IMPACT OF TILLAGE ON YIELD AND QUALITY TRAITS OF GRAINS OF SPRING WHEAT CULTIVARS

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Abstract. The aim of the study was to determine the influence of different tillage methods on the yield and quality characteristics of spring wheat grain. Field tests were carried out in 2013 and 2014 in the Agricultural Experimental Station of Osiny, belonging to the Institute of Soil Science and Plant Cultivation - State Research Institute in Puławy. Two tillage methods of plough tillage (conventional tillage) and ploughless tillage (simplified tillage) as well as two spring wheat cultivars – Kandela (common wheat) and SMH 87 (durum wheat), were used in the study. The grain yield and its components were evaluated. Selected qualitative traits of grains were evaluated – total protein content, amount and quality of gluten, and activity of amylolytic enzymes. The influence of the tillage method on the yield of spring wheat was variable in years. In 2013, spring wheat obtained a higher yield (by 10 %) cultivated by conventional tillage compared to ploughless tillage. In 2014 there was no impact of soil cultivation on the yield of spring wheat. Lower wheat grain yield in the conditions of ploughless tillage in comparison with the obtained conditions of conventional tillage was mainly conditioned by a lower number of ears per unit area and a lower weight of 1000 grains, and to a less extent, by a decrease in the number of grains per ear. The quality traits of grains depended to a greater degree on the wheat genotype than on the applied tillage method.

Keywords: yield, wheat, cultivars, tillage, quality.

Introduction

The main purpose of tillage is to prepare optimal conditions for the growth and development of plants. Traditional plough tillage is the most energy and labour-intensive element of agro-technology [1]. In modern crop production, an alternative to plough tillage is ploughless tillage, also known as no-plough tillage. Conservation cultivation is popular, which results in lowering the fuel consumption and working time in crop cultivation [2;3]. By simplifying tillage it is possible to improve the stability of the soil structure and increase soil ventilation by creating a stable system of large pores [4]. However, ploughless tillage leads to an increase in soil compaction, especially in the first years of its application, which may contribute to difficult plant emergence, weaker root system development, and lower yields of agricultural plants. The results of the studies on the response of cereals to tillage simplification are inconclusive. Many authors [5-8] indicate that ploughless cultivation leads to higher weed infestation and reduced cereal yields. Blecharczyk et al. [9], De Vita et al. [10] found a positive effect of ploughless tillage on winter wheat yield, whereas in the studies by Jaśkiewicz [11] and Jaśkiewicz and Jasińska [12], the tillage systems did not have an unambiguous effect on winter triticale yields. The yields depended mainly on the genotype of plants and weather conditions during the growing season, as well as the interaction between these factors. Literature contains little information on the quality of wheat grain from plough and ploughless cultivation, and the available data [13-15] are ambiguous.

The aim of the study was to determine the influence of different tillage methods on the yield and quality traits of spring wheat grain.

Materials and methods

Field tests were carried out in 2013 and 2014 in the Agricultural Experimental Station of Osiny, belonging to the Institute of Soil Science and Plant Cultivation – State Research Institute in Puławy. The experiment was established using the method of random blocks, in three replications, on soil belonging to the good wheat complex, quality class II and III b. The pseudobacterial soil was characterized by neutral pH (pH_{KCl} 6.77), and contained 19.3 mg P_2O_5 and 16.3 mg K_2O in 100 g of soil. The first research factor was 2 tillage methods, plough (conventional) and ploughless tillage (simplified tillage). In plough cultivation after harvesting the forecrop, straw was crushed, and ploughing to a depth of 10 cm with a disc aggregate, and ploughing to a depth of 20-22 cm, were performed. Then in spring, a disc aggregate, medium harrow, and tilling-and-sowing aggregate were

