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THE EFFECT OF SOIL TILLAGE SYSTEM AND NITROGEN FERTILIZATION ON BAKING QUALITY OF WINTER SPELT CULTIVARS

WPŁYW SYSTEMU UPRAWY ROLI I NAWOŻENIA AZOTEM NA WARTOŚĆ WYPIEKOWĄ ZIARNA ODMIAN ORKISZU OZIMEGO

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Streszczenie. Materiał do badań stanowiły próbki ziarna uzyskane z doświadczenia prowadzonego w latach 2009–2011 w Rolniczej Stacji Doświadczalnej w Lipniku k. Szczecina. W doświadczeniu 3-czynnikowym porównano: 2 systemy uprawy roli (uproszczony i konwencjonalny), 4 poziomy nawożenia azotem (0, 50, 100 i 150 kg N · ha^{-1}) oraz 3 odmiany orkiszu ozimego ('Franckenkorn', 'Oberkulmer Rothkorn', 'STH 12'). Oznaczono cechy jakościowe i farinograficzne ziarna, mąki i ciasta. Systemy uprawy roli (uproszczony i konwencjonalny) nie miały wpływu na jakość ziarna i mąki. Istotną różnicę stwierdzono jedynie w przypadku zawartości glutenu. Nawożenie azotem wpłynęło na badane cech jakościowe w istotny sposób. Optymalną dawką azotu okazała się dawka 100 kg N · ha^{-1}. Jedynie w przypadku indeksu glutenu i rozpływalności glutenu największe wartości odnotowano w wariancie kontrolnym bez nawożenia azotem. Nie stwierdzono interakcji pomiędzy nawożeniem a odmianami, z wyjątkiem indeksu glutenu. Średnie wartości tej cechy dla odmian 'Oberkulmer Rothkorn' i 'Franckenkorn' były na tym samym poziomie, niezależnie od dawki azotu. Indeks glutenu dla odmiany 'STH 12' zmniejszał się istotnie w miarę wzrostu dawki azotu. Wyniki badań farinograficznych wskazują, że odmianą najlepszej jakości była odmiana 'Oberkulmer Rothkorn,' a najgorszej jakości – 'Franckenkorn'.

Key words: soil tillage systems, nitrogen fertilization, spelt wheat, cultivars, baking quality.
Słowa kluczowe: system uprawy roli, nawożenie azotem, orkisz ozimy, odmiana, wartość wypiekowa.

INTRODUCTION

The recent years alternative wheat cereals as food grains: einkorn, emmer, spelt, kamut, and triticale are more and more popular (Stallknecht et al. 1996). Spelt (*Triticum aestivum* ssp *spelta* L.) is one of the oldest cereal used by man. It has recently gained popularity in Europe as part of the growing interest in foods with high nutritional and gustatory value (Campbell 1997; Gabrovská et al., 2002). The lesser agronomic requirements of spelt and its high competitive ability against weeds (compared to wheat) make it an attractive crop for

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both organic farms and small conventional farms that use integrated methods of crop production (Campbell 1997). In terms of nutritional value spelt is more valuable than wheat. Spelt flour is a valuable raw material for the baking industry and in comparison to wheat flour, contains more total fat, vitamins, microelements, macroelements and high value protein with increased content of essential amino acids (Abdel-Aal et al. 2002; Marconi et al. 2002; Schober et al. 2006).

Grain quality of cereals is affected by many factors such as soil tillage. fertilization, cultivar properties and environmental conditions. The high energy consumption of conventional tillage and its negative impact on the natural environment prompted the search for alternative solutions in tillage systems (Morris et al. 2010). Woźniak and Gontarz (2011) indicate that the quality of wheat grain is little affected by tillage system, Debaeke et al. (1996) demonstrated that reduced tillage of wheat had a negative impact on protein content and quality of grain. According to De Vita et al. (2007), the quality of wheat grain depends on the tillage system and habitat conditions. The conventional tillage positively affect grain quality in the regions with higher sums of precipitation, whereas the no-tillage system – in the region with lower precipitation. Peigne (2014) indicate for similar results in grain quality as affected by different soil tillage systems – conventional and reduced.

