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YIELD OF SOME WINTER TRITICALE CULTIVARS AS AFFECTED BY THE TILLAGE SYSTEM

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Abstract. In recent years cereals, including triticale, have been more often grown in simplified crop rotations. This study aimed to determine the effect of zero tillage and ploughing on the yield level of winter triticale cultivars Pizarro and Pigmej under conditions of 50, 75 and 100% of cereals in the structure of cropland. The study was conducted in 2010/2011 and 2013/2014 at SD IUNG – PIB in Osiny in the soil classified as the good wheat complex. Yield of winter triticale depended mainly on the course of the weather conditions and the winter triticale cultivar. Tillage systems did not exert the explicit effect on yield of winter triticale. The cultivar Pigmej gave higher yields than cv. Pizarro. At moderate rainfall deficit, plants cultivated with simplified tillage managed better, whereas at the optimal rainfalls, ploughing ensured higher grain yields of winter triticale. The highest yields of winter triticale were obtained at 50% of cereals in the structure of cropland, and the lowest under conditions of cereal monoculture.

Key words: percentage of cereals in the structure of cropland, ploughing, winter triticale cultivars, zero tillage

INTRODUCTION

In modern agriculture a trend is observed to abandon the traditional soil cultivation for different variants of zero tillage system. Zero tillage favours the idea of sustainable agriculture and is based in large measure on reducing the intensity of tillage in the crop rotation [Dzienia *et al.* 2006, Smagacz 2011]. Particular interest is focused on conservation tillage, which leads to reduction in fuel consumption and working time in plant cultivation, and at the same time, it improves physical, chemical and biological soil properties and reduces soil erosion [Holland 2004, Lal *et al.* 2007, Smagacz 2011]. Simplifying soil cultivation, one can improve the stability of soil structure, increase

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water infiltration and improve its aeration by forming a stable system of large pores [Małecka *et al.* 2012]. On the other hand, zero-tillage leads to increased soil density, it may hinder plant emergences and cause weaker development of the root system, which in consequence reduces the yield level of cultivated crops.

The results of the study concerning winter wheat response to cultivation simplifications are not explicit. Reduction in wheat yield was noted in zero-tillage cultivation variants [Małecka *et al.* 2012, Rieger *et al.* 2008], as well as no response to varied tillage systems [Anken *et al.* 2004]. However, the favourable effect of zero tillage on the yield of winter wheat was observed in the studies by Blecharczyk *et al.* [2006], Melaj *et al.* [2003]. There are few publications regarding the effect of tillage systems on triticale yield. In German experiments triticale gave similar yields after traditional and simplified tillage, whereas the species gave the highest yields when direct sowing was applied [Kornmann and Köller 1997]. The studies conducted in Poland indicate a negative effect of direct sowing on the yield of winter triticale [Małecka and Blecharczyk 2002, Starczewski *et al.* 2006]. Although many different cultivars of winter triticale are currently registered, there is no results in the literature regarding their response to tillage, especially in simplified crop rotations.

It is assumed that triticale cultivars under conditions of growing percentage of cereals in the structure of cropland will respond in different ways to simplifications in tillage.

The aim of this study was to estimate the effect of simplified tillage and ploughing on the yield level of winter triticale cultivars under conditions of 50%, 75% and 100% of cereals in the structure of cropland.

