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VARIABILITY OF WINTER WHEAT CULTIVARS YIELD DEPENDING ON TILLAGE SYSTEMS AND MANAGEMENT METHOD OF STUBBLE OF PRECEDING CROP*

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Abstract. The aim of this investigation was assessment of variability of winter wheat cultivars yield under variable stubble height conditions and different tillage systems. The study was carried out during 2009-2011 and it was localized on good rye complex. The first factor was stubble height: a) low stubble (10 cm), b) high stubble (40 cm). Within the second factor three systems of tillage were evaluated: a) conventional tillage, b) reduced tillage, c) no- tillage. The third experimental factor was winter wheat cultivar: a) Mewa, b) Rapsodia, c) Legenda. Plowless tillage contribute to decrease wheat yield in comparison with conventional tillage applied after cereals. In treatments with high and low stubble the yield of winter wheat cultivars Legenda and Rapsodia was the highest while Mewa gave the lowest yield. Yield stability under high stubble conditions in plough and simplified tillage was much lower than under low stubble conditions.

Key words: cultivars, no-tillage, reduced tillage, stubble height, winter wheat, yield stability

INTRODUCTION

The basic factor limiting yield under conditions of no-tillage or reduced tillage is the lack of diversified crop rotation. Homogenous cereal crop rotations or cereal monoculture cause a decrease in yield as a result of increased pressure of weeds, diseases, pests and a substantial amount of post-harvest residue on the soil surface [Williams *et al*. 2009]. Plant yields in zero-tillage system under conditions of large amounts of mulch can be comparable with the results obtained in conventional tillage, particularly in years with limited total precipitation. Layer of post-harvest residues on the field surface reduces unproductive evaporation of water and contributes to more

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stable yields, irrespective of climatic changes during the plant growth [Halvorson *et al*. 2002, Pabin *et al*. 2007, Sainju *et al*. 2009]. However, considerable amounts of post-harvest residue create high difficulty in maintaining precise sowing depth. Classic drills for zero tillage equipped with disc drilling units have problems with cutting a layer of straw. The straw brushers applied fulfill their purpose under conditions of the successive crop. Whereas in the case of cereals, they move cut straw stems to the neighboring rows of sowing. Disc drilling units press cut straw stems into the bottom of sowing furrow sowing cereal seeds on uncut layer of organic matter [Köller and Linke 2001]. This effect is referred to as "hairpinning" in the literature. Lack of direct contact of seeds with soil results in uneven emergences and drying of germinating plants. Decreased number of plants per area unit is the main cause of lower cereal yields under conditions of no tillage. Problem of improving its effectiveness in cereal crop rotations can be eliminated to a great extent by sowing seeds of the successive crop in high stubble. Quality of sowing with drills for no-tillage can be higher, since long straw is arranged along the drive the drill and there is no excessive concentration of post-harvest residue in the sowing furrow [Köller and Linke 2001]. Also harvesting of the preceding crop involving high cut of straw contributes to considerable reduction in harvest costs. Studies from the area of Germany [Pfeiffer and Mehner 2006, Kratzmann and Reckleben 2006, Vosshenrich *et al*. 2006], proved the following advantages of that system: increased efficiency of the combine unit by 40-100%, longer time of harvesting (1 hour in the morning; 2 hours in the evening), reducing seed moisture by 1-4%, lower fuel consumption by 5-7 $dm^3 \cdot ha^{-1}$, smaller load of working parts of the combine unit, lower seed losses by 3-4%, costs reduced by 30-70 $euro \cdot ha^{-1}$. So far there have been no reports concerning variability analysis of yields of successive crop cultivars under conditions of different variants of high stubble cultivation. Initial results of the study indicate that cultivars may show varied responses in the newly created environment. [Weber 2010, 2011]. The aim of this study was to analyze yields and variability of yield of several winter wheat cultivars using different tillage systems under conditions of high and low stubble of a preceding crop.

MATERIAL AND METHODS

The study was carried out over 2009-2011in the area of the commune Jelcz--Laskowice (51°1' N; 17°21' E) on the soil of the good rye complex. The three-factorial experiment was established in the split-split-plot design in 4 replications, on lessive soil – heavy loamy sand depositing on light loam. Preceding crop was spring wheat. The following experimental factors were examined: factor I – stubble height: a) low stubble (10 cm), b) high stubble (40 cm); factor II – tillage systems: a) conventional tillage (plowing), b) reduced tillage, c) no-tillage (with the use of direct sowing) (Table 1); factor III – winter wheat cultivars: a) Mewa, b) Rapsodia, c) Legenda. The above-mentioned cultivars of winter wheat differ substantially in respect of technological seed quality and are among those most often cultivated in the area of Lower Silesia.

