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IMPACT OF WEATHER CONDITIONS ON CHEMICAL COMPOSITION OF THE SEEDS OF THREE SOYBEAN CULTIVARS

WPŁYW WARUNKÓW POGODOWYCH NA SKŁAD CHEMICZNY TRZECH ODMIAN SOI

Abstract: The paper presents the results of a three-year field experiment aimed at an assessment of the effect of the weather conditions on the yield and the contents of macroelements (P, Mg, Ca, Na and K) and microelements (Fe, Mn, Cu and Zn) in seeds of three soybean cultivars (2 large seed Aldana and Gaj and 1 small seed Nawiko). A significant effect of meteorological conditions on the yield and chemical composition of the analyzed soybean seeds was demonstrated. In the year 2002 when the course of thermal and moisture conditions was the most advantageous, the largest seed yields were obtained (3.1 Mg · ha^{-1}) with the highest mineral content. Among the analyzed varieties in the subsequent years the small seed one accumulated in its seeds greater amounts of Mg, Ca, K, Mn and Zn in comparison with the large seed cultivars.

Keywords: soybean, yield, microelements, macroelements

Versatile applications of soybean *Glycine max* (L.) raise great interest in this plant not only abroad but also in Poland. Its seeds are a rich source of protein containing all crucial amino acids, particularly great amounts of exogenic amino acids, which are not synthetized by living organism [1, 2]. Soybean also supplies about 20 % of fat which contains considerable quantities of linolic acid and enzymes counteracting rancidity. In comparison with other plant oils, soybean oil is abundant in omega-3 and omega-6 fatty acids. Soybean seeds are also a reserve of nutritious and non-nutritious substances important for the organism, vitamins (from B, PP and R group) and mineral salts. They also contain a considerable amount of macro- and microelements, particularly phosphorus, potassium, calcium, magnesium, iron, zinc, copper and sodium [3, 4]. Because of growing consumption of soybean seeds and soybean derived products there is a

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necessity to conduct investigations on the effect of habitat conditions on the chemical composition of the seeds.

The investigations aimed at comparing the effect of habitat conditions on the content of macroelements (P, K, Ca, Na and K) and microelements (Fe, Mn, Cu and Zn) in the seeds of three national soybean cultivars: two large seed Aldana and Gaj and one small seed Nawiko variety.

Material and methods

The investigations were conducted in the years 2002–2004 at the Experimental Station of the Crop Production Department in Prusy near Krakow on a degraded chernozem well abundant in phosphorus and potassium. The content of basic nutrient available forms in soil, as determined by the analyses carried out by the Chemical--Agricultural Station in Krakow, was as follows: 25.0 mg P_2O_5, 23.0 mg K_2O and 14.1 Mg 100 g^{-1} of air-dried soil, and abundance in microelements: 264 mg Mn, 6.6 mg Cu, 43.5 mg Zn and 148 mg Fe · kg^{-1} of soil. The soil contained 0.127 % of nitrogen and its pH was 6.2.

A one-factor field experiment was set up in a split-plot design in four replications. The analyzed factor were three soybean cultivars: two large seed Aldana and Gaj and one small seed Nawiko.

In the subsequent years of the experiment, cultivation measures did not differ from those commonly applied in large seed legume cultivation. Following the forecrop (spring cereals) harvesting first ploughing and harrowing were conducted. Phosphorus and potassium fertilizers: 70 kg P_2O_5 · ha^{-1} as triple superphosphate and 120 kg K_2O as 57 % potassium salt were sown in autumn and then pre-winter ploughing was done. Nitrogen fertilization, dosed 30 kg N/ha as ammonium nitrate, was applied as pre-sowing in spring. Prior to sowing the seeds were treated with Zaprawa Nasienna T (seed dressing) and inoculated with *Bradyrhizobium japonicum* bacteria. The quantity of sown seeds for individual varieties were calculated for the density of 80 pieces per m^2. The seeds were sown in the first days of May using Bratek plot seeder in rows 25 cm apart. After sowing the field was sprayed with Gesagard 50WP and during vegetation with Basagran 600SL. The seeds were collected at a single-phase by means of a plot combine harvester in the first days of September.

Dried and crushed seeds were mineralized in a muffle furnace (in two replications, at 450 ^oC for 5 hours), the remains were dissolved in a diluted nitric acid 1:2 (v/v) [5]. The contents of calcium, sodium and potassium in the solutions were determined using flame photometry (FES), magnesium by means of atomic absorption spectrometry (AAS) and concentrations of phosphorus and trace elements (Cr, Zn, Pb, Cu, Cd, Ni, Fe and Mn) were assessed using ICP-AES method. A reference sample of plant material (NCS DC733448 China National Analysis Center for Iron & Steel) was added to the analysed series and the result was regarded reliable if the *relative standard deviation* (RSD) did not exceed 5 %.