MATERIAL AND METHODS

The study was carried out in 2010/2011 and 2013/2014 at SD IUNG – PIB in Osiny (51°15' N; 22°18' E) in soil classified as the good wheat complex, soil quality class IIIa and IIIb. The soil was characterized by the pH value similar to neutral (pH_{KCL} 6.5). It contained 17.3 mg P_2O_5 and 18.1 mg K_2O in 100 g of soil and 1.08% of humus. The two-factorial experiment with the split-plot design was established in 3 replications. Sowing of winter triticale was performed from 20 to 20 of September. Experiments were established simultaneously in three fields. Winter triticale was cultivated in crop rotations with 50% of cereals in the structure of cropland (winter oilseed rape, winter wheat, faba bean, winter triticale), with 75% of cereals in the structure of cropland (spring barley, winter oilseed rape, winter wheat, winter triticale)and on the existing many years; field experiments in cereal monoculture (winter wheat, winter triticale, spring barley). The first experimental factor was the tillage system – traditional (ploughing) and simplified (zero tillage). In ploughing, after harvest of the previous crop the straw was fragmented, skimming was performed at a depth of 8-10 cm and harrowing with a heavy harrow, and then pre-sowing ploughing was applied at a depth of 20-22 cm. In simplified tillage, after fragmentation of straw the soil was cultivated with a cultivator with coulters of duckfoot type at a depth of 16-18 cm. The combined tillage unit (cultivator plus a string roller) was used for pre-sowing cultivation. The secondary factor was winter triticale cultivars: Pigmej – a short-strawed form, Pizarro – a cultivar with the traditional straw length. These cultivars derived from different breeding centres, from the Plant Breeding Strzelce – cv. Pigmej and the Plant Breeding DANKO in Chorynia – cv. Pigmej. The plot area was 45 m^2. The applied sowing density was 4 million grains per ha. Mineral fertilization was applied at the following rates per 1 ha: N – 120 kg, P – 32 kg and K – 75 kg (oxide forms should be converted to elemental). On the treatments with direct sowing, preparation Lontrel 300SL (0.5 $dm^{-3} \cdot ha^{-1}$) + ammonium sulphate in an amount of 4 $kg \cdot ha^{-1}$ was applied prior to sowing. Alister Grande 190 OD (0.8 $dm^{-3} \cdot ha^{-1}$) and Aminopielik D 450 SL (3 $dm^{-3} \cdot ha^{-1}$) were used to control weeds, and Baytan Universal (0.4$dm^{-3} \cdot 100$ kg^{-1}), Alert 375 S.C. (1 $dm^{-3} \cdot ha^{-1}$) against diseases. Additionally, in zero tillage Tilt Turbo 375 EC (1 $dm^{-3} \cdot ha^{-1}$) was applied. Plant lodging was prevented using preparations Moddus 250 EC (0.2 $dm^{-3} \cdot ha^{-1}$).

At the stage of full maturity the grain yield and its components were determined (the number of ears, the ear weight and the number of grains per ear, and 1000 grain weight).

The obtained results were statistically worked out in the software Statistica, with the method of the analysis of variance ANOVA, and found differences were estimated with Tukey's test at the significance level P = 0.05.

In order to determine the variation of winter triticale yield in the years of the study and at varied tillage systems, the values of mean squares were calculated. Such calculations were performed for particular percentages of cereals in the structure of cropland. Characterization and statistical analysis of winter triticale grain yields deriving from different percentages of cereals in the structure of cropland was performed in order to separate homogenous groups and to determine the significance of differences between them.

The weather conditions in the autumn of 2010 and 2013 had a favourable effect on emergences and tillering of winter triticale plants. In 2011 the spring was characterized by a much lower precipitation in comparison with the long-term period (Table 1).

Table 1. Temperature and rainfalls during growth and long-term period
Tabela 1. Temperatura i opady atmosferyczne w okresie wegetacji i wieloleciu

Month – Miesiąc	2010/2011	2013/2014	Long-term period – Wielolecie
Temperature – Temperatura, °C			
September – wrzesień	12.3	11.9	13.3
October – październik	5.5	9.9	8.0
November – listopad	6.5	5.6	2.8
December – grudzień	-4.6	1.8	-1.3
January – styczeń	-0.4	-2.2	-3.3
February – luty	-3.7	2.0	-2.3
March – marzec	3.0	6.7	1.6
April – kwiecień	10.7	10.7	7.8
May – maj	14.6	14.3	13.5
June – czerwiec	19.2	16.5	16.8
July – lipiec	18.7	20.9	18.5
Rainfalls – Opady, mm			
September – wrzesień	105	57	51
October – październik	8.5	5	43
November – listopad	56	47	39
December – grudzień	17	16	37
January – styczeń	28	39	31
February – luty	17	19	30
March – marzec	11	31	30
April – kwiecień	27	58	40
May – maj	60	172	57
June – czerwiec	54	93	70
July – lipiec	250	68	84

