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EFFECT OF AGRONOMIC FACTORS ON PROTEIN YIELD AND CONTENT OF NITROGEN IN GRAIN OF NAKED OAT (*Avena sativa*)

WPŁYW WYBRANYCH ZABIEGÓW AGROTECHNICZNYCH NA ZAWARTOŚĆ AZOTU I PLON BIAŁKA W ZIARNIE OWSA NAGOZIARNISTEGO (*Avena sativa*)

Abstract: Mineral fertilization, particularly with nitrogen is a factor visibly modifying the quantity and quality of oat grain yield. The range of changes in protein yield and the element contents depend not only on the level of mineral fertilization but also on the genotype and growth regulators. Because of high dependence of agronomic measures efficiency on the genotype, it is necessary to investigate this interaction.

Field experiments were conducted in Wierzbica on typical brown soil, where protein yield ranged from 75 to 88 $g \cdot m^{-2}$, whereas in the experiment conducted in Prusy on degraded chernozem, protein yield fell within the range of 540 to 740 $kg \cdot ha^{-1}$. The field experiment conducted in Wierzbica demonstrated that protein yield in naked oat was stimulated by the genotype and phosphorus-potassium fertilization and apparently limited by the application of Moddus growth regulator. Under conditions of a better site in Prusy only genotype statistically significant effect was registered, with persisting influence of the other factors. An apparent difference was noticed in the efficiency of nitrogen fertilization effect on the protein yield, because under site conditions in Prusy the increase in yield by 0.3 of standard deviation unit was demonstrated in comparison with very slight growth in its yield in Wierzbica.

Because protein yield is the resultant of grain yield and its nitrogen content, a less significant effect of the tested factor on its content was observed. The main factor which statistically significantly determined nitrogen content was the choice of oat cultivar/strain. Both in Wierzbica and Prusy both oat strains (STH 4770 and STH 7000) contained bigger nitrogen quantities than Akt cv. The other tested agronomic factors caused changes in nitrogen content but they were not statistically significant.

Keywords: naked oat, protein yield, nitrogen, mineral fertilization, plant growth regulator

Nitrogen is one of basic elements crucial for the proper growth and development of plants. Moreover, it determines the quality and level of crop yields [1, 2]. The uptake

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and utilization of nitrogen by plants depend on the localities, including soil, agronomic and climatic conditions [3, 4].

Mineral fertilization, particularly with nitrogen, is a factor apparently modifying the quantity and quality of oat grain [5, 6]. The range of changes in protein yield and component contents depends not only on the fertilization level but also on the genotype and growth regulators [7]. A serious dependence of agronomic factors on genotype makes necessary to examine this interaction. The research aimed at an assessment of the effect of mineral fertilization, kind and dose of growth regulator and genotype on total nitrogen content and protein yield in naked oat grain.

Materials and methods

The field experiments were conducted in 2003 in two localities: in Prusy near Krakow (one experiment) and in Wierzbica (two experiments). Agronomic measures applied were the same as generally used.

The field experiments in Wierzbica were set up using fractional design 2^{5-1} in two replications. Each plot area was 6 m^2, but the yield and its components were estimated basing on the test area of 1 m^2. The seeds were sown at 500 pcs · m^{-2} density. The experimental factors and their levels were shown in Table 1. The experiment was located on typical brown soil classified to IV class of soil quality, with pH = 5.9. The strains selected for the experiments revealed some specific properties, such as increase in 1000 grains weight (STH 4770) and shortened stem (STH7000).

Table 1

Agronomic factors and their levels in experiments conducted in Wierzbica

Agronomic factors	The factor levels	
	1 [low]	2 [high]
Genotype [experiment I]	STH 4770 Strain	Akt Cultivar
Genotype [experiment II]	STH 7000 Strain	Akt Cultivar
PK fertilization	0 kg · ha^{-1} PK	226 kg · ha^{-1} PK
Foliar application of urea	0 kg · ha^{-1} N	17 kg · ha^{-1} N
Moddus plant growth regulator	0 dm^3 ha^{-1} [M 1]	0.4 dm^3 ha^{-1} [M 2]
Promalin plant growth regulator	0 dm^3 · ha^{-1}	0.15 dm^3 · ha^{-1}

The field experiment conducted in Prusy was set up using fractional design 3^{4-1} in two replications. The plot for harvest area was 10 m^2 and the seeds were also sown at the density of 500 pcs · m^{-2}. The experiment was conducted on degraded chernozem counted to the first soil quality class. The experimental factors and their levels were listed in Table 2.