Results and discussion

Soybean yielding was significantly influenced by the climatic conditions during the conducted experiments (Table 1).

Table 1

Characteristics of climatic conditions in years 2002–2004 at Prusy

Year	Months						Mean
	IV	V	VI	VII	VIII	IX	
Temperature [°C]							
2002	10.4	18.4	18.7	21.3	21.6	14.0	17.4
2003	7.8	16.5	19.1	19.5	19.9	14.2	16.2
2004	9.5	12.7	16.8	18.3	18.9	13.7	15.0
1984–1994	8.8	13.8	16.4	18.5	18.4	13.6	14.9
Rainfall [mm]							Sum
2002	85.2	49.3	102.1	42.9	62.7	50.7	392.9
2003	34.3	125.4	35.4	126.2	23.6	30.4	375.3
2004	32.4	42.6	56.4	97.4	77.2	36.1	342.1
1984–1994	44.4	72.0	79.3	56.6	67.2	57.5	377.0

The year 2002 proved the most advantageous for soybean growth and development as it was the year of relatively long vegetation (ca 240 days). Average air temperature in this period was 17.4 °C and precipitation total 392 mm. The years 2003 and 2004 were characterized by lower air temperatures and a small amount of precipitation, which created hardly favourable conditions for growth and development of soybean and negatively affected the obtained seed yields (Table 2).

Table 2

Seed yield of soybean [Mg · ha^{-1}]

Years	Cultivar			Mean for years	$LSD_{\alpha=0.05}$ for years
	Aldana	Gaj	Nawiko		
2002	2.75	3.17	3.10	3.10	
2003	1.32	1.76	1.38	1.38	0.89
2004	1.30	1.20	1.73	1.73	
Mean for cultivars	1.79	2.04	2.32		
$LSD_{\alpha=0.05}$ for cultivars	n.s.				

The highest seed yields from the analyzed soybean cultivars were obtained from the small seed Nawiko c.v. in 2002 (3.2 Mg · ha^{-1}). In the subsequent years the yields, although smaller, were always higher than those obtained from the other varieties, which on average were lower by 22 % for Aldana c.v. and by 12 % for Gaj c.v. Great differences in the yields of the studied varieties during the period of the experiment confirmed soybean sensitivity to the course of weather conditions during plant

vegetation. Bobrecka-Jamro and Pizlo as well as Michalek and Borowski obtained similar results in their research [6, 7].

The mineral content in soybean seeds depends on many factors, among which the most important are: the soil concentrations of these elements, appropriate fertilization, the course of vegetative conditions and the cultivar variety [8, 9]. In the discussed experiment the course of meteorological conditions in the subsequent years of the investigations had the greatest influence on the content of macro and microelements in soybean seeds (Tables 3, 4).

Table 3

Content of P, Mg, Ca, Na, K in seeds of soybean cultivars under analysis [%]

Years	Cultivar			Mean for years	$LSD_{\alpha=0.05}$ for years
	Aldana	Gaj	Nawiko		
P					
2002	0.78	0.81	0.90	0.83	
2003	0.69	0.70	0.71	0.70	0.04
2004	0.93	1.01	1.10	1.01	
Mean for cultivars	0.80	0.84	0.90		
$LSD_{\alpha=0.05}$ for cultivars	n.s.				
Mg					
2002	0.110	0.107	0.120	0.112	
2003	0.102	0.102	0.112	0.105	0.004
2004	0.107	0.107	0.117	0.110	
Mean for cultivars	0.106	0.105	0.116		
$LSD_{\alpha=0.05}$ for cultivars	0.004				
Ca					
2002	0.17	0.17	0.18	0.17	
2003	0.17	0.17	0.20	0.18	0.01
2004	0.21	0.20	0.23	0.21	
Mean for cultivars	0.18	0.18	0.20		
$LSD_{\alpha=0.05}$ for cultivars	0.01				
Na					
2002	0.020	0.017	0.020	0.019	
2003	0.010	0.010	0.010	0.010	0.002
2004	0.012	0.010	0.010	0.010	
Mean for cultivars	0.014	0.012	0.013		
$LSD_{\alpha=0.05}$for cultivars	n.s.				
K					
2002	2.11	2.00	2.14	2.08	
2003	1.41	1.52	1.49	1.47	0.03
2004	1.62	1.61	1.63	1.62	
Mean for cultivars	1.71	1.71	1.75		
$LSD_{\alpha=0.05}$ for cultivars	0.02				

Table 4

Content of Fe, Mn, Cu, Zn in seeds of soybean cultivars under analysis [mg · kg^{-1} d.m.]

