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EFFECT OF TILLAGE SIMPLIFICATIONS ON YIELD AND GRAIN QUALITY OF WINTER WHEAT AFTER DIFFERENT PREVIOUS CROPS*

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Abstract. Economic, organizational and natural determinants of modern plant field production enforce far-reaching limitations of classical components of cultivation regime. In 2010-2012, a study was carried out at the Agricultural Production Farm in Kowróz (Kuyavian-Pomeranian voivodeship) in soil of the very well rye complex. This study aimed at determining the effect of plowing tillage, reduced tillage and minimal tillage on the grain yield and quality of winter wheat sown after winter oilseed rape, winter wheat and maize for grain. Plowing tillage involved performing: skimming, harrowing, pre-sow plowing and cultivation with a passive pre-sow unit after harvesting oilseed rape and wheat or single plowing and cultivation with a cultivation unit after maize for grain. Reduced tillage was performed using a stubble unit, grubber and pre-sow unit after oilseed rape and wheat, and a grubber and passive pre-sowing unit after maize. Minimal tillage consisted only of disking the stubble in each position. Yield components, grain yield and its quality were usually more dependent on the previous crop than on the tillage system. The highest yield of winter wheat – 5.57 $Mg \cdot ha^{-1}$ – with favorable traits of grain quality was observed in the position after winter oilseed rape, and the lowest – 4.92 $Mg \cdot ha^{-1}$ – after maize. Abandoning plowing tillage did not have a negative effect on spike density, grain yield and grain quality. Nevertheless, tillage simplification only to disking the stubble negatively affected the yield. However, in the position after winter wheat, and particularly after winter oilseed rape, this cultivation system did not have a negative effect on grain yield, grain bulk density and protein content. After harvesting maize for grain, each simplification of plowing tillage caused a reduction in winter wheat grain yield.

Key words: minimal tillage, plowing tillage, position in crop rotation, reduced tillage

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INTRODUCTION

Winter wheat has high requirements concerning the previous crop. Largest yields with a high grain quality are obtained at a small proportion of cereals in the structure of cropland and in positions immediately after non-cereal crops [Suwara *et al*. 2007, Woźniak 2007, Bednarek et al. 2009]. Naturally improper crop rotation, in turn, leads to far-reaching, unfavorable changes in the site. Soil properties, the phytosanitary conditions of plants are worsened, and weed infestation increases [Parylak 2006, Wojciechowski and Zawieja 2007]. In favorable positions, winter wheat can be grown in soils of a poorer quality [Piekarczyk 2010]. Suitable choice of the previous crop also allows a reduction in outlays on means of production and raising their effectiveness. In the modern plant field production, a possibility of reducing tillage gains particular importance. This allows not only a decrease in production costs, but also the pressure to the environment [Tebrügge and Düring 1999, Morris *et al*. 2010]. Nevertheless, abandoning the classic, plowing tillage for zero tillage or further-reaching simplifications in the cultivation technology of winter wheat are often connected with a reduction in yield [Kordas 2009], in spite of favorable changes in soil properties [Wojciechowski *et al*. 2004]. Therefore it is essential to learn about the interaction effect of simplified tillage methods and the previous crop on the yield and grain quality of winter wheat. There are empirical premises indicating that, particularly in favorable positions, it is possible to abandon the plowing tillage without any harm to the productivity of this crop [López-Bellido *et al*. 2000, Blecharczyk *et al*. 2004].

The aim of this study, assuming the utmost importance of position in the crop rotation to the plant response to tillage, was to estimate the effect of a previous crop on the yield and grain quality of winter wheat under conditions of a plowing cultivation and its simplifications.

MATERIAL AND METHODS

Empirical research material included the results of field experiments conducted in 2010-2012 in the soil of the very good rye complex at the Agricultural Production Farm in Kowróz, in the Kuyavian-Pomeranian voivodeship, as a part of research carried out within the project „Production-economic and environmental optimization of tillage in crop rotation". This project involves the evaluation of tillage in 12 combinations the previous crop – the successive crop. This study discusses the results of winter wheat yield after different previous crops under conditions of diversified tillage methods. The results were worked out as a two-factorial experiment. The first rate factor was the previous crop: winter oilseed rape, winter wheat and maize for grain, and the second rate factor, three methods of tillage under winter wheat as the successive crop: plowing tillage, reduced tillage and minimal tillage, limited to disking. Plowing tillage in positions after oilseed rape and wheat involved skimming and harrowing, and then pre-sow plowing and cultivation with a passive pre-sow unit, whereas after maize, single plowing and cultivation with a cultivation unit. Reduced tillage was performed to the same depth as plowing tillage, but with the use of a stubble unit for post-harvest cultivation and a grubber and a passive pre-sow unit in the first two positions (after oilseed rape and wheat), and grubbering the stubble and cultivation with a unit in the third position (after maize). Minimal tillage, after each previous crop, including only

