TECHNOLOGICAL VALUE OF SPRING WHEAT OF ZEBRA CULTIVAR AS RELATED TO THE WAY OF NITROGEN AND MAGNESIUM APPLICATION

WARTOŚĆ TECHNOLOGICZNA PSZENICY JAREJ ODMIANY ZEBRA W ZALEŻNOŚCI OD SPOSOBU APLIKACJI AZOTU I MAGNEZU

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ABSTRACT

A significant increase in grain yield was observed following soil fertilization with nitrogen up to the level of 90 kg·ha^{-1}, independently of foliar fertilization. Among the examined variants of foliar fertilization on average, the significantly highest grain yield was obtained in the objects in which nitrogen and magnesium were administered in parallel. Within the entire range of nitrogen doses administered to soil, a moderately significant increase was noted in total protein content, to the level of 90 kg N·ha^{-1} a moderately increased content of wet gluten, sedimentation ratio and bread volume were recorded and following application of 60 kg N·ha^{-1} an increase in water absorbability of flour was observed. Independently of the soil fertilization with nitrogen, the most favourable of the studied variants of foliar fertilization for principal parameters of baking value proved to be a parallel application of nitrogen and magnesium or administration of nitrogen only.

Key words: spring wheat, nitrogen fertilization, foliar fertilization, grain yield, technological parameters

STRESZCZENIE

Istotny wzrost plonu ziarna stwierdzono po zastosowaniu doglebowo dawki azotu do poziomu 90 kg·ha^{-1}, niezależnie od nawożenia dolistnego. Spośród badanych wariantów nawożenia dolistnego średnio istotnie najwyższy plon ziarna uzyskano na obiektach, gdzie zastosowano łącznie azot i magnez. Stwierdzono, w całym zakresie zastosowanych doglebowo dawek azotu, średnio istotny wzrost zawartości białka ogólnego, do poziomu 90 kg N·ha^{-1} średnio istotny wzrost zawartości mokrego glutenu, wskaźnika sedymentacji i objętości pieczywa, a po zastosowaniu 60 kg N·ha^{-1} wodochłonności mąki. Najkorzystniejszym spośród badanych wariantów nawożenia dolistnego, niezależnie od zastosowanego doglebowo nawożenia azotem, dla najważniejszych wyróżników wartości wypiekowej okazało się łączne zastosowanie azotu i magnezu lub tylko azotu.

Słowa kluczowe: pszenica jara, nawożenie azotem, nawożenie dolistne, plon ziarna, parametry technologiczne

DETAILED ABSTRACT

Celem niniejszej pracy było określenie wysokości dawki azotu zastosowanej doglebowo oraz wskazanie wariantu nawożenia nalistnego, które pozwoliłyby na osiągnięcie wysokiego plonu ziarna pszenicy jarej odmiany Zebra o wymaganych parametrach wypiekowych. Badania prowadzono w latach 2005-2007 w RZD Minikowo na glebie płowej typowej, według międzynarodowej klasyfikacji FAO-UNESCO jest to Albic Luvisols, zaliczanej do kompleksu żytniego bardzo dobrego, w układzie dwuczynnikowym w trzech powtórzeniach. Pierwszym czynnikiem doświadczenia było doglebowe nawożenie azotem (n=4; obiekt kontrolny, 60, 90 i 120 kg $N \cdot ha^{-1}$), które stosowano w formie saletry amonowej. Natomiast drugim czynnikiem (n=4) było nawożenie nalistne stosowane w następujących formach: mocznik, siarczan magnezu, mocznik + siarczan magnezu i obiekt bez nawożenia. Istotny wzrost plonu ziarna stwierdzono po zastosowaniu doglebowo dawki azotu do poziomu 90 $kg \cdot ha^{-1}$, niezależnie od nawożenia dolistnego. Spośród badanych wariantów nawożenia dolistnego średnio istotnie najwyższy plon ziarna uzyskano na obiektach, gdzie zastosowano łącznie azot i magnez. Stwierdzono, w całym zakresie zastosowanych doglebowo dawek azotu, średnio istotny wzrost zawartości białka ogólnego, do poziomu 90 kg $N \cdot ha^{-1}$ średnio istotny wzrost zawartości mokrego glutenu, wskaźnika sedymentacji i objętości pieczywa, a po zastosowaniu 60 kg $N \cdot ha^{-1}$ wodochłonności mąki. Najkorzystniejszym spośród badanych wariantów nawożenia dolistnego, niezależnie od zastosowanego doglebowo nawożenia azotem, dla najważniejszych wyróżników wartości wypiekowej okazało się łączne zastosowanie azotu i magnezu lub tylko azotu. Wyniki badań wskazują również, że w przypadku odmiany Zebra, nawożenie azotem już na poziomie 60 $kg \cdot ha^{-1}$ zabezpiecza uzyskanie minimalnych parametrów jakościowych, które determinują ziarno dla potrzeb piekarnictwa.

