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Effect of tillage system and nitrogen fertilization on the yield of selected spring triticale varieties

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Abstract. The aim of this study was to determine the effect of varying levels of nitrogen fertilization (0, 70, 100 kg ha^{-1}) on yield of spring triticale varieties Milewo, Mazur, Puzon and Sopot under conditions of simplified and traditional tillage. The research was conducted in 2017, 2018 and 2020 in Experimental Station of IUNG-PIB in Osiny on soil of good wheat complex. The yield level of spring triticale was affected by the course of weather conditions during the study period, tillage system, nitrogen doses and variety. Under conditions of more favorable precipitation distribution during the growing season (2017, 2018), grain yields were 32% higher than in 2020. The traditional tillage system ensured higher yields of spring triticale. The applied rate of nitrogen fertilization of 70 kg ha^{-1} proved to be sufficient for spring triticale yielding under experimental conditions. Under both tillage systems the highest yields were obtained from Sopot. Under conventional tillage Milewo and under reduced tillage Mazur yielded similarly to Sopot. The lowest yield was obtained from Puzon.

Keywords: nitrogen fertilization, varieties, yield, spring triticale, cultivation system

INTRODUCTION

In recent years, interest in no-tillage has increased (Smagacz, 2011, 2016). Tillage is one of the main factors determining the possibility of obtaining high and stable yields (Klikocka et al., 2014b; Schillinger, 2005). By simplifying tillage, it is possible to increase soil water content, improve soil structure, and improve soil aeration by creating stable large pores. However, no-till cultivation compacts the soil, can hinder emergence, and contributes to lower root system development, leading to lower grain yields.

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Good soil preparation for spring triticale promotes plant growth and development and allows the use of intensive fertilization. Cereal varieties have different responses to environmental conditions, nitrogen fertilization and tillage system (Jaśkiewicz, 2015, 2017; Smagacz, 2011, 2016).

It was assumed that spring triticale varieties under conditions of increasing nitrogen fertilization will respond differently to simplified tillage.

The aim of the study was to determine the effect of different levels of nitrogen fertilization on yields of selected spring triticale varieties under conditions of simplified and traditional tillage.

MATERIALS AND METHODS

The study was conducted in 2017, 2018 and 2020 in Experimental Station of IUNG-PIB in Osiny, Poland (51°15' N, 22°18' E) on *Luvisol* of good wheat complex of quality class IIIa and IIIb. The soil of slightly acidic reaction contained 18.1 mg K_2O, 17.3 mg P_2O_5 and 4.4 mg Mg in 100 g of soil. The content of mineral nitrogen in the soil in spring was low, amounting to 39.1 kg ha^{-1} (year 2017), 36.5 kg ha^{-1} (year 2018) and 30.2 kg ha^{-1} (year 2020). The three-factor split-plot experiment was established in 3 replications. Sowing of spring triticale in 2017 and 2018 was performed in the third decade of March and in 2020 in the first decade of April. Spring triticale was grown in crop rotation with 75% share of cereals in the sowing structure after spring wheat.

The first factor of the experiment was the tillage system – traditional (ploughing) and simplified (no-tillage). In the plough system after harvesting of the previous crop the straw was crumbled, the soil was ploughed to a depth of 8–10 cm and harrowed with a heavy harrow, then the pre-sowing ploughing was applied to a depth of 20–22 cm. In reduced tillage, after straw shredding, the soil was cultivated with a cultivator to a depth of 16–18 cm. The pre-sowing cultivation was carried out with a cultivator plus a string roller).

The second factor were nitrogen fertilization rates: 0, 70, 100 kg ha^{-1}. We applied 50% of the total nitrogen fertilization rate before sowing and another 50% at the stem shooting stage (BBCH 31) in the form of ammonium nitrate (34%).

The third factor of the experiment were spring triticale varieties: Mazur, Milewo, Puzon and Sopot.

The experimental plot area was 90 m^2. A sowing density of 4.5 mln grains per ha was used. Before sowing, 60 kg P_2O_5 and 90 kg K_2O were applied to the soil. Protection against the occurrence of diseases, weeds and pests was carried out according to the integrated method to reduce weed infestation and the perpetrators of diseases and pests after exceeding the threshold of harmfulness (Korbas, Mrówczyński, 2011). At the full maturity stage (BBCH 81), grain yield was determined from a plot with a harvest area of 75 m^2. Then it was calculated in t per ha for grain moisture content of 14%.

The results were statistically analyzed with Statystica v.10.1, using ANOVA for three factors, and the differences were estimated with Tukey's test at the significance level of $p<0.05$.

Statistical analysis of spring triticale grain yields for the years of study was performed to separate homogeneous groups and to determine the significance of differences between them.

Mean squares were calculated to determine yield variability of spring triticale varieties under varying tillage systems and nitrogen fertilization rates on average for two years (2017 and 2018) and 2020.

