Organic C (g kg^{-1} d.m.)	7.60
Inorganic N (g kg^{-1} d.m.)	1.03
P (g kg^{-1} d.m.)	0.21
K (g kg^{-1} d.m.)	0.24
Mg (g kg^{-1} d.m.)	0.04
PH_{KCl}	7.20
Clay fraction (%)	24.0
Silt (%)	13.1

On the study area, the annual sum of atmospheric precipitation (data of the years 1963-2010) is at 578 mm, including 352 mm in the period since sowing till harvest of cereals (since March till August). The mean annual air temperature reaches 7.5 ºC, whereas since March till August it accounts for 12.6 ºC. In the study years, the highest sum of precipitation (March-August) occurred in 2009 and 2010, whereas the highest average monthly air temperature-in 2010 and 2012 (Table 3).

Spring triticale of 'Legalo' cultivar was sown in the first decade of April after pea, in the quantity of 500 grains m^{-2}. Mineral fertilization was as follows 26 kg P ha^{-1} and 83 kg K ha^{-1}. Fertilization with N in the quantity of 90 kg ha^{-1} was applied in two terms: 45 kg N before sowing and 45 kg N at the shooting stage (32/33 in Zadoks scale) (Zadoks et al., 1974). Crops were protected from fungal diseases by fungicides: flusilazol 125 g L^{-1} + karbendazym 250 g L^{-1} (1 L ha^{-1}) and propikonazol 125 g L^{-1} + fenpropidyna 275 g L^{-1} (1 L ha^{-1}), whereas weed infestation was reduced by harrowing before and after triticale sprouting (22/23 in Zadoks scale) (Brandsæter et al., 2012).

Table 3. Weather conditions at the Uhrusk Experimental Station.

Years	Months						Total or mean
	March	April	May	June	July	August	
			Precipitation (mm)				
2009	107	27	81	169	43	60	487
2010	30	34	150	73	58	129	474
2011	12	34	42	87	147	64	386
2012	19	45	32	58	37	63	254
1963-2010	29	41	64	73	80	65	352
			Air temperature (^{o}C)				
2009	1.0	10.0	13.1	16.4	20.0	17.8	13.1
2010	2.1	8.8	14.8	18.6	21.6	19.7	14.3
2011	2.1	10.2	14.2	18.5	20.1	18.5	13.9
2012	3.9	8.7	14.9	17.1	21.6	18.7	14.2
1963-2010	1.2	7.8	13.6	16.7	18.4	17.6	12.6

The experiment evaluated productivity parameters: grain yield and its components, number of plants after sprouting and spike number, content of total protein, starch and crude fiber, number and air-dry weight of weeds and species composition of weeds. Further determinations included: yield at 14% moisture content of grain, number of plants (m^2) after sprouting (12/13 in Zadoks scale), number of spikes (m^2) (90/91 in Zadoks scale), weight of 1000 grains (2×500 grains), as well as the weight and number of grain from spike (m^2). The content of nitrogen in grain was determined with the Kjeldahl method and converted into total protein (N×6.25). Starch content was assayed by shaking grain samples with a TRIS buffer (pH=9.2) until complete dissolution of protein. The remaining precipitate was hot-dissolved in water. Starch was determined spectrophotometrically (λ=660 nm) in the form of a complex with iodine. Crude fiber was determined with the use of the Fibertec TM 2010 system for dietary fiber assays in food products according to AOAC, AACC and AOCS standards. This method was based on the application developed by FOSS TECATOR producer. Weed infestation of triticale was evaluated with the botanical-gravimetric method at the stage of waxy maturity of grain (83/85 in Zadoks scale). This method consists in the determination of the species composition of weeds as well as the number and air-dry weight of weeds per m^2 of plot. This area was determined at random (twice) using a 1×0.5 m frame (Woźniak, 2011). 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 in an airy and dry place until constant weight has been reached.