The amount of NPK fertilization in both localities resulted from the naked oat grain harvest assumed on the level of 4 Mg · ha^{-2} and the site abundance. Nitrogen foliar fertilization constituted 1/4 of the nitrogen fertilization used (17 kg · ha^{-1} in Wierzbica and 9 kg · ha^{-1} in Prusy). The second, higher dose of N used foliarly in Prusy resulted from the doubling of the lower dose, which approximately equalled the dose applied in

Wierzbica (18 kg · ha^{-1}). After oat grain harvesting and determining the crop yield, nitrogen content was determined using Kjeldahl distilling method.

Table 2

Agronomic factors and their levels in experiment conducted in Prusy

Agronomic factors	The factor levels		
	1 [low]	2 [medium]	3 [high]
Genotype	Strain STH 7000	Cultivar Akt	Strain STH 4770
PK fertilization	0 kg · ha^{-1} PK [PK 1]	72 kg · ha^{-1} P [PK 2]	256 kg · ha^{-1} PK [PK 3]
Foliar application of urea	0 kg · ha^{-1} N	9 kg · ha^{-1} N	18 kg · ha^{-1} N
Moddus plant growth regulator	0 dm^3 · ha^{-1}	0.4 dm^3 · ha^{-1}	0.6 dm^3 · ha^{-1}

The course of rainfall-thermal conditions was shown in Gaussen-Walter diagrams. The diagram analysis reveals that more advantageous rainfall-thermal conditions for growth and development of oat plants occurred in Wierzbica. The course of rainfall curve, lowered in relation to mean temperatures curve, points to alternate occurrence of decades fulfilling or not fulfilling oat water needs. Three such decades fulfilling oat water needs were registered in Prusy locality, including two subsequent ones (2^{nd} and 3^{rd} decade in May), with the remaining part of vegetation period revealing considerable rainfall deficiency (Fig. 1 and 2). The reference of the course of lowered rainfall curve to lowered curve of water needs acc. to Dziezyc points rather to their fulfillment, but only until the first decade of June.