Nitrogen fertilization has the biggest influence on grain quality among all agronomical factors (Cacak-Pietrzak et al. 1999; Podolska 2007; Podolska et al. 2010). High nitrogen doses improve protein content, gluten content and Zeleny test value. There are not many investigations connected with nitrogen fertilization effect on spelt wheat, because in general it is cultivated in ecological farms. Johansson (2001) show the increase of protein content and decrease of its quality. The results of Nowak et al. (2004) indicate different reaction of spelt cultivars. Similar effect was obtained by Podolska et al. (2011). Cultivars from different countries show interaction between the dose of nitrogen and quality of grain.

The aim of this research was to evaluate the effect of tillage systems and nitrogen fertilization dose on quality of grain and flour of German and Polish cultivars.

MATERIAL AND METHODS

The material for investigation were grain samples derived from an experiment carried out in 2009–2011 at Agricultural Experimental Station in Lipnik, near Szczecin (53º12'N, 14º27'E). The study compared 3 factors: two methods of soil tillage (reduced and conventional), 4 nitrogen doses (0, 50, 100 and 150 kg · ha $^{-1}$) and 3 cultivars (2 German – 'Franckenkorn', 'Oberkulmer Rohtkorn' and Polish unregistered cultivar 'STH 12').

Reduced tillage variant consisted of disc harrowing with surface roller and conventional principal ploughing with furrow press Seeds sowing was done using tractor drill with Øyord system between 24–25 of September in each year. Nitrogen fertilization was applied at vegetation start (first dose 50 kg · ha^{-1}), seconde dose in shooting time and the third at earing using ammonium nitrate 34%.

The soil on which the experiment was conducted belongs to the typical rusty soil group (CPS 2011) and classified as Haplic Cambisol (IUSS Working Group WRB 2014). The soil was developed from light loamy sand (plg), with weak loamy sand underneath (psg), and

light silt in some spots (gl). In typological terms, this soil is classified to brown soils. Thickness of the humus layer is 14–25 cm, humus content amounts to 1.3–1.5%. Content of alluvial parts 11–13%, pHKCL – 6.3, average content of K – 103.8 mg · kg^{-1}, P – 58.1 mg · kg^{-1} of the soil. In terms of agronomical categories, the soil is typical for West Pomerania region.

The fore crop in each year was oat. Phosphorus and potassium fertilization was applied in autumn in amount 100,150, 25 P_2O_5,K_2O and MgO kg · ha^{-1}, respectively. Harvesting was done with Wintersteiger plot harvester at full maturity stage of grains.

Grain samples from each experimental variant were subjected to quality analyses. The following grain parameters were determined: nitrogen percentage of grain was determined based on the Kjeldahl micro-method, followed by colorimetric reading using a Buchi B-324 (Switzerland), protein concentration was calculated by multiplying nitrogen by 6.25, weight of 1000 grains and test weight. The flour parameters were determined by ICC standard methods: Hagberg-Perten falling number using an SWD-83 camera (Poland) (ISO 3093), sedimentation rate (ISO 5529), gluten content, gluten weakening, gluten index (ISO 21415). Also the rheological properties of the dough were determined; water absorption of flour, dough development time, dough stability and dough softening after 10 and 12 min, using a Brabender Farinograph (Duisburg, Germany) according to the standard method (ISO 5530-1).

The results were analyzed statistically using a three-way analysis of variance in randomized blocks design. The number of replications was 3.The years were treated as replications. Confidence half-intervals for multiple comparisons were calculated using the Tukey's test at a confidence level p = 0.95.

RESULTS AND DISCUSSION

The effect of soil tillage systems – reduced and conventional – have been presented in Table 1 and 2. The physical traits of grain – thousand grain weight and test weigh – were similar at both investigated systems. Protein content and falling number was not significant different. Higher values for reduced soil tillage system in comparison with conventional was noticed for gluten content, only. The difference amounted 4.5 percent. The parameters informing about gluten quality have been on the same level. The farinograph traits were not differentiated by tillage systems. Only one significant difference was observed for water absorption of flour, but it was rather small – about 1%. The results obtained by other scientist indicate that tillage systems – conventional, reduced or zero tillage- are not a factor which is very important for grain quality. Woźniak et al. (2014) indicate that at conventional tillage system in comparison with reduced total protein, gluten content and test weight values are higher. Peigne (2014) obtained similar results of quality traits under different systems. According to De Vita et al. (2007) the most important factors for changing quality of grain are environment conditions.