INTRODUCTION

Technological values of spring wheat grain determine high demand for products made of the flour. Thus, grain of consumable wheat must manifest a high technological value, which assures good quality of baking products and stability of the technological process [15,16]. The properties are genetically conditioned and are dependent on the involved cultivar but they may vary depending upon natural environment and agrotechnical procedures, including fertilization [6,9,11,12,13,21,27,]. Literature data indicate that nitrogen fertilization represents not only the most important yield-stimulating procedure but also the most important variable, which affects quality of the yield [5,7,8,13,17,26,29]. Progressive increase in doses of the component not always is equivalent to its increased quality. Therefore, determination of optimum nitrogen doses remains to represent a current problem [2,12,15,26]. Foliar application of aqueous solution of urea proved to be a rational and highly effective procedure in field cultivation and, according to the literature of the subject, parallel application of urea and magnesium sulphate is particularly advantageous [4,23]. The principal benefit of foliar fertilization involves its speed of action and the high utilisation of the introduced in this way alimentary components [14].

Present study aimed at determining the size of nitrogen dose introduced to the soil and selection of foliar fertilization variant, which would assure high yield of spring wheat grain of Zebra cultivar, manifesting the required baking parameters.

MATERIALS AND METHODS

The field experiment was conducted in 2005-2007, in RZD Minikowo (Kujawy-Pomerania voivodship) in a typical lessive soil, in the international FAO-UNESCO classification the Albic Luvisols. The soil, classified as a rye complex of a very good quality, manifests a neutral pH and a high or average content of absorbable forms of phosphorus, potassium, and magnesium.

The bifactorial experiment was established using the method of the drawn at random sub-blocks with three repetitions. The first variable of the experiment involved soil fertilization with nitrogen (n=4), in which Norway saltpetre was used at the following levels of fertilization: I. 60 kg $N \cdot ha^{-1}$ (N_{60}) in a single dose before sowing, II. 90 kg $N \cdot ha^{-1}$ (N_{90}) in a divided dose, including 2/3 of the dose applied before sowing and 1/3 of the dose applied at the full phase of shooting (phase 33 according to Zadox et al.); III. 120 kg $N \cdot ha^{-1}$ (N_{120}) in a divided dose, including 1/2 of the dose applied before sowing, 1/4 kg applied at the full phase of shooting (phase 33 according to Zadox et al.) and 1/4 of the dose applied at the beginning of heading (phase 53 according to Zadox et al.); IV. control object with no nitrogen fertilization (N_0). The other variable (n=4) included foliar fertilization applied in the following forms: urea, magnesium sulphate, urea + magnesium sulphate, and the object with no fertilization. Variants of foliar fertilization were applied at the beginning of shooting phase (phase 31 according to Zadox et al.) in the form of 10 % solution of urea and 5 % solution of magnesium sulphate and at the beginning of the heading phase (phase 53 according to Zadox et al.) (5 % solution of urea, 5 % solution of magnesium sulphate). The applied doses of urea solution introduced 20.7 kg N·ha^{-1} while the applied doses of magnesium sulphate introduced 4.8 kg MgO·ha^{-1}. The cultivated plant involved spring wheat, cultivar Zebra.

The experiment was conducted basing on a uniform level of fertilization with phosphorus and potassium. The forecrop for spring wheat involved oats, collected to obtain green forage. Agrotechnical procedures were conducted in line with recommendations for the species.

In the experiment the size of grain yield was determined and indices of baking value were established, including falling number (according to Hagberg, PN-ISO-3093), total protein content (%N·5.7, PN-75A-04018), gluten content (PN-A-74-043), sedimentation value (test according to Zeleny, PN-ISO-5529), water absorption by flour (PN-ISO 5530) and volume of baking products obtained from 100 g flour (PN-A-74108).

The obtained results of studies were subjected to statistical analysis, employing analysis of variance, and limiting differences were appraised employing the test of Tukey at the significance level of 0.05. In order to establish relationships and dependencies between soil fertilization with nitrogen and the obtained values of qualitative traits in spring wheat, the obtained results were subjected to analysis of direct correlations and of linear regression.

