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Effect of Long-term Reduced Tillage on Grain Yield, Grain Quality and Weed Infestation of Spring Wheat

A. Woźniak[1*], M. Wesołowski[1], and M. Soroka[2]

ABSTRACT

This study was undertaken to investigate the effect of long-term reduced tillage on grain yield, grain quality, and weed infestation of spring wheat. The experimental variables were three tillage systems: (a) conventional tillage (CT): shallow ploughing (10-12 cm) and harrowing after harvest of the previous crop, ploughing (25-30 cm) in the autumn; (b) reduced tillage (RT): only a cultivator (10-15 cm) used after harvest of the previous crop; and (c) herbicide tillage (HT): only using Roundup 360 SL after harvest of the previous crop. In the spring, a cultivation set consisting of a cultivator, a string roller, and a harrow (10-12 cm) was used on all plots. Spring wheat of Brawura cultivar was cultivated after two types of previous crop: (1) pea, and (2) spring wheat. The yield of wheat was higher in CT and RT systems, compared to the HT system. Higher yields were also obtained after pea than after spring wheat. Reduced grain yield on the HT plots resulted from a lower number of wheat plants per m^2 and their lower productivity than in the CT and RT systems. The HT system reduced the grain volume weight and increased ash content in the grain, compared to CT and RT systems, whereas it had no effect on protein and gluten contents in the grain. Greater weed infestation of spring wheat crop occurred on HT and RT plots than on the CT plot.

Keywords: Ash content, Gluten content, Grain protein, Tillage systems.

INTRODUCTION

The need to increase cost-effectiveness of crop cultivation and to comply with the principles of sustainable development lead to the search for novel solutions in crop cultivation (Lahmar, 2010). Not all solutions may, however, be optimal, as their efficiency depends on many environmental and economic factors (Ozpinar and Ozpinar, 2011; Gruber *et al.*, 2012). Many investigations show that no-till system increases weed infestation of crops (Mohler *et al.*, 2006; Woźniak and Haliniarz, 2012). Pekrun and Claupein (2006), Gruber and Claupein (2009), and Woźniak (2012) report that the plowless systems increase the contribution of annual weeds. Falling down seeds are accumulated in the topsoil, from where they germinate and thereby increase weed infestation of the after-crop (Cardina *et al.*, 2002; Chauhan *et al.*, 2006). According to Davis *et al.* (2005), Peigné *et al.* (2007) as well as Woźniak and Kwiatkowski (2013), the increased weed infestation leads to reduced crop yield. However, as claimed by Lahmar (2010), Jug *et al.* (2011), and Gruber *et al.* (2012) opinions on the impact of reduced tillage system on crop yield are diverse, and production effects are determined by soil and climatic conditions as well as by the extent of reduced tillage practices. According to Knight (2004), plant yield depends on many agrotechnical and habitat factors that directly affect one another and

[1]Department of Herbology and Plant Cultivation Techniques, University of Life Sciences, Lublin, Akademicka 13, 20-950 Lublin, Poland.
[2]Department of Botany, Ukrainian National Forestry University, 79057 Lviv, Ukraine.
[*]Corresponding author; e-mail: andrzej.wozniak@up.lublin.pl

are difficult to predict. It is commonly believed that, in moderately humid areas, high crop yields in the conventional tillage system (Gruber *et al.*, 2012; Woźniak and Kwiatkowski, 2013), whereas in dry areas, they are achieved in the no-till system (López-Bellido *et al.,* 1996; Guy and Cox, 2002; Hemmat and Eskandari, 2004; De Vita *et al.*, 2007). Also Lahmar (2010) reports that cereal yields in Spain in dry years are higher by 10-15% in the no-till than in the ploughing system. The system of tillage influences also the quality and chemical composition of grain (Morris *et al.,* 2010; Woźniak and Makarski, 2012; Woźniak, 2013a), although a study by Gomez-Becerra *et al.* (2010) demonstrates that these traits are strongly dependent on agroclimatic and habitat conditions.

The aim of this study was to investigate the effect of long-term reduced tillage on grain yield, grain quality, and weed infestation of spring wheat.

