The influence of soil conditions on grain quality of spring wheat

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Abstract. In years 2007-2008 field experiment with spring wheat was conducted on the parcels (14 m ^{2}) with 2m deep concrete walls, filled with six different soils. The goal of this experiment was to evaluate the influence of soil quality on yield and technological properties of spring wheat varieties. The results of the conducted experiment showed that the highest level of spring wheat yielding were obtained on the soils: good wheat (loess) and very good (black earth). The lowest yields were obtained on defective wheat (limestone soil) and good rye soil complex. Spring wheat grain quality was modified by soil conditions. Grain obtained from the best complexes of soil (very good wheat, alluvial soil) was characterized by lower protein and gluten content but a higher 1000 grain weight which shows a better milling quality of grain when harvested from the good soils.

Keywords: Spring wheat, soil, grain yield, protein content, gluten content, sedimentation value.

1 Introduction

Grain yield and quality of spring wheat depends on genotype and is shaped by habitat and agrotechnology (Budzyński, 2008, Goodling, 1998). Soil quality has the strongest influence on crop yields among the habitat factors (Górski et al., 1999). Wheat grown on lighter soil, particularly rye complex is characterized by low grain accuracy, 1000 grain weight and hectoliter weight, particularly in years of low precipitation, therefore, there is a concern that grain can be characterized by low milling quality (Mazurek et al., 2001). Wheat grain quality was evaluated on the basis of studies conducted in different localities in terms of habitat (soil, weather). Therefore, it is difficult to assess to what extent the technological value of grain was shaped by the weather factors, and to what extent by the soil conditions. The impact of soil conditions on the grain quality should be determined under the same weather conditions. This possibility exists in Pulawy, where more than 100 years ago large plots were created and filled with soil typical for Polish conditions. This facility was used to carrying out a strict experiment, the aim of which was to determine the

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impact of soil conditions on grain yield, and also on the technological value of two spring wheat varieties.

2 Material and Methods

The research material consisted of spring wheat varieties samples (Breeze and Hewilla) from experiments conducted in 2007-2008. The plots with concrete walls (area approx. 14 m^2), were filled with six different soils (thickness 2 m), qualified for the five complexes of the agricultural suitability of soils (Table 1). Recent chemical analysis of soils are shown in Table 2. These soils had the natural profile and the home ground without insulation. The experiment was a randomized block design using three replications. Potassium and phosphorus fertilization was used before a sowing term at the amount of 100 kg K_20 and 80 kg ha^{-1} P_2O_5 kg ha^{-1}, respectively. Nitrogen fertilization of 90 kg N · ha^{-1} was applied at two terms, 45 kg N kg ha^{-1} before the sowing term and 45 kg N · ha^{-1} during the shooting phase. Weeds were removed manually. For each varieties, the 450 seeds per square meter were used. Sowing was carried out on the 27th March and the 8th April, in 2007 and 2008, respectively. Harvest was conducted at the stage of the full maturity: in 2007 – 30th July and 2008 – 5th August. After harvesting, the grain yield was determined and an assessment of selected parameters of the technology value was conducted. It included the determination of 1000 grain weight, protein content by Kjeldahl method (N · 5.75), the quantity and quality of gluten using Glutomatic System, and SDS sedimentation value. Quantity and quality of wet gluten and dry gluten content were determined using Glutomatic system (Perten, Germany) [ICC Standard no. 155]. Falling number value was determined using Falling Number apparatus [ISO 3093]. SDS sedimentation values of whole meal flour, 1000 Kernels Weight (TKW), hectoliter weight were also determined.

The results in the system of randomized block design were analyzed statistically using two-way variance analysis (ANOVA). The significance of differences was assessed using Tukey's test at–(P =0.05). Correlation coefficients were calculated between soils properties and quality traits.

Table 1. Characteristics of soils

Plot number	*Type and kind of soil*	*Valuation class*	*Soil suitability complex*	*Index of quality*
1	Black earth	I	Very good wheat complex	100
2	Brown alluvial soil	II	Good wheat complex	92
3	Brown soil developed from loess	III a	Good wheat complex	83
4	Typical brown soil	III b	Very good rye complex	70
5	Limestone soil	IV a	Defective wheat complex	57
6	Typical brown soil	IV b	Good rye complex	42

Table 2. Chemical characteristics of soil. Chemical determination: pH_{KCl} – potentiometric method; P_2O_5 – colorimetric method; K_2O – flame emission spectrometry; humus – Tiurin's method; Mg, Cu, Mn, Zn – atomic absorption spectrometry; B, Mo – plasma emission method

