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THE EFFECT OF VARIABLE MINERAL FERTILIZATION ON YIELD AND GRAIN MINERAL COMPOSITION OF COVERED AND NAKED OAT CULTIVARS

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Abstract

Among the cereals grown in Poland, oat grain contains the highest amount of ash, composed of macro- and microelements. It has been suggested that applying increased levels of mineral fertilization, to newer cultivars of oat could have an impact on their grain yield and mineral composition.

A two-factorial (2x2) field experiment was conducted for three years (1999-2001) in the south of Poland. The experiment involved two cultivars of oat, i.e. the covered cultivar Dukat and the naked cultivar Akt, and two fertilization levels, i.e. low (30 kg N, 30 kg P_2O_5 and 45 kg K_2O ha^{-1}) and high (60 kg N, 60 kg P_2O_5 and 90 K_2O ha^{-1}). There was no significant difference in grain yield between the studied cultivars. On the other hand, the high NPK level increased the content of Mg and Fe in the grain of Akt. At the same time, there were no significant differences in the grain content of Cu, Fe, Mn and Zn between Dukat and Akt. Overall, the high level of mineral fertilizing decreased the grain content of microelements as a result of dilution effect.

The content of Cu and Zn in oat grain was suitable for human consumption according to the IUNG-PIB standards. Generally, it was shown that cv. Akt was richer in mineral elements, especially in P, K, Ca, Mg, Fe and Zn, than cv. Dukat.

Key words: oats, fertilizing, yield, chemical composition.

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WPŁYW ZRÓŻNICOWANEGO NAWOŻENIA MINERALNEGO NA PLON ORAZ SKŁAD MINERALNY ZIARNA OWSA OPLEWIONEGO I NAGOZIARNISTEGO

Abstrakt

Ziarno owsa oraz produkty jego przerobu zawierają stosunkowo dużo popiołu, w tym makro- i mikroskładników. W porównaniu z czterema innymi zbożami uprawianymi w Polsce, owies zawiera znacznie więcej składników mineralnych, dlatego też istnieje konieczność badań wpływu czynników agrotechnicznych na skład chemiczny ziarna owsa. W Polsce południowej, w latach 1999-2001, przeprowadzono dwuczynnikowe doświadczenie polowe celem określenia wpływu zróżnicowanego nawożenia mineralnego na plon oraz zawartość makro- i mikroelementów w ziarnie dwóch form owsa siewnego. Pierwszym czynnikiem badawczym były odmiany: oplewiona Dukat i nagoziarnista Akt, a drugim – zróżnicowane nawożenie mineralne, poziom pierwszy: 30 kg N, 30 kg P_2O_5 i 45 kg $K_2O \cdot ha^{-1}$, poziom drugi: 60 kg N, 60 kg P_2O_5 oraz 90 $K_2O \cdot ha^{-1}$. Badane odmiany nie różniły się istotnie plonami ziarna. Wyższy poziom nawożenia NPK wpływał na wzrost zawartości Mg i Fe w ziarnie odmiany nieoplewionej Akt. Nie stwierdzono istotnego zróżnicowania zawartości Cu, Fe Mn i Zn między oplewioną odmianą Dukat a nagoziarnistą odmianą Akt. Poziom nawożenia mineralnego wpływał na obniżenie zawartości mikroelementów, co było związane z efektem „rozcieńczenia". Zawartość Cu i Zn w ziarnie owsa według wytycznych IUNG-PIB i Rozporządzenia MZ spełniała kryteria przydatności konsumpcyjnej. Z badań wynika, że nagoziarnisty owies był zasobniejszy w składniki mineralne, zwłaszcza w P, K, Ca, Mg, Fe, Zn, w porównaniu z formą oplewioną Dukat.

Słowa kluczowe: owies, nawożenie, plon, skład chemiczny.