Nitrogen fertilization is a factor which has the biggest influence on wheat grain quality (Cacak-Pietrzak et al. 1999; Podolska 2007; Podolska et al. 2010). In general there are not a many investigation with spelt, because mainly it is cultivated in ecological farm. Increasing dose of nitrogen from 0 to 100 kg N · ha^{-1}caused significant difference in 1000 grain weight (Table 3).

Table 1. Effect of soil tillage system on quality traits of winter spelt grain
Tabela 1. Wpływ systemu uprawy roli na cechy jakościowe ziarna orkiszu ozimego

Trait Cecha	Soil tillage system System uprawy roli		Mean Średnia	$LSD_{0.05}$ $NIR_{0,05}$
	reduced uproszczony	conventional konwencjonalny		
Weight of 1000 grains Masa 1000 ziaren [g]	42.1	42.9	42.5	ns.
Test weight Gęstość ziarna w stanie zsypnym [kg · hl^{-1}]	72.4	72.7	72.5	ns.
Protein content Zawartość białka [g · kg^{-1}]	143.0	135.0	139.0	ns.
Falling number – Liczba opadania [s]	340.0	339.0	339.0	ns.
Wet gluten content Zawartość glutenu mokrego [%]	41.6	37.1	39.4	2.35
Gluten weakening Rozpływalność glutenu [mm]	2.78	2.43	2.61	ns.
Gluten index – Indeks glutenu [%]	47.2	51.3	49.3	ns.
Zeleny test Wskaźnik sedymentacji Zeleny'ego [ml]	17.0	15.1	16.0	ns.

ns. – non significant difference – różnica nieistotna.

Table 2. Effect of soil tillage system on faringraph traits of winter spelt flour and dough
Tabela 2. Wpływ system uprawy roli na cechy farinograficzne mąki i ciasta

Trait Cecha	Soil tillage system System uprawy roli		Mean Średnia	$LSD_{0.05}$ $NIR_{0,05}$
	reduced uproszczony	conventional konwencjonalny		
Water absorption of flour Wodochłonność mąki [%]	57.00	55.90	56.40	0.94
Dough development time Czas rozwoju ciasta [min]	3.73	3.47	3.60	ns.
Dough stability – Stałość ciasta [min]	5.42	5.61	5.51	ns.
Dough softening after 10 min (FU) Rozmiękczenie ciasta po 10 min (jB)	83.60	84.90	84.20	ns.
Dough softening after 12 min (FU) Rozmiękczenie ciasta po 12 min (jB)	140.00	141.00	141.00	ns.

ns. – non significant difference – różnica nieistotna.

Table 3. Effect of nitrogen fertilization on quality traits of winter spelt grain
Tabela 3. Wpływ nawożenia azotem na cechy jakościowe ziarna orkiszu ozimego

Trait Cecha	Nitrogen fertilization Nawożenie azotem [kg · ha^{-1}]				$LSD_{0.05}$ $NIR_{0,05}$
	0	50	100	150	
Weight of 1000 grains Masa 1000 ziaren [g]	40.8	42.8	44.2	42.0	2.48
Test weight Gęstość ziarna w stanie zsypnym [kg · hl^{-1}]	72.6	72.7	72.2	72.6	ns.
Protein content Zawartość białka [g · kg^{-1}]	125.0	130.0	145.0	155.0	12.0
Falling number – Liczba opadania [s]	352	347	330	327	ns.
Wet gluten content Zawartość glutenu mokrego [%]	32.2	35.4	43.9	45.9	4.39
Gluten weakening Rozpływalność glutenu [mm]	1.90	2.53	3.00	3.00	0.84
Gluten index – Indeks glutenu [%]	60.1	48.3	44.8	43.8	9.45
Zeleny test Wskaźnik sedymentacji Zeleny'ego [ml]	14.4	15.4	18.2	16.0	3.66

ns. – non significant difference – różnica nieistotna.

