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ORIGINAL PAPER

HYBRID WHEAT RESPONSE TO TOPDRESSING AND FOLIAR APPLICATION OF NITROGEN

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Abstract

The quantity and quality of winter wheat grain yield is dependent on appropriate cultivation practices, including mineral fertilization. During the growth period of plants, nutrients can be applied both to soil and on leaves. For new hybrid cultivars, determination of the optimal doses and timing of fertilization with nitrogen and other mineral elements should be considered as particularly important. A controlled field experiment with winter wheat of the hybrid cultivar Hybred was carried out in 2011-2014, at the Experimental Station of Cultivar Assessment in Przecław. The first factor consisted of different topdressing nitrogen doses, applied to soil. The other factor was foliar fertilization (Plonvit Z) compared with the control. Topdressing nitrogen application resulted in a significant increase in the number of spikes per 1 m^2 and grain yield in comparison with the control. Application of 100 and 150 kg N ha^{-1} increased the number of grains per spike and the content of total protein, manganese and zinc in grain. Fertilization with a dose of 150 kg N ha^{-1} increased additionally the thousand grain weight and the content of magnesium and calcium in grain. Foliar application, in comparison to the control, resulted in a significant increase in TGW, grain yield and the content of ash, magnesium, manganese and zinc in grain. Interaction of nitrogen fertilization with foliar application was found for the content of manganese and zinc in the grain at a dose of 150 kg N ha^{-1}.

Keywords: winter wheat, mineral nitrogen, foliar application, yield structure, yield, chemical composition, macroelements and microelements.

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INTRODUCTION

Winter wheat has high requirements in respect of nitrogen fertilization, particularly in the period after starting the growth in spring. Nitrogen can be applied as a single dose, or in several doses adjusted to the needs and plant developmental stages (BLANKENAU et al. 2002, EHLERT et al. 2004), which ensures high yields of good quality (PODOLSKA 2008, KOCHURKO 2009). The effects of applied nitrogen are possible to obtain if proper and sustainable fertilization of wheat with all other necessary nutrients is performed (KOCOŃ 2005). One of methods for fast supplementation of macroelements and microelements is foliar fertilization of cultivated crops. Numerous studies (SOYLU et al. 2005, FAGERIA et al. 2009, RAHMAN et al. 2014, KOSTADINOVA et al. 2015) indicate that nutrients applied in this way usually have favourable effects on the wheat grain yield and its quality traits.

Biological progress and improved techniques of plant breeding have paved the way to introduce hybrid wheat cultivars, with superior agronomic properties, into agricultural practice (MÜHLEISEN et al. 2014). The acreage cropped with hybrid wheat in Europe amounts to about 250 thousand ha, of which most hybrid cultivars are grown in France (160 thousand ha), Germany (25 thousand ha), followed by Hungary, Italy, Czech Republic, Slovakia, and Portugal; in Poland, the estimated acreage is over 1 thousand ha in Poland (ZHAO et al. 2013). Hybrid wheat cultivars, in comparison with population wheat, are characterized by higher grain yield (from 3.5 to 15.0%), better tolerance to being grown in monoculture and stronger resistance to stressful climate and soil conditions (PLESSIS et al. 2013, WHITFORD et al. 2013).

Therefore, the impact of some agronomic factors, including determination of the optimal nitrogen fertilization, both to soil and on leaves, is an important subject of research in the context of the yield volume and particularly the grain quality of hybrid cultivars.

The aim of the study was to estimate the effect of increasing nitrogen doses and foliar application on the grain yield, yield structure components and the chemical composition of the hybrid wheat grain of the cultivar Hybred. It was assumed that different doses of nitrogen and foliar application would significantly modify the quantity and quality of the grain yield.

MATERIALS AND METHODS

Field experiments and plant material

A two-factorial field experiment was carried out in 2011-2014 at the Station of Cultivar Assessment in Przecław (50°11′ N, 21°29′ E), Poland. The soil of the experimental area is with the texture of clay loam. According to

Table 1

Basic soil characteristics prior to the experiment (0-35 cm)