INTRODUCTION

Among the major cereal crops, oat grain is characterized by particularly valuable chemical composition. Both nutrients and non-nutrients present in oat grain determine its considerable value for human and animal nutrition (PETERSON 2001, BARTNIKOWSKA 2003, GAMBUŚ et al. 2003, CUDDEFORD 1995). Until relatively recently, oat grain has been used almost exclusively for oatmeal manufacturing, whereas nowadays it is also raw material sought for health-related foods, medicines and highly valued cosmetics (PETERSON 2004, GAMBUŚ et al. 2003). In animal nutrition, oat grain is a traditional horse feed. More recently, it has also been used for feeding pigs, poultry, ruminants and husky dogs used for sledding (KEMPE et al. 2004). The nutrient content of oat grain, both covered and naked cultivars, has been described in detail in numerous papers (GĄSIOROWSKI 1995, PISULEWSKA et al. 1998), whereas relatively few research projects have focused on its concentrations of macro- and microelements.

The purpose of this study has been to assess the yield and mineral composition of covered (Dukat) and naked (Akt) cultivars of oat as affected by variable mineral fertilization.

MATERIAL AND METHODS

A two-factorial experiment was conducted using a split-splot design on soil of IIIb quality class in Nawojowa situated in Kotlina Sądecka, at an altitude of 345-360 m AMSL, in the Kamienica River catchment. The experiment was conducted over a 3-year period (1999-2001). Oat was sown as a pure culture at the rate of 500 grains/m^2. In all the years spring barley was the forecrop. Oat crop was harvested from 12 m^2 plots. The first experimental factor was the type of oat cultivar (Dukat vs. Akt), while the second one was differentiated NPK fertilization: I level: 30 kg N, 30 kg P_2O_5 and 45 kg $K_2O \cdot ha^{-1}$ vs II level: 60 kg N, 60 kg P_2O_5 and 90 kg$\cdot$ha^{-1}. The soil abundance in P, K and Mg (mg/100 g) in the consecutive years of the experiment (1999, 2000 and 2001) was as follows: 30, 37, 15; 18, 28, 12; and 7, 15 and 12. The cultivation of plots was the same for all experimental treatments (Pisulewska et al. 2004).

The analysis of oat grain, after combustion in a muffle furnace at 450°C for 12 hours, involved determination of Mg, Ca, P, K, Na, Cu, Fe, Mn and Zn by the ICP-AES method on a sequential JY-238 Ultrace spectrometer. The data (grain yield and mineral composition of grain) were subjected to analysis of variance using the STAT (Skierniewice) statistical programme. The significance of differences between treatment means was assessed at the level of P=0.95. The weather conditions in the consecutive years of the experiment are presented in Figures 1 and 2.