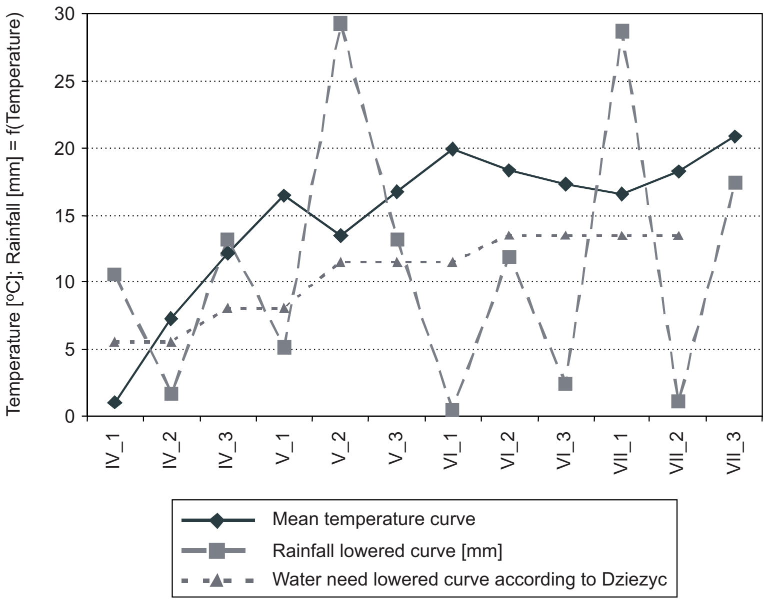

Fig. 1. Weather diagram for the vegetation period in Wierzbica

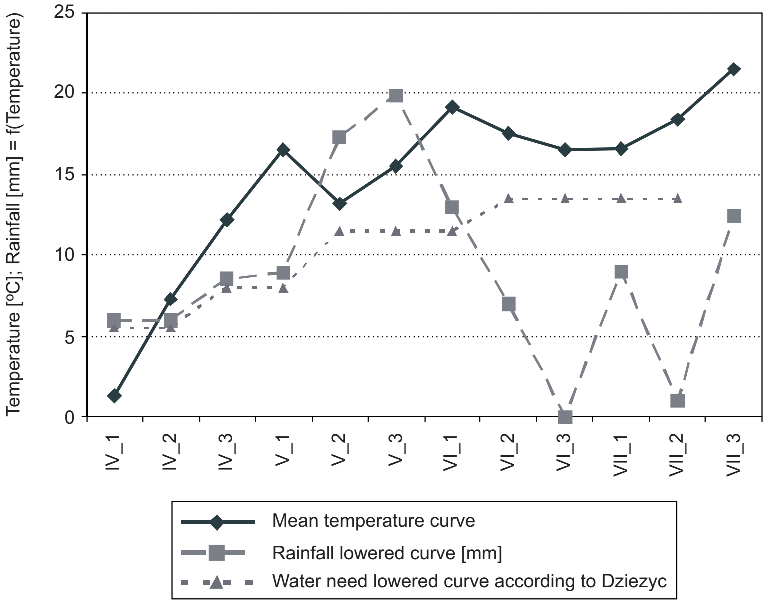

Fig. 2. Weather diagram for the vegetation period in Prusy

The obtained results were verified using ANOVA procedure. STATISTICA 7.1 packet, module planning of two and three-value experiments was used. In case of three-value experiment, variation caused by the experimental factors was divided into linear and square factor. It was determined by a suspicion that a parabola may describe the effect of investigated factors on the yield and protein content in grain better than the straight line.

Verification of the basic assumed, null working hypotheses H_0: $\sum_{i=1}^{k} k_i^2 = 0$ was conducted on the basis of F-Fisher-Snedecor test. Before conducting analyses of variance the distribution of features fit to normal distribution was checked using Kolmogorow--Smirnow test, as well as homogeneity of error variance assumption using Bartlett's test. Multiple regression analysis of variance was also conducted with the use of ANOVA models. Standardized regression coefficients were presented in the Tables in order to facilitate comparison of the effect of individual factors. Their statistical significance confirms statistically significant effect of respective variability source. Statistical significance on $\alpha = 0.05$ level was marked in bold and on $\alpha = 0.01$ level in bold and italics [8].

Results and discussion

The environment conditions in Wierzbica allowed to accumulate higher content of total nitrogen in oat grain, ranging from 24.02–26.45 $g \cdot kg^{-1}$. In Prusy nitrogen concentrations were lower and fluctuated from 17.66 to 19.05 $g \cdot kg^{-1}$. Despite the site differences, the interrelations in nitrogen content between the genotypes remained unchanged. Definitely the highest nitrogen content was characteristic for STH4770 strain and the lowest for Akt cultivar (Table 3 and 4).

In Wierzbica, the genotype used in the experiment comparing STH4770 strain with Akt cultivar as the only one from among tested factors had a statistically significant effect. Akt cv. revealed lower nitrogen content by 0.72 of standard deviation unit, which constituted 2.43 $g \cdot kg^{-1}$. Negative, but statistically insignificant results obtained in Wierzbica were also caused by the application of phosphorus-potassium fertilization and Promalin growth regulator. Foliar application of urea and the use of Moddus regulator had definitely stronger and also positive influence on nitrogen content. Standardised regression coefficients for urea fertilization for experiments I and II were respectively 0.297 and 0.303, which indicated increase in N content, respectively by 0.99 and 0.79 $g \cdot kg^{-1}$. The effect of Modus growth regulator in these experiments was respectively 0.132 and 0.265, which showed increase in N content respectively by 0.45 and 0.69 $g \cdot kg^{-1}$ (Table 3).

Table 3

The effect of tested factors on nitrogen content in oat grains and protein yield in the experiment in Wierzbica

Factor	Experiment I			Experiment II		
	STH 4770 – Akt			STH 7000 – Akt		
	The factor level and standardized regression coefficient*					
	1	2	Coefficient	2	1	Coefficient
Content N [$g \cdot kg^{-1}$]						
Cultivar/Strain	26.45	24.02	***–0.720***	24.73	24.02	–0.272
PK	25.39	25.08	–0.092	24.55	24.20	–0.133
N	24.74	25.73	0.297	23.98	24.77	0.303
Moddus	25.01	25.46	0.132	24.03	24.72	0.265
Promalin	25.28	25.19	–0.029	24.50	24.25	–0.096
Protein yield [$g \cdot m^{-2}$]						
Cultivar/Strain	83.50	85.04	0.084	76.99	85.04	**0.337**
PK	80.41	88.13	**0.424**	75.24	86.79	***0.483***
N	83.88	84.66	0.043	80.11	81.92	0.076
Moddus	83.45	85.09	0.090	85.85	76.18	**–0.405**
Promalin	84.62	83.92	–0.039	81.87	80.16	–0.072

* – see Table 1.