Particularly heavy rainfall deficits were noted in March and April during formation of shoots on plants and in June, that is in the period of earing. An exceptionally wet month was July with rainfalls exceeding 2.5 times the long-term mean. More optimal arrangement of temperatures and precipitation was recorded in 2014. The average air temperature in February, March and April was higher as compared with the long-term period, whereas in the other months it was similar. In the analysed year, rather favourable rainfall distribution was recorded, only in May 115 mm more rain fell, and in June there was by 33% more rainfall than in the long-term period.

RESULTS AND DISCUSSION

Statistical analysis indicated a significant differentiation of grain yields of winter triticale cultivars in individual years (Table 2). There were found high values of mean squares for the years and cultivars of winter triticale, interactions of the years with the tillage system (only for 50% of cereals in the structure of cropland), the years with the cultivars, the tillage system with the cultivars (for 75% of cereals in the structure of cropland). These indicate considerable differences in average yields of winter triticale, at particular percentages of cereals in the structure of cropland.

Table 2. Variation of the grain yield of winter triticale cultivars depending on the soil cultivation system and percentage of cereals in the structure of cropland
Tabela 2. Zmienność plonu ziarna odmian pszenżyta ozimego w zależności od systemu uprawy roli i udziału zbóż w strukturze zasiewów

Sources of variation Źródła zmienności	Percentage of cereals in the structure of cropland, % Udział zbóż w strukturze zasiewów, %		
	50	75	100
	mean square średni kwadrat	mean square średni kwadrat	mean square średni kwadrat
Years – Lata (L)	16.415*	17.081*	18.625*
Soil cultivation system (S) System uprawy	0.527	0.012	0.241
Cultivar – Odmiana (O)	12.990*	20.163*	21.897*
Interaction – interakcja:			
L × S	2.770*	0.610	0.216
L × O	1.908	3.526*	1.733
S × O	0.074	1.509*	0.706
L × S × O	0.642	0.054	0.087
Error – Błąd	0.677	0.765	0.814

* significance at P < 0.05 – istotność przy P < 0,05

The yield level was mostly determined by the year of conducting the study (L) and the winter triticale cultivars (O) (Table 2). Significant interaction was found only for L × S (S – tillage system) for 50% of cereals in the structure of cropland, as well as L × O and S × O for 75% of cereals in the structure of cropland (Table 2). No interactions, however, were found between the years of the study, tillage system and winter triticale cultivars.

The yield level of winter triticale was affected by the course of the weather conditions during the growth. Cereal plants are characterized by sensitivity to periodical water deficits and they respond with changes in grain yield [Weber and Hryńczuk

2007]. Favourable weather conditions in 2014 during the period of shoot formation on plants and grain formation had a positive effect on the grain yield of winter triticale. These were higher by 17% to 33% in relation to 2011 under conditions of 50, 75 and 100% of cereals in the structure of cropland (Table 3).

Table 3. Grain yield for the year of harvest and winter triticale cultivars depending on percentage of cereals in the structure of cropland, $Mg \cdot ha^{-1}$
Tabela 3. Plon ziarna dla roku zbioru i odmian pszenżyta ozimego w zależności od udziału zbóż w strukturze zasiewów, $Mg \cdot ha^{-1}$

Year/cultivar Rok/odmiana	Percentage of cereals in the structure of cropland, % Udział zbóż w strukturze zasiewów, %		
	50	75	100
2011	7.02b	6.50b	6.30b
2014	8.19a	8.67a	7.55a
Pizarro	7.08b	6.43b	6.25b
Pigmej	8.20a	7.73a	7.60a

The cultivar Pigmej was characterized by significantly higher grain yields as compared with the cultivar Pizarro (Table 3). The grain yield of the winter triticale cultivar Pigmej was higher by 17% in relations to cv. Pizarro at 50% of cereals in the structure of cropland and, respectively, by 20-22% at 75% and 100% of cereals in the structure of cropland. At 50% of cereals in the structure of cropland, interactions of winter triticale with the years and tillage systems (Fig. 1) and the years and cultivars (Fig. 2) was found.