MATERIALS AND METHODS

A field experiment with tillage systems was conducted in the years 2007-2013 at the Experimental Station Uhrusk (51°18'12"N, 23°36'50"E), University of Life Sciences in Lublin, south-eastern Poland. It evaluated grain yield, grain quality and weed infestation of spring wheat Brawura cv. sown in three tillage systems: (a) conventional (CT); (b) reduced (RT); and (c) herbicide (HT) after two types of previous crops: (1) pea (*Pisum sativum* L.), and (2) spring wheat (*Triticum aestivum* L.). The two-factor experiment was established using randomized sub-blocks design in three replications. The main experimental factor (main plots) was the tillage system, and the second order factor (subplots) was the previous crop of wheat. Blocks of 8 m x 75 m in size were divided into 3 sub-blocks, and each of the sub-blocks were divided into 2 plots. The conventional tillage (CT) included shallow plowing (10-12 cm) and harrowing after the harvest of the previous crop and then pre-winter plowing (25-30 cm) in the autumn. The reduced tillage (RT) involved only plot cultivation (10-15 cm), whereas the herbicide tillage (HT) treatment included the use of Roundup 360 SL herbicide (a.s. glyphosate) – at a dose of 4 L ha^{-1}. In the spring, a cultivation set consisting of a cultivator, a string roller, and a harrow (10-12 cm), was used on all plots. The tested wheat cultivar was characterized by good fertility and grain quality and classified in the Common Catalogue of Varieties of Agricultural Plant Species (EU 2009).

Soil of the experimental plots was Rendzic Phaeozem (IUSS Working Group WRB, 2006) with a composition of light, poorly sandy clay, rich in available forms of phosphorus and potassium, with a slightly alkaline pH (Table 1). On the study area, the annual sum of atmospheric precipitation (average of 45 years) is 578 mm, including 352 mm in the growing season of cereals i.e. March till August. The mean annual air temperature is 7.5 ºC, with average of 13.8 ºC for the growing season.

Spring wheat was sown in the first decade of April at the rate of 500 seeds per m^2. Mineral fertilization was applied as follows: 120 kg N ha^{-1}, 34 kg P ha^{-1} and 83 kg K ha^{-1}. Nitrogen fertilizers were applied in the following four terms and doses: 50 kg ha^{-1} before sowing, 30 kg ha^{-1} at the propagation stage, 20 kg ha^{-1} at the shooting stage, and 20 kg ha^{-1} at the ear stage. In addition, Alert 375 SC (flusilazole + carbendazim) 1 L ha^{-1}

Table 1. Physicochemical properties of the studied soil (0-35 cm).

Traits	Value
Total N (g kg^{-1} d.m.)	1.03
P (g kg^{-1} d.m.)	0.17
K (g kg^{-1} d.m.)	0.24
Mg (g kg^{-1} d.m.)	0.04
Organic C (g kg^{-1} d.m.)	7.60
pH_{KCl}	7.20
Clay fraction (%)	24.0
Dust fraction (%)	13.1

(32-33 in Zadoks scale) (Zadoks *et al.*, 1974) and Tilt Plus 400 EC (propiconazol + fenpropidin) 1 L ha^{-1} (53-54 stage) were applied as fungicides for crop protection against fungi, and Chwastox Trio 540 SL (a.s. mecoprop + MCPA + dicamba) 1.5 L ha^{-1} (at 23-24 stage) as a herbicide for weed control.