Results achieved were developed statistically with the analysis of variance (ANOVA) method, whereas the significance of differences between mean values was evaluated with Tukey's HSD test, $P \leq 0.05$. Correlations between the analyzed parameters were evaluated using Pearson's correlation coefficients.

Results

The tillage systems were observed to significantly affect the productivity of spring triticale (Table 4). The highest yields of grain were achieved in the CT system, lower in NT and the lowest in the RT system. The difference in yields between the CT system and the NT and RT systems reached 28.2 and 45.3%, respectively. Great differences in grain yield (23.9%) were also noted between NT and RT systems. The lower productivity of triticale in NT and RT systems, compared to the CT system, resulted from a reduced number of spikes as well as weight and number of grains from spike. In turn, the lower number of spikes (m^2) on RT and NT plots than on CT plots was due to poorer sprouting of triticale. Variability coefficients (CV%) allow concluding that the variability of grain yield in the study years reached 28.6%, whereas that of spike number (m^2) reached 21.3%. The other analyzed parameters of productivity were subject to lesser variability. In turn, the determined coefficients of correlation demonstrated correlations between grain yield and spike number, weight of grain from spike and grain number from spike (Table 5).

Table 4. Grain yield and biometric traits of spring triticale.

Specification	Tillage systems			Mean	CV%[***]
	CT[*]	RT	NT		
Crop yield (t ha^{-1})	4.08^{a**}	2.23^{c}	2.93^{b}	3.07	28.6
Number of plants m^{-2} at 12/13 Zadoks stage	474^{a}	440^{b}	452^{b}	455	12.0
Number of spike m^{-2} at 90/91 Zadoks stage	370^{a}	250^{b}	262^{b}	294	21.3
Weight of grain from spike (g)	1.18^{a}	0.89^{b}	0.97^{b}	1.01	14.1
Number of grains from spike	24.6^{a}	19.4^{b}	21.3^{b}	21.8	11.4
Weight of 1000 grains (g)	45.4^{a}	37.0^{c}	40.3^{b}	40.9	10.0

[*] CT-conventional tillage, RT-reduced tillage, NT-no-tillage.

[**] mean values denoted with the same letters do not differ significantly, $P \leq 0.05$.

[***] CV% - coefficient of variability in years.

Table 5. Coefficients of Pearson correlation between grain yield and its components.

Traits	Yield	Spike number m^{-2}	Grain weight per spike	1000 grains weight
Spike number m^{-2}	0.80			
Grain weight per spike	0.74	0.51		
1000 grains weight	0.42	0.69	0.75	
Number of grains from spike	0.71	0.60	0.73	0.34

The tillage systems affected also parameters of grain quality (Table 6). In grain from the RT and NT systems the total content of protein was significantly higher than in the grain from CT plots. Analogous observation was made for crude fiber content of the grain. In contrast, the content of starch in grain was significantly higher in the CT system than in the RT and NT systems.

The tillage system had also a significant effect on weed infestation (Table 7). Both the NT and RT system caused an increase in weed number in triticale, compared to the CT system. In the NT system this increase accounted for 38.9%, whereas in the RT system-for 27.9%, compared to the CT system. Analogous changes were observed in air-dry weight of weeds which in the NT system was 3-fold higher and in the RT system 2-fold higher than in the CT plots.

Table 6. Quality parameters of spring triticale grain.

Specification	Tillage systems			Mean	CV%[***]
	CT[*]	RT	NT		
Total protein (%)	14.3^{b**}	15.1^{a}	15.2^{a}	14.9	4.1
Starch (%)	75.1^{a}	69.2^{b}	68.7^{b}	71.0	4.7
Crude fiber (%)	2.9^{b}	3.4^{a}	3.3^{a}	3.2	7.3

[*] explanations as in Table 4.

Table 7. Number and air-dry weight of weeds in spring triticale crop.