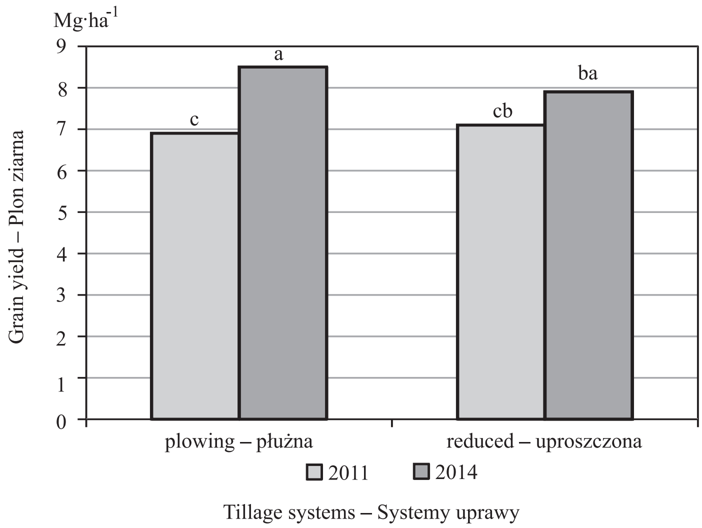

Fig. 1 Winter triticale grain yield depending on the year of harvest and cultivation system at 50% of cereals in the structure of cropland
Rys. 1. Plon ziarna pszenżyta ozimego w zależności od roku zbioru i systemu uprawy przy 50% udziale zbóż w strukturze zasiewów

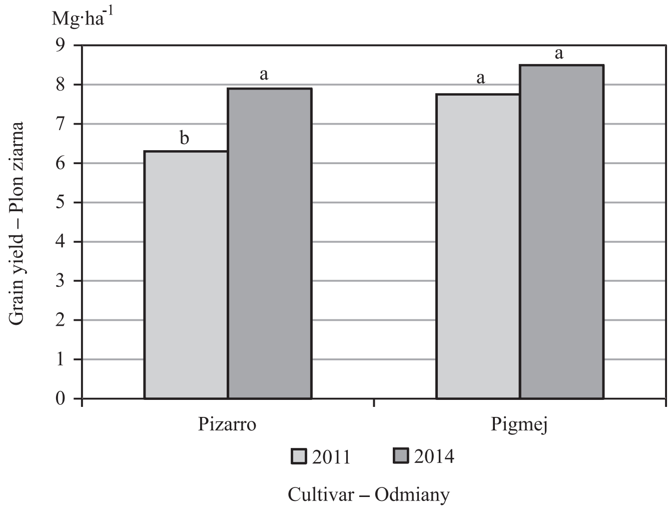

Fig. 2. Grain yield of winter triticale cultivars depending on the year of harvest at 50% of cereals in the structure of cropland
Rys. 2. Plon ziarna odmian pszenżyta ozimego w zależności od roku zbioru przy 50% udziale zbóż w strukturze zasiewów

In 2014 winter triticale grain yield as compared with 2011 under conditions of ploughing was higher by 24% in relation to ploughing and by 19% in relation to simplified tillage. In 2011, under conditions of lower precipitation in relations to the long-term period, triticale plants manager slightly better at simplified tillage than at ploughing. Post-harvest residue prevented water evaporation from the soil and provided better moisture conditions for plants. Hence a similar level of triticale yield in both tillage systems in 2011. Nevertheless, in 2014 the yield of winter triticale grain obtained under conditions of ploughing was higher by 9% as compared with simplified tillage (Fig. 1). Generally the yield level of winter triticale in 2011 was lower by 1.17 $Mg \cdot ha^{-1}$ as compared with the grain yield obtained in 2014. In the study by Małecka *et al.* [2012] the triticale cultivar Fidelio responded negatively to zero-tillage in comparison with ploughing. The average grain yield of winter triticale from treatments of simplified tillage was lower by 24% in relation to the traditional tillage system. In German experiments similar yield of winter triticale was obtained in the traditional and simplified tillage [Kornmann and Köller 1997]. The study by Starczewski *et al.* [2004] indicates a negative effect of Surface cultivation on winter triticale yield. Starczewski *et al.* [2006] in turn reported that the weather conditions in individual years differentiated grain yields of winter triticale much more than the method of pre-sowing soil preparation. In the present study, the triticale yield largely depended on the weather conditions during the growth. In the study by Pabin *et al.* [2008], irrespective of the cultivation measures applied, the occurrence of draught was the main factor limiting the plant yield. At the moderate rainfall deficit, the plants cultivated with the simplified system gave significantly lower yields.