Weather conditions throughout the experiment (2005-2007 growing seasons) are given in Table 1. In the first year of the experiments both the mean air temperature and the total rainfall were lower, as compared with the 1995-2005 means, respectively by: 0.8^{0}C and 41.9 mm, which accounted for 15.6%, while in 2006 and 2007 mean air temperature and total rainfall were higher than the multi-year means by a respective of: 0.2^{0}C and 0.3^{0}C and 38.2 mm, which accounted for 14.2% and 74.7 mm, namely 27.8%.

RESULTS AND DISCUSSION

The mean grain yield for Zebra cultivar amounted to 3.82 t·ha^{-1} (Table 2) and it was higher by 0.5 t·ha^{-1}, as compared to the yield obtained for the same cultivar in the experiment of Biskupski et al. [1]. Most of studies documented a favourable effect of increasing doses of nitrogen on yield of spring wheat, although the recommended doses of the component were quite variable [5,10,16,25,26,29]. A moderately significant increase in grain yield was obtained using nitrogen doses up to 90 kg ·ha^{-1} and, as compared to N_{60} and N_0 objects, it was higher by 11.3 and 45.9 %, respectively (Table 2). The relationship between grain yield and variable nitrogen fertilization was described by the equation of linear regression (Table 4). Independently of soil fertilization with nitrogen, foliar fertilization in all its variants increased grain yield as compared to the control object (Table 2). Similarly, to experiments of Czuba et al. [4], parallel application of urea and of magnesium sulphate proved to be particularly advantageous. Application of the parallel fertilization with nitrogen and magnesium induced a moderately significant increase in wheat grain yield, as compared to objects fertilized exclusively with nitrogen or magnesium or to the control object, by 4.7%, 5.7% and 14.7 %, respectively (Table 2).

In determination of grain quality, attention is paid to its enzymatic properties and, in particular, to amylolytic activity, which is characterized by a falling number. Similarly as proved by Nowak et al. [15], in our experiment average values of falling number for the studied wheat pointed to low activity of alpha-amylase and they did not disqualify the studied grain from the point of view of its baking suitability (Table 5). According to Sułek et al. [20,22], value of the falling number depends more from genetic traits of the cultivar and weather conditions than from the applied in their experiment ways of nitrogen application. Independently of the foliar fertilization, the applied to soil nitrogen doses up to the level of 90 kg·ha^{-1} have induced a significant increase in falling number, but only in comparison to the value obtained in the control object (Table 5). Application of the foliar fertilization has resulted in falling numbers at the level resembling those obtained in objects fertilized in parallel with nitrogen and magnesium or with magnesium alone. However, the trait value has proven to be significantly higher than the value obtained in the control object only in objects fertilized with magnesium (Table 5).

A number of studies indicate that an increased level of fertilization with nitrogen induces in the wheat grain an increased content of total protein [3,8,12,16,17,25,29], representing one of the most important factors determining its technological quality. Ralcewicz and Knapowski [18] noted a significant increase in content of the component following application of fertilization doses up to 90 kg N·ha^{-1}, while Klupczyński et al. [10] noted this also after application of 120 kg N·ha^{-1}. Similarly to our experiment, a moderately significant increase in total protein content resulted from soil fertilization with any nitrogen doses up to the level of 120 kg ·ha^{-1} and, as compared to $N_{90,}$ N_{60} and N_0 objects, it was higher by 12.2% , 19.1% and 25.2 %, respectively (Table 5). Results of studies of Wróbel [29] also have shown that content of the component is most favourably affected by the dose of 120 kg N·ha^{-1} but applied on two occasions, i.e. 60 kg before sowing and 60 kg at the beginning of heading. The relationship between the applied soil fertilization with nitrogen and content of total protein

Table 1. Weather conditions in the vegetation seasons of 2005-2007
Tabela 1. Warunki pogodowe w sezonach wegetacyjnych 2005-2007

Month Miesiąc	2005		2006		2007		Mean (średnia) 1995 -2005	
	Temper. (^{0}C)	Rainfall Opady (mm)	Temper. (^{0}C)	Rainfall Opady (mm)	Temper. (^{0}C)	Rainfall Opady (mm)	Temper. (^{0}C)	Rainfall Opady (mm)
IV	8.0	23.8	7.7	66.0	8.5	17.6	8.2	29.3
V	12.7	86.1	12.4	58.8	13.8	73.1	13.4	53.2
VI	14.8	30.2	17.1	22.7	18.2	105.5	16.2	48.4
VII	18.6	43.2	21.0	46.1	18.0	104.7	18.3	77.9
VIII	16.5	43.1	17.0	112.9	17.8	42.1	18.4	59.5
Mean; Sum Średnia; Suma	14.1	226.4	15.1	306.5	15.2	343.0	14.9	268.3