Tillage system	Number of weeds m^{-2}	Air-dry weight of weeds (g m^{-2})
CT[*]	77.3^{a**}	21.4^{a}
RT	107.2^{b}	40.7^{b}
NT	126.6^{b}	63.3^{c}
Mean	103.7	41.8
CV%[***]	49.3	61.0

[*] explanations as in Table 4.

The experimental plots were mainly colonized by annual species of weeds (Table 8). In the CT system, these included: *Chenopodium album* L., *Echinochloa crus-galli* (L.) P.B., *Stellaria media* (L.) Vill. and *Lamium purpureum* L., whereas perennial weeds were represented by *Elymus repens* (L.) P.B. and *Cirsium arvense* (L.) Scop. In the RT system the predominating species included: *Echinochloa crus-galli* (L.) P.B., *Galium aparine* L., *Amaranthus retroflexus* L. and *Stellaria media* (L.) Vill., that together constituted over 57% of weeds. Also 3 species of perennial weeds occurred on this plot, including: *Convolvulus arvensis* L. In the NT system, the most abundant appeared to be: *Echinochloa crus-galli* (L.) P.B., *Consolida regalis* S.F. Gray, *Capsella bursa-pastoris* (L.) Med., *Poa annua* L. and *Avena fatua* L., which represented over 62% of total weeds occurring in this tillage system.

Table 8. Species composition of weeds in spring triticale crop.

Species composition	Tillage system			Mean
	CT*	RT	NT	
Annual weeds				
Chenopodium album L.	8.0	4.6	-	4.2
Echinochloa crus-galli (L.) P.B.	6.6	33.6	31.3	23.8
Stellaria media (L.) Vill.	6.6	6.3	-	4.3
Lamium purpureum L.	6.3	2.3	-	2.9
Avena fatua L.	4.9	-	10.3	5.1
Apera spica-venti (L.) P.B.	4.6	-	6.6	3.7
Amaranthus retroflexus L.	4.6	10.6	-	5.1
Veronica persica Poir.	3.9	2.6	5.3	3.9
Thlaspi arvense L.	3.9	-	-	1.3
Galinsoga parviflora Cav.	3.3	-	-	1.1
Fallopia convolvulus (L.) A. Löve	3.3	1.3	-	1.5
Geranium pusillum Burm.	3.3	0.3	-	1.2
Matricaria inodora L.	2.9	4.9	5.0	4.3
Galeopsis tetrahit L.	2.9	-	0.6	1.2
Anagallis arvensis L.	1.3	0.3	7.3	3.0
Viola arvensis Murr.	1.3	3.3	1.6	2.1
Sonchus asper (L.) Hill.	0.9	1.3	0.9	1.0
Gypsophila muralis L.	0.9	-	-	0.3
Veronica hederifolia L.	0.6	-	0.3	0.3
Berteroa incana DC.	0.3	-	-	0.1
Galium aparine L.	-	11.3	0.3	3.9

Continue Table 8.

Species composition	Tillage system			Mean
	CT*	RT	NT	
Annual weeds				
Papaver rhoeas L.	-	4.6	4.6	3.1
Melandrium album Garcke	-	4.3	6.3	3.5
Consolida regalis S.F. Gray	-	3.6	15.6	6.4
Poa annua L.	-	3.3	10.6	4.6
Capsella bursa-pastoris (L.) Med.	-	3.3	10.9	4.7
Erigeron canadensis L.	-	2.6	-	0.9
Euphorbia helioscopia L.	-	-	1.3	0.4
Solanum nigrum L.	-	-	0.9	0.3
Lapsana commins L.	-	-	0.9	0.3
Perennial weeds				
Elymus repens (L.) P.B.	4.6	0.9	5.3	3.6
Cirsium arvense (L.) Scop.	2.3	0.6	0.3	1.1
Convolvulus arvensis L.	-	1.3	0.3	0.5
Number of weeds (m^2)	77.3	107.2	126.5	-
Number of species	22	22	22	33

* CT-conventional tillage, RT-reduced tillage, NT-no-tillage.