Years	Cultivar			Mean for years	$LSD_{\alpha=0.05}$ for years
	Aldana	Gaj	Nawiko		
Fe					
2002	81.90	82.10	81.94	81.98	
2003	64.56	73.03	69.99	69.19	n.s.
2004	63.31	64.54	66.19	64.68	
Mean for cultivars	69.92	73.23	72.70		
$LSD_{\alpha=0.05}$ for cultivars	n.s..				
Mn					
2002	14.00	13.87	14.35	14.07	
2003	13.98	13.72	14.89	14.20	n.s.
2004	14.29	13.29	13.83	13.81	
Mean for cultivars	14.09	13.63	14.36		
$LSD_{\alpha=0.05}$ for cultivars	0.57				
Cu					
2002	12.51	14.46	14.68	13.88	
2003	6.11	6.27	6.32	6.23	0.90
2004	11.21	12.41	13.78	12.46	
Mean for cultivars	9.94	11.05	11.59		
$LSD_{\alpha=0.05}$ for cultivars	0.59				
Zn					
2002	49.18	46.01	46.76	47.32	
2003	45.40	42.82	44.32	44.18	1.66
2004	47.87	44.56	46.48	46.30	
Mean for cultivars	47.48	44.46	45.85		
$LSD_{\alpha=0.05}$ for cultivars	1.38				

The concentrations of macroelements: phosphorus, magnesium, sodium and potassium in the seeds were the highest in 2002 in comparison with the other years. Optimal conditions for absorption and accumulation of these elements in seeds occurred that year. Only for calcium, the highest content was registered in 2004. Warm spring in 2002 also affected higher cumulation of Cu and Zn in seeds. Gorlach [10] obtained similar results concerning the influence of meteorological conditions on heavy metal accumulation in seeds. On the other hand, no effect of atmospheric conditions was noted on Fe or Mn content.

Statistically significant differences were registered among the investigated soybean varieties concerning concentrations of Mg, Ca and K. Nawiko c.v. accumulated the highest Mg amounts (by 0.116 %), whereas the other cultivars had on average 10 % less Mg. Also the contents of calcium and potassium were the highest in Nawiko c.v. seeds (0.20 and 1.75 %). Aldana and Gaj c.vs. contained respectively 10 and 2 % less of these elements.

Among the analyzed microelements greater amounts of Fe and Zn were found in the compared soybean cultivars. Accumulation of the analyzed heavy metals in the seeds of studied soybean varieties did not exceed the value critical for the plant growth [9]. High concentration of iron in seeds improves their value; therefore they may be used in human nutrition for people with anemia symptoms. No differences between the studied soybean cultivars were registered for Fe content. Large seed Aldana c.v. had the highest Zn concentrations in its seeds (47.48 mg · kg^{-1}), whereas the smallest quantities of this element were also noted in large seed Gaj c.v. (44.46 mg · kg^{-1}). A similar dependence occurred for zinc content. Aldana c.v. seeds had the greatest amounts of Zn (47.48 mg · kg^{-1}) whereas Gaj c.v. had the smallest (44.46 mg · kg^{-1}).

Conclusions

1. The yields of the researched soybean cultivars were significantly diversified depending on the variety and the course of weather conditions in the years of the experiment. Considering the three compared soybean cultivars, the highest yields were obtained from the small seed Nawiko c.v. The yields from this variety were on average 12 % and 23 % higher in comparison with Aldana and Gaj large seed varieties.

2. Cumulation of macro and microelements in the seeds of the investigated soybean cultivars was diversified and depended on the soybean cultivar variety and the course of meteorological conditions. The contents of individual elements may be put in the following order: macroelements [%] Na < P < Mg < Ca < K and microelements (mg · kg^{-1} d.m.) Cu < Mn < Zn < Fe.

3. Small seed Nawiko c.v. accumulated more macroelements in its seeds in comparison with the analyzed large seed Aldana and Gaj c.vs.

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WPŁYW WARUNKÓW POGODOWYCH NA SKŁAD CHEMICZNY TRZECH ODMIAN SOI

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Abstrakt: Przedstawiono wyniki trzyletniego doświadczenia polowego, mającego na celu ocenę wpływu warunków pogodowych na plon i zawartość makroelementów (P, Mg, Ca, Ma, K) i mikroelementów (Fe, MN, Cu, Zn) w nasionach trzech odmian soi (dwóch odmian grubonasiennych Aldana i Gaj oraz jednej drobnonasiennej Nawiko). W doświadczeniu stwierdzono istotny wpływ warunków meteorologicznych na plon i skład chemiczny nasion badanych odmian soi. W roku 2002 odznaczającym się najkorzystniejszym przebiegiem warunków termiczno-wilgotnościowych uzyskano największe plony nasion (3,1 $Mg \cdot ha^{-1}$) o największej zawartości składników mineralnych. Z badanych odmian soi odmiana drobnonasienna w kolejnych latach uprawy gromadziła w nasionach więcej Mg, Ca, K, Mn, Zn w porównaniu z odmianami grubonasiennymi.

Słowa kluczowe: soja, plon, mikroelementy, makroelementy