Diversified weather conditions in individual years of the study were presented in Table 2.

Table 1. Tillage systems
Tabela 1. Systemy uprawy roli

Tillage system Uprawa roli	Cultivation measures – Zabiegi uprawowe
Conventional tillage Tradycyjna (płużna)	post-harvest cultivation – grubber at 15 cm + string roller – uprawa pożniwna – gruber na głębokość 15 cm + wał strunowy basic land preparation – ploughing to the depth of 25 cm + harrow – uprawa podstawowa – orka pługiem na głębokość 25 cm + brona pre-plant tillage – combined tillage unit (cultivator + string roller) – uprawa przedsiewna – agregat uprawowy (kultywator + wał strunowy)
Reduced tillage Uproszczona (uprawa bezpłużna)	post-harvest cultivation – gruber at 15 cm + string roller – uprawa pożniwna – kultywator z redlicami typu gęsiostopka pre-plant tillage – combined tillage unit (cultivator + string roller) – uprawa przedsiewna – agregat uprawowy (kultywator + wał strunowy)
No-tillage Zerowa (siew bezpośredni)	direct sowing – Great Plains drill with a double disc drilling unit and a cultivating disc – siew bezpośredni – siewnik Great Plains z podwójnymi talerzowymi redlicami wysiewającymi i krojem tarczowym przed redlicami

Table 2. Amounts of precipitation [mm] and mean twenty-four hours air temperature [°C] during the growth
Tabela 2. Zmienność opadów [mm] i średniej temperatury [°C] w trakcie wegetacji

Specification Wyszczególnienie	Month – Miesiąc						Term – Okres March-August marzec – sierpień
	March marzec	April kwiecień	May maj	June czerwiec	July lipiec	August sierpień	
Precipitation – Opady							
Multi-years mean Średnie z wielolecia	30.3	36.1	63.7	70.8	77.4	69.9	348.2
2009	60.9	24.7	65.7	180.8	145.1	50.4	527.6
2010	44.0	50.6	136.8	49.4	124.4	83.4	488.6
2011	25.6	25.6	41.1	63.9	112.4	76.6	345.2
Temperature – Temperatura							
Multi-years mean Średnie z wielolecia	3.1	8.0	13.3	16.6	17.8	17.3	76.1
2009	3.8	11.3	13.8	15.6	19.5	18.9	82.9
2010	3.4	8.6	12.4	17.5	21.0	18.9	81.8
2011	4.4	11.4	14.4	18.8	17.9	19.1	86.0

Reduced tillage was limited to scarifying the top soil layer at a depth of 15 cm by a cultivator. The plot area was 30 m^2. In autumn in the whole area of the experiment the fertilizer Polifoska 6 was applied in the amount of 350 $kg \cdot ha^{-1}$. In spring during the start of growth, plants were fertilized with ammonium nitrate 34% (70 $kg\ N \cdot ha^{-1}$). At the shooting stage, additional fertilization with nitrogen was conducted in the amount of 23 $kg\ N \cdot ha^{-1}$. On plots for no tillage system Roundup was applied before sowing plants in the amount of 4 $dm^3 \cdot ha^{-1}$. At the two-leaf stage of wheat the herbicide Maraton was used on all the tillage variants in the amount of 4 $dm^3 \cdot ha^{-1}$. Statistical calculations were made using the program AWAR, developed by the Institute of Applications of Mathematics and Computer Science IUNG in Puławy. Evaluation of significance of mean treatment differences was carried out using Tukey's test.

Yield stability of wheat cultivars was evaluated using the classic mixed model of variance derived by Shukla [1972]. Mixed model of analysis of variance by Shukla has the form:

$$\text{mean } y_{ij} = m + g_i + e_j + ge_{ij} + \text{śr.}e_{ij}$$

where:

- mean y_{ij} – mean for i-th genotype in j-th environment,
- m – general mean,
- g_i – constant main effect for i-th genotype,
- e_j – random main effect of j-th environment,
- ge_{ij} – random effect of interaction of i-th genotype with j-th environment,
- śr.e_{ij} – experimental error for mean y_{ij}.

Shukla gave an approximate F test for testing zero hypothesis about the lack of variability in analyzed environments: $F_{ge(i)} = \sigma^2_i / MS_e$; where σ^2_i is the estimator of stability variance, MS_e is the mean square of experimental error for the given mean y_{ij}.