Discussion

Optimization of expenditures incurred on plant production necessitates the search for novel solutions in crop cultivation (Lahmar, 2010). The ploughing tillage is increasingly often replaced by new ploughless methods. Productivity achieved upon implementation of these methods is, however, diversified, and each of these methods needs to be adjusted to specific conditions of individual farms (Gruber et al., 2012). Diverse is also plants response to the no-till system. In the presented study spring triticale sown in the CT system had significantly higher yields than in RT and NT systems, whereas yields of durum wheat (*Triticum durum* Desf.) sown in the same biotope conditions were similar in all analyzed tillage systems (Woźniak, 2013). As reported by De Vita et al. (2007), the no-tillage system ensures better effects in regions with lower precipitation. It results from lesser evaporation of water from soil and thereby from its greater availability to plants. Also according to López-Bellido et al. (1996) and Celik et al. (2011) crop yield in the no-till system decreases along with an increasing sum of precipitation. Considering the aforementioned views (López-Bellido et al., 1996; De Vita et al., 2007), at the study area (south-eastern Poland) better production effects are achieved in the ploughing than in the ploughless system, which was confirmed in this study. Compared to the CT system, the RT and NT systems afforded poorer conditions for the growth and development of plants, which resulted in poor sprouting, insufficient number of spikes and their low productivity. Also grain ripeness (1000 grains weight) was significantly worse in these conditions, which resulted in a lower content of starch in grain. In turn, grain with a lower starch content contained more protein and crude fiber. In a study by Woźniak and Makarski (2013) the no-till system was additionally increasing contents of total ash, zinc and copper in grain, compared to the ploughing system.

Generally, the no-till system is believed to increase weed infestation of crops (Davis et al., 2005; Peigné et al., 2007; Woźniak, 2012; Woźniak and Haliniarz, 2012). Also our experiment demonstrated a significant increase in the number and weight of weeds in RT and NT systems, compared to the CT system. This increase may be explained by the storage of freshly-fallen grain on soil surface, from where they germinate and thus increase crop infestation (Tørresen and Skuterud, 2002; Mohler et al., 2006; Woźniak, 2007; Mahmoodi and Rahimi, 2009).

In summary, it oughts to be concluded that better conditions for spring triticale growth and yielding were assured by conventional tillage (CT), compared to reduced (RT) and no-tillage (NT) systems. The tillage systems affected also grain quality. In the CT system grain contained more starch but less protein and crude fiber than in the RT and NT systems. The no-till systems (NT and RT) were observed to increase weed infestation of spring triticale, compared to the conventional system (CT).

References

Brandsæter, L.O., Mangerud, K., Rasmussen, J., 2012. Interactions between pre- and post-emergence weed harrowing in spring cereals. Weed Res. 52, 338-347.

Cardina, J., Herms, C.P., Doohan, D.J., 2002. Crop rotation and tillage system effects on weed seedbanks. Weed Sci. 50, 448-460.

Celik, I., Barut, Z.B., Ortas, I., Gok, M., Demirbas, A., Tulun, Y., Akpinar, C., 2011. Impacts of different tillage practices on some soil microbiological properties and crop yield under semi-arid Mediterranean conditions. Inter. J. Plant Prod. 5 (3), 237-254.

Chauhan, B.S., Gill, G.S., Preston, C., 2006. Tillage system effects on weed ecology, herbicide activity and persistence: a review. Aust. J. Exp. Agr. 46, 1557-1570.

Davis, A.S., Renner, K.A., Gross, K.L., 2005. Weed seedbank community shifts in a long-term cropping experiment. Weed Sci. 53, 296-306.

De Vita, P., Di Paolo, E., Fecondo, G., Di Fonzo, N., Pisante, M., 2007. No-tillage and conventional tillage effects on durum wheat yield, grain quality and soil moisture content in Southern Italy. Soil Till. Res. 92, 69-78.

Gruber, S., Pekrun, C., Möhring, J., Claupein, W., 2012. Long-term yield and weed response to conservation and stubble tillage in SW Germany. Soil Till. Res. 121, 49-56.