Traits	Value		
	2011/2012	2012/2013	2013/2014
pH in KCl	6.91	5.70	6.37
Organic C (g kg^{-1} D.M.)	13.70	12.00	13.51
Inorganic N (g kg^{-1} D.M.)	1.37	1.20	1.35
P (mg kg^{-1})	175.1	54.01	320.1
K (mg kg^{-1})	190.0	115.2	315.5
Mg (mg kg^{-1})	154.0	174.0	109.0
S-SO_4 (mg kg^{-1})	0.54	0.46	0.57
Fe (mg kg^{-1})	1985	2706	3241
Zn (mg kg^{-1})	16.10	15.60	21.80
Mn (mg kg^{-1})	420.0	189.1	301.2
Cu (mg kg^{-1})	6.20	9.20	7.00
B (mg kg^{-1})	1.70	0.50	0.90

the classification by the World Reference Base, this soil was Gleic Fluvisol (WRB 2014). The physical and chemical soil properties in 2011-2014 are presented in Table 1.

The experiment was set up as a split-plot design with 4 replications. The area of an individual plot was 16 m^2. Material for the study comprised a winter wheat hybrid cultivar Hybred (breeder Saaten-Union GmbH, France), which is classified in the Common Catalogue of Varieties of Agricultural Plant Species (EU 2007). In all the years, wheat was sown between the 20th and 30th of September, at the sowing density of 220 seeds m^{-2}.

The first experimental factor was topdressing application of nitrogen to winter wheat in doses: 50, 100, 150 kg N ha^{-1} as compared with the control: 0 kg N ha^{-1}. The other factor was foliar fertilization with the preparation Plonvit Zboża (Plonvit Z), made by INTERMAG Sp. z o.o., Poland (Tables 2 and 3).

Nitrogen was applied as topdressing in the solid form (ammonium nitrate 34%) at the beginning of the following stages: tillering, stalk shooting, ear formation. Foliar fertilization was applied in autumn at the 3-6 leaf stage and during the spring-summer growth at the growth stages: tillering, flag leaf and the kernel milk stage (Table 3). The amount of working liquid was 300 dm^3 ha^{-1}. Fertilization with phosphorus and potassium was applied under pre-sow ploughing in the amount of 26.2 P kg ha^{-1} and 74.7 K kg ha^{-1}. The preceding crop for wheat in all the years was winter oilseed rape.

Weed infestation was controlled in spring, with the use of Puma Uniwersal 069 EW and Sekator 125 OD (1.2 + 0.15 dm^3 ha^{-1}). Also, the fungicides

Table 2

Chemical composition of the fertilizer Plonvit Z

Nutrients	Content ($g\ dm^{-3}$)	Content (% by weight)
N	195.0	15.0
NH_2	195.0	15.0
MgO	26.0	2.0
SO_3	59.0	4.5
B	0.18	0.014
Cu	11.7	0.9
Fe	10.4	0.8
Mn	14.3	1.1
Mo	0.06	0.005
Zn	13.0	1.0

Table 3

Fertilization design

Fertilizers, dose	Application time, dose			
Plonvit Z ($dm^{-3}\ ha^{-1}$)	BBCH (13-16)	BBCH (25-27)	BBCH (39-41)	BBCH (70-73)
	1.5	1.5	1.5	1.5
NH_4NO_4 ($kg\ ha^{-1}$)		BBCH (20-22)	BBCH (30-32)	BBCH (51-53)
0		–	–	–
50		50	–	–
100		60	40	–
150		70	50	30

Juwell TT 483 SE and Swing Top 183 SE in a dose of 1.2 $dm^3\ ha^{-1}$ each were applied for protection, as well as the insecticides Bi 58 Nowy EC 400 (0.5 $dm^3\ ha^{-1}$) and Karate Zeon 050 CS (0.1 $dm^3\ ha^{-1}$) and the growth retardant Moddus 250 EC (0.4 $dm^3\ ha^{-1}$). The preparations were applied in accordance with the manufacturer instructions at appropriate developmental stages of wheat.

Analytical methods

The grain yield obtained from plots was calculated as the yield per 1 ha, taking into account the moisture content of 14%, and then it was supplemented with missing spikes collected for biometric analyses. Prior to harvest, the number of spikes per 1 m^2 was determined. From each plot, 100 spikes were collected and the number of grains per spike and thousand grain weight were determined. After drying and grinding the grain, determinations of the total nitrogen content was performed with the Kjeldahl method, and total protein was calculated with the use of the multiplier 5.75. Crude fat, ash and fibre were determined with the NIRS (near infrared spectroscopy) method on a Bruker FT-NIR apparatus.