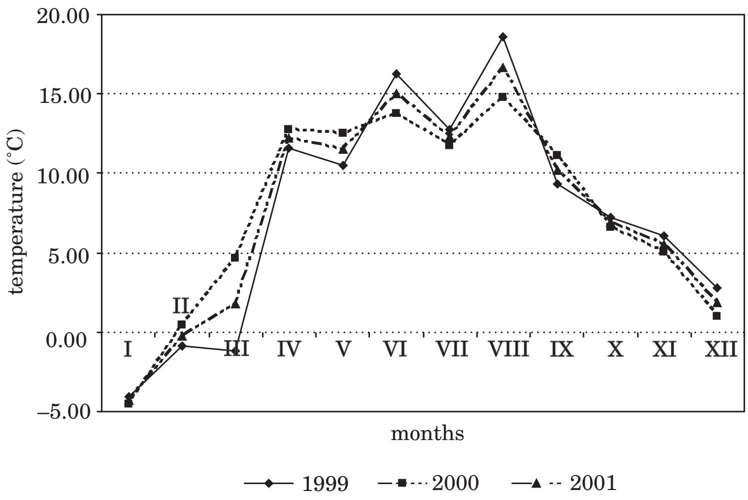

Fig. 1. Month’s mean temperature during the years 1999–2001

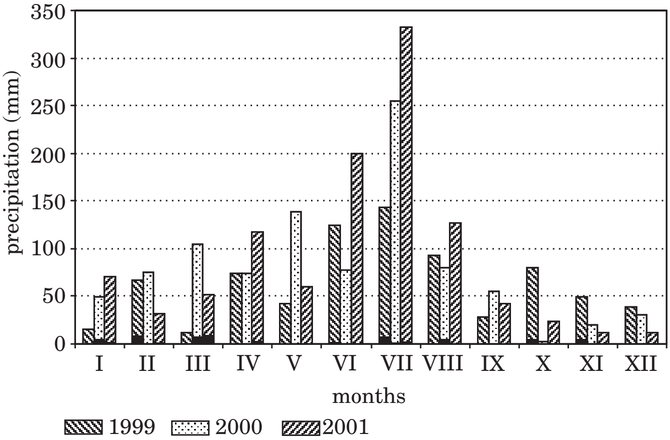

Fig. 2. Month's mean rainfall during the years 1999–2001

RESULTS AND DISCUSSION

The two different levels of mineral fertilization, tested in the field experiments, did not have any significant influence on the grain yields of the oat cultivars (Table 1). On the other hand, the weather conditions in the individual years of the experiment (Figures 1 and 2) modified the effects of the applied NPK doses. The covered cultivar Dukat gave the highest grain yields in the year with the highest rainfall and the highest mean air temperatures in July and August in 2001, whereas the naked cultivar Akt produced the highest yields in the season with the lowest rainfall in 1999. Dukat gave 27% higher yields compared with Akt. However, none of the analyzed experimental factors, nor the weather conditions in the individual vegetation seasons had any significant influence on yielding of the compared oat cultivars (Table 1). The grain yields obtained in these studies are typical for the region in which the field experiments were conducted, as has been confirmed by the literature data (PISULEWSKA et al. 2000).

The mineral content of cereal grain depends on many factors, of which the most important are the mineral composition of soil, applied fertilization level and the course of weather conditions during the vegetation season. In addition, the species, forms and cultivars of cereals are important (GEMBARZEWSKI 2000, KLIMA, PISULEWSKA 2000, WRÓBEL et al. 2003).

In the present experiment, the content of macro- and microelements in the analyzed oat cultivars was mostly affected by the course of weather conditions during the consecutive vegetation seasons. The weather conditions notably affected the mineral uptake by oat plants. In 2000, oat grain

Table 1

Effects of the level of NPK fertilization and vegetation season on the yield of studied cultivars of oat (t ha^{-1})

Years	Cultivars				Means for years	$LSD_{\alpha=0.05}$ for years
	Dukat		Akt			
	levels of fertilization					
	I	II	I	II		
	grain yield					
1999	4.06	3.25	3.08	3.13	3.38	n.s.
2000	2.93	3.13	2.48	2.99	2.88	
2001	3.90	4.39	2.00	2.03	3.08	
Means for cultivars	3.61		2.62			
$LSD_{\alpha=0.05}$ for cultivars	n.s.					
Means for felrilizations	I – 3.07		II – 3.15			
$LSD_{\alpha=0.05}$ for fertilizations	n.s.					

n.s. – not significant

had higher K content compared with the years 1999 and 2001 (Table 2). The content of P was characteristic for this species in all the years of the experiment, whereas K content in the years 1999 and 2001 was lower than stated by literature data (GĄSIOROWSKI 1995). Low content of Na and high content of Cu and Fe in the analyzed grain was within the range stated for this species in the literature (GĄSIOROWSKI 1995). The final year of the field experiments (2001) with very high rainfall and the highest mean air temperatures led to increased uptake of Ca, Mg and Na (Table 3) as well as Cu, Fe, Mn and Zn (Table 4). The experiment showed higher concentrations of K, Ca, Mg, Fe and Zn in the grain of the naked cultivar Akt. However, the differences between the compared cultivars were insignificant.