applied. In the simplified tillage, after grinding the straw, the subsoiling was carried out with a disc aggregate to the depth of 10 cm and the tillage was carried out with a Gruber aggregate. In spring the soil was cultivated with a disc aggregate and a medium harrow, and before sowing, a tilling-and-sowing aggregate was applied. The second research factor was 2 spring wheat cultivars: Kandela (common wheat) and SMH 87 (durum wheat). The sowing density of common wheat grains of Kandela cultivar and SMH 87 durum wheat was respectively: 5,5 and 6,5 mln·ha^{-1}. Nitrogen fertilization in the form of ammonium nitrate was applied at a dose of 50 kg N·ha^{-1} before sowing, 50 kg N·ha^{-1} in the stem formation stage, and 30 kg N·ha^{-1} in the earing stage. Phosphorus and potassium fertilization was applied in spring before wheat sowing at the rates of 70 kg P_2O_5·ha^{-1} and 105 kg K_2O·ha^{-1}, respectively. The plot area for harvesting was 45 m^2.

In the full maturity stage, the grain yield and its components (number of ears per 1 m^2, weight of 1000 grains and number of grains per ear), were determined. Grain quality assessment included determination of: total protein content by Kjeldahl method in Kjel-Foss Automatic apparatus (N·5.83) according to AACC Method 46-11.02 (AACC 2010), quantity and quality of gluten in Glutomatic 2200 apparatus according to AACC Method 38-12.02 (AACC 2010), falling number by Hagberg-Perten method in apparatus type 1400 according to AACC Method 56-81.03 [16]. All determinations were made in three replications. The results obtained were statistically elaborated in the Statistica program, using the ANOVA variance analysis method, and the differences between the averages were estimated at the level of significance of the Tukey's test $\alpha = 0.05$.

Table 1

Monthly precipitation in 2013 and 2014 compared to the long-term average 1981-2010

Month	Growing season						Long-term average 1981-2010
	2013			2014			
	decades						
	1	2	3	1	2	3	
IV	27.4	4.7	14.2	7.3	15.6	38.7	39
V	14.8	8.6	79.9	17.0	85,5	93.0	58
VI	56.6	10.2	27.4	8.8	2.2	90.3	65
VII	9.1	22.3	0.5	5.6	36.1	28.0	80

Table 2

Monthly average temperatures in 2013 and 2014 compared to the long-term average 1981-2010

Month	Growing season						Long-term average 1981-2010
	2013			2014			
	decades						
	1	2	3	1	2	3	
IV	1.6	10.9	14.0	7.9	8.6	13.1	8.7
V	15.8	17.6	13.4	11.0	13.4	19.8	14.5
VI	17.8	19.9	19.1	17.8	16.1	15.5	17.2
VII	20.5	18.1	21.2	20.0	20.3	22.1	19.3

Weather conditions were evaluated on the basis of monthly rainfall and average monthly air temperature. Data were obtained from a field automatic meteorological station, located in the experimental fields. The course of the weather conditions in the years of the study varied. The year 2013 was characterized by a lower amount of precipitation in the period from April to July (275 mm) compared to the state of 2014 (428.0 mm) (Table 1).

Total precipitation in the growing season in the years of the study was 34 and 186 mm higher, respectively, as compared to the long-term average (1981-2010). The year 2013 was moderately humid, while 2014 can be described as very humid, as the annual rainfall was 137 mm higher than normal (over 230 %), particularly heavy rainfall occurred in May. In 2014, from April to June, the air temperature was moderate and high air temperatures occurred in July during the grain ripening stage (Table 2).