Analyses conducted for production parameters of spring wheat included grain yield (t ha^{-1}), number of plants after sprouting per m^2 (at 12–13 stage), number of spikes per m^2 (at 90–91), weight of grains per spike (g), 1000 grain weight (g), total protein content (%), wet gluten content of grain (%), grain volume weight (kg hL^{-1}), total ash content (%), as well as species composition, number, and air-dry weight of weeds per m^2 of each plot. Grain was harvested with a Wintersteiger plot harvester. The number of plants and spikes per m^2 was assayed at each plot twice in a frame of 0.5 x 1.0 m^2. Determination of 1000 grains weight consisted of twofold counting out of 500 grains, whereas the weight of grains was determined as a mean value from 40 spikes collected at random from each plot. Weed infestation was evaluated with the botanical-gravimetric method at the waxy maturity stage (83-84 stage). This method consists of the determination of species composition of weeds as well as the number and air-dry weight of weeds per m^2 of a plot. This area was marked at random (twice) using a 1.0 x 0.5 m frame. To determine air-dry weight, all weeds were collected from the frame, their root system was removed, and they were placed in a ventilated and dry place until they had reached constant weight (Woźniak, 2012; Woźniak and Haliniarz, 2012). Protein and gluten contents were determined by the near infrared reflectance spectroscopy (NIRS) method using the Inframatic 9200 grain analyzer, whereas the other grain traits were evaluated in accordance with applicable standards (Woźniak and Makarski, 2012; Woźniak, 2013a).

Results were statistically analyzed with Statistical PL and the significance of differences between means was evaluated with the Tukey's HSD test (HSD–honestly significant difference), $p< 0.05$.

RESULTS AND DISCUSSION

Grain Yield and Its Components

Grain yield of spring wheat cultivated in CT and RT systems was significantly higher compared to the HT system (Table 2). Higher yields were also achieved in the plot after pea than in the plot after wheat. Variance components (*F*-Value) analysis demonstrated that grain yield was influenced to a greater extent by the previous crops than by the tillage systems (Table 3). The CT and RT systems facilitated better plant density and number of spikes per m^2 compared to the HT system. A higher number of plants (by 15.8-22.2%) at the sprouting stage (12-13 stage), and a higher number of spikes (by

Table 2. Grain yield of spring wheat in t ha^{-1} (average of the years 2007-2013).

Previous crop (PC)	Tillage system (TS)			
	CT [a]	RT [b]	HT [c]	Mean
Pea	4.98	4.82	4.70	4.83
Spring wheat	4.69	4.66	4.36	4.57
Mean	4.83	4.74	4.53	-
$HSD_{0.05}$ values				
TS		0.15		
PC		0.10		
TS x PC		ns [d]		

[a] Conventional tillage; [b] Reduced tillage; [c] Herbicide tillage, [d] Not significant p<0.05

Table 3. Analysis of variance for grain yield and its components, p<0.05

Effects	DF [c]	Yield	Number of plants	Spikes number	Grain weight per spike	1000 grains weight
		F-Value				
TS [a]	2	14.7	19.2	16.9	3.42	22.2
PC [b]	1	30.9	1.3	16.8	7.89	10.1
TS x PC	2	1.3	1.4	1.7	5.78	2.0

[a] Tillage system, [b] Previous crop , [c] Degrees of Freedom.

Table 4. Spring wheat plant density after sprouting and number of spikes before harvest (average of the years 2007-2013).

Previous crop (PC)	Number of plants per m^2 (12-13 in Zadoks scale)				Spikes per m^2 (90-91 in Zadoks scale)			
	Tillage system (TS)							
	CT [a]	RT [b]	HT [c]	Mean	CT	RT	HT	Mean
Pea	532	522	429	494	445	440	422	436
Spring wheat	515	485	441	480	439	416	401	418
Mean	523	504	435	-	442	428	412	-
$HSD_{0.05}$ values								
TS	40				14			
PC	ns [d]				9			
TS x PC	ns				ns			

[a] Conventional tillage; [b] Reduced tillage; [c] Herbicide tillage, [d] Not significant p<0.05

3.9-7.3%) before harvest (at 90-91 stage) were determined in CT and RT than in HT plots (Table 4). Also, a higher number of spikes was noted in the plot after pea than in the plot after wheat. The analysis of variance components (*F*-Value) showed that spike number was similarly influenced by tillage system and the previous crop.

The weight of grain per spike depended only on the type of previous crop (Table 5). Higher grain weight was noted in spikes harvested from the plot after pea than after wheat. Spring wheat sown in the CT and RT systems produced grain with a higher value of 1000- grain weight (TGW) than wheat grown in the HT system. Also, in the plot after pea, wheat grain had higher TGW compared to the plot after wheat. The analysis of *F*-Value demonstrated that the TGW was affected to a greater extent by the tillage system than by the previous crop.