Oat grain and products of its processing have a relatively high mineral content, including macro- and microelements. In comparison with four other cereals cultivated in Poland, the naked cultivar Akt contains much more minerals (PETKOV et al. 1999). The content of P, K, Ma and Ca in the tested oat kernels was on a similar level as in the kernels obtained in traditional and zero tillage systems (KORZENIOWSKA, STANISŁAWSKA-GLUBIAK 2006). The present experiments demonstrated that naked oat was more abundant in mineral components, particularly P, K, Ca, Mg, Fe and Zn in comparison with the covered cultivar Ducat.

The higher level of NPK fertilization resulted in a slight but statistically significant increase in Mg (Table 3) and Fe (Table 4) content in the naked Akt cultivar. It seems that the naked form, developing kernels with much higher TGW (diminished by a seedling weight), has a higher relative share

Table 2

Effects of the level of N fertilization and vegetation season on the content of P and K in the grain of covered and naked cultivars of oat (g kg^{-1})

Years	Cultivars				Means for years	$LSD_{\alpha=0.05}$ for years
	Dukat		Akt			
	levels of fertilization					
	I	II	I	II		
	P					
1999	3.00	3.00	4.10	4.30	3.60	n.s.
2000	2.80	3.10	3.70	4.00	3.40	
2001	3.30	3.20	4.40	4.10	3.80	
Means for cultivars	3.00		4.10			
$LSD_{\alpha=0.05}$ for cultivars	n.s.					
Means for felrilizations	I – 3.50		II – 3.60			
$LSD_{\alpha=0.05}$ for fertilization	n.s.					
K						
1999	2.40	2.50	2.80	2.80	2.60	0.13
2000	4.10	4.10	4.10	4.10	4.10	
2001	2.60	2.50	2.70	2.80	2.60	
Means for cultivars	3.00		3.20			
$LSD_{\alpha=0.05}$ for culti	n.s.					
Means for felrilizations	I – 3.10		II – 3.10			
$LSD_{\alpha=0.05}$ for fertilizations	n.s.					

n.s. – not significant

of minerals compared with the covered cultivar. The content of Cu and Zn in oat grain met the nutritional criteria suggested by IUNG-PIB (Kabata-Pendias et al. 1993) because it did not exceed respectively 20 and 50 mg·kg^{-1} d.m. Moreover, zinc concentration in the analyzed oat grain did not exceed the concentration limits recommended in cereal products for consumption (*Regulation of the ministry of health* 2000). On the other hand, considering needs of breeding animal, zinc content in oat kernels was insufficient because the requirements of most animal groups are on the level between 40 to 100 mg·kg^{-1} d.m. (*Nutrient reguirenents...* 2000).

The mean microelement content in the tested 474 grain samples was as follows: Mn – 66; Cu – 4.49; Zn – 1.2; Fe – 76.3 mg·kg^{-1} d.m. (Kamińska et al. 1976). The authors' own investigations showed low concentrations of Mn and Zn and higher content of Cu. The concentrations of Fe were on a similar level. Relatively low Mn content assessed in the tested oat kernels was

Table 3

Effects of N fertilization level and vegetation season on the content of Ca, Mg and Na in the grain of covered and naked cultivars of oat (g kg^{-1})

Years	Cultivars				Means for years	$LSD_{\alpha=0.05}$ for years
	Dukat		Akt			
	levels of fertilization					
	I	II	I	II		
	Ca					
1999	0.67	0.67	0.71	0.73	0.69	0.04
2000	0.68	0.68	0.72	0.73	0.70	
2001	0.76	0.75	0.74	0.71	0.74	
Means for cultivars	0.70		0.72			
$LSD_{\alpha=0.05}$ for cultivars	n.s.					
Means for felrilizations	I –0.70		II – 0.71			
$LSD_{\alpha=0.05}$ for fertilizations	n.s.					
Mg						
1999	0.80	0.90	0.95	1.00	0.91	0.03
2000	0.59	0.59	0.69	0.66	0.63	
2001	0.90	0.90	1.00	0.95	0.93	
Means for cultivars	0.78		0.87			
$LSD_{\alpha=0.05}$ for cultivars	n.s.					
Means for felrilizations	I –0.82		II – 0.83			
$LSD_{\alpha=0.05}$ for fertilizations	0.004					
Na						
1999	0.16	0.23	0.17	0.23	0.20	0.05
2000	0.25	0.28	0.25	0.25	0.26	
2001	0.29	0.27	0.30	0.26	0.28	
Means for cultivars	0.25		0.24			
$LSD_{\alpha=0.05}$ for cultivars	n.s.					
Means for felrilizations	I – 0.24		II – 0.25			
$LSD_{\alpha=0.05}$ for fertilizations	n.s.					