IUSS Working Group WRB, 2006. World Reference Base for Soil Resources 2006. 2nd edition. World Soil Resources reports No. 103. FAO, Rome, 132p.

Jones, C.A., Basch, G., Baylis, A.D., Bazzoni, D., Bigs, J., Bradbury, R.B., Chaney, K., Deeks, L.K., Field, R., Gomez, J.A., Jones, R.J.A., Jordan, V., Lane, M.C.G., Leake, A., Livermore, M., Owens, P.N., Ritz, K., Sturny, W.G., Thomas, F., 2006. Conservation Agriculture in Europe: An Approach to Sustainable Crop Production by Protecting Soil and Water? SOWAP, Jealott’s Hill, Bracknell, UK.

Knight, S.M., 2004. Plough, minimal till or direct drill? - Establishment method and production efficiency. In: Anon. (Eds.), HGCA Conference 2004: Managing Soil and Roots for Profitable Production. London, Home Grown Cereals Authority.

Lahmar, R., 2010. Adoption of conservation agriculture in Europe lesson of the KASSA project. Land Use Policy. 27, 4-10.

Locke, M.A., Reddy, K.N., Zablotowicz, R.M., 2002. Weed management in conservation crop production systems. Weed Biol. Manag. 2, 123-132.

López-Bellido, L., Fuentes, M., Castillo, J.E., López-Garrido, F.J., Fernández, E.J., 1996. Long-term tillage, crop rotation and nitrogen fertilizer effects on wheat yield under rainfed Mediterranean conditions. Agron. J. 88, 783-791.

Mahmoodi, S., Rahimi, A., 2009. The critical period of weed control in corn in Birjand region, Iran. Inter. J. Plant Prod. 3 (2), 91-96.

Mohler, C.L., Frisch, J.C., McCulloch, C.E., 2006. Vertical movement of weed seed surrogates by tillage implements and natural processes. Soil Till. Res. 86, 110-122.

Morris, N.L., Miller, P.C.H., Orson, J.H., Froud-Williams, R.J., 2010. The adoption of non-inversion tillage systems in the United Kingdom and the agronomic impact on soil, crops and the environment-A review. Soil Till. Res. 108, 1-15.

Peigné, J., Ball, B.C., Roger-Estrade, J., David, C., 2007. Is conservation tillage suitable for organic farming? Soil Use Manage. 23, 129-144.

Thompson, K., Grime, J.P., 1983. A comparative study of germination responses to diurnal- fluctuating temperatures. J. Appl. Ecol. 20, 141-156.

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.

Woźniak, A., 2007. Content of weed seed in rendzina soil under spring triticale. Annales Universitais Mariae Curie-Skłodowska, sectio E. 62 (2), 250-256. (In Polish, abstract in English)

Woźniak, A., 2011. Weed infestation of a spring wheat (*Triticum aestivum* L.) crop under the conditions of plough and ploughless tillage. Acta Agrobot. 64 (3), 133-140.

Woźniak, A., 2012. Weed infestation of pea (*Pisum sativum* L.) crop under the conditions of plough and ploughless tillage. Acta Sci. Pol.-Hortoru. 11 (2), 253-262.

Woźniak, A., Haliniarz, M., 2012. The after-effect of long-term reduced tillage systems on the biodiversity of weeds in spring crops. Acta Agrobot. 65 (1), 141-148.

Woźniak, A., 2013. The effect of tillage systems on yield and quality of durum wheat cultivars. Turk. J. Agric. For. 37 (2), 133-138.
Woźniak, A., Makarski, B., 2013. Content of minerals, total protein and wet gluten in grain of spring wheat depending on cropping systems. J. Elem. 18 (2), 297-305.
Zadoks, J.C., Chang, T.T., Konzak, C.F., 1974. A decimal code for the growth stages of cereals. Weed Res. 14, 415-421.