

THE INFLUENCE OF MINERAL FERTILIZATION ON WINTER WHEAT YIELD AND QUALITY

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Abstract

The effect of the N, P and K fertilisation on yield and quality parameters of cultivar Žitarka during two growing seasons (2002/03 and 2003/04) was studied. Fertilization increased yield, although only treatment with 200 kg N ha⁻¹ yielded significantly higher than treatments with 80 kg N ha⁻¹. Protein content increased significantly ($P < 0.001$) with the application of 80 kg N ha⁻¹, 120 kg N ha⁻¹ and 160 kg N ha⁻¹. The highest N applications with 200 kg N ha⁻¹ and 240 kg N ha⁻¹ increased protein content on the same level as with 160 kg N ha⁻¹. Wet gluten and sedimentation value were also significantly ($P < 0.001$) affected by N fertilizer treatments. Although increment of N fertilization increased values of these quality parameters, 120 kg N ha⁻¹, 160 kg N ha⁻¹ and 200 kg N ha⁻¹ treatments showed similar effect, while treatment with 240 kg N ha⁻¹ resulted with significantly higher values. Gluten index increased only with applying 80 kg N ha⁻¹ while the highest N levels (200 kg N ha⁻¹ and 240 kg N ha⁻¹) showed dramatically gluten weakening. Considering grain hardness only treatment with 80 kg N ha⁻¹ had significant ($P < 0.001$) influence. Simultaneously, P and K did not affect grain yield and quality, neither comparing PK to controle, or N₂P₁K₁ to N₂P₂K₂.

Key words: wheat, N, P and K fertilization, grain yield, quality

Introduction

The amount of plant nutrients, especially nitrogen, phosphorus and potassium has an important influence not just on grain yield, but on quality too. A numerous authors investigated effect of one, mostly nitrogen (Delin *et al.*, 2005), two (Bonfil *et al.*, 2004) or all three mentioned nutrients (Pepo, 2003; Tanacs *et al.*, 2005) and year (Assad and Paulsen, 2002; Drezner *et al.* 2003) on wheat grain quality. Nitrogen fertilization management offers the opportunity for increasing wheat yield and quality. However, some studies have shown that increase in protein content, as result of N application, can also lead to changes in gluten quality (Achremowicz, 1995; Klupczyński and Ralcewicz, 1997.) On the other hand high N rates may lead to the increase of nitrate pollution, thus more efficient use of N fertilizer must be considered (Luo *et al.*, 2000; Campell *et al.*, 1995). This paper reports the differences in yield and quality responses to fertilization with P, K and different N amounts during two wheat growing seasons in eastern Croatia.

Material and methods

The winter wheat (cultivar Žitarka) field trials were set up in the autumn of 2002 on silty loam stagnic luvisol at site Donji Miholjac in eastern Croatia. The soil layer 0-30 cm was analyzed for pH_{KCl}, organic matter, phosphorus and potassium extracted by ammonium-lactate method according to Egner-Riehm-Domingo (Page, 1982). The soil was very acid (pH_{KCl} = 3.61) with low organic matter content (1.56%), low P level (102 mg P₂O₅ kg⁻¹) and low K level (135 mg K₂O kg⁻¹).

Treatments in the field trials conducted in growing seasons 2002/03 and 2003/04 were: 1. no fertilizer, 2. N_1P_1 (80:100:0 $kg\ ha^{-1}$ N:P₂O₅:K₂O), 3. N_1K_1 (80:0:100), 4. P_1K_1 (0:100:100), 5. $N_1P_1K_1$ (80:100:100), 6. $N_2P_1K_1$ (120:100:100), 7. $N_2P_2K_2$ (120:200:200), 8. $N_3P_2K_2$ (160:200:200), 9. $N_4P_2K_2$ (200:200:200) and 10. $N_5P_2K_2$ (240:200:200). The size of each plot was 70 m² (7×10 m) using a randomised block design with 4 replicates. Grain yield and indirect quality traits (protein content, Zeleny sedimentation value and grain hardness) was measured by NIT technology (Infratec 1241, Foss Tecator). Wet gluten and Gluten Index were determined according to ICC standard method No 155 (1994). The statistic analyses for all data were done by analysis of variance according to Mead et al. (1996) using PC applications Microsoft Excel and StatSoft Statistica. The results were calculated as an experiment with two factors: growing season (A) and fertilization (B).

Results and discussion

The average grain yield in 2003 (6.43 t ha⁻¹) was significantly higher ($P<0.001$) than in 2004 (5.32 t ha⁻¹) and fertilization had significant ($P<0.001$) influence on yield (Table 1). The lowest yields were without fertilization in both years and fertilization with P and K increased yield without statistical significance. There was no doubt that N was the most important yield forming nutrient, because all the treatments with N significantly increased yield comparing to treatments without N what is in agreement with Pepo (2003), Tanacs *et al.* (2005). Same, although increment of N fertilization increased yields, with exception of the highest N level (240 kg N ha⁻¹), just treatment with 200 kg N ha⁻¹ yielded significantly higher than treatments with only 80 kg N. Simultaneously, P and K did not affect yield, neither comparing PK to controle, or comparing $N_2P_1K_1$ to $N_2P_2K_2$.