Table 2 Size of grain yield as related to the applied soil fertilization with nitrogen and variants of foliar fertilization [t·ha^{-1}]
Tabela 2. Wielkość plonu ziarna w zależności od zróżnicowanego nawożenia azotem i wariantów nawożenia nalistnego [t·ha^{-1}]

Nitrogen fertilization (I factor) Nawożenie azotem (I czynnik) [kg·ha^{-1}]	Foliar fertilization (II factor) Nawożenie dolistne (II czynnik)				mean średnia
	without fertilization bez nawożenia	urea mocznik	magnesium sulphate siarczan magnezu	urea+magnesium sulphate mocznik+ siarczan magnezu	
N_0	2.58	2.86	2.83	3.33	2.90
N_{60}	3.55	3.87	3.83	3.95	3.80
N_{90}	3.93	4.35	4.27	4.38	4.23
N_{120}	4.05	4.40	4.40	4.52	4.34
średnia	3.53	3.87	3.83	4.05	3.82
LSD - NIR$_{(p=0,05)}$ for-dla:	I 0.394	II 0.172	I x II n.s. - n.i.		

in wheat grain has been confirmed by the calculated coefficients of direct correlation (Table 3) and it has been described by the equation of linear regression (Table 4). Sztuder and Świerczewska [23] have provided the opinion that percentage content of total protein in spring wheat grain is determined not only by specific cultivar traits but also by the applied foliar fertilization. The most extensive effect of applied foliar fertilization on the protein content in wheat grain has been noted in the case of Sigma cultivar, for which protein content has ranged from 106 g·kg^{-1} in an object with no foliar fertilization to 138 g·kg^{-1} in the object treated three times with spray of urea plus magnesium sulphate and with Polvit Z/J. In studies of Sułek et al. [21] peak protein content has been noted in the grain obtained following application of 90 kg N·ha^{-1} in a dose divided in the following manner: 40 kg to the soil before sowing, 30 kg at the phase of shooting and 20 kg at the phase of heading, in the form of a solution with double spray aimed to prevent diseases. In present experiment, independently of soil fertilization, all the applied variants of foliar fertilization have induced a significant increase in total protein content, as compared to the control object (Table 5). The most favourable values of the discussed parameter have been obtained in the objects in which either nitrogen or magnesium have been applied in parallel or urea only has been applied and the content has been significantly higher than that in control object and the object fertilized with magnesium only, by 4.7% and 2.3 %, respectively (Table 5). Similarly to studies of other authors [18,28], a significant positive

Table 3. Significant indices of direct correlation between soil fertilization with nitrogen and studied traits of spring wheat Zebra cultivar
Tabela 3. Istotne współczynniki korelacji prostej pomiędzy zastosowanym doglebowo nawożeniem azotem a badanymi cechami pszenicy jarej odmiany Zebra

Parameter - Parametr	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Ferilization–Nawożenie (**1**)	-	0.80	0.43	0.93	0.85	0.87	0.73
Grain yield–Plon ziarna (**2**)	0.80	-	0.36	0.85	0.91	0.82	0.43
Falling number–Liczba opadania (**3**)	0.43	0.35	-	0.51	0.42	0.38	n.s.n.i.
Protein content – Zawartość białka (**4**)	0.93	0.85	0.52	-	0.93	0.91	0.62
Gluten content–Zawartość glutenu (**5**)	0.85	0.91	0.43	0.93	-	0.91	0.56
Sedimentation value–Wskaźnik sedymentacji (**6**)	0.87	0.82	0.38	0.91	0.91	-	0.79
Water absorbtion – Wodochłonność mąki (**7**)	0.73	0.43	n.s.n.i.	0.62	0.56	0.79	-
Bread volume–Objętość pieczywa (**8**)	0.85	0.88	0.49	0.93	0.92	0.84	0.50

Tabela 4. Współczynniki regresji i determinacji (d) dla zależności między zastosowanym doglebowo nawożeniem azotem (x) a badanymi parametrami (y)
Table 4. Coefficients of regression and determination (d) as related to soil fertilization with nitrogen (x) and studied parameters (y)

Parametr Parameter	y = ax + b		
	a	b	d (%)
Grain yield - Plon ziarna	0.013	2.90	64.00
Falling number - Liczba opadania	0.185	357.02	18.49
Protein content - Zawartość białka	0.240	114.81	86.49
Gluten content - Zawartość glutenu	0.092	26.65	72.25
Sedimentation value -Wskaźnik sedymentacji	0.128	33.08	75.69
Water absorbtion - Wodochłonność mąki	0.045	54.19	53.29
Bread volume - Objętość pieczywa	0.595	438.32	72.25

correlation has been noted between total protein content in the grain, content of gluten and sedimentation value (Table 3); the relationships have been described by the calculated equations of linear regression (Fig.1).