disking of the stubble. The other elements of the winter wheat cultivation regime were in accordance with the rules of moderately intensive cultivation technology of this crop. Qualified, dressed grain of the Batuta cultivar was sowed on the last ten days of September, at a density of 450 pcs·m^{-2}. Phosphorus and potassium fertilization was applied according to the soil fertility and nitrogen at a rate of 120 kg N·ha^{-1}. Mono- and dicotyledonous weeds were controlled in the autumn at the BBCH 12 stage (Legato Plus 600 SC – 1.3 dm^3·ha^{-1}). Fungal diseases were limited using fungicides (BBCH 31 – Capalo 337,5 SE 1.5 dm^3·ha^{-1} and BBCH 51 – Duett Ultra 497 SC 0.5 dm^3·ha^{-1}) twice in the spring. Before harvesting, the spike density and grain weight per spike were determined. The harvest was performed at the full maturity stage with the use of a plot combine harvester by Wintersteiger. The yield was expressed in t·ha^{-1} at 15% water content and representative samples of grain were collected. The period of the study, particularly of the spring and summer growth of winter wheat, was characterized by the course of meteorological conditions similar to the average in the region. Only the monthly total precipitations in June and July in 2011 and 2012 were almost two times higher than on average in the long-term period. Very low air temperatures in February 2012 in turn caused plant losses, which however did not disqualify the plantation in the spring.

The grain obtained from field experiments were subject to the qualitative assessment. Some physical parameters will be determined, such as: thousand grain weight (PN-68/R-74017), uniformity (BN-69/9131-02), grain bulk density (PN-ISO 7971-2), as well as the content of crude protein (with the close infrared method – Instalab 600) and wet gluten (PN-A-74043-2) and the sedimentation index (PN-ISO-5529).

The results of the study were analyzed statistically using the calculation sheet Microsoft Excel and a packet of statistic programs FR-ANALWAR-5. The analysis of variance was made in the model suitable for single two-factorial experiments, evaluating the significance of differences between treatment means with Tukey's test at $P = 0.05$, and then their synthesis from the years of the study, and the results were presented in this work. In the case of lack of the significant interaction effect of research factors on wheat traits, only their main effects were presented. Otherwise, the main effects, not essential to the results interpretation, were omitted, pointing the interaction of the previous crop and tillage system in determining the spike density, grain yield and some traits of its quality.

RESULTS AND DISCUSSION

Winter wheat yield depended both on the previous crop and the tillage system. Spike density, grain weight per spike and grain yield in the position after winter oilseed rape were significantly higher than those after cereal previous crops (Table 1). Growing winter wheat in monoculture resulted in a decrease in yield by 7.5%, and after maize by 11.7%. Such a response to cereal previous crops is confirmed by the results of many other studies. Woźniak [2006] reported that winter wheat of the cultivar Korweta grown in monoculture gave by more than 10.0% worse yields than in the position after pea. Reduction in yield in the case of prolonging monoculture to three years was still higher, i.e. reaching up to 25.0%. In turn in the study by Małecka *et al*. [2005] the mean yield

of winter wheat cultivated in 5-year monoculture was by 15.3% lower than in crop rotation.

Table 1. Effect of previous crop and tillage method on spike density, grain weight per spike and grain yield of winter wheat

Previous crop / Tillage	Spike density pcs·m^{-2}	Grain weight per spike g	Grain yield Mg·ha^{-1}
Winter oilseed rape	524	1.23	5.57
Winter wheat	500	1.18	5.15
Maize	461	1.19	4.92
$LSD_{0.05}$	17	0.02	0.31
Plowing	503	1.22	5.36
Reduced	501	1.19	5.20
Minimal	480	1.19	5.09
$LSD_{0.05}$	17	0.02	0.18

Moreover, simplification of tillage to disking after the harvesting of the previous crop had a negative effect on winter wheat yield. This resulted in a decrease in most yield components, as well as grain yield, by 5.0% in relation to the yield in treatment with classic growing. Also reduced tillage performed with the use of a stubble unit and grubber had a limiting effect on the grain weight per spike, as compared with plowing tillage.