According to the literature, in moderately

Table 5. Weight of spring wheat grain per spike and 1000 grains weight (average of the years 2007-2013).

Previous crop (PC)	Weight of grain per spike (g)				1000 grains weight (g)			
	Tillage system (TS)							
	CT [a]	RT [b]	HT [c]	Mean	CT	RT	HT	Mean
Pea	1.12	1.10	1.11	1.11	42.7	42.3	40.2	41.7
Spring wheat	1.07	1.12	1.01	1.07	41.9	40.7	40.0	40.8
Mean	1.09	1.11	1.06	-	42.3	41.5	40.1	-
$HSD_{0.05}$ values								
TS	ns [d]				0.9			
PC	0.03				0.6			
TS x PC	0.08				NS			

[a] Conventional tillage; [b] Reduced tillage; [c] Herbicide tillage, [d] Not significant p<0.05

humid areas, higher crop yields are usually achieved in the conventional tillage system (Jug *et al.*, 2011; Małecka *et al.*, 2012), whereas in dry and semi-arid areas, the no-till system produces higher (López-Bellido *et al.*, 1996; Guy and Cox, 2002). As reported by De Vita *et al.* (2007), in areas with seasonal precipitation below 300 mm, higher yields are obtained from direct sowing, whereas in the areas with more precipitation, the conventional system yield higher. According to Josa and Hereter (2005) as well as De Vita *et al.* (2007), this results from lower evapo-transpiration and, hence, from a higher water content in the topsoil and its greater availability to plants. In investigations conducted by Woźniak (2013b) and Woźniak and Kwiatkowski (2013) in a moderately humid region, the diminished grain yield on plots with reduced tillage system was caused by a lower number of plants per m^2 and their lower productivity than in the conventional tillage system.

Grain Quality

Contents of total protein and wet gluten in grain were differentiated only by the previous crops (Table 6), and were significantly higher on the plot after pea than on the plot after wheat. Test weight of wheat grain depended on both the tillage system and previous crop (Table 7). In the CT and RT system its values were significantly higher than in the HT system. Higher grain volume weight (kg hL^{-1}) was also achieved on the plot after pea than on the plot after wheat. The *F*-Value analysis demonstrated that the test weight of grain was more dependent on the tillage system than on the previous crop (Table 8).

Total ash content in wheat grain was

Table 6. Contents of total protein and wet gluten in spring wheat grain (average of the years 2007-2013).

Previous crop (PC)	Total protein (%)				Wet gluten (%)			
	Tillage system (TS)							
	CT [a]	RT [b]	HT [c]	Mean	CT	RT	HT	Mean
Pea	13.5	13.3	13.3	13.5	31.2	30.8	31.0	31.0
Spring wheat	13.1	13.0	13.1	13.1	29.6	30.1	29.5	29.7
Mean	13.3	13.2	13.2	-	30.4	30.4	30.2	-
$HSD_{0.05}$ values								
TS	ns				ns			
PC	0.2				0.6			
TS x PC	ns				ns			

[a] Conventional tillage; [b] Reduced tillage; [c] Herbicide tillage, [d] Not significant p<0.05

Table 7. Grain volume weight of and total ash content in spring wheat grain (average of the years 2007-2013).

Previous crop (PC)	Grain volume weight (kg hL^{-1})				Total ash (%)			
	Tillage system (TS)							
	CT [a]	RT [b]	HT [c]	Mean	CT	RT	HT	Mean
Pea	73.2	71.9	69.6	71.6	1.79	1.89	1.98	1.88
Spring wheat	72.3	70.5	68.7	70.5	1.90	1.94	2.05	1.96
Mean	72.7	71.2	69.1	-	1.84	1.91	2.02	-
$HSD_{0.05}$ values								
TS	1.5				0.06			
PC	1.0				0.04			
TS x PC	ns				ns			

[a] Conventional tillage; [b] Reduced tillage; [c] Herbicide tillage, [d] Not significant p<0.05

significantly higher in HT than in RT and CT plots (Table 7). Higher ash content was also determined in the grain harvested from RT than from CT plot. Grain harvested after wheat as the previous crop contained more ash than the grain sown after pea. Analysis of *F*-Value showed that the content of ash in grain was influenced to a greater extent by tillage systems than by previous crops.