The positive traits of baking products obtained from wheat flour are determined by the amount and quality of the gluten contained in the flour. According to several authors [3,8,16,17], an increase in gluten content results from intensified fertilization with nitrogen, although the procedure can also deteriorate quality of gluten [27]. In our experiment soil fertilization with nitrogen up to the dose of 90 kg·ha^{-1} has induced a significant increase in content of the component, which has been higher than that obtained in N_{60} and N_0 objects by 10% and 32.8 %, respectively (Table 5). Independently of the applied soil fertilization with nitrogen doses, a similar gluten content has been disclosed in objects fertilized in parallel with urea and magnesium sulphate or with urea alone and the content has proven to be significantly higher both as compared to the object fertilized with magnesium only (magnesium sulphate) and the control object. Evident increase in gluten content under effect of foliar fertilization of spring wheat was disclosed by Sztuder and Świerczewska [23] and, as compared to the control, it was most pronounced (higher by 17.6 %) in the case of Sigma cultivar, following parallel application of solution containing urea, magnesium sulphate and Polvit Z/J. The proven in earlier studies [18,28] high correlation between gluten content and sedimentation value causes that gluten content used to be defined by the index. The relationship between sedimentation value and wet gluten content is illustrated in Fig.2. According to criteria used in international wheat trade [19], the raw material of a good baking value in the aspect of its usefulness for bakery is provided in grain of the studied spring wheat Zebra cultivar, obtained in objects in which no soil fertilization with nitrogen but foliar fertilization with urea alone or with urea plus magnesium sulphate was applied in parallel as well as individual variants of foliar and soil fertilization with nitrogen were applied at the level of 60 and 90 kg N·ha^{-1}. On the other hand, a raw material of a very high baking quality involves grain obtained from objects of foliar fertilization with urea and magnesium sulphate in parallel following soil fertilization with the dose of 90 kg N·ha^{-1} and objects in which all variants of foliar and soil fertilization

Table 5. Values of technological parameters for spring wheat Zebra cultivar as related to the applied soil fertilization with nitrogen and variants of foliar fertilization (average values for 2005-2007)
Tabela 5. Wartości parametrów technologicznych pszenicy jarej odmiany Zebra w zależności od nawożenia azotem i wariantów nawożenie dolistnego (średnie z lat 2005-2007)

Parameter Parametr	N fertilization (I factor) Nawożenie N (I czynnik) [$kg \cdot ha^{-1}$]	Foliar fertilization (II factor) Nawożenie nalistne (II czynnik)				Mean Średnio	$LSD_{p=0,05}$ - $NIR_{p=0,05}$			
		without fertilization bez nawożenia	urea mocznik	magnesium sulphate siarczan magnezu	urea+magnesium sulphate mocznik+ siarczan magnezu		I	II	I x II	II x I
Falling number Liczba opadania [s]	0	448	453	458	462	455				
	60	462	466	476	475	470				
	90	473	470	481	484	477	21.3	12.2	ns ni	ns ni
	120	463	477	486	475	476				
Mean - Średnio		462	467	475	474	469				
Protein content Zawart. białka [$g \cdot kg^{-1}$]	0	112	118	112	116	115				
	60	123	132	128	132	129				
	90	134	138	137	140	137	5.6	2.6	ns ni	ns ni
	120	140	146	144	145	144				
Mean - Średnio		127	133	130	133	131				
Gluten content Zawart. glutenu [%]	0	24.4	28.2	25.0	28.5	26.5				
	60	28.6	34.0	30.7	34.5	32.0				
	90	33.6	35.8	34.3	36.9	35.2	2.83	1.19	ns ni	ns ni
	120	36.0	38.7	37.1	38.7	37.6				
Mean - Średnio		30.7	34.2	31.8	34.7	32.8				
Sediment. value W. sedymentacji [cm^3]	0	30.7	35.2	31.2	34.4	32.9				
	60	35.9	44.3	38.7	43.4	40.6				
	90	43.2	48.4	44.0	47.6	45.8	5.04	1.72	ns ni	ns ni
	120	44.1	50.2	46.0	49.7	47.5				
Mean - Średnio		38.5	44.5	40.0	43.8	41.7				
Water absorbtion Wodochł. mąki [%]	0	53.2	54.3	53.2	54.8	53.9				
	60	56.3	58.0	57.1	57.9	57.3				
	90	57.7	58.9	58.4	59.0	58.5	2.30	0.44	0.87	0.84
	120	58.6	59.5	59.7	59.2	59.3				
Mean - Średnio		56.5	57.7	57.1	57.7	57.2				
Bread volume Objęt. pieczywa [cm^3]	0	418	445	431	451	434				
	60	464	489	466	488	477				
	90	493	502	485	501	496	14.1	7.3	ns ni	ns ni
	120	500	513	499	510	506				
Mean - Średnio		469	487	470	488	479				