Spike density and grain yield of winter wheat depended on mutual relationships of the position and tillage system (Table 2).

Table 2. Effect of tillage method on winter wheat yield depending on the previous crop

Tillage (B)	Previous crop (A)		
	winter oilseed rape	winter wheat	maize
	Spike density, pcs·m^{-2}		
Plowing	524	507	479
Reduced	526	500	479
Minimal	521	494	426
$LSD_{0.05}$	A/B 29	B/A 29	
	Grain yield, Mg·ha^{-1}		
Plowing	5.54	5.28	5.24
Reduced	5.55	5.14	4.90
Minimal	5.63	5.03	4.62
$LSD_{0.05}$	A/B 0.40	B/A 0.31	

After winter oilseed rape the tillage method did not differentiate those traits, whereas in the positions after cereal crops, grain yield was smaller, although not always significantly. After maize as the previous crop, winter wheat yield after performing reduced tillage was by 6.5% smaller, and after minimal tillage by 11.8% smaller than in treatments with classic cultivation. Similar results of the study of the interaction effect of crop sequence and tillage were presented by Blecharczyk *et al*. [2006]. The authors found that the winter wheat yield in direct sowing was higher after legumes than after performing the traditional tillage. In the position after spring barley, in turn, the classic, plowing tillage system had a favorable effect on wheat yield. At the same time,

similarly to Weber [2008], they indicated that a decrease in winter wheat yield due to a reduction in tillage is mostly a result of a decrease in spike density. This is confirmed in part by this study, since disking of the stubble, but only after the harvest of maize, resulted also in a decrease in spike density. The causes of this situation may be a large amount of plant residues after the harvesting of maize for grain. Disking alone did not allow their careful covering and thorough sowing of wheat. Weber [2011] however points that a high stubble does not limit the number of spikes or grain yield even at zero or minimal tillage. Nevertheless, thorough sowing the seeds is required in such a case, using a seeder for direct sowing.

The previous crop determined the physical traits of winter wheat grain to a larger extent than the tillage method (Table 3). Thousand grain weight, uniformity and grain bulk density of winter wheat grown in monoculture were slightly smaller, and after maize significantly smaller than those in the position after winter oilseed rape. Simplification of tillage to harrowing the stubble, as compared with the classic – plowing tillage system – had a negative effect only on grain uniformity.

Table 3. Effect of previous crop and tillage method on physical traits of winter wheat grain

Previous crop/ Tillage	Thousand grain weight g	Uniformity %	Bulk density $kg \cdot hl^{-1}$
Winter rape	43.9	85.1	77.9
Winter wheat	43.2	84.4	76.3
Maize	42.6	83.5	75.4
$LSD_{0.05}$	0.8	1.2	2.1
Plowing	43.6	84.7	76.8
Reduced	43.2	84.5	76.8
Minimal	42.8	83.6	76.0
$LSD_{0.05}$	ns	1.0	ns

ns – non significant differences

Stronger effect of the previous crop compared with tillage was also observed in changes in grain quality resulted from the protein and gluten content and the sedimentation index (Table 4). Grain of wheat grown after winter oilseed rape was characterized by a higher gluten content and sedimentation index value, as compared with growing in monoculture. In turn the grain of wheat from the position after maize contained the most total protein. This could resulted from a negative correlation between the protein content and grain yield, since in the yield was the lowest in this position. This is in accordance with the results of the study by Woźniak [2006]. According to this author, winter wheat grain quality depends on the previous crop, and the grain yield is negatively correlated with the protein and gluten content and positively with grain bulk density and uniformity. The author found the highest content of total protein, wet gluten and the Zeleny sedimentation index value not only in winter wheat grain grown in the position after potato and field pea, but also after wheat sown 3 times in monoculture.

The effect of the tillage method on some traits of winter wheat grain quality depended on its previous crop (Table 5). By simplification of tillage after harvesting maize to grubbering, grain with a smaller content of protein was obtained, whereas using only a disk harrow, grain with a smaller bulk density. However, it contained more protein than after the application of plowing. Carrying out the plowing tillage under

winter wheat, no significant effect of the previous crop was found on grain bulk density, and applying reduced tillage – on the total protein content in grain.