The cultivar Pizarro showed a considerable differentiation in yield in the years of the study (Fig. 2). In 2011, when there were rainfall deficits in the spring and during grain formation, cv. Pizarro gave yields lower by 25% than in 2014 at the optimal weather conditions. The cultivar Pigmej showed a higher yield stability.

At 75% of cereals in the structure of cropland, the interaction of the grain yield with the years and winter triticale cultivars (Fig. 3) and tillage systems and winter triticale cultivars (Fig. 4) were observed.

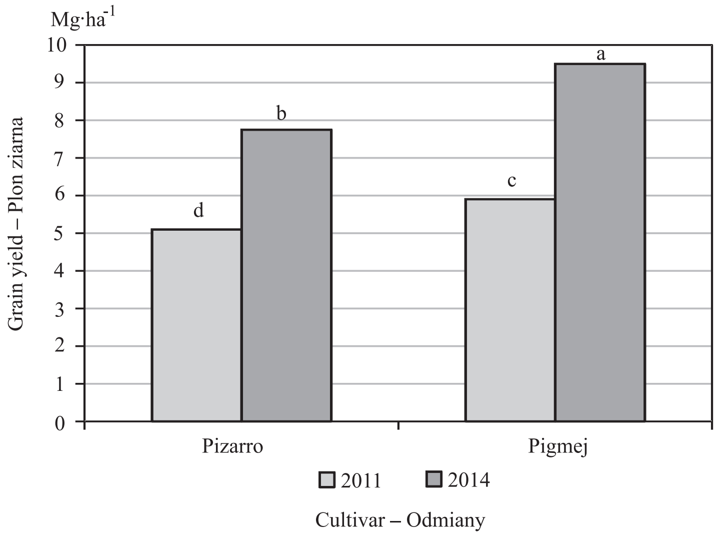

Fig. 3. Grain yield of winter triticale cultivars depending on the year of harvest at 75% of cereals in the structure of cropland

Rys. 3. Plon ziarna odmian pszenżyta ozimego w zależności od roku zbioru przy 75% udziale zbóż w strukturze zasiewów

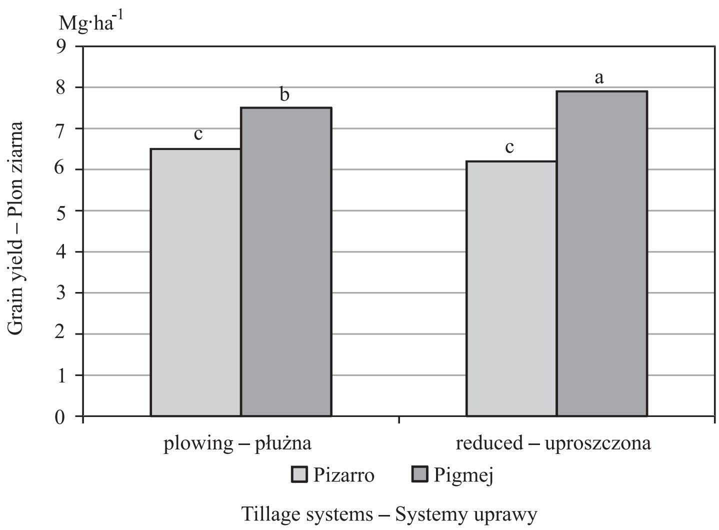

Fig. 4. Grain yield of winter triticale cultivars depending on the cultivation system at 75% of cereals in the structure of cropland