The other physical trait – test weight – was not influenced by fertilization. Also falling number did not change its value at different levels of nitrogen. Results obtained by Sułek et al. (2004) indicate that falling number value is dependent on genotype, namely cultivars. Results obtained by Budzyński et al. (2008) and Dubis and Borysewicz (2008) indicate that there is no correlation between nitrogen dose and falling number value. Protein content, gluten content and Zeleny test increased their values according to higher nitrogen rates up to 100 kg. The gluten quality, expressed by gluten weakening and gluten index, was lower after nitrogen fertilization. The rheological values of spelt dough were higher only for development time. For the rest of traits was no differences or better values have been observed at low nitrogen level. Achremowicz et al. (1993) and Johansson (2001) showed that high doses of nitrogen increase yield and protein content in grain but decrease the quality. Interaction between cultivars and nitrogen fertilization was noticed only for gluten index (Table 4). Mean values of this trait for 'Oberkulmer Rothkorn' and 'Franckenkorn' were on the same level at different nitrogen dose. Gluten index for 'STH 12' was the highest at 0 N level and decreased significantly at higher doses, up to 150 kg N · ha^{-1}. Similar results were obtained by Podolska et al. (2011). Nitrogen dose had not effect on gluten index of cultivar Szwabenkorn and negative for STH 8 strain. Nowak et al. (2004) and Stankowski et al. (2004) indicate that high doses of nitrogen have a positive effect on gluten quality for some cultivars while negative for others. It could be explained as the effect of interaction between cultivars and environmental conditions and agronomical factors (Budzyński et al. 2004).

Table 4. Effect of nitrogen fertilization (N) on gluten index of winter spelt cultivars (C)
Tabela 4. Wpływ nawożenia azotem (N) na indeks glutenu odmian orkiszu ozimego (C)

Cultivar Odmiana	Nitrogen fertilization Nawożenie azotem [kg · ha^{-1}]			
	0	50	100	150
'Franckenkorn'	29.9	25.6	26.3	28.9
'Oberkulmer Rothkorn'	61.5	50.7	51.1	51.1
'STH 12'	89.0	68.8	56.9	50.9
$LSD_{0.05}$ – $NIR_{0,05}$	N/C – 16.4			

Increase of nitrogen fertilization dose caused significant had positive effect on water absorption of flour and dough development time (Table 5). Dough stability was longer, but the differences were not significant. Dough softening after 12 min was bigger at higher nitrogen fertilization dose.

The quality traits of 3 compared cultivars are presented in Table 6. We could observe great differences between the grain and flour parameters but it was not possible to indicate the best one. 'Franckenkorn' had the biggest grain weight, protein and gluten content, Polish 'STH 12' was characterized by highest falling number and gluten index. 'Oberkulmer Rothkorn' quality was in general on the middle level of the earlier described cultivars. Many authors report a higher protein and gluten content in spelt compared to common wheat Pruska-Kędzior et al. (2008), Escarnot et al. (2012), Mikos and Podolska (2012), Hofmanová et al. (2014).

Farinograph traits (Table 7) indicate that the best values have been obtained for 'Oberkulmer Rothkorn'. Gluten index for this cultivar was stable at about 50%, independently from nitrogen fertilization level. Results of Mikos and Podolska (2012), indicated that gluten index of 50–60% is best for baking purposes, while flour with an index of less than 50% is more difficult to process.

Table 5. Effect of nitrogen fertilization on faringraph traits of winter spelt flour and dough
Tabela 5. Wpływ nawożenia azotem (N) na cechy farinograficzne mąki i ciasta z orkiszu ozimego

Trait Cecha	Nitrogen fertilization Nawożenie azotem [kg · ha^{-1}]				$LSD_{0.05}$ $NIR_{0,05}$
	0	50	100	150	
Water absorption of flour Wodochłonność mąki [%]	54.0	55.1	57.6	59.0	1.76
Dough development time Czas rozwoju ciasta [min]	2.98	3.31	3.69	4.42	0.61
Dough stability Stałość ciasta [min]	4.97	5.26	6.07	5.76	ns.
Dough softening after 10 min (FU) Rozmiękczenie ciasta po 10 min (jB)	72.4	77.0	90.9	96.6	ns.
Dough softening after 12 min (FU) Rozmiękczenie ciasta po 12 min (jB)	107.0	117.0	161.0	169.0	38.60

ns. – non significant difference – różnica nieistotna.