Literature data indicate that tillage systems have little effect on protein and gluten contents in grain, but significantly differentiate its grain volume weight and ash content (Woźniak, 2013a). Woźniak and Makarski (2012) demonstrated that reduced tillage increased ash content in the grain and, simultaneously, decreased its grain volume weight. In addition, they showed that ash content of the grain was also affected by the previous crop and nitrogen fertilization. Wheat sown after soybean contained more ash, K, and Mn than that sown after pea. In turn, wheat sown after pea was characterized by significantly higher contents of Ca as well as Fe and Zn.

Weed Infestation

The HT system was observed to increase the number of weeds per m^2 and their air-dry weight compared to CT and RT systems (Table 9). Higher weed infestation occurred also in the RT than in the CT system as well as in the plot after wheat than in the plot after pea. The analysis of variance components (*F*-Value) showed that weed

Table 8. Analysis of variance for grain quality parameters, p<0.05.

Effects	DF [c]	Protein content	Gluten content	Test weight	Ash content
		F-Value			
TS [a]	2	1.1	0.2	19.8	26.6
PC [b]	1	8.1	18.1	5.4	15.4
TS x PC	2	0.4	0.9	0.1	0.9

[a] Tillage system, [b] Previous crop, [c] Degrees of Freedom

Table 9. Number of weeds and air-dry weight of weeds in spring wheat crop (average of the years 2007-2013).

Previous crop (PC)	Number of weeds m^{-2}				Air-dry weight of weeds g m^{-2}			
	(TS) Tillage system							
	CT [a]	RT [b]	HT [c]	Mean	CT	RT	HT	Mean
Pea	21.1	56.9	97.8	58.6	36.3	58.0	88.3	60.8
Spring wheat	49.8	74.0	111.8	78.5	58.8	77.5	103.0	79.8
Mean	35.4	65.5	104.8	-	47.5	67.7	95.6	-
$HSD_{0.05}$ values								
TS	15.3				15.6			
PC	10.2				10.4			
TS x PC	ns [d]				ns			

[a] Conventional tillage; [b] Reduced tillage; [c] Herbicide tillage, [d] Not significant p<0.05

Table 10. Analysis of variance for weed infestation parameters, p<0.05.

Effects	DF [c]	Number of weeds	Air-dry weight of weeds
		F-Value	
TS [a]	2	73.6	34.3
PC [b]	1	18.1	15.8
TS x PC	2	0.9	0.3

[a] Tillage system, [b] Previous crop, [c] Degrees of Freedom

infestation of wheat was affected to a greater extent by tillage system than by previous crops (Table 10). This was in accordance with results reported by other authors (Gruber *et al*., 2012; Woźniak and Haliniarz, 2012). Usually it is believed that the reduced tillage system increases weed infestation of crops (Davis *et al.* 2005; Gruber and Claupein, 2009; Woźniak, 2012), because the falling down seeds are accumulated in the topsoil, from where they germinate and thus increase the number of weeds (Cardina *et al*., 2002). As reported by Pekrun and Claupein (2006), the no-till systems increase the contribution of annual weeds. Also, in our study, the annual weeds predominated in all tillage systems. The crop of wheat sown in CT system after pea (Table 11) was mainly infested by *Stellaria media* (L.) Vill., *Fallopia convolvulus* (L.) A. Löve, *Viola arvensis* Murr., and *Veronica persica* Poir.; whereas in the RT system the main weeds were *Papaver rhoeas* L., *Chenopodium album* L., *F. convolvulus* and *S. media*; and the HT system was mainly infested by *P. rhoeas*, *Avena fatua* L., *Matricaria inodora* L. and *C. album*. In the case of wheat sown after wheat, the crop from the CT system was predominated by *S. media*, *Amaranthus retoflexus* L., *F. convolvulus* and *Galium aparine* L.; that grown in the RT system by: *A. retoflexus*, *S. media*, *C. album* and *P. rhoeas*; and that grown in the HT system by: *C. album*, *A. retoflexus*, *S. media*. and *A. fatua* (Table 12).