Rys. 4. Plon ziarna odmian pszenżyta ozimego w zależności od systemu uprawy przy 75% udziale zbóż w strukturze zasiewów

In 2011 cv. Pizarro gave yields loer by 15% than cv. Pigmej. However, in 2014 the grain yield of cv. Pigmej in relation to 2011 was higher by 63% and by 24% in relations to the grain yield of cv. Pizarro in 2014 (Fig. 3).

At the applied tillage systems, cv. Pigmej gave significantly higher yields (Fig. 4). In simplified cultivation, its grain yield was higher by 0.38 $Mg \cdot ha^{-1}$ than under conditions of ploughing.

Under conditions of cereal monoculture no interactions were found between the studied factors (Table 2). Weber and Hryńczuk [2004], Blecharczyk *et al.* [2006] as well as Parylak and Pytlarz [2013] showed the risk of a reduction in wheat yield due to the application of simplifications in tillage after cereals as previous crops. Małecka and Blecharczyk [2002] found a significant reduction in the triticale grain yield after introduction of simplifications, whereas Kelley and Sweeney [2005] after the application of direct sowing technology observed only 5% reduction. In the present study, tillage systems did not differentiate the yield of winter triticale cultivars under conditions of cereal monoculture. Similar to the study by Orzech *et al.* [2002], no effect of the tillage system on the number of ears per 1 m^2 and the number of grains per ear was proved.

The statistical analysis of winter triticale grain yields obtained from treatments with 50, 75 and 100% of cereals in the structure of cropland was performed in order to separate homogenous groups. This shows that the *p* value at 50 and 75% of cereals in the structure of cropland amounts to 0.096, therefore we find that the average grain yields for those two groups do not differ significantly (Table 4). It was similar at 75 and 100% of cereals in the structure of cropland, whereas significant differences between average triticale yields were found at 50% and 100% of cereals in the structure of cropland.

Table 4. Variation of winter triticale grain yield depending on percentage of cereals in the structure of cropland (mean from years)
Tabela 4. Zmienność plonu ziarna pszenżyta ozimego w zależności od udziału zbóż w strukturze zasiewów (średnia z lat)

Percentage of cereals in the structure of cropland, % Udział zbóż w strukturze zasiewów, %		Mean yield – Średni plon		*P-value*
Group 1 – Grupa 1	Group 2 – Grupa 2	Group 1 – Grupa 1	Group 2 – Grupa 2	
50	75	7.61	7.08	0.096
50	100	7.61	6.93	0.007*
75	100	7.08	6.93	0.630

* significance at $P < 0.05$ – istotność przy $P < 0,05$

The statistical characteristic indicates that the winter triticale grain yields at 50% and 100% of cereals in the structure of cropland are characterized by relatively low variation coefficients (V = 15.1% and 18.4%) as compared with the grain yields of winter triticale grain yields obtained at 75% of cereals in the structure of cropland (Table 5).

Table 5. Some statistical characteristics for grain yield of winter triticale depending on proportion of cereals in the structure of cropland (mean from years)
Tabela 5. Wybrane charakterystyki statystyczne dla plonu ziarna pszenżyta ozimego w zależności od udziału zbóż w strukturze zasiewów (średnia z lat)

Parameter – Parametr	Percentage of cereals in the structure of cropland, % Udział zbóż w strukturze zasiewów, %		
	50	75	100
Mean – Średnia, $Mg \cdot ha^{-1}$	7.61	7.08	6.93
Minimal value – Wartość minimalna, $Mg \cdot ha^{-1}$	5.47	4.58	4.57
Maximal value – Wartość maksymalna, $Mg \cdot ha^{-1}$	9.84	10.27	9.09
Variation coefficient – Współczynnik zmienności *V*, %	15.1	25.8	18.4

No significant difference was found between the tillage systems, therefore only grain yield components for the cereal percentage in the structure of cropland were given (Table 6).