During the 2017 and 2020 growing seasons, the average air temperature was similar to the long-term period while in 2018 it was higher by 2.4°C (Table 1). Weather conditions in 2017 and 2018 had a positive effect on the emergence and tillering of spring triticale plants. The 2017 and 2018 growing seasons were characterized by similar rainfall totals of 326 mm and 280 mm. In both growing seasons, the amount of rainfall in June was almost twice less, while in July there was more rainfall by 43%, 45%, respectively, compared to the long-term period. The distribution of precipitation in 2020 differed from the long-term period. The exceptionally dry months were April and July. The 2020 growing season had 39% more precipitation (390 mm) compared to the long-term. The total precipitation in May and June of this year was higher than the long-term period by 56 mm and 120 mm, respectively.

Table 1. Temperature and rainfalls during growth and long-term period.

Months	2017	2018	2020	Long-term period
Temperature [°C]				
III	5.9	0.1	4.5	1.6
IV	7.5	13.6	8.5	7.8
V	13.8	17.1	11.1	13.5
VI	18.1	18.8	18.4	16.8
VII	18.6	20.6	18.6	18.5
Mean	12.8	14.0	12.2	11.6
Rainfalls [mm]				
III	33	31	25	30
IV	72	30	12	40
V	67	59	113	57
VI	34	38	190	70
VII	120	122	50	84
Sum	326	280	390	281

RESULTS AND DISCUSSION

Statistical analysis of spring triticale grain yields obtained in 2017, 2018, and 2020 was conducted. The value of *p* for 2017 and 2018 is 0.2364, which means that the average grain yields for these years are not significantly different (Table 2). Significant differences occurred between the average triticale yields obtained in 2017 and 2018 and the yields from the 2020 harvest. Therefore, the results are presented for 2020 and the average for the two years (2017 and 2018), between which no significant differences were found.

Yield levels of spring triticale in 2017 and 2018 growing seasons were significantly influenced by tillage system, nitrogen fertilization, varieties, and interactions between tillage system and nitrogen fertilization rates but in harvest year 2020 by nitrogen fertilization, varieties and interactions between tillage system and these factors (Table 3).

The average grain yield of spring triticale in the harvest years of the two-year period (2017 and 2018) was 32% higher than the yield obtained in the last year of the study (Table 4). The lower grain yield in 2020 was influenced by stress caused by lower temperatures in May compared to the long-term period and soil water deficiency in March, April (Table 2, 4).

In the two-year period (2017, 2018), spring triticale grain yields depended on cultivation system, nitrogen fertilization and variety and interactions between tillage system and nitrogen fertilization rates. Significantly higher grain yields (by 0.20 t ha^{-1}) compared to reduced tillage,

Table 2. Variation of spring triticale grain yield depending harvest year.

Harvest year		Average yield		*P-value*
Group 1	Group 2	Group 1	Group 2	
2017	2018	5.55	5.87	0.2364
2017	2020	5.55	4.32	0.0000*
2018	2020	5.87	4.32	0.0000*

* significant at $\alpha <0.05$

Table 3. Variability of grain yield of spring triticale depending on the tillage system, nitrogen fertilization and variety.

Sources of variation	Harvest years					
	2017, 2018			2020		
	MS	*F-ratio*	*P-value*	*MS*	*F-ratio*	*P-value*
Tillage system (U)	1.33	2.62	0.048*	0.31	1.83	0.183
Nitrogen fertilization (N)	137.89	271.42	0.000*	55.12	328.17	0.000*
Variety (O)	3.60	7.08	0.000*	4.11	24.46	0.000*
U x N	1.31	2.60	0.044*	0.51	3.07	0.046*
U x O	0.16	0.32	0.814	0.78	4.65	0.006*
N x O	0.65	1.29	0.266	0.21	1.22	0.311
U x N x O	0.05	0.10	0.996	0.11	0.67	0.670
Error	0.51			0.17		

*significant at α <0.05

Table 4. Grain yield of spring triticale [t ha^{-1}] depending on the tillage system, nitrogen fertilization doses and variety.

Harvest year	2017-2018	2020
Tillage system		
conventional tillage	5.81 a	4.38 a
reduced tillage	5.61 b	4.25 a
Nitrogen fertilization [kg·ha^{-1}]		
0	3.75 b	2.57 b
70	6.67 a	5.24 a
100	6.71 a	5.17 a
Varieties		
Milewo	5.31 c	4.47 b
Mazur	5.64 b	4.42 b
Puzon	5.84 ab	3.63 c
Sopot	6.05 a	4.75 a
Average for the harvest year	5.71	4.32

Values marked with the same letter do not differ significantly

Table 5. Average grain yield of spring triticale [t ha^{-1}] depending on the tillage system and nitrogen fertilization.

Tillage system	Nitrogen fertilization [kg ha^{-1}]		
	0	70	100
	Harvest year 2017 and 2018 (average)		
Conventional	3.81 c	6.85 a	6.74 a
Reduced	3.69 c	6.48 b	6.67 a
	Harvest year 2020		
Conventional	2.80 b	5.19 a	5.16 a
Reduced	2.33 c	5.23 a	5.19 a

Values marked with the same letter do not differ significantly

were recorded for the plough (conventional) tillage system. Nitrogen fertilization in doses of 70 and 100 kg ha^{-1} did not significantly vary the yield of triticale grain, but it was significantly higher by 78% as compared to the treatment without fertilization. The spring triticale variety Sopot gave the highest yield. The grain yield of Puzon variety was by 0.21 t ha^{-1}, Mazur by 0.41 t ha^{-1}, and Milewo by 0.74 t ha^{-1} lower compared to Sopot.