The only statistically significant effect in the experiment conducted in Prusy was the genotype square effect resulting from apparently lower nitrogen content in Akt cv., constituting medium level of the experimental factor (genotype). Estimating the effect of phosphorus-potassium fertilization in Prusy one should emphasize the fact of increased nitrogen content already after application of solely phosphorus fertilizer.

Introduction of additional potassium fertilization on the 3rd level of this factor did not cause any greater changes in N content. Foliar fertilization with increasing doses of urea led to elevated N content in oat grain. Application of Moddus growth regulator caused also statistically insignificant increase in oat grain N concentrations (Table 4).

Table 4

The effect of tested factors on nitrogen content in oat grains and protein yield in the experiment in Prusy

Factor	The factor level*			Standardized coefficient of regression effects		
	1	2	3	Linear	Square	Intercept
N Content [$g \cdot kg^{-1}$]						
Cultivar/Strain	19.03	17.66	19.05	0.004	***0.401***	–0.200
PK	17.74	18.46	18.33	0.138	–0.079	
N	17.98	18.27	18.55	0.135	0.032	
Moddus	17.84	18.58	17.93	0.221	–0.150	
Protein yield [$Mg \cdot ha^{-2}$]						
Cultivar/Strain	0.545	0.651	0.740	***0.580***	–0.073	–0.252
PK	0.656	0.639	0.659	0.010	0.020	
N	0.624	0.652	0.659	0.103	–0.076	
Moddus	0.645	0.659	0.621	–0.073	–0.128	

* – see Table 2.

In this experiment N content in oat grain was affected (within the limit of statistical significance) also by two interactions: 1 – genotype with phosphorous-potassium fertilization and 2 – phosphorus–potassium fertilization with Moddus regulator application. The first of the interactions revealed a different response of dwarf strain (STH 7000) to subsequent levels of phosphorus-potassium fertilization. On its subsequent levels the treatment caused a decline in grain N concentration. On the other hand, STH 4770 strain (the highest) revealed increase in nitrogen content in result of complex phosphorus-potassium fertilization. Behaviour of Akt cv. may be described as undirected or as a lack of reaction to this experimental factor (Fig. 3). The second of the interactions mentioned above revealed a decrease in nitrogen concentration in grain in effect of a higher dose of Moddus growth regulator at simultaneous lack of phosphorus--potassium fertilization. On the treatments where only phosphorus or complex phosphorus-potassium fertilization was applied, an increase in nitrogen content in oat grain was observed with increasing doses of Moddus regulator (Fig. 4). Therefore, it seems that the analysed fertilizer factor may alleviate the unfavourable consequence of lowering nitrogen content in grain after the application of a higher dose of Moddus growth regulator (0 $dm^3 \cdot ha^{-1}$).

Protein yield as a resultant of nitrogen content and grain yield was shaped by the analysed experimental factors in a different way. In both experiments conducted in Wierzbica the protein yield was statistically significantly increased by phosphorus-

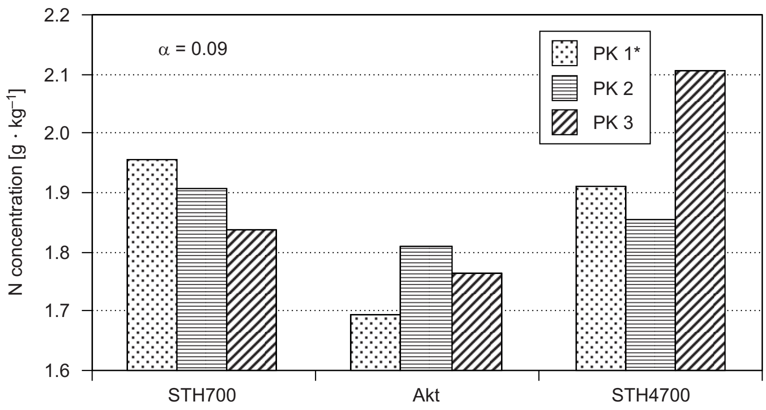

Fig. 3. N concentration under the influence of PK fertilization and genotype interaction in Prusy: * – see Table 2