Character of soils	Type and kind of soil					
	Black earth	Brown alluvial soil	Brown soil developed from loess	Typical brown soil	Limestone soil	Typical brown soil
pH_{KCl}	7,68	7,70	5,75	6,61	7,80	5,43
mg per 100 g of soil						
P_2O_5	16,3	49,5	19,5	22,3	10,3	5,43
K_2O	2,3	8,4	4,4	4,7	4,8	6,4
absorbed Mg	2,7	5,4	2,9	8,5	1,6	1,8
Humus content %	3,38	1,16	1,00	1,18	1,50	1,27
content in mg/1 per kg soil						
B	5,18	1,75	0,62	1,27	2,59	0,90
Cu	5,41	6,16	4,86	6,87	5,48	7,46
Mn	177	195	127	172	135	167
Mo	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
Zn	47,0	72,4	49,6	36,5	102	31,9

3 Results

3.1 Grain yield

Weather conditions (Fig. 1) in the years of research had been different and had modified both technological value and grain yield of spring wheat varieties (Table 3). The year 2007 proved to be very detrimental to the yield of spring wheat. Large deficits in soil moisture during the plant emergence, high temperatures and lack of rainfall during the grain filling (Fig. 1) contributed to lower yields by 39% compared to the year 2008. In 2007, Bryza wheat variety yielded about 6% higher compared to Hewilla wheat variety. In 2007, significantly higher grain yield was obtained from wheat grown on soil of good wheat complex (loess), the lowest on the defective wheat complex (limestone soil). Grain yields obtained from soil of very good rye and good rye complexes were at similar levels. In 2008, the highest grain yield was obtained with good wheat complex (loess) and very good wheat (black earth), while the yield was slightly lower on the good wheat complex (alluvial soil) and very good rye complex. The lowest grain yield was obtained on the defective wheat complex (limestone soil) (Table 3).

Table 3. Grain yield of spring wheat cultivars depending on soils conditions in the years 2006-2007. r.n. – not statistically significant difference

Soil suitability complex	*Grain yield [g m^{-2}]*					
	2007			2008		
	Bryza	Hewilla	Średnio	Bryza	Hewilla	Means
Very good what complex	612	600	602	890	907	899
Good wheat complex (brown alluvial)	630	580	605	846	874	860
Good wheat complex (loess)	710	620	665	992	960	976
Very good what complex	598	593	582	822	813	818
Defective wheat complex	370	339	534	570	584	577
Good rye complex	571	564	567	617	582	600
Means	581	549		790	787	
LSD α $_{0,05}$ soils cultivars	51,89 20,06			88,4 r.n		

Technological value

Technological value of spring wheat grain was dependent on the soil quality and weather conditions during the research. There was no interaction of the tested cultivars with soil conditions in determining the quality characteristics of grains, so the paper presents averages for the varieties (Table 4, 5).

The 1000 grain weight was significantly dependent on soil quality and weather conditions during the study (Table 4, 5). Moisture deficits in the soil and high air temperatures occurred during the grain filling in 2007 (Fig. 1), which negatively affected the formation of grains. Wheat gained significantly the highest 1000 grain weight on good wheat complex (loess), the lowest on the defective wheat complex (limestone soil). The difference was 28%. In 2008, with favorable weather conditions for the wheat growing, the spring wheat grain was characterized by a higher 1000 grain weights with the average of 46.5 g (Table 4). The highest 1000 grain weight gain was observed wheat grown on good wheat complex (alluvial soil), a very good rye complex, good rye and good wheat complex (loess). Wheat grains derived from the cultivation on defective wheat complex (limestone soil) were characterized by the lowest 1000 grain weight.

Gluten content and gluten index were significantly dependent on the soil quality. In 2007, gluten content ranged from 29.3 to 34.8%. Amount of eluted gluten was significantly higher in the grains originating from the wheat cultivated on defective wheat complex soil (limestone soil). The lowest amount of gluten was obtained from wheat grains growing on the soil of very good wheat complex (black earth) and good wheat (alluvial). The difference was 2.3% and 2.0%, respectively (Table 4). In 2008, the highest gluten content was obtained from the grains originating from soil of good rye complex. Indeed, the lowest gluten index was found in the grain from soil of very good wheat (black earth) and defective wheat complex (limestone soil). This difference amounted to 9.7% and 9.1%, respectively (tab.5).

Average total protein content in wheat grains in 2007 was 13.5% and it was higher by 8.2% in comparison to the average protein content in 2008. In 2007 wheat grains collected from the defective wheat complex (14.8%) and good rye complex (14.1%) (limestone soil) had significantly highest protein content. The lowest protein content in recorded in the grain of wheat cultivated on a very good wheat (black earth) (12.5%) and good wheat complex (alluvial soil) (12.8%). In 2008 grain of wheat cultivated on good rye complex was characterized by the highest protein content (14.1%), while the lowest (11.8%) on the defective wheat (limestone soil) and good wheat (alluvial soil) complexes. Grain of wheat which was cultivated on the soil of a very good wheat (black earth), good wheat (loess) and very good rye wheat complex was characterized by similar protein content.