In summary, it may be concluded that spring wheat cultivated in the CT and RT systems produced higher grain yield than in the HT system. Higher grain yields were also achieved in plots after pea than in plots after wheat. The reduced grain yield on HT plots was due to a lower spikes number per m^2 and their lower productivity compared to the CT and RT systems. Additionally, the HT system reduced grain volume weight of the grain, but increased its ash content

Table 11. Species composition and number of weeds per m^2 in spring wheat on the plot after pea (average of the years 2007-2013).

Species composition	Tillage systems		
	CT [a]	RT [b]	HT [c]
Annual weeds			
1. *Stellaria media* (L.) Vill.	5.8	4.9	8.1
2. *Fallopia convolvulus* (L.) A. Löve	3.3	7.0	6.3
3. *Viola arvensis* Murr.	2.9	1.5	6.9
4. *Veronica persica* Poir.	2.2	4.4	0.2
5. *Amaranthus retroflexus* L.	1.3	0.2	-
6. *Consolida regalis* Gray.	1.3	0.3	2.1
7. *Galium aparine* L.	1.3	1.4	4.2
8. *Avena fatua* L.	0.6	4.1	14.1
9. *Chenopodium album* L.	0.6	8.6	10.2
10. *Papaver rhoeas* L.	0.6	12.0	15.6
11. *Apera spica-venti* (L.) P.B.	0.6	4.5	3.3
12. *Galeopsis tetrahit* L.	0.6	-	4.9
13. *Matricaria inodora* L.	-	1.4	13.5
14. *Sonchus asper* (L.) Hill.	-	1.6	-
15. *Polygonum lapathifolium* L.	-	4.2	5.9
16. *Galinsoga parviflora* Cav.		0.3	2.5
Perennial weeds			
17. *Cirsium arvense* (L.) Scop.	-	0.5	-
Number of species	12	16	14

[a] Conventional tillage; [b] Reduced tillage; [c] Herbicide tillage.

Table 12. Species composition and number of weeds per m^2 in spring wheat on the plot after spring wheat (average of the years 2007-2013).

Species composition	Tillage systems		
	CT [a]	RT [b]	HT [c]
Annual weeds			
1. *Stellaria media* (L.) Vill.	12.3	11.6	16.9
2. *Amaranthus retroflexus* L.	9.8	18.9	20.5
3. *Fallopia convolvulus* (L.) A. Löve	3.9	0.6	0.8
4. *Galium aparine* L.	3.9	6.0	4.5
5. *Chenopodium album* L.	3.6	16.8	21.4
6. *Papaver rhoeas* L.	2.9	10.4	9.8
7. *Viola arvensis* Murr.	2.4	0.3	6.9
8. *Matricaria inodora* L.	2.2	4.0	7.3
9. *Galeopsis tetrahit* L.	2.2	2.1	-
10. *Avena fatua* L.	2.0	1.2	10.4
11. *Echinochloa crus-galli* (L.) P.B	1.8	1.0	8.6
12. *Apera spica-venti* (L.) P.B.	1.2	0.5	1.5
13. *Consolida regalis* Gray	1.2	-	0.2
Perennial weeds			
14. *Cirsium arvense* (L.) Scop.	0.4	-	0.9
15. *Elymus repens* (L.) Gould	-	0.2	2.1
Number of species	14	13	14

[a] Conventional tillage; [b] Reduced tillage; [c] Herbicide tillage.

compared to the CT and RT systems, whereas it had no impact on protein and gluten contents in the grain. Contrary to CT system, the HT and RT systems increased weed infestation of spring wheat.