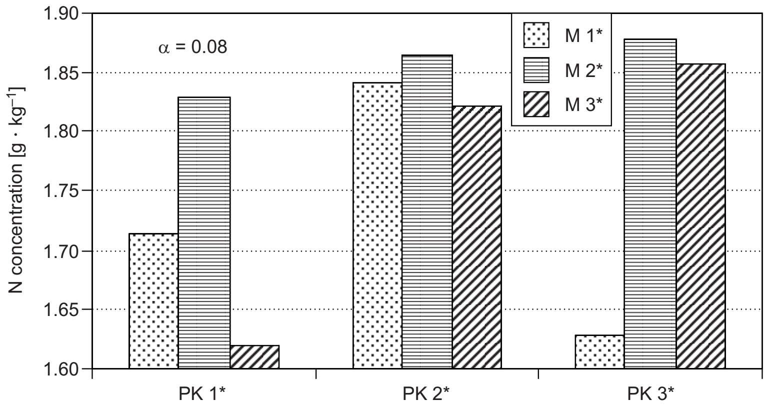

Fig. 4. N concentration under the PK fertilization and plant growth regulator Moddus interaction in Prusy. * – see Table 2

-potassium fertilization, respectively for experiments I and II by 0.424 and 0.483 of standard deviation unit. In the experiment with dwarf STH 7000 strain, Moddus growth regulator also had statistically significant effect since it considerably decreased protein yield (by 0.405 of standard deviation unit, ie by 9.67 g $\cdot$ m^{-2}). Also statistically lower protein yield was confirmed for the dwarf strain (a decline in comparison with Akt cv. by 0.337 of standard deviation unit). Protein yield in Wierzbica in the experiment I was also shaped by the cooperation of the genotype with the applied Moddus growth regulator. STH 4770 strain responded by an apparent increase in protein yield after Moddus growth regulation application, contrary to Akt cv. (Fig. 5).

In Prusy only the genotype determined statistically the protein yield. The highest yield (740 kg $\cdot$ ha^{-1}) was obtained from STH 4770 strain, whereas Akt cv. yielded by 89 kg $\cdot$ ha^{-1} lower, and the dwarf STH 7000 strain produced even 195 kg $\cdot$ ha^{-1} lower yield. In Prusy, a decline in protein yield from dwarf STH 7000 strain was registered with

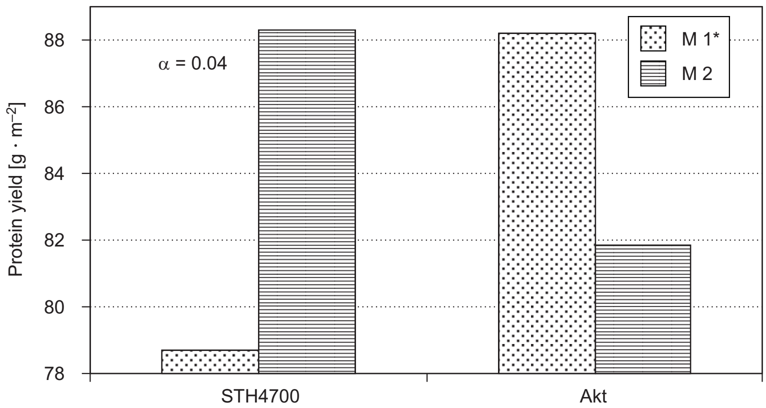

Fig. 5. Protein yield under the genotype and Moddus plant growth regulator interaction in Wierzbica: * – see Table 1