were applied at the level of 120 kg $N \cdot ha^{-1}$ (Table 5). In our experiment, similarly to the earlier conducted experiments with spring wheat [10,17], soil fertilization with increasing doses of nitrogen have induced increase in the sedimentation value. Nevertheless, a significant increase in the qualitative index has been induced by application of nitrogen doses up to the level of 90 $kg \cdot ha^{-1}$ and, as compared to N_{60} and N_0 objects, it has amounted to 12.8% and 39.2 %, respectively (Table 5). Similarly, to gluten content, the value of sedimentation value has significantly positively correlated with the nitrogen dose applied to the soil (Table 3). The relationships have been described by linear regression equations (Table 4). In objects fertilized with nitrogen and magnesium in parallel and in the object fertilized with nitrogen alone similar values of sedimentation test have been noted and they, on the average, have proven to be moderately significantly higher than values of the index obtained in the object fertilized with magnesium only or the control object. Sułek et al. [21] have indicated that improved value of the sedimentation value has resulted from application of nitrogen fertilizers in three doses, i.e., before sowing in a solid form and in phases of shooting and heading in a liquid form. The calculated coefficients of direct correlation have indicated a significant positive relationship between sedimentation value and contents of not only protein and gluten, as confirmed by the earlier publications [18,28], but also, i.e., water absorption of the flour (Table 3).

The amount and quality of gluten and the extent of damage to starch exert a significant effect of water absorption of flour [2, 6]. Similarly to studies of Podleśna and Cacak [16], in our experiment increase in nitrogen doses applied to the soil has resulted in augmented water absorption of the flour. Nevertheless, the statistically proven maximum increase in value of the qualitative trait has been noted after application of 60 $kg \cdot ha^{-1}$, and the absorption has

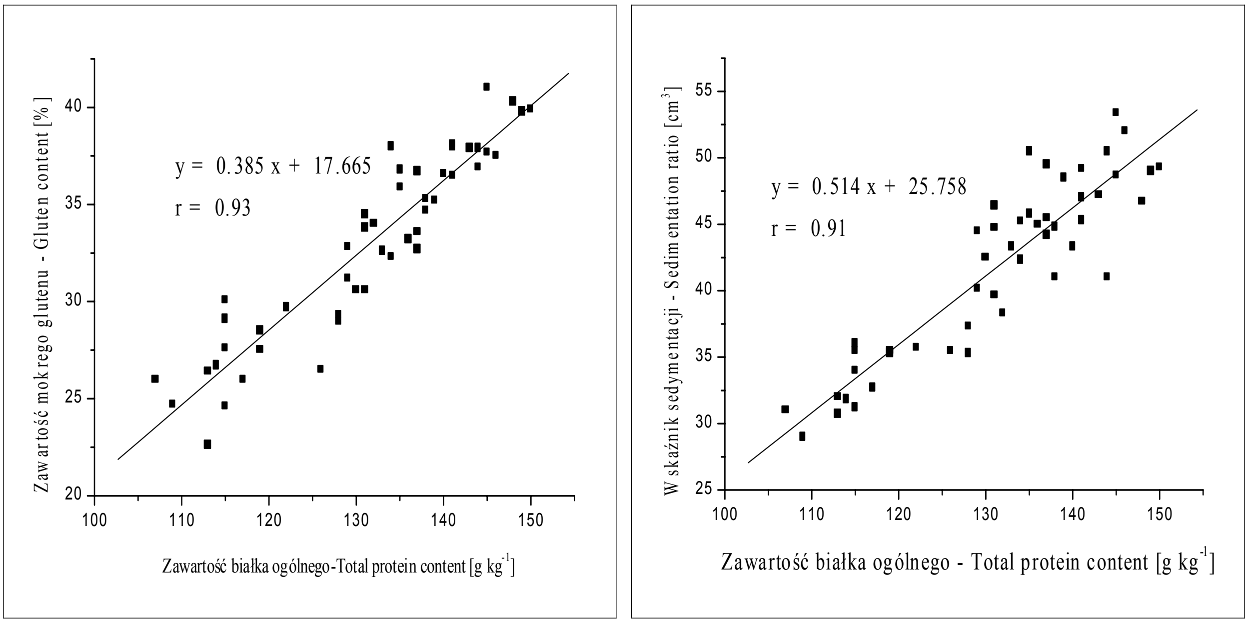

Fig. 1. Relationships between the total protein content and the content of wet gluten and the sedimentation value of spring wheat Zebra cultivar