Soil conditions had influence on SDS sedimentation value (Table 4, 5). The highest SDS sedimentation value was observed in 2007 in grain of wheat grown on defective wheat complex, very good rye and good rye complexes compared to SDS sedimentation value of grain from the other types of soils. In 2008 SDS sedimentation value was the highest in the grain originating from very good rye complex soil, while the lowest from the defective wheat (limestone soil) and a good rye complex soil. There was no significant difference in the value of this parameter between soils representing wheat complexes.

The analysis of correlation (Table 6) shows a negative correlation between soil quality and indicators of technological value of spring wheat grain. With an improvement of the soil complex, there was a decrease in the parameters such as: protein content, gluten content, SDS sedimentation value and gluten index. It was found that gluten content is significantly correlated with protein content and SDS sedimentation value. Gluten index is also correlates significantly with the sedimentation value and the protein content showed a significant correlation with SDS sedimentation value.

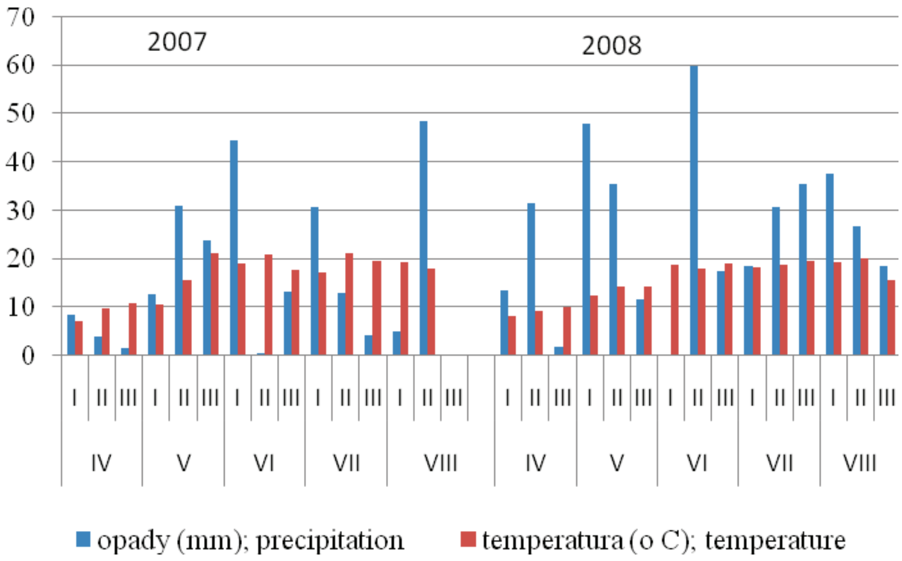

Fig.1. Precipitation and temperature during vegetation period in 2007-2008

Table 4. Grain quality traits depending on soil complex in 2007 years. r.n. – not statistically significant difference

Experimental factors	*Grain quality traits*				
	Glut en content (%)	Glut en index	SDS sedimentation value (cm^3)	Prote in content (% s.m.)	1000 grain weights (g)
Very good wheat complex	29,3	48,2	62,4	12,5	41,5
Good wheat complex (brown alluvial)	30,8	50,5	61,9	12,8	44,4
Good wheat complex (loess)	32,8	52,3	61,4	13,2	45,0
Very good rye complex	31,8	70,6	67,1	13,4	423
Defective wheat complex	34,3	77,3	71,4	14,8	35,1
Good rye complex	32,8	72,4	69,3	14,1	43,9
LSD ($\alpha_{0,05}$)	2,07	3,17	2,79	1,55	3,52
Bryza	32,0	66,0	65,0	13,6	40,3
Hewilla	31,9	51,6	66,1	13,3	43,6
LSD ($\alpha_{0,05}$)	r.n	12,0 2	r.n	r.n	3,33

Table5. Grain quality traits depending on soil complex in 2008 years

Experimental factors	Grain quality traits				
	Gluten content (%)	Gluten index	SDS sedimentation value (cm^3)	Protein content (% s.m.)	1000 grain weights (g)
Very good wheat complex	27,8	71,6	65,5	12,0	45,5
Good wheat complex (brown alluvial)	29,7	56,5	63,0	11,8	47,9
Good wheat complex (loess)	31,0	49,5	63,0	12,4	46,9
Very good rye complex	31,8	58,2	68,0	12,6	47,5
Defective wheat complex	28,4	70,1	61,8	11,8	43,6
Good rye complex	37,5	46,5	70,3	14,1	47,3
LSD ($\alpha_{0,05}$)	1,95	9,37	1,81	1,48	3,06
Bryza	31,4	62,3	65,6	12,4	45,7
Hewilla	30,6	56,8	64,9	12,4	46,8
LSD ($\alpha_{0,05}$)	r.n	4,02	r.n	r.n	r.n