The cultivar Pizarro was characterized by a higher number of ears per area unit and 1000 grain weight as compared with the cultivar Pigmej. Plants of cv. Pizarro were more tillered than the plants of cv. Pigmej. Therefore, cv. Pizarro had a lower ear productivity, i.e. the number of grains per ear was lower by 22-43% and the grain weight per ear was lower by 18-25% as compared with cv. Pigmej.

Bertholdsson and Stoy [1995] and Podolska [2004] explain this with varied needs of the genotype which changes values of yield components under conditions of limited access of specimens to light, resulting from increasing number of ears per area unit.

Table 6. Yield components of winter triticale cultivars at different proportions of cereals in the structure of cropland (mean from years)
Tabela 6. Składowe plonu odmian pszenżyta ozimego przy różnym udziale zbóż w strukturze zasiewów (średnia z lat)

Yield components Składowe plonu	Percentage of cereals in the structure of cropland, % Udział zbóż w strukturze zasiewów, %					
	50		75		100	
	Cultivar – Odmiana					
	Pizarro	Pigmej	Pizarro	Pigmej	Pizarro	Pigmej
Number of ears, $no. \cdot m^{-1}$ Liczba kłosów, $szt. \cdot m^{-1}$	576a	546b	568a	521b	577a	561a
Number of grains per ear, no. Liczba ziaren z kłosa, szt.	29b	37a	25b	44a	25b	33a
Grain weight per ear, g Masa ziarna z kłosa, g	1.22b	1.48a	1.12b	1.50a	1.08b	1.35a
1000 grain weight, g Masa 1000 ziaren, g	41.4a	40.3b	44.4a	42.2b	42.8a	40.9b

CONCLUSIONS

1. Yield of winter triticale depended mostly on the course of the weather conditions and the winter triticale cultivar. Tillage systems did not have an explicit effect on yields of both winter triticale cultivars.

2. Under conditions of 50% of cereals in the structure of cropland at moderate rainfall deficit, triticale gave higher yields when simplified cultivation was applied, whereas at the optimal rainfalls, higher grain yields of winter triticale were ensured by ploughing.

3. The highest grain yields of winter triticale were obtained in crop rotation with 50% of cereals in the structure of cropland, and the lowest in cereal monoculture.

4. In both tillage systems cv. Pigmej gave higher yields than cv. Pizarro.

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PLONOWANIE WYBRANYCH ODMIAN PSZENŻYTA OZIMEGO W ZALEŻNOŚCI OD SYSTEMU UPRAWY ROLI

Streszczenie. W ostatnich latach coraz częściej uprawia się zboża, w tym pszenżyto, w płodozmianach uproszczonych. Celem badań było określenie wpływu uprawy bezorkowej i płużnej na poziom plonowania odmiany Pizarro i Pigmej pszenżyta ozimego w warunkach 50, 75 i 100% udziału zbóż w strukturze zasiewów. Badania przeprowadzono w latach 2010/2011 i 2013/2014 w SD IUNG – PIB w Osinach na glebie zaliczanej do kompleksu pszennego dobrego. Plonowanie pszenżyta ozimego zależało głównie od przebiegu warunków pogodowych oraz odmiany pszenżyta ozimego. Systemy uprawy roli nie wywarły jednoznacznego wpływu na plonowanie pszenżyta ozimego. Wyżej plonowała odmiana Pigmej niż odmiana Pizarro. Przy umiarkowanym niedoborze opadów lepiej radziły sobie rośliny w uprawie uproszczonej, natomiast przy optymalnych opadach wyższe plony ziarna pszenżyta ozimego zapewniła uprawa płużna. Najwyższe plony pszenżyta ozimego uzyskano przy 50% udziale zbóż w strukturze zasiewów, a najniższe w warunkach monokultury zbożowej.

Słowa kluczowe: odmiany pszenżyta ozimego, udział zbóż w strukturze zasiewów, uprawa bezorkowa, uprawa płużna

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