Results and discussion

In 2013, the yields of spring wheat cultivars were significantly affected by the tillage method and genotype (Table 3). Higher grain yields of both common wheat and durum wheat were obtained from the treatments using the plough tillage system. Regardless of the tillage system, common wheat yields were significantly higher than the yields of durum wheat (mean: 5.33 and 4.81 $t \cdot ha^{-1}$, respectively). Weber et al. [17] and Włodek et al. [18] showed that the simplification of tillage by replacing plough tillage with procedures performed with a cultivator did not significantly affect the wheat grain yield. Lower yield level of spring wheat in simplified tillage was influenced by the weather conditions in the period of sowing and plant emergence in April and at the beginning of May. During this period there was a shortage of precipitation as well as a high air temperature. In 2014 no effect of the tillage method on spring wheat grain yield was found. There was only a tendency of higher yields of SMH 87 durum wheat in plough cultivation. In the Woźniak and Gontarz study [14], durum wheat yielded higher by 23.4-26.9 % compared to the yield on ploughless tillage. In the study by Kulig et al. [19], the lower level of wheat yields in the simplified system was determined by precipitation deficiency and high temperature in April. Studies conducted in Italy show that durum wheat in regions with low rainfall during the growing season (up to 300 mm) yielded higher in the direct sowing system than in the plough sowing system [10]. Studies with other cereal species also indicate that simplified tillage with the use of a ripper, disc harrow, or stubble cultivator and direct sowing results in lower yields of cereals than those found in plough tillage [20].

In 2013, the influence of the tillage method on the weight of 1000 grains was noted. On average, a significantly higher weight of 1000 grains was observed for wheat cultivars from treatments on which the plough tillage system was applied. The tillage system did not differentiate the weight of 1000 grains of the Kandela cultivar, whereas in the case of durum wheat SMH 87, a significant increase in the weight of 1000 grains in plough tillage was observed. In 2014, there was no impact of the tillage method on the weight of 1000 grains. In 2014, the weight of 1000 grains depended significantly on the genotype. A significantly higher value of this index, indicating higher grain plumpness, was noted for the grain of SMH 87 durum wheat than of common wheat (40.4 and 35.9 g, respectively). The results of a few studies on the influence of tillage on the weight of 1000 grains are inconclusive. In the Woźniak and Gontarz study [14], the weight of 1000 grains of durum wheat depended on the tillage method. More plump grains of durum wheat came from ploughless than plough cultivation. Smagacz [21], on the other hand, showed that this cultivation factor does not affect the weight of 1000 winter wheat grains. On the other hand, Małecka et al. [22] achieved an increase in the weight of 1000 grains of spring barley in simplified tillage and direct sowing compared to that found in the traditional system.

Regardless of the tillage system, in 2013 a significantly higher number of ears per unit area was characteristic of the common wheat cultivar Kandela. The number of ears of durum wheat SMH 87 per 1 m2 also depended on the tillage system (Table 3). A significant increase in the value of this feature, by 12.0 %, occurred in the cultivation of wheat in the plough system. In 2014, there was no effect of tillage on the number of ears per unit area. Woźniak [14] states that durum wheat responded with the decrease in the number of ears per unit of area in a ploughless tillage with herbicide in a post-harvest cultivation as compared to plough cultivation.

The results of the study on the number of grains per ear indicate that in 2013 durum wheat SMH 87 cultivated in the plough system developed a significantly higher number of grains per ear (by 12.5 %) compared to the simplified system. In 2014, a study did not reveal the impact of different tillage systems on this feature (Table 3). A Weber study [23] with winter wheat shows that in the simplified tillage, the number of grains per ear was 6.3 % lower than in the conditions of ploughless tillage. Also Małecka et al. [20] and Parylak et Pytlarz [24] showed that cultivation systems have little influence on the value of this trait in cereal crops.

Total protein content in grain of common wheat of the cultivar Kandela and durum wheat SMH 87 depended significantly on the genotype (Table 4). Both in 2013 and 2014, no influence of tillage method on the content of this component in wheat grain cultivars was found, and there were no interactions between the tillage method and genotype. In both years of the study, the grain of durum wheat SMH 87 was characterized by significantly higher total protein content than common wheat of Kandela cultivar. In 2013 the difference in the content of this component in durum wheat and common

wheat grain was 20.2 %, an even greater difference (24.1 %) was noted in 2014. In 2014, the grains of both wheat cultivars contained more protein in total, which resulted from more favourable weather conditions during the grain ripening period. Literature data show that grains of durum wheat sown in the plough system contain significantly more protein than those from ploughless cultivation [14], but this finding was not confirmed in our own studies. As in our own studies, Woźniak [15] showed no influence of the tillage method on the protein content in durum wheat grain, whereas Weber [13] showed no influence on the protein content in common wheat grain.