RESULTS

Analysis of variance showed a significant variability of yield of the studied cultivars in individual years of the study. Significant interactions of the years with tillage systems and the years with cultivars confirm a large impact of the weather conditions on diversity of yield of cultivars in individual tillage variants (Table 2). In contrast, the yields of winter wheat, both on plots with high stubble and on those with low stubble, did not differ significantly (Table 3).

Table 3. Yields of winter wheat as affected by tillage system and height of stubble [$Mg \cdot ha^{-1}$] (interaction stubble height x tillage systems)
Tabela 3. Plony pszenicy ozimej [$Mg \cdot ha^{-1}$] w zależności od systemu uprawy i wysokości ścierni (interakcja wysokość ścierni x systemy uprawy)

Low stubble – Niska ścierń				High stubble – Wysoka ścierń			
tillage system – system uprawy			mean średnia	tillage system – system uprawy			mean średnia
no-tillage zerowa	reduced tillage bezpłużna	conventional tillage tradycyjna		no-tillage zerowa	reduced tillage bezpłużna	conventional tillage tradycyjna	
4.54 ab	4.69 a	4.89 a	4.71 A	4.22 b	4.78 a	5.14 a	4.71 A

homogenous groups were marked with letters – literami oznaczono grupy jednorodne

Considerable differences in wheat yield were proved between tillage systems (Table 4). Under conditions of no tillage the cultivars were characterized by lower yields as compared with conventional and reduced tillage systems. Insignificant value of interactions of cultivars with tillage systems indicates a similar response of cultivars in respect of yield, irrespective of cultivation intensity. Legenda and Rapsodia were characterized by higher yields as compared with the cultivar Mewa, which gave lower yields in each tillage system. Significant value of interaction between stubble height and yields of winter wheat cultivars is notable, which indicates their variable responses to the analyzed experimental factor (Table 5). Under conditions of low stubble, Rapsodia was characterized by slightly higher yields as compared with the other cultivars. In contrast, the environment of high stubble favored insignificantly higher yield of the cultivar Legenda. Values of approximate test by F Shukla determining variability of yield of cultivars during three years showed a considerable diversification depending on the cultivar and stubble height (Table 6). However, it may be noticed that yield stability of cultivars under conditions of high stubble in conventional tillage and reduced tillage was substantially lower than when stubble was low. Reverse relationship was found using no-tillage. Considerably higher values of F test under conditions of low stubble for no tillage show significantly lower yield stability of examined winter wheat cultivars.

Table 4. Yields of winter wheat cultivars as affected by tillage system and cultivars [$Mg \cdot ha^{-1}$] (interaction cultivars x tillage systems)
Tabela 4. Plony odmian pszenicy ozimej [$Mg \cdot ha^{-1}$] w zależności od systemu uprawy i odmiany (interakcja odmiany x systemy uprawy)

Cultivar Odmiana	Tillage system – System uprawy			Mean Średnia
	conventional tillage tradycyjna	reduced tillage bezpłużna	no-tillage zerowa	
Legenda	5.06	4.82	4.46	4.78 A
Mewa	4.80	4.57	4.38	4.58 B
Rapsodia	4.99	4.81	4.52	4.77 AB
Mean – Średnia	4.95 A	4.73 AB	4.45 B	4.71

homogenous groups were marked with letters – literami oznaczono grupy jednorodne

Table 5. Yields of winter wheat cultivars as affected by cultivars and height of stubble [$Mg \cdot ha^{-1}$] (interaction cultivars x stubble height)
Tabela 5. Plony odmian pszenicy ozimej [$Mg \cdot ha^{-1}$] w zależności od odmiany i wysokości ścierni (interakcja odmiany x wysokość ścierni)

Cultivar – Odmiana	Stubble height – Wysokość ścierni		Mean – Średnia
	low – niska	high – wysoka	
Legenda	4.69 ab	4.87 a	4.78 A
Mewa	4.64 b	4.53 b	4.58 B
Rapsodia	4.80 a	4.75 ab	4.77 AB
Mean – Średnia	4.71 A	4.71 A	4.71

homogenous groups were marked with letters – literami oznaczono grupy jednorodne

Table 6. Assessment of yield stability of winter wheat cultivars – F test for interaction years x varieties
Tabela 6. Ocena stabilności plonowania odmian pszenicy ozimej – test F dla interakcji lata x odmiany