Phosphorus was determined on an absorption spectrophotometre within the UV-VIS range. Potassium, magnesium, calcium and microelements were determined after mineralization in nitric acid with the AAS technique on a Hitachi Z-2000 (Japan). Analyses were carried out in two replications at the Faculty Laboratory of Analysis of Environment Health and Materials of Agricultural Origin, at the Faculty of Biology and Agriculture of the University of Rzeszów.

Weather conditions

Data about the weather conditions were obtained from a local observation measurement unit located at the Experimental Station. During the winter wheat growing period, the average air temperatures in the years of the study were similar, within the range from 8.6 to 9.0°C, at the average long-term air temperature equal to 8.5°C (Table 4). The highest rainfall in

Table 4

Weather conditions over the plant growing season of winter wheat

Year	A	W	Spring-summer period						M/S
			March	Apr	May	June	July	Aug	
Temperature (°C)									
2011/2012	8.2	-2.8	3.9	9.9	14.7	18.2	20.8	18.4	8.6
2012/2013	9.4	-2.1	-1.2	8.8	15.0	18.5	19.4	18.6	8.4
2013/2014	8.7	0.8	5.4	8.8	13.3	15.1	19.3	17.7	9.0
1956-2010	8.6	-1.3	2.6	8.8	14.2	17.5	19.4	18.1	8.5
Rainfall (mm)									
2011/2012	41.1	101.7	27.8	21.7	66.7	66.9	65.6	61.8	453.3
2012/2013	151.7	127.9	73.6	39.4	111.7	192.4	58.3	21.2	776.2
2013/2014	170.8	56.1	49.6	34.8	108.9	71.7	146.8	101.8	740.5
1956-2010	135.7	101.1	5.9	48.1	39.2	79.3	101.6	71.3	612.2

A – autumn vegetation period (Sept - Nov)
W – winter rest (Dec - Feb)
M/S – mean/sum (from sowing to harvest)

comparison with the long-term period was recorded in May in the growing periods 2012/2013 and 2013/2014 and in June 2012/2013, and the lowest occurred at the time of wheat sowing and emergence in 2011. The growing season of 2011/2012 was characterized by the smallest amount of rainfall

(453.3 mm), different from the long-term total by 26.0%. Particularly little rainfall (41.1 mm) occurred during the autumn growth. The total precipitation in the last two years of the study was higher by 21.1 and by 17.3%, respectively, than the long-term total, whereas little rainfall (56.1 mm) occurred in the third year of the study during the winter rest of wheat.

Statistical analyses

The results were elaborated statistically with the analysis of variance (ANOVA), whereas the significance of differences between mean values was evaluated with the Tukey's HSD test, $P \leq 0.05$. The computations were done using the Statistica 9.0 programme (StatSoft, USA).

RESULTS AND DISCUSSION

Fertilization is the main yield-forming factor, and one of the key indicators of agricultural production intensity and efficiency. The yield of cereals is determined by their nutritional status at the early stages of growth. The optimum nutrient supply during the critical growth stages enables crops to reach their full yield potential. Rational fertilization of winter wheat is determined by the amounts of primary nutrients supplied, and their relative proportions (Nogalska et al. 2012).

The applied nitrogen topdressing resulted in a significant increase in the number of spikes per 1 m^2 in comparison with the control treatment. The highest number of spikes was obtained after the application of 100 kg N ha^{-1}. On average, the number of spikes in the conducted experiment prior to the harvest was 465.0 pcs m^{-2} (Table 5). Podolska (2008) and Ellmann (2011) also indicated that nitrogen fertilization increases the number of spikes per 1 m^2. The actual increase was dependent on the years of the study.

The number of grains per spike significantly increased after the application of 100 and 150 kg N ha^{-1} as compared with the control. The average difference was, respectively, 2.5 and 2.0 pieces (Table 5). Ellmann (2011) did not confirm the effect of topdressing with nitrogen on the number of grains per spike. Khan et al. (2009), however, indicated an increase in the number of grains per spike, but after foliar fertilization with urea.

The significant increase in the thousand grain weight was effected by the highest applied topdressing nitrogen doses. The difference in comparison with the control was 6.6 g (Table 5). Kochurko (2009) usually obtained the highest 1000 grain weight under the influence of the fertilization variant $N_{60+30+30}$. He noted the least plump grains in the control treatment. Podolska (2008) and Ellmann (2011), in turn, did not confirm any significant effect of topdressing with nitrogen on the TGW of wheat.