Rys.1 Zależności pomiędzy zawartością białka ogólnego a zawartością mokrego glutenu, wskaźnika sedymentacji i objętością pieczywa pszenicy jarej odmiany Zebra

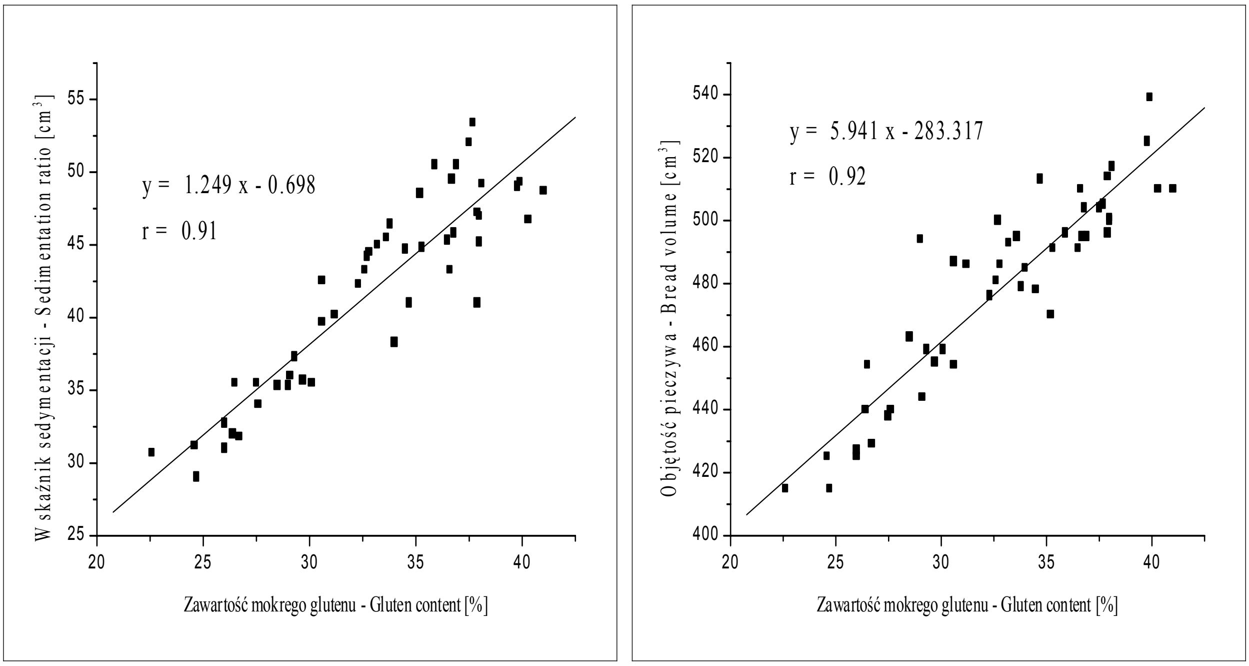

Fig. 2. Relationships between the content of wet gluten and the sedimentation value and the bread volume of spring wheat Zebra cultivar

Rys.2 Zależności pomiędzy zawartością mokrego glutenu a wskaźnika sedymentacji i objętością pieczywa pszenicy jarej odmiany Zebra