Table 3

Grain yield and its components of spring wheat cultivars depending on the tillage system in years 2013 and 2014

Method of tillage (A)	2013			2014		
	Cultivars (B)					
	Kandela	SMH 87	Means	Kandela	SMH 87	Means
Grain yield ($t \cdot ha^{-1}$)						
Tillage	5.84	4.83	5.34	4.86	4.50	4.68
No-tillage	5.40	4.22	4.81	4.96	4.20	4.55
Means	5.62	4.53		4.91	4.35	
$LSD_{0.05}$ for A – 0.226; B – 0.311; B/A – n.s. $LSD_{0.05}$ for A – n.s.; B – 0.422; B/A – n.s.						
1000 grain weight (g)						
Tillage	41.7	44.0	42.9	35.5	41.3	38.4
No-tillage	40.4	38.1	39.3	36.3	39.5	37.9
Means	41.1	41.1		35.9	40.4	
$LSD_{0.05}$ for A – 1.23; B – n.s.; B/A – 2.04 $LSD_{0.05}$ for A – n.s.; B – 2.32; B/A – n.s.						
Number of ears per m^2						
Tillage	552	460	506	534	552	543
No-tillage	580	405	493	538	580	559
Means	566	433		536	566	
$LSD_{0.05}$ for A – n.s.; B – 39.1; B/A – 54.0 $LSD_{0.05}$ for A – n.s.; B – n.s.; B/A – n.s.						
Number of grains per ear						
Tillage	25.4	23.9	24.7	25.2	19.7	22.5
No-tillage	23.0	27.3	25.2	25.4	18.3	21.9
Means	24.2	25.6		25.3	19.0	
$LSD_{0.05}$ for A – n.s.; B – n.s.; B/A – 3.20 $LSD_{0.05}$ for A – n.s.; B –5.01; B/A – n.s.						

n.s. – not significant ($\alpha = 0.05$)

In 2013, the tillage method and genotype interacted with the amount of washed out wet gluten (Table 4). Significantly more gluten (11.1 %) was washed from the grain of Kandela wheat cultivar, grown in a ploughless system than in a plough system. Grains of durum wheat SMH 87 from treatments on which plough and ploughless tillage were applied contained a similar amount of gluten proteins (29.3 and 29.9 %, respectively). In 2014 no significant influence of the tillage method on the amount of wet gluten washed out from both common and durum wheat grain was found. There was only a tendency to accumulate more gluten proteins in the grains of common wheat of the Kandela cultivar grown in a ploughless system. In both years of the study, significantly more gluten was washed from durum wheat grain than from common wheat. More favourable conditions for accumulation of gluten proteins in spring wheat grain, as well as total proteins, were observed in 2014. Data available in literature on the influence of tillage method on wet gluten yield in wheat grain are inconclusive. Woźniak [15] and Woźniak and Gontarz [14] demonstrated that the tillage system had a significant effect on the amount of gluten washed out from durum wheat grain. Significantly more of these proteins were found in the grains from treatments on which plough tillage was applied. Weber [13] stated that the tillage systems had no effect on the amount of gluten washed out of common wheat grain. The literature lacks data on the influence of the tillage method on the quality of gluten (IG). In our own research, the influence of this factor occurred only in 2013. Significantly higher IG value, indicating better quality of gluten, was found for wheat grains from treatments with plough tillage. The quality of gluten was also significantly influenced by the genotype. Significantly

higher IG values were observed for common wheat grain than for durum wheat (82 and 43, respectively). In 2014, the quality of gluten washed out from grain of both wheat cultivars was very even, and none of the experimental factors had any influence on the IG values.