Table 4. Effect of previous crop and tillage method on total protein and wet gluten content and sedimentation index of winter wheat grain

Previous crop / Tillage	Protein content %	Gluten content %	Sedimentation index ml
Winter rape	13.0	31.1	41.0
Winter wheat	13.2	29.9	39.7
Maize	13.3	30.5	40.7
$LSD_{0.05}$	0.2	1.0	1.1
Plowing	13.2	30.7	40.5
Reduced	13.1	30.5	40.4
Minimal	13.3	30.5	40.5
$LSD_{0.05}$	0.1	ns	ns

ns – non significant differences

Table 5. Effect of tillage method on grain quality traits of winter wheat depending on the previous crop

Tillage (B)	Previous crop (A)		
	winter oilseed rape	winter wheat	maize
	Bulk density, $kg \cdot hl^{-1}$		
Plowing	77.5	76.0	77.0
Reduced	78.2	76.9	75.4
Minimal	78.0	76.1	73.8
$LSD_{0.05}$	A/B 2.7	B/A 2.2	
	Total protein content, %		
Plowing	13.0	13.3	13.3
Reduced	13.0	13.2	13.1
Minimal	13.0	13.2	13.6
$LSD_{0.05}$	A/B 0.3	B/A 0.2	

CONCLUSIONS

1. Yield and grain quality of winter wheat were to a larger extent determined by the previous crop than by the tillage method.

2. The best previous crop for obtaining a high yield with favorable traits of grain quality was winter oilseed rape, and the worst was maize cultivated for grain.

3. Reduced tillage under winter wheat did not have a negative effect on spike density, grain yield and its quality. However, simplification the plowing tillage only to disking of the stubble negatively affected the yield and yield components.

4. In position after winter wheat, and particularly after winter oilseed rape, tillage could be limited into disking of the stubble without the negative effect on grain yield, its bulk density and protein content.

5. Plowing tillage simplification after harvesting maize for grain resulted in a decrease in winter wheat grain yield.

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WPŁYW UPROSZCZEŃ UPRAWY ROLI NA PLONOWANIE I JAKOŚĆ ZIARNA PSZENICY OZIMEJ PO RÓŻNYCH PRZEDPLONACH

Streszczenie. Uwarunkowania ekonomiczno-organizacyjne i przyrodnicze współczesnej polowej produkcji roślinnej wymuszają daleko idące ograniczenia klasycznych elementów agrotechniki. W latach 2010-2012 w Zakładzie Produkcji Rolnej w Kowrozie (woj. kujawsko-pomorskie) na glebie kompleksu żytniego bardzo dobrego przeprowadzono badania, których celem było określenie wpływu orkowej, bezorkowej i minimalnej bezorkowej uprawy roli na plonowanie i jakość ziarna pszenicy ozimej wysiewanej po rzepaku ozimym, pszenicy ozimej i kukurydzy na ziarno. Uprawa orkowa polegała na wykonaniu: podorywki, bronowania, orki siewnej i uprawy biernym agregatem przedsiewnym po zbiorze rzepaku i pszenicy lub orki razówki i uprawy agregatem po kukurydzy na ziarno. Uprawę bezorkową wykonano przy użyciu agregatu ścierniskowego, grubera i agregatu przedsiewnego po rzepaku i pszenicy, a grubera i biernego agregatu przedsiewnego po kukurydzy. Minimalną uprawę roli, w każdym stanowisku, stanowiło jedynie talerzowanie ścierniska. Elementy plonowania, plon ziarna i jego jakość były na ogół bardziej zależne od przedplonu niż sposobu uprawy roli. Największy plon pszenicy ozimej – 5,57 $Mg \cdot ha^{-1}$ – o korzystnych cechach jakości ziarna stwierdzono w stanowisku po rzepaku ozimym, a najmniejszy – 4,92 $Mg \cdot ha^{-1}$ – po kukurydzy. Rezygnacja z orkowej uprawy roli nie miała negatywnego wpływu na obsadę kłosów, plon ziarna i jego jakość. Niekorzystnie na plonowanie oddziaływało natomiast ograniczenie uprawy roli tylko do talerzowania ścierniska. W stanowisku po pszenicy ozimej, a zwłaszcza rzepaku ozimym, ten sposób uprawy nie miał jednak negatywnego wpływu na plon ziarna, gęstość ziarna w stanie zsypnym i zawartość białka. Po zbiorze kukurydzy na ziarno każde uproszczenie uprawy orkowej powodowało zmniejszenie plonu ziarna pszenicy ozimej.

Słowa kluczowe: stanowisko w zmianowaniu, uprawa bezorkowa, uprawa minimalna, uprawa orkowa

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