Table 1. Influences of year and fertilization on yield of winter wheat grain

Year	0	N_1P_1	N_1K_1	P_1K_1	$N_1P_1K_1$	$N_2P_1K_1$	$N_2P_2K_2$	$N_3P_2K_2$	$N_4P_2K_2$	$N_5P_2K_2$	mean
Grain yield (t ha ⁻¹)											
2003	3.17	6.14	5.73	3.86	7.07	7.60	7.45	7.87	8.25	7.14	6.43 b
2004	2.70	5.11	5.34	2.93	5.56	5.73	6.46	6.44	6.46	6.45	5.32 a
mean	2.94	5.63	5.54	3.39	6.31	6.67	6.96	7.15	7.36	6.79	
	a *	b	b	a	bc	cd	cd	cd	d	cd	

*differences between values with the same letters are not significant at the 1% level

The average protein content in 2003 (14.91%) was significantly higher ($P<0.001$) than in 2004 (13.11%). Protein content increased significantly ($P<0.001$) with the application of 80 kg N ha⁻¹ and 120 kg N ha⁻¹ (Table 2). Treatment with 160 kg N ha⁻¹ increased protein content on the same significance level as 120 kg N ha⁻¹. The highest N levels with 200 kg N ha⁻¹ and 240 kg N ha⁻¹ had additional effect on protein content but these increment was not significant comparing to treatment with 160 kg N ha⁻¹. Obtained results correspond with results of Tanacs *et al.* (2005), Delin *et al.* (2005). Regarding P and K fertilization, there was not any significant influence on protein.

As result of strong positive correlation with protein content, the average wet gluten and sedimentation value was also significantly higher ($P<0.001$) in 2003 than in 2004 and influence of N fertilization on these features was very significant ($P<0.001$) (Table 2) what correspond to Klupczyński and Ralcewicz (1997).

Although increment of N fertilization increased values of these quality parameters, treatments with 160 kg N ha⁻¹ and 200 kg N ha⁻¹ were on the same level as 120 kg N ha⁻¹, while treatment with 240 kg N ha⁻¹ had additional significant effect. Fertilization with P and K did not affect these parameters, too.

Table 2. Influences of year and fertilization on quality of winter wheat grain

Year	0	N ₁ P ₁	N ₁ K ₁	P ₁ K ₁	N ₁ P ₁ K ₁	N ₂ P ₁ K ₁	N ₂ P ₂ K ₂	N ₃ P ₂ K ₂	N ₄ P ₂ K ₂	N ₅ P ₂ K ₂	mean
Protein (%)											
2003	11.6	14.5	14.0	11.3	14.0	15.2	16.3	16.8	17.2	18.2	14.9b
2004	11.2	12.1	12.4	11.0	12.0	14.1	13.7	14.3	15.2	15.2	13.1a
mean	11.4	13.3	13.2	11.3	13.0	14.6	15.0	15.6	16.2	16.7	
	a [*]	b	b	a	b	c	c	cd	d	d	
Wet Gluten (%)											
2003	32.0	44.3	43.0	32.1	43.1	47.6	51.5	53.2	54.6	57.4	45.9b
2004	29.5	33.2	34.4	27.9	35.1	41.8	40.2	43.0	45.0	45.1	37.5a
mean	37.8	38.8	38.7	30.0	39.1	44.7	45.8	48.1	49.8	51.3	
	a	b	b	a	b	c	cd	cd	cd	d	
Zeleny sedimentation value (ml)											
2003	38	48	47	37	47	51	54	56	58	62	50b
2004	34	36	38	34	37	44	43	44	47	47	40a
mean	36	42	42	36	42	47	49	50	53	54	
	a	b	b	a	b	c	cd	cde	de	e	
Gluten Index											
2003	55	69	72	71	73	65	63	63	52	56	64a
2004	74	76	73	90	86	63	65	68	55	53	70b
mean	64	72	72	80	79	64	64	65	53	54	
	c	cd	cd	d	d	bc	bc	c	a	ab	
Hardness											
2003	63	77	77	60	77	78	81	82	82	82	76b
2004	66	71	73	64	69	73	74	75	74	76	72a
mean	65	74	75	62	73	76	78	79	78	79	
	a	b	b	a	b	b	b	b	b	b	

* differences between values with the same letters are not significant at the 1% level

Determining the protein and wet gluten contents in winter wheat grain is not sufficient to evaluate the baking value. The quality of gluten must be taken into consideration. Gluten Index is very useful tool, as fast and reliable method, in evaluation of gluten strength. Gluten Index of cultivar Žitarka increased only with applying 80 kg N ha⁻¹ (Table 2).

Further increment of N fertilizer (120 kg N ha⁻¹ and 160 kg N ha⁻¹) did not have any influence on this feature while the highest N fertilization levels (200 kg N ha⁻¹ and 240 kg N ha⁻¹) showed dramatically gluten weakening through decrease of Gluten Index what is in agreement with results obtained by Klupczyński and Ralcewicz (1997). Considering P and K fertilization, the best gluten strength was obtained in combination with 80 kg N ha⁻¹.

As well as other indirect quality parameters the average grain hardness was significantly higher ($P < 0.001$) in 2003 than in 2004. Regarding N fertilization influence, only fertilization with 80 kg N ha⁻¹ affected grain hardness (Table 2). Others N increment did not have additional significant effect. P and K fertilization did not affect this feature. Luo *et al.* (2000) investigated the effect of 200 kg N ha⁻¹, supplied early or late during growing season, noticed that N application did also significant increase of grain hardness.

Conclusions

The increment of N fertilization has increased grain yield and quality depending on N amounts and year, while P and K did not affect yield and quality parameters. Grain yield reach a plateau with lower N rates (120 kg N ha⁻¹) rather than the indirect quality parameters (160 kg N ha⁻¹), but concerning gluten strength the application of 80 kg N ha⁻¹ represented optimal N level.

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