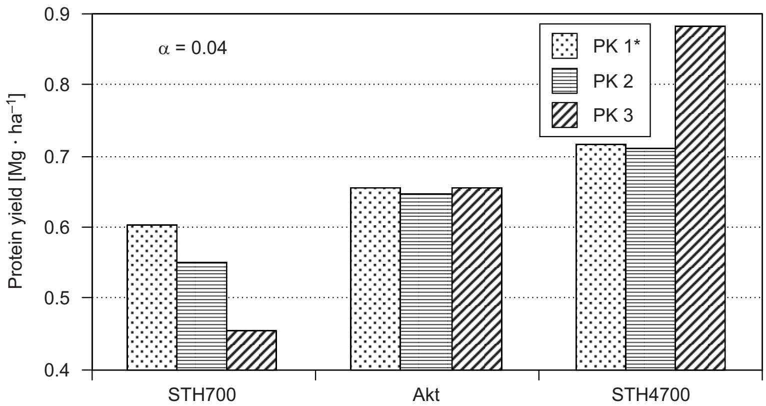

Fig. 6. Protein yield under the influence of PK fertilization and genotype interaction in Prusy: * – see Table 2

increasing level of phosphorus-potassium fertilization, whereas the opposite response of STH4770 strain was observed and no response from Akt cv. to this factor (Fig. 6).

The factor which in either of the two localities did not affect protein yield was urea foliar fertilization, while application of Promalin growth regulator had no influence in Wierzbica, and phosphorus-potassium fertilization in Prusy. The obtained results confirm that chemical composition of oat grain depends among others on the cultivar or genotype [7] but also on a number of agronomic factors [9, 10].

One of the major chemical components determining grain quality is protein. An important agent modifying biological value of protein in oat grain is introduction of new cultivar varieties and genotypes of this plant [7, 11]. Also investigations of other authors [12, 13] confirm that naked oat cultivars contain greater amounts of crude protein in comparison with the husked one.

Conclusions

1. In Wierzbica a higher nitrogen content in oat grain and higher protein yield were obtained.

2. Application of growth regulators resulted in the decline in naked oat protein yield but Moddus growth regulator caused also increased N grain concentrations.

3. Phosphorus-potassium fertilization and foliar urea application did not affect nitrogen concentrations in oat grain cultivated in Prusy, whereas phosphorus-potassium fertilization used in Wierzbica apparently increased protein yield.

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WPŁYW WYBRANYCH ZABIEGÓW AGROTECHNICZNYCH NA PLON BIAŁKA I ZAWARTOŚĆ AZOTU W ZIARNIE OWSA NAGOZIARNISTEGO (*Avena sativa*)

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Abstrakt: Nawożenie mineralne, zwłaszcza azotem jest czynnikiem modyfikującym w wyraźny sposób ilość i jakość ziarna owsa. Zakres zmian w plonie białka oraz zawartości składników uzależniony jest nie tylko od poziomu nawożenia mineralnego, ale również genotypu i regulatorów wzrostu. Z uwagi na dużą zależność skuteczności zabiegów agrotechnicznych od genotypu zachodzi konieczność badania tej interakcji.

Doświadczenia polowe przeprowadzano w Wierzbicy na glebie brunatnej typowej właściwej i uzyskany plon białka wahał się od 75 do 88 g $\cdot$ m^{-2}. Natomiast w eksperymencie przeprowadzonym w Prusach, na czarnoziemie zdegradowanym, plon białka zawierał się w zakresie od 540 do 740 kg $\cdot$ ha^{-1}. Z przeprowadzonych doświadczeń polowych w Wierzbicy wynika, że plon białka owsa nagoziarnistego był stymulowany przez genotyp oraz nawożenie fosforowo-potasowe i wyraźnie ograniczany przez zastosowanie regulatora wzrostu Moddus. W Prusach stwierdzono statystycznie istotny wpływ tylko genotypu, przy zachowaniu tendencji wpływu pozostałych badanych czynników. Zaobserwowano wyraźną różnicę w skuteczności oddziaływania nawożenia azotem na plon białka, bowiem w warunkach siedliskowych Prus wykazano zwiększenie jego plonu aż o 0,3 jednostki odchylenia standardowego przy bardzo niewielkim zwiększeniu jego plonu w Wierzbicy.

Zaobserwowano również mniej istotny wpływ badanych czynników na zawartość N w ziarnie owsa. Zasadniczo czynnikiem w sposób statystycznie znaczący warunkującym zawartość azotu był dobór odmiany/rodu owsa. Zarówno w Wierzbicy, jak i w Prusach obydwa rody (STH 4770, STH 7000) zawierały więcej azotu niż odmiana Akt. Pozostałe badane czynniki agrotechniczne powodowały zmiany w zawartości azotu, ale nie były one statystycznie istotne.

Słowa kluczowe: owies nagoziarnisty, plon białka, azot, nawożenie mineralne, regulator wzrostu