n.s. – not significant

Table 4

Effects of N fertilization level and vegetation season on the content of Cu, Fe, Mn and Zn in the grain of covered and naked cultivars of oat (g kg^{-1})

Years	Cultivars				Means for years	$LSD_{\alpha=0.05}$ for years
	Dukat		Akt			
	levels of fertilization					
	I	II	I	II		
	Cu					
1999	6.7	6.7	7.1	7.3	6.9	0.17
2000	5.0	4.3	4.1	3.7	4.2	
2001	7.6	7.5	7.4	7.1	7.4	
Means for cultivars	6.3		6.1			
$LSD_{\alpha=0.05}$ for cultivars	n.s.					
Means for felrilizations	I –6.3		II – 6.1			
$LSD_{\alpha=0.05}$ for fertilizations	n.s.					
Fe						
1999	80.0	90.0	95.0	100	91.0	0.35
2000	59.0	59.0	69.0	66.0	63.0	
2001	90.0	90.0	100	95.0	93.0	
Means for cultiva	78.0		87.0			
$LSD_{\alpha=0.05}$ for cultivars	n.s.					
Means for felrilizations	I –82.0		II – 83.0			
$LSD_{\alpha=0.05}$ for fertilizations	0.04					
Mn						
1999	16.0	23.0	17.0	23.0	20.0	0.05
2000	25.0	30.0	25.0	25.0	26.0	
2001	29.0	27.0	30.0	26.0	28.0	
Means for cultivars	0.25		0.24			
$LSD_{\alpha=0.05}$ for cultivars	n.s.					
Means for felrilizations	I –25.0		II – 24.0			
$LSD_{\alpha=0.05}$ for fertilizations	n.s.					
Zn						
1999	22.5	30.0	31.7	29.2	28.3	0.38
2000	37.8	35.7	36.1	32.3	35.4	
2001	32.2	38.0	39.1	41.7	37.7	
Means for cultivars	32.7		35.0			
$LSD_{\alpha=0.05}$ for cultivars	n.s.					
Means for felrilizations	I –33.2		II – 34.5			
$LSD_{\alpha=0.05}$ for fertilizations	n.s.					

n.s. – not significant

confirmed by the research conducted by GEMBARZEWSKI (2000). Also the study conducted by BŁAZIAK (2007) demonstrated high Fe concentrations in oat grain, but slightly lower content of Mn. Oat has considerable requirements for Mn and a low demand for Zn, but is moderately demanding for Fe (KACZOR, KOZŁOWSKA 2000). Despite such requirements for microelements, the content of the analyzed elements in oat grain was arranged in the following order: Fe > Zn > Mn > Cu, which has been confirmed by other authors (GĄSIOROWSKI 1995, WRÓBEL, OBOJSKI 1998).

CONCLUSIONS

1. The two oat cultivars, Dukat and Akt, responded differently to the course of weather conditions during the analyzed vegetation seasons. The covered cultivar Dukat gave the highest yields in the year with the greatest rainfall, i.e. 2001, while the naked cultivar Akt gave the highest yields in the season with the lowest rainfall, i.e. 1999.

2. The course of weather conditions, different in the consecutive years of the experiment and particularly the season with very high rainfall, increased the content of macro- and microelements in oat grain.

3. The higher NPK fertilization level resulted in a slight increase in Mg and Fe content in the naked cultivar Akt. Naked oat was more abundant in minerals, especially in P, K, Ca, Mg, Fe and Zn, compared with the covered cultivar Dukat.

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