REFERENCES

1. Cardina, J., Herms, C. P. and Doohan, D.J. 2002. Crop Rotation and Tillage System Effects on Weed Seed Banks. *Weed Sci*., **50**: 448–460.
2. Chauhan, B. S., Gill, G. S. and Preston, C. 2006. Tillage System Effects on Weed Ecology, Herbicide Activity and Persistence: A Review. *Aust. J. Exp. Agr.,* **46**: 1557–1570.
3. Davis, A. S., Renner, K. A. and Gross, K. L. 2005. Weed Seedbank and Community Shifts in a Long-Term Cropping Experiment. *Weed Sci.,* **53**: 296–306.
4. De Vita, P., Di Paolo, E., Fecondo, G., Di Fonzo, N. and 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.
5. European Union. 2009. *Common Catalogue of Varieties of Agricultural Plant Species.* 28th Complete Edition (2009/C 302 A/01), Official Journal of the European Union 12.12.2009.
6. Gomez-Becerra, H. F., Erdem, H., Yazici, A., Tutus, Y., Torun, B., Ozturk, L. and Cakmak, I. 2010. Grain Concentrations of Protein and Mineral Nutrients in a Large Collection of Spelt Wheat Grown under Different Environments. *J. Cereal Sci*., **52**: 342-349.
7. Gruber, S. and Claupein, W. 2009. Effect of Tillage Intensity on Weed Infestation in Organic Farming. *Soil Till. Res*., **105**: 104-111.
8. Gruber, S., Pekrun, C., Möhring, J. and Claupein, W. 2012. Long-term Yield and Weed Response to Conservation and Stubble Tillage in SW Germany. *Soil Till. Res*., **121**: 49-56.
9. Guy, S. O. and Cox, D. B. 2002. Reduced Tillage Increases Residue Groundcover in Subsequent Dry Pea and Winter Wheat

Crops in the Palouse Region of Idaho. *Soil Till. Res*., **66**: 69-77.
10. Hemmat, A. and Eskandari, I. 2004. Tillage System Effects upon Productivity of a Dryland Winter Wheat-chickpea Rotation in the Northwest Region of Iran. *Soil Till. Res*., **78**: 69-81.
11. IUSS Working Group WRB. 2006. World Reference Base for Soil Resources 2006: World Soil Resources Reports No. 103. 2nd Edition, FAO, Rome, 132 PP.
12. Josa, R., Hereter, A. 2005. Effects of Tillage Systems in Dryland Farming on Near-surface Water Content during Late Winter Period. *Soil Till. Res*., **82**: 173–183.
13. Jug, I., Jug, D., Sabo, M., Stipeševic, B. and Stošic, M. 2011. Winter Wheat Yield and Components as Affected by Soil Tillage Systems. *Turk. J. Agric. For.,* **35**: 1–7.
14. Knight, S. M. 2004. Plough, Minimal Till or Direct Drill? Establishment Method and Production Efficiency. In: "*HGCA Conference 2004*: *Managing Soil and Roots for Profitable Production"*, (Eds.): Anon.. Home Grown Cereals Authority, London.
15. Lahmar, R. 2010. Adoption of Conservation Agriculture in Europe Lesson of the KASSA Project. *Land Use Policy*, **27**: 4-10.
16. López-Bellido, L., Fuentes, M., Castillo, J. E., López-Garrido, F. J. and 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.
17. Małecka, I., Blecharczyk, A., Sawinska, Z. and Dobrzeniecki, T. 2012. The Effect of Various Long-term Tillage Systems on Soil Properties and Spring Barley Yield. *Turk. J. Agric. For.*, **36**: 217-226.
18. Mohler, C. L., Frisch, J. C. and McCulloch, C. E. 2006. Vertical Movement of Weed Seed Surrogates by TillageI and natural Processes. *Soil Till Res*., **86**: 110-122.
19. Morris, N. L., Miller, P. C. H., Orson, J. H. and 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.
20. Ozpinar, O., and Ozpinar, A. 2011. Influence of Tillage and Crop Rotation Systems on Economy and Weed Density in a Semi-arid Region. *J. Agr. Sci. Tech*., **13**: 769-784.
21. Peigné, J., Ball, B. C., Roger-Estrade, J. and David, C. 2007. Is Conservation Tillage Suitable for Organic Farming? A Review. *Soil Use Manage*., **23**: 129–144.
22. Pekrun, C. and Claupein, W. 2006. The Implication of Stubble Tillage for Weed Population Dynamics in Organic Farming. *Weed Res*., **46**: 414-423.
23. Woźniak, A. 2012. Weed Infestation of Pea (*Pisum sativum* L.) Crop under the Conditions of Plough and Ploughless Tillage. *Acta Sci. Pol. – Hortorum Cultus*, **11(2)**: 253-262.
24. Woźniak, A. and 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.
25. Woźniak, A. and Makarski, B. 2012. Content of Minerals in Grain of Spring Wheat cv. Koksa Depending on Cultivation Conditions. *J. Elem*. **17(3)***:* 517-523.
26. Woźniak, A. 2013a. The Effect of Tillage Systems on Yield and Quality of Durum Wheat Cultivars. *Turk. J. Agric. For*., **37**: 133-138.
27. Woźniak, A. 2013b. The Yielding of Pea (*Pisum sativum* L.) under Different Tillage Conditions. *Acta Sci. Pol. – Hortorum Cultus,* **12(2):** 133-141.
28. Woźniak, A. and Kwiatkowski, C. 2013. Effect of Long-term Reduced Tillage on Yield and Weeds of Spring Barley. *J. Agr. Sci. Tech*., **15**: 1335-1342.
29. Zadoks, J. C., Chang, T. T. and Konzak, C. F. 1974. A Decimal Code for the Growth Stages of Cereals. *Weed Res*., **14**: 415-421.