Table 6. Correlation coefficients of grain quality parameters of spring wheat to soil conditions (mean from 2007 – 2008). Level of significance* - p , 0,05

Parameters	Soils quality	Gluten content	Gluten index	SDS sedimentation value	Protein content	1000 grain weights
Soils quality	x					
Gluten content	-0,675*	x				
Gluten index	-0,320*	-0,145	x			
Sedimentation value	-0,627*	0,618*	0,295*	x		
Protein content	-0,592*	0,797*	0,095	0,631*	x	
1000 grain weights	0,065	0,145	-0,178	-0,058	-0,007	x

4 Discussion

Spring wheat has very high soil requirements. Studies (Sułek, 2001, Sułek et al., 2009) suggest that the issue of wheat grain yield requires a high soil concise, well-sustained water complexes belonging to the very good and good wheat complex. The presented research confirms that spring wheat had the highest yield on good wheat complex (loess), while the lowest grain yield was found on soil of defective wheat complex (limestone soil) and good wheat complex. In the studies conducted by Sulek and Filipiak (Sułek et al., 2009) the difference in grain yield between wheat (very good and good) and the good rye complexes was 24.0%. In the present study the difference was at a similar level.

It is important to determine the total protein content and gluten content while assessing the quality of wheat. In the present study, the soil quality and weather conditions in the wheat ripening period differentiated the protein content and gluten content in spring wheat grains. The year 2007, in which high temperatures and lack of rainfall were recorded at the ripening period, was more favorable for storing protein. Other authors (Daniel et al., 1998a, Daniel et al., 1998b, Stankowski et al., 2001) emphasize that the most favorable weather for the formation of large amounts of protein is that with moderate rainfall and high air temperature The presented studies show that the highest amount of protein was accumulated in the grains growing on the soil of good wheat complex (2007 and 2008). In the 2007 the lowest amount of protein was accumulated in wheat grains grown on defective wheat complex in 2007. Research conducted by Podolska (Podolska et al., 2005) with winter wheat showed no impact of the soil complex on protein content. Studies of Kuś and et al. (Kuś et al., 1999) indicate that winter wheat grown on soils with a greater abundance of humus (black earth and alluvial soil) are distinguished by greater amounts of protein and gluten than wheat grown on the soil of loamy sand granulometric composition (good rye complex). Research conducted by Sulek and Filipiak (Sułek et al., 2009) showed, however, that the wheat grain grown on good rye complex was characterized by a protein content higher by 1.7% in reference to wheat grown on the soil of a very good wheat complex.

SDS sedimentation value characterizes the gluten quality and quantity, which determines the suitability of varieties for baking purposes. The study indicates that this parameter was dependent on the soil quality. In 2007, grain had the highest SDS sedimentation value from wheat grown on rye and defective wheat complexes (limestone soil), while in 2008 on the very good wheat and wheat defective complexes. According to the research conducted by Sulek and Filipiak, Filipiak and Podolska (Sułek et al., 2009, Podolska et al., 2009), Nowak and et al. (Nowak et al., 2004) the grain from the very good wheat complex was characterized by the highest SDS sedimentation value. However, the studies conducted by Podolska and et al. (Podolska et al., 2005) showed that there were no significant differences in SDS sedimentation value with the deterioration of the soil complex.

The results indicate a significant negative correlation between soil conditions, and grain quality parameters. Research conducted by Podolska and et al. (Mazurek et al., 2001) with winter wheat showed that soil conditions have a little influence on the baking quality of wheat. They affect the milling value, which is indirectly confirmed by this study.

5 Conclusion

1. Spring wheat grown on soil of good wheat, very good wheat, good wheat (alluvial soil) and very good rye complexes had the highest grain yield, whereas significantly lowest grain yield was detected on defective wheat (limestone soil) and a good rye complexes.

2. Soil conditions modified the quality parameters of spring wheat grains. Grain of wheat grown on soils belonging to the best soil complexes (very good wheat - the black earth and good wheat - alluvial) accumulated the lowest amounts of protein and gluten, and exhibited the highest 1000 grain weight.

3. Further research, on the influence of soil conditions on yield and grain quality, expanded over longer period of time (more than two years) is of high interest. We speculated that the stability of both; yield and yield quality is higher on good quality soils; however additional experiments should be performed to confirm that hypothesis. Moreover, the future investigations should include the determination of the protein content as well as the dough quality and baking properties.

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