Effect of increased nitrogen fertilisation on the breadmaking quality of winter wheat (*Triticum aestivum L.)*

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VESELINKA ĐURIĆ[1], JOVANKA POPOV-RALJIĆ [2], M. MALEŠEVIĆ[1]

[1] *Institute of Field and Vegetable Crops, M. Gorkog 30, 21 000 Novi Sad, Serbia, tel: +381 21 4898 100, fax: +381 21 4898 222*

[2] *Faculty of Agriculture, University of Belgrade, Nemanjina 6, 11 081 Zemun, Serbia*
E-mail: djuricve@ifvcns.ns.ac.yu

Abstract

This paper presents the results of a three-year research on the influence of different nitrogen (N) doses on the grain protein content (GPC), wet gluten content (WGC) and on baking score (BS) of 8 varieties of winter wheat. In all the years, the average GPC increased as the level of N fertilizers went up. The average growth GPC, depending on the variety was from 1.22 to 1.88 % per 100 kgNha^{-1}. The WGC increased to the maximum of applied doses of N fertilizers (180 kgNha^{-1}) in all the years of research, 4.0 to 6.4% per 100 kgNha^{-1} in average. Any notable differences in BS appeared only between different varieties. The distinction in variation was mainly determined by different protein quality, where the effect of N fertilizers was more significant for the quality than GPC. The year also influenced the researched indicators of quality. The improvement of wheat quality was an important goal of the research.

Keywords: wheat, nitrogen nutrition, protein, wet gluten, baking score

Introduction

Proteins play a role in many aspects of bread making quality in wheat including nutritive value, dough properties, matrix formation around starch granules (that may restrict hydrolysis of the granules during mashing), and aggregate or gel formations. Although GPC has a heritable component, the environment, including soil fertility and moisture, plays a major role in determining final grain protein content levels [1,2 and 3]. The dough physical properties of wheat flour are determined by its protein constituents, especially the gluten proteins. Reserve proteins (gluten) are specific for grain tissues. These tissues are the only sites of their synthesis and they accumulate there relatively late when compared with starch accumulation. Under conditions of insufficient nutrition, wheat grains synthesize mostly structural and metabolic proteins [4]. Still, a small amount of reserve proteins is synthesized, no matter how harsh the nutritive stress. The portion of reserve proteins increases with mineral fertilization [5].

Gluten is described as a highly elastic material left over after starch is thoroughly rinsed from dough. Gluten features two important properties, elasticity and viscosity. Baking properties depend to a large measure on the content and quality of gluten [6]. Gluten consists of complex group of proteins, gliadin and glutenin, that are insoluble in water. Changing the ratios of the protein fractions changes the protein properties [7]. Gluten structure has a big influence on flour rheological properties and quality. Gluten quality determines the ability of dough to keep CO_2 during fermentation in gas cells in order to provide loaf volume and bread crumb. A high positive correlation (r = 0.9) exists between protein content and the grain gluten content of wheat [8]. Application of nitrogen fertilizers tends to change protein structure, changes dough elasticity and viscoelastic properties. High N treatments increase the ratio of high- and low-molecular subunits. Bread volume, water absorption power and baking score increase considerably in response to increased N dose [9]. Dough tolerance under conditions of N nutrition is chiefly determined by the genetic structure of reserve proteins and a significant interaction between these two factors [10].

Material and Methods

Eight winter wheat varieties have been studied: Libellula, Drina, Sremica, Novosadska rana-2 (NSR-2), Yugoslavija, Somborka, Lasta and Pobeda. The varieties differed in the biological and production characteristics as well as in technological quality. The analyzed samples belonged to the Internationale Stickstoff-Dauer-Versuche (ISDV) stationary field trial established at Rimski Šančevi experiment field of Institute of Field and Vegetable Crops in Novi Sad, R. Serbia. The variants of N fertilization were: 0, 60, 90, 120, 150 and 180 kgNha^{-1}. Nitrogen was applied two times, 50% in the fall and 50% in the spring. Equal amounts of phosphorus and potassium, 80 kgha^{-1}, were applied in all variants. The tested materials were taken from the 25th, 26th and 27th year of the trial (1995-1997), which mutually differed in weather conditions during the period of wheat growth, development and maturation. Grain samples were analyzed for grain protein content (GPC) and wet gluten content (WGC) as indirect indicators, and baking score (BS) as a direct indicator of technological quality. GPC (N X 5,7 moisture basis) of whole meal was determined according to Kjeldahl (Tecator, Höganäs, Sweden) by the ICC method 105/2, WGC were determined according to ICC methods 116/1 and 106/2, respectively. Baking score (BS) after pilot baking in the laboratory [11,12], made on the scale 0-7 (where 7 is excellent), was determined as a numerical expression based on the sensory assessment of bread crumb representing the sum of points for elasticity (0.0 - 4.5, where 4.5 is excellent) and pore structure fineness (0.0 - 2.5, 2.5 is extremely fine).