In 2020, the yield level of spring triticale did not depend on the tillage system (Table 4). The level of nitrogen fertilization in the amount of 70 and 100 kg ha^{-1} in the studied growing seasons had no effect on grain yield. Compared to the treatment without fertilization, it was higher on average by 2.63 t ha^{-1} (year 2020). In 2020, the yield level of Milewo and Mazur varieties was similar, but lower by, respectively, 0.28 and 0.33, t ha^{-1} than the grain yield of the variety Sopot. The variety Puzon was the lowest yielding variety in 2020.

There was an interaction between tillage system and nitrogen fertilization (Table 5). In the biennium under more uniform rainfall to the multiyear, plants had better moisture conditions, benefited from soil nutrients, and performed better under conventional tillage at a rate of 70 kg N ha^{-1}. Under these conditions, we obtained by 0.37 t ha^{-1} higher grain yield of spring triticale compared to reduced tillage. In other studies conducted in the 2010/2011 and 2013/2014 growing seasons with winter triticale varieties sown in a good site with optimal rainfall, higher yields were also provided by plough tillage (Jaśkiewicz, 2016). Research results on the response of cereals to tillage simplifications are not conclusive. Arvidsson et al. (2013) and Małecka et al. (2012) showed lower wheat yields in no-till variants. A positive effect of no-tillage on winter wheat yield was found by Blecharczyk et al. (2006). In a study by Jaśkiewicz (2016, 2017, 2018), the tillage system did not clearly differentiate the yield of winter triticale, while it depended on the variety, saturation of the crop rotation with cereals, production intensity and weather conditions.

In the presented experiment there was a tendency of spring triticale yield decrease under the influence of simplified tillage. In the growing season of 2020 on the control plot, under conditions of conventional tillage, the yield of triticale was higher by 0.47 t ha^{-1} compared to the grain yield obtained under reduced tillage (Table 6). Nitrogen fertilization in the amount of 70 and 100 kg ha^{-1} did not vary spring triticale yield under the applied tillage systems. According to the study of D'Haene et al. (2008), soil under reduced tillage impedes the development of the root

Table 6. Grain yield spring triticale [t ha^{-1}] for the year of harvest 2020 depending on tillage system and varieties.

Tillage system	Varieties			
	Mazur	Milewo	Puzon	Sopot
Conventional	4.28 b	4.74 a	3.70 c	4.81 a
Reduced	4.67 ab	4.11 b	3.56 d	4.68 ab

Values marked with the same letter do not differ significantly

system, while under drought conditions it improves water transport. The content of organic matter in the topsoil increases, although reduced tillage limits its mineralization, while soil compaction can reduce yields.

According to Jaśkiewicz (2016), triticale yield under different tillage methods depended on hydrothermal conditions during the study years. Under moderate rainfall deficiency, winter triticale plants fared better under reduced tillage, while under optimal rainfall (similar to multi-year), higher grain yields of winter triticale were provided by plough tillage. Post-harvest residues in the reduced tillage prevented evaporation of water from soil and ensured better moisture conditions for plants in dry years. Cereal plants are sensitive to periodical water shortages and react with variable grain yield (Weber, Hryńczuk, 2007). The rainfall optimum in May in 2017 and 2018 translated effectively into triticale grain yield. Favorable weather conditions during the period of formation of shoots on the plant and grains positively affected the yield of spring triticale in the analyzed biennium. According to Klikocka et al. (2014a), the application of conventional tillage and mineral fertilization (NPK) enriched with sulphur positively influences the increase of spring triticale grain yield and spike density as compared to reduced tillage.

An interaction in spring triticale yield between tillage system and varieties was found in 2020 (Table 6). Significantly higher grain yield of the varieties Sopot and Milewo compared to Mazur and Puzon was determined under the traditional tillage system. The yield level of var. Sopot was similar under both tillage systems. Under reduced tillage the grain yield of Milewo and Puzon was significantly lower by 0.63 t ha^{-1} and 0.14 t ha^{-1} respectively, compared with conventional tillage. Nevertheless, there was a tendency of spring triticale to yield higher under conventional tillage. On the other hand, Mazur variety yielded by 0.39 t ha^{-1} higher under reduced than conventional tillage.

CONCLUSIONS

1. Yield of spring triticale depended on the course of weather conditions during the study period, tillage system, nitrogen fertilization, and variety.
2. With a favourable distribution of precipitation during the growing season (2017, 2018), grain yields were by 32% higher than in 2020.
3. The use of traditional tillage system resulted in higher yields of spring triticale.
4. The applied nitrogen fertilization of 70 kg ha^{-1} proved to be sufficient for obtaining satisfactory yield of spring triticale under experimental conditions.
5. Under both tillage systems Sopot variety gave the highest yield. Under conventional tillage Milewo and under reduced tillage Mazur yielded similarly to Sopot. The lowest yield was recorded for Puzon variety.

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