The grain yield, on average, reached 6.77 t ha^{-1}. The applied topdressing

Table 5

Yield components and yield of hybrid wheat

Details	Nitrogen amount (A) (kg N ha^{-1})	Foliar fertilization (B)		Mean for A
		Plonvit Z	control	
Number of ears (pcs. m^{-2})	0	452.0	452.0	452.0
	50	469.5	468.0	468.8
	100	471.0	470.0	470.5
	150	469.0	468.5	468.8
	mean for B	465.4	464.6	465.0
	$LSD_{0.05}$ for A – 15.92, for B – n.s., for AxB – n.s.			
Number of grains per ear (pcs.)	0	34.2	33.3	33.8
	50	34.8	34.2	34.5
	100	36.6	35.9	36.3
	150	35.9	35.6	35.8
	mean for B	35.4	34.8	35.1
	$LSD_{0.05}$ for A – 1.89, for B – n.s., for AxB – n.s.			
Thousand grain weight (g)	0	38.2	37.2	37.7
	50	42.3	40.3	41.3
	100	44.3	42.1	43.2
	150	45.0	43.5	44.3
	mean for B	42.5	40.8	41.6
	$LSD_{0.05}$ for A – 5.99, for B – 1.53, for AxB – n.s.			
Grain yield (t ha^{-1})	0	5.85	5.51	5.68
	50	6.96	6.47	6.72
	100	7.48	6.87	7.18
	150	7.68	7.34	7.51
	mean for B	6.99	6.55	6.77
	$LSD_{0.05}$ for A – 0.98, for B – 0.39, for AxB – n.s.			

n.s. – non-significant differences

nitrogen doses resulted in a significant increase in yield as compared with the control. The highest increase in yield was mostly effected by the top-dressing dose of 150 kg N ha^{-1} (Table 5). Podolska (2008) indicated that wheat grain yield is determined by a nitrogen dose and often by a method of its application. In their pot experiments, Podolska and Wyzińska (2011) also proved that an increase in nitrogen doses had a positive effect on wheat yield, which was the result of increasing the number of spikes per pot, the number of grain per plant and, to a lesser extent, the thousand grain weight.

The applied foliar fertilization resulted in an increase in TGW and the grain yield (Table 5). The increase in grain yield in comparison with the control was 0.44 t ha^{-1}. In the earlier studies (Soylu et al. 2005, Zeidan et al. 2010, Njuguna et al. 2011, Kostadinova et al. 2015), it was also confirmed that foliar fertilizers usually had a favourable effect on winter wheat yielding. The actual increase in grain yield depends on a cultivar, applied fertilizer and site-specific conditions. KHAN et al. (2009) observed that TGW and grain yield increased under the influence of foliar application of urea. However, they noticed that high concentrations of urea might have a phytotoxic effect on plants.

Higher topdressing nitrogen doses, i.e.: 100 and 150 kg ha^{-1}, increased the total protein content in grain as compared with the control. Foliar application, in turn, effected a significant increase in the content of ash in grain (Table 6). WEBER et al. (2008) report that nitrogen fertilizers cause a significant increase in the total protein content in winter wheat grain.

Table 6

Content of the components in the seeds of hybrid wheat (% D.M.)

Component	Nitrogen amount (A) (kg N ha^{-1})	Foliar fertilization (B)		Mean for A
		Plonvit Z	control	
Total protein	0	13.5	13.2	13.4
	50	14.4	14.1	14.3
	100	14.8	14.5	14.7
	150	15.0	14.7	14.9
	mean for B	14.4	14.1	14.3
	$LSD_{0.05}$ for A – 1.22, for B – n.s.. for AxB – n.s.			
Crude fat	0	1.92	1.91	1.92
	50	1.91	1.91	1.91
	100	1.86	1.90	1.88
	150	1.86	1.92	1.89
	mean for B	1.89	1.91	1.90
	$LSD_{0.05}$ for A – n.s., for B – n.s., for AxB – n.s.,			
Ash	0	1.66	1.64	1.65
	50	1.75	1.65	1.70
	100	1.74	1.63	1.69
	150	1.72	1.62	1.67
	mean for B	1.72	1.64	1.68
	$LSD_{0.05}$ for A – n.s., for B – 0.07, for AxB – n.s.			
Fiber	0	1.43	1.43	1.43
	50	1.40	1.45	1.43
	100	1.39	1.42	1.41
	150	1.39	1.46	1.43
	mean for B	1.40	1.44	1.42
	$LSD_{0.05}$ for A – n.s., for B – n.s., for AxB – n.s.			

n.s. – non-significant differences

EHLERT et al. (2004) did not prove any significant effect of different nitrogen doses on some quality parameters of wheat grain. NJUGUNA et al. (2011) proved that an increase in the protein content in grain was determined only by the increased foliar application of urea. ZEIDAN et al. (2010) confirmed the effect of foliar application of microelements on the rise in the total protein content in wheat grain.