Table 6. Effect of cultivar on quality traits of winter spelt grain
Tabela. 6. Wpływ odmiany na cechy jakościowe ziarna orkiszu ozimego

Trait Cecha	Cultivar Odmiana			$LSD_{0.05}$ $NIR_{0.05}$
	'Franckenkorn'	'Oberkulmer Rothkorn'	'STH 12'	
Weight of 1000 grains Masa 1000 ziaren [g]	45.7	42.4	39.3	1.95
Test weight Gęstość ziarna w stanie zsypnym [kg · hl^{-1}]	71.2	70.9	75.5	0.85
Protein content Zawartość białka [g · kg^{-1}]	153.0	138.0	124.0	10.10
Falling number Liczba opadania [s]	301.0	289.0	428.0	39.20
Wet gluten content Zawartość glutenu mokrego [%]	43.2	36.4	38.5	3.46
Gluten weakening Rozpływalność glutenu [mm]	4.08	2.16	1.58	0.66
Gluten index Indeks glutenu [%]	27.7	53.7	66.4	7.43
Zeleny test Wskaźnik sedymentacji Zeleny'ego [ml]	15.5	18.3	14.2	2.64

Table 7. Effect of cultivar on faringraph traits of winter spelt flour and dough
Tabela 7. Wpływ odmiany na cechy farinograficzne mąki i ciasta z orkiszu ozimego

Trait Cecha	Cultivar Odmiana			$LSD_{0.05}$ $NIR_{0.05}$
	'Franckenkorn'	'Oberkulmer Rothkorn'	'STH 12'	
Water absorption of flour Wodochłonność mąki [%]	57.40	53.50	58.30	1.39
Dough development time Czas rozwoju ciasta [min]	2.42	4.93	3.46	1.15
Dough stability Stałość ciasta [min]	3.10	8.17	5.26	1.70
Dough softening after 10 min (FU) Rozmiękczenie ciasta po 10 min (jB)	131.00	43.00	79.00	27.80
Dough softening after 12 min (FU) Rozmiękczenie ciasta po 12 min (jB)	180.00	116.00	126.00	30.40

CONCLUSIONS

1. Soil tillage systems – reduced and conventional – had practically no effect on physical and quality traits of winter spelt grain and flour. Significant difference was observed only for gluten content.
2. Nitrogen fertilization influenced significantly most of the quality traits. Optimal nitrogen level was 100 kg · ha^{-1}. Only for gluten index and gluten weakening the highest values have been observed for control variant of fertilization – without nitrogen.
3. There was no interaction between cultivars and nitrogen fertilization except for gluten index. Mean values of this trait for 'Oberkulmer Rothkorn' and 'Franckenkorn' were on the same level at different nitrogen dose. Gluten index for 'STH 12' decreased significantly at higher doses.
4. Results of farinograph analyses indicate that cultivar with the best baking quality was 'Oberkulmer Rothkorn', while with the worst – 'Franckenkorn'.

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Abstract. The material for investigation were grain samples obtained from an experiment conducted in 2009–2011 at the Agricultural Experimental Station in Lipnik, near Szczecin. The study compared 3 factors: two systems of soil tillage (reduced and conventional), 4 nitrogen doses (0, 50, 100 and 150 kg · ha^{-1}) and 3 winter spelt cultivars (‘Franckenkorn’, ‘Oberkulmer Rothkorn’, ‘STH 12’). The quality and farinograph traits of grain, flour and dough were estimated. Soil tillage systems – reduced and conventional – practically had not effect on grain and flour quality. Significant difference was observed only for gluten content. Nitrogen fertilization influenced significantly most of the quality traits. The optimal nitrogen level was 100 kg N · ha^{-1}. Only for gluten index and gluten weakening the highest values have been observed at control variant without nitrogen fertilization. There was no interaction between cultivars and nitrogen fertilization except for gluten index. Mean values of this trait for cultivars ‘Oberkulmer Rothkorn’ and ‘Franckenkorn’ was on the same level at different nitrogen dose. Gluten index for cultivar ‘STH 12’ decreased significantly at higher doses. The results of farinograph analyses indicate that cultivar with the best baking quality was ‘Oberkulmer Rothkorn’, while with the worst quality – ‘Franckenkorn’.