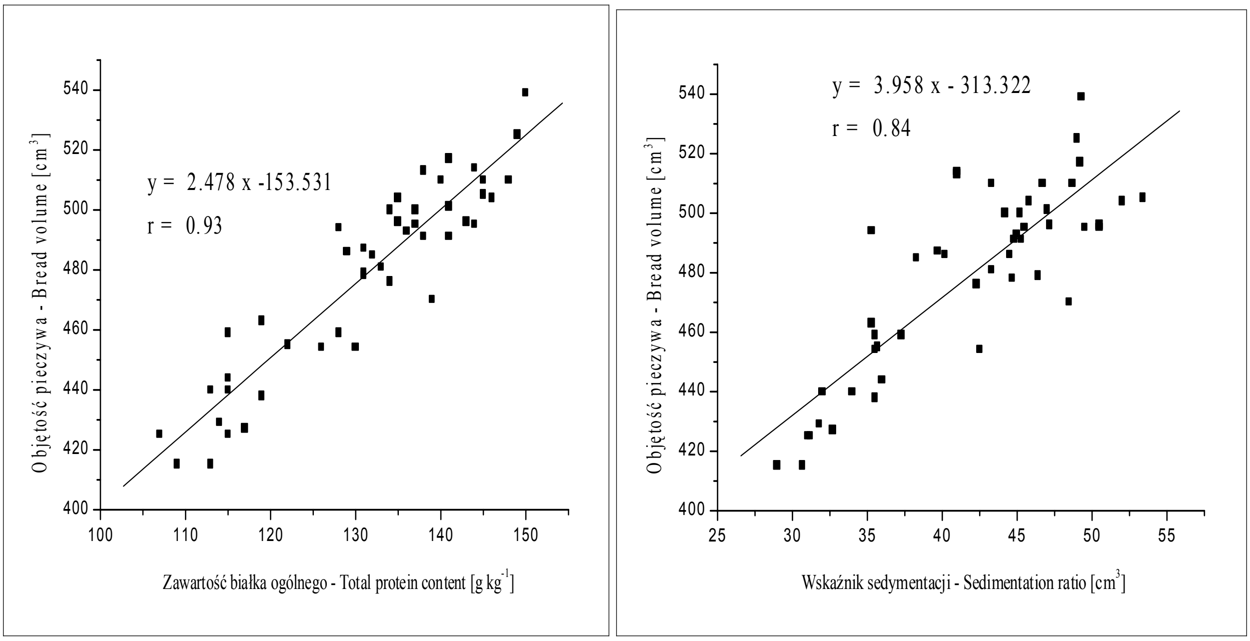

Fig. 3. Relationships between the bread volume and the total protein content and sedimentation value of spring wheat Zebra cultivar

Rys.3 Zależności pomiędzy zawartością białka ogólnego i wskaźnika sedymentacji a objętością pieczywa pszenicy jarej odmiany Zebra

been higher by 6.3% than that noted in the control object (Table 5). The applied foliar fertilization variants, independently from soil fertilization have induced a significant increase in water absorption by the flour, as compared to the control object (Table 5). Similarly, in studies of Żmijewski et al. [30] water absorption proved to be significantly correlated with, i.e., protein content (Table 3).

A direct qualitative index, which indicates baking value of wheat grain, involves volume of bread following test baking. Similarly to other studies on spring wheat [10,16,17,18,20], in our experiment the applied to soil increasing doses of nitrogen fertilization on the average have induced increase in bread volume obtained from flour of Zebra cultivar, and a significant increase in the trait has been noted following the dose of up to 90 kg N $\cdot ha^{-1}$. The bread volume obtained in the N_{90} object has been higher than the values obtained in objects of N_{60} and N_0 by 4% and 14.3 %, respectively (Table 5). According to Sułek et al. [21], a more extensive effect on bread volume in exerted by cultivar properties than by the way of nitrogen fertilization. In our experiment, independently of the applied soil fertilization with nitrogen, bread volumes obtained from objects fertilized with nitrogen and magnesium or with nitrogen only have been significantly higher both as compared to the control, unfertilized object and as compared to the object fertilized with magnesium only. Bread volume has significantly and positively correlated with, i.a., value of sedimentation value (Table 3), which confirms the view that higher content of high molecular weight glutenin increases, i.e., the bread volume [24]. In turn, Żmijewski et al. [30] have confirmed the significant positive correlation between bread volume and protein content while for the relationship between the discussed trait and sedimentation value they have noted a negative correlation (Table 3). The relationship between bread volume on one hand and total protein content, gluten content and sedimentation value are described by the calculated equations of linear regression (Fig. 2 and 3).

CONCLUSIONS

1. Soil fertilization with nitrogen up to the dose of 90 kg $\cdot ha^{-1}$ was followed by a moderately significant increase in size of grain yield while among the variants of foliar fertilization the moderately significant peak grain yield was noted in objects in which nitrogen and magnesium were applied in parallel.

2. The applied soil fertilization with nitrogen, within the entire range of applied doses, induced a moderately significant increase in total protein content. The

moderately significant increase in total protein content, as compared to the control object, resulted also from any variant of foliar fertilization.

3. Independently of the applied variants of foliar fertilization, significant increases in wet gluten content, sedimentation value and bread volume were detected following soil fertilization with nitrogen doses up to 90 kg·ha^{-1}, and of water absorption by the flour following fertilization up to 60 kg·ha^{-1}.

4. Independently of the applied soil fertilization with nitrogen, among the studied variants of foliar fertilization the most favourable for principal indices of baking value, such as wet gluten content, sedimentation value and bread volume, proved to be parallel application of nitrogen and magnesium or of nitrogen only.

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