The content of macroelements in wheat grain was differentiated depending on nitrogen fertilization (Table 7). Increasing doses of nitrogen had a

Table 7

Content of macroelements in the seeds of hybrid wheat (g kg^{-1})

Component	Nitrogen amount (A) kg N ha^{-1}	Foliar fertilization (B)		Mean for A
		Plonvit Z	control	
P	0 50 100 150	3.85 3.82 3.86 4.02	3.81 3.85 3.87 3.95	3.83 3.84 3.87 3.99
	mean for B	3.89	3.87	3.88
	$LSD_{0.05}$ for A – n.s., for B – n.s., for AxB – n.s.			
K	0 50 100 150	3.48 3.47 3.45 3.68	3.50 3.46 3.52 3.65	3.49 3.47 3.49 3.67
	mean for B	3.52	3.53	3.53
	$LSD_{0.05}$ for A – n.s., for B – n.s., for AxB – n.s.			
Mg	0 50 100 150	0.76 0.77 0.85 0.86	0.70 0.72 0.77 0.80	0.73 0.75 0.81 0.83
	mean for B	0.81	0.75	0.78
	$LSD_{0.05}$ for A – 0.09., for B – 0.05, for AxB – n.s.			
Ca	0 50 100 150	0.24 0.26 0.33 0.36	0.25 0.28 0.33 0.39	0.25 0.27 0.33 0.38
	mean for B	0.30	0.31	0.31
	$LSD_{0.05}$ for A – 0.12, for B – n.s., for AxB – n.s.			

n.s. – non-significant difference

unidirectional effect on the content of magnesium and calcium in grain. Nitrogen fertilization at 150 kg ha^{-1} contributed to a significantly higher concentration in grain of magnesium (0.83 g kg^{-1}) and calcium (0.38 g kg^{-1}) as compared with the control. Similar relationships for magnesium in grain were observed by Chwil (2000) in wheat and by Wojtkowiak (2014) in triticale.

A tendency towards an increasing phosphorus content in wheat grain under the influence of a higher nitrogen dose was demonstrated, whereas the content of potassium both in the control treatments and in the ones fertilized with nitrogen was similar (Table 7). Brzozowska (2008) reports that varied fertilization with nitrogen did not have any effect on the content of magnesium, calcium and potassium in wheat grain, although, same as in the present study, the highest content of potassium (4.19 g kg^{-1}) was obtained after applying nitrogen three times.

An average content of phosphorus (3.88 g kg^{-1}) and potassium (3.53 g kg^{-1}) in the grain of the analyzed hybrid wheat cultivar was similar to the amounts of these elements determined in spring wheat grain by Woźniak and Makarski (2013). In the study by Rachoń et al. (2012), higher concentrations of these macroelements were found in the grain of *Triticum aestivum* ssp. *vulgare* (4.60 g kg^{-1} for P and 5.00 g kg^{-1} for K) and *Triticum durum* (4.73 g kg^{-1} for P and 5.23 g kg^{-1} for K). The grain of the hybrid wheat showed a lower content of calcium (0.31 g kg^{-1}) and, particularly, magnesium (0.78 g kg^{-1}) compared to the results obtained by Suchowilska et al. (2012) and Rachoń et al. (2012). Foliar application caused a significant increase in the magnesium content in the grain wheat in the treatments with nitrogen application at the doses of 100 and 150 kg N ha^{-1}. Foliar fertilizer did not increase the concentration of the other macroelements (K, P, Ca). Likewise, in the study by Chwil (2014), foliar application of the fertilizers Insol PK and Ekosol U caused a significant increase in the amount of magnesium, but also of calcium, in wheat grain.