اثر دراز مدت خاکورزی کمینه روی عملکرد و کیفیت دانه و آلودگی علف هرز در گندم بهاره

ا. وزنیاک، م. وسولووسکی، و م. سوروکا

چکیده

هدف از این پژوهش بررسی اثرات دراز مدت خاکورزی کمینه روی عملکرد و کیفیت دانه و آلودگی علف هرز در گندم بهاره بود. متغییر های آزمایش سه سامانه کشت شامل (a) خاکورزی رایج در منطقه(CT) یعنی شخم سطحی(۱۰ تا ۱۲ سانتی متری) و زدن هرس بعد از برداشت کشت قبلی و سپس شخم زنی تا عمق (۲۵ تا۳۰ سانتی متری) در پاییز، (b) خاکورزی کمینه (RT) که تنها شامل استفاده از کولتیواتر برای سله شکنی و شخم تا عمق ۱۰تا ۱۵ سانتی متری بعد از برداشت کشت قبلی بود، (C)کار برد علف کش راند آپ 360 SL بعد از برداشت کشت قبلی(HT). در بهار در همه کرت ها از دستگاهی شامل کولتیواتر، غلطک ، و هرس برای خاکورزی تا عمق ۱۰ تا ۱۲ سانتی متری استفاده شد. سپس، گندم بهاره رقم Brawura در کرت هایی با دو کشت قبلی متفاوت یعنی نخود و گندم بهاره کاشته شد. بر اساس نتایج به دست آمده، عملکرد گندم در سامانه های CT وRT بیشتر از عملکرد سامانه HT بود. همچنین، عملکرد در کرت هایی که کشت قبلی آنها نخود بود بیشتر از کرت های با کشت قبلی گندم بود. کاهش عملکرد در کرت هایHT در نتیجه کم بودن تعداد بوته گندم در متر مربع و بهره وری کمتر آنها در مقایسه با دو سامانه دیگر بود. سامانه HT در مقایسه با سامانه های CT وRT منجر به کم شدن وزن آزمونی (احتمالا منظور وزن واحد حجم دانه است- مترجم) ولی خاکستر موجود در دانه را افزایش داد. اما سامانه HT هیچ اثری روی پروتئین و گلوتن دانه نداشت. همچنین، آلودگی علفها در گندم بهاره در کرت های HTو RT بیشتر از کرت هایCT بود.