In 2013 the amylolytic activity of spring wheat grain was significantly influenced by the tillage method and genotype (Table 4). Higher values of falling numbers, indicating lower activity of amylolytic enzymes, were recorded for the grains collected from treatments with ploughless tillage. Significantly lower activity of amylolytic enzymes was observed in durum wheat grain than in common wheat (falling numbers: 402 and 339 s, respectively). However, statistically significant differences in falling number values had no technological significance, because the grains of both wheat cultivars, regardless of the tillage method, were characterized by low activity of amylolytic enzymes – falling number > 300 s. In 2014, the method of tillage had no significant impact on the value of the falling number. The values of this parameter depended significantly only on the genotype. The grain of durum wheat SMH 87 was characterized by significantly higher amylolytic activity than the grain of common wheat of Kandela cultivar (falling numbers: 231 and 335 s, respectively). The activity of amylolytic enzymes in wheat grain SMH 87 was at a medium level, which may be a problem with obtaining appropriate quality of semolina.

Few results available in literature concerning the influence of tillage on amylolytic activity of grain, are ambiguous. Woźniak and Gontarz [14] showed that the grains of durum wheat from plough tillage treatments showed lower amylolitic activity than the grains from ploughless tillage. In another study by Woźniak [15] no significant differences in amylolytic activity of durum wheat grain from plough and ploughless tillage systems were found, but there were interactions between the tillage system and nitrogen fertilization in shaping this grain characteristic.

Table 4

Quality characteristics of grains of spring wheat cultivars depending on the cultivation system in 2013 and 2014

Method of tillage (A)	**2013**			**2014**		
	Cultivars (B)					
	Kandela	**SMH 87**	**Means**	**Kandela**	**SMH 87**	**Means**
Protein content (% s.s.)						
Tillage	11.8	14.4	13.1	12.6	16.2	14.4
No-tillage	12.2	14.9	13.6	13.0	16.4	14.7
Means	12.0	14.7		12.8	16.3	
$LSD_{0.05}$ for A – n.s.; B – 1.85; B/A – n.s. $LSD_{0.05}$ for A – n.s.; B – 2.18; B/A – n.s.						
Gluten content (%)						
Tillage	26.3	29.3	27.8	27.5	34.2	30.9
No-tillage	29.4	29.9	29.7	29.6	34.8	32.2
Means	27.9	29.4		28.6	34.5	
$LSD_{0.05}$ for A – 1.16; B – 1.21; B/A – 1.72 $LSD_{0.05}$ for A – n.s.; B – 2.63; B/A – n.s.						
Gluten index (-)						
Tillage	85	44	65	72	72	72
No-tillage	79	41	60	69	72	71
Means	82	43		71	72	
$LSD_{0.05}$ for A – 2.9; B – 6.6; B/A – n.s. $LSD_{0.05}$ for A – n.s.; B – n.s.; B/A – n.s.						
Falling number (s)						
Tillage	320	399	360	332	241	287
No-tillage	358	404	381	337	221	279
Means	339	402		335	231	
$LSD_{0.05}$ for A – 16.5; B – 25.6; B/A – n.s. $LSD_{0.05}$ for A – n.s.; B – 30.3; B/A – n.s.						

n.s. – not significant ($\alpha = 0.05$)

Conclusions

1. The influence of the tillage method on the yield of spring wheat was variable in years. In 2013, spring wheat obtained a higher yield (by 10 %) cultivated by conventional tillage compared to ploughless tillage. In 2014 there was no impact of soil cultivation on the yield of spring wheat.
2. Lower wheat grain yield in the conditions of ploughless tillage, in comparison with the obtained conditions of conventional tillage, was mainly caused by a lower number of ears per unit area and a lower weight of 1000 grains, and to a lesser extent, by a decrease in the number of grains per ear.
3. Quality characteristics of grain depended more on the wheat genotype than on the applied tillage method. The influence of the tillage method was found only in 2013 and concerned the quantity and quality of gluten and amylolytic activity of common wheat grain of the Kandela cultivar. The application of ploughless tillage resulted in an increase in gluten proteins content in grain, deterioration of gluten quality, and decrease in amylolytic enzymes activity.

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