The differentiated nitrogen doses had an effect on the content of some microelements in wheat grain. Along with an increase in nitrogen doses applied as topdressing on wheat plants, the amounts of zinc and manganese in wheat grain significantly increased and were higher by 11.3 and 28.6%, respectively, in the treatment with the dose of 150 kg N ha^{-1} than in the control (Table 8). In the study by Shi et al. (2010), fertilization with nitrogen in a dose of 300 kg N ha^{-1} caused an increase in the content of iron, copper and zinc in wheat grain compared to grain from the control treatments, but it did not affect the accumulation of manganese. In the present study, nitrogen did not tend to differentiate the content of copper significantly, while causing directional changes in amounts of iron, although the differences were not confirmed statistically. Morgounov et al. (2007) points out the positive relationship between Fe and Zn and the protein content in wheat grain.

In the present study the foliar application of the fertilizer Plonvit Z caused a significant increase relative to the control in the content of manganese and zinc in wheat grain. No such relationship was proven for iron and copper concentrations. An interaction of the experimental factors (AxB) was demonstrated with respect to the content of manganese and zinc in wheat grain in the treatment with thhe dose of 150 kg N ha^{-1} (Table 8). According to Cakmak et al. (2010) and Zhang et al. (2010), the knowledge of different forms of foliar fertilizers and the time of their use together with topdressing nitrogen fertilization is of the utmost importance for increasing the concentrations of Zn and Cu in wheat grain.

Table 8

Content of microelements in the seeds of hybrid wheat (mg kg^{-1})

Component	Nitrogen amount (A) (kg N ha^{-1})	Foliar fertilization (B)		Mean for A
		Plonvit Z	control	
Fe	0 50 100 150	42.6 43.2 43.0 44.9	42.4 44.6 42.9 44.6	42.5 43.9 43.0 44.8
	mean for B	43.4	43.6	43.5
	$LSD_{0.05}$ for A – n.s., for B – n.s., for AxB – n.s.			
Cu	0 50 100 150	2.36 2.26 2.29 2.42	2.37 2.24 2.31 2.41	2.37 2.25 2.30 2.42
	mean for B	2.33	2.33	2.33
	$LSD_{0.05}$ for A – n.s., for B – n.s., for AxB – n.s.			
Mn	0 50 100 150	28.6 30.2 32.3 37.5	28.1 30.2 31.9 35.2	28.3 30.2 32.1 36.4
	mean for B	32.2	31.4	31.8
	$LSD_{0.05}$ for A – 3.64, for B – 0.74, for AxB – 8.40			
Zn	0 50 100 150	32.6 33.9 35.8 36.9	32.5 32.6 33.9 35.6	32.6 33.3 34.9 36.3
	mean for B	34.8	33.7	34.2
	$LSD_{0.05}$ for A – 2.13, for B – 0.95, for AxB – 3.82			

n.s. – non-significant differences

Irrespective of the form and doses of nitrogen fertilization, the highest level of available microelements in the hybrid wheat grain was found for iron, and the lowest value was detected for copper (Fe> Zn> Mn> Cu). The content of iron, zinc and manganese in the grain of cv. Hybred was higher than the values determined by Kocoń (2009) and by Stępień and Wojtkowiak (2015) in the grain of spring and winter wheat cultivars. Nonetheless, the average amount of copper (2.33 mg kg^{-1}) was considerably lower in comparison with the range (6.62-9.17 mg kg^{-1}) observed by Ficco et al. (2009), and similar to the content of this element (3.50 mg kg^{-1}) in the study by Suchowilska et al. (2012). It should also be noted that the content of nutrients in wheat grain largely depends on the course of the weather conditions, as well as the interaction of the environment with the wheat genotype (Morgounov et al. 2007, Ficco et al. 2009).

CONCLUSIONS

1. Nitrogen fertilization significantly increased the grain yield and the number of spikes per 1 m^2 as compared with the control. Higher nitrogen doses, 100 and 150 kg ha^{-1}, increased the number of grains per spike and the content of total protein, manganese and zinc in grain. The highest nitrogen dose, 150 kg ha^{-1}, additionally increased the thousand grain weight and the content of magnesium and calcium in grain.

2. Foliar fertilization resulted in a significant increase in TGW, grain yield and the content of ash, magnesium, manganese and zinc in grain as compared with the control.

3. Topdressing nitrogen fertilization combined with foliar fertilization significantly increased the concentration of manganese and zinc in grain in the treatment with the dose of 150 kg N ha^{-1}.

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