Cultivar Odmiana	Conventional tillage Uprawa tradycyjna	Reduced tillage Uprawa bezpłużna	No-tillage Uprawa zerowa
High stubble – Wysoka ścierń			
Legenda	19.05**	4.73**	2.39
Mewa	33.90**	3.55*	1.84
Rapsodia	6.71**	5.14**	5.36*
Low stubble – Niska ścierń			
Legenda	0.08	0.67	51.25**
Mewa	5.52*	1.00	22.62**
Rapsodia	2.18	1.55	15.42**

* significance at P = 0.05 – istotne na poziomie P = 0,05
** significance at P = 0.01 – istotne na poziomie P = 0,01

DISCUSSION

One of the reasons for lower yields under conditions of reduced tillage is considerable accumulation of post-harvest residue at the top layers of soil in reduced tillage or no-tillage. Straw, in comparison with other fertilizers, contains much organic carbon, whereas little nitrogen. Introduction into the soil organic matter poor in nitrogen results in biological fixing of N in the biomass of microorganisms. Sowings of winter cereals are thinned out, which leads to an increased weed infestation of plantations and consequently, to a decrease in yield. Application of an additional nitrogen rate on stubble can reduce the unfavorable C:N ratio and cause an increase in yields of the successive crop [Król and Smagacz 208]. Schillinger *et al*. [2010] report that wheat grain yield at properly managed harvest residue can be higher than in the case of their plowing in or burning.

Although burning stubble facilitates tillage under the successive crop, it causes an increase in soil density, decreases stability of soil aggregates and disturbs continuation of soil macropores [Zhang *et al*. 2007]. Results of the present study indicate that yield of winter wheat cultivars under conditions of no tillage and high stubble is more balanced in the years than in treatments when stubble is low. Conventional or reduced tillage with high stubble is usually very difficult [Liu *et al*. 2007]. The results of the study showed variable reaction of cultivars to stubble height and tillage systems. Under conditions of high stubble, Legenda gave higher yields than the other cultivars. Probably an increased stem length of this cultivar, as compared with the others, contributed to high yields under conditions of high stubble. Cultivars of field crops are characterized by high diversification of yield at using reduced tillage system [Weber 2010]. Highly diversified response of field crop cultivars to changes in the soil environment caused by no-tillage or reduced tillage force breeders to create new cultivars which are characterized by good adaptation to unfavourable environmental conditions. New cultivars should be characterized by fast growth at initial developmental stages, better utilization of available water during the growth and increased resistance to pathogens and pests colonizing post-harvest residue [Joshi *et al*. 2007].

CONCLUSIONS

1. Seed yields of winter wheat cultivars did not depend on the stubble height. Both after high and low stubble higher seed yields were obtained from the cultivars Legenda and Rapsodia than from the cultivar Mewa.

2. During the first three years of using no-tillage system, seed yields of winter wheat cultivars were significantly lower than those obtained after conventional tillage.

3. Yield stability of cultivars under conditions of high stubble in conventional and reduced tillage was considerably lower than when stubble was low cut. The reverse relationship was found at the use of no-tillage.

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ZMIENNOŚĆ PLONOWANIA WYBRANYCH ODMIAN PSZENICY OZIMEJ W ZALEŻNOŚCI OD SYSTEMU UPRAWY I SPOSOBU ZAGOSPODAROWANIA RESZTEK POŻNIWNYCH PRZEDPLONU

Streszczenie. Celem badań realizowanych w latach 2009-2011 była analiza plonów i zmienności plonowania kilku odmian pszenicy ozimej przy stosowaniu zróżnicowanych systemów uprawy roli w warunkach niskiej i wysokiej ścierni przedplonu. Badano następujące czynniki doświadczenia: I – wysokość ścierni: a) niska, b) wysoka; II – systemy uprawy roli: a) tradycyjna, b) bezpłużna c) zerowa; III – odmiany pszenicy ozimej.

Przy pozostawieniu wysokiej i niskiej ścierni wysokie plony wydały odmiany Legenda i Rapsodia, natomiast istotnie niższe odmiana Mewa. Plony odmian w warunkach uprawy zerowej były istotnie niższe w stosunku do uzyskanych w uprawie konwencjonalnej. Stabilność plonowania odmian w warunkach wysokiej ścierni w uprawie płużnej i bezpłużnej była znacznie mniejsza niż tam, gdzie ścierń była przycięta nisko.

Słowa kluczowe: pszenica ozima, stabilność plonowania, uprawa bezorkowa, uprawa zerowa, wysokość ścierni

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