An analysis of variance (ANOVA) was used to determine the significance of fertilizer treatments, varieties and years. Fertilizer treatments and varieties were considered fixed effects and years were considered random effects. Least significant difference (LSD) test was used to determine the significance of the differences among the average values for the indicators under study. Statistics for MSTAT-C (Crop &Soil Sciences Dept., Michigan St. Univ., USA) and SPSS (User's guide for SPSS for Win., ver. 6.0. SPSS Inc., USA) was used for computation of the ANOVA and LSD values. Since the objective of the paper was also to investigate the importance of cultivar for the parameters of wheat technological quality, correlation analysis was used to determine the link between nitrogen fertilizer and the technological quality parameters studied in each of the cultivars. Linear correlation and regression methods were used for computation of regression coefficients (b) and the coefficients of correlation (r) and determination (r^2).

Results and Discussion

The meteorological conditions in the years of the experiment differed considerably regarding both, rainfall and temperature. The conditions were good in 1994/95., intermediate in 1996/97 and poor in 1995/96. The intensity of nitrogen mineralization depends on soil temperature and aeration. Depending on the amount of rainfall during autumn, different levels of nitrate N are mobilized along the soil profile [3].

Nitrogen nutrition caused higher increases in GPC in the first two years than in 1997. (Table 1). In 1997, N fertilizations above 60 kg ha^{-1} did not cause significant increases in GPC. The weather during the growing season is the major overriding factor in determining protein levels [13].

Table 1. Effect of N dose and year on GPC (% dm^{-1}) in wheat

Year	kg N ha^{-1}						Average GPC (%)))dm^{-1})
	0	60	90	120	150	180	
1995	10.2	10.5	11.7	12.6	13.4	13.6	12.0
1996	10.4	11.0	12.6	12.8	13.3	13.7	12.3
1997	10.0	10.8	11.0	11.3	11.7	11.7	11.1
Average	10.2	10.8	11.7	12.2	12.8	13.0	11.8

LSD (P<0,05) for different years within a N treatments =0,4; for different N treatments within a year = 0,5; for different years at different N treatments=0,9

The highest average GPC (13,0%) was achieved with the highest N dose (180 kgN ha^{-1}) however, the difference between the variants with 150 and 180 kgNha^{-1} was not significant. There is not significant increase in GPC with a higher than typical N treatment [14].

The value of regression coefficient was 0.0169 % of protein per kg Nha^{-1} (Table 2).

The highest effect (r^2) of N nutrition on protein content 76,2%, was registered in the variety Sremica, followed by Pobeda (71,0%), NSR-2 (69,9%), Somborka (67,8%), Libellula (66,5%), Lasta (64,4%) and Yugoslavija (50,1 %). The increase was only 37,4% in the variety Drina. Sremica, however, was significantly higher than the other cultivars in GPC at all N treatments.

Table 2. Regression equations showing the increases of GPC per kg of applied N ha^{-1}

Variety	Regression equation	r	r^2
Libellula	$\hat{Y}$ = 9.559 + 0.0188 N	0.815	0.665
Drina	$\hat{Y}$ = 10.673 + 0.0122 N	0.611	0.374
Sremica	$\hat{Y}$ = 10.610 + 0.0186 N	0.873	0.762
NSR-2	$\hat{Y}$ = 10.488 + 0.0176 N	0.836	0.699
Yugoslavija	$\hat{Y}$ = 10.347 + 0.0153 N	0.708	0.501
Somborka	$\hat{Y}$ = 10.031 + 0.0178 N	0.823	0.678
Lasta	$\hat{Y}$ = 9.064 + 0.0184 N	0.802	0.644
Pobeda	$\hat{Y}$ = 9.901 + 0.0167 N	0.843	0.710
Average	$\hat{Y}$ = 10.099 + 0.0169 N	0.789	0.629
$r_{0.05\ (16)} = 0.468$	$r_{0.01\ (16)} = 0.590$		

Significant increases in WGC were achieved with 120 $kgNha^{-1}$ in 1995, and with 150 $kgNha^{-1}$ in 1996. (Table 3). In 1997, however, no significant increase was registered even with 180 $kgNha^{-1}$. Obviously, conditions during grain filling period were more favorable in 1995 than in 1997. Variability of WGC due to environmental factors was commented by [15,16].

Table 3. Effects of N dose and year on WGC (%) in wheat

Year	kg N ha^{-1}						Average WGC per year
	0	60	90	120	150	180	
1995	21.0	22.0	26.0	31.0	32.0	34.0	27.7
1996	20.0	21.0	24.0	26.0	28.0	29.0	24.7
1997	21.0	22.0	22.0	24.0	24.0	26.0	23.2
Average	20.7	21.7	24.0	27.0	28.0	29.7	25.2

LSD ($P<0,05$) for different years within a N treatments =2.0; for different N treatments within a year = 3.0; for different years at different N treatments= 6.0

WGC kept increasing with increases in N dose up to 180 $kgNha^{-1}$. However, statistically significant differences were found only between alternate variants (Table 4). Most intensive increases in wet gluten content, by 0.0646% and 0.0613% per $kgNha^{-1}$, were registered in the varieties Sremica and Pobeda. Correlations (r = 0.744) between N treatments and WGC were highly significant on the average for all varieties. The only exception was the variety Drina which exhibited a significant correlation.

Table 4. Regression equations showing the increase of WGC per kg of applied N ha^{-1}

Variety	Regression equation	r	r^2
Libellula	$\hat{Y}$ = 20.224 + 0.0531 N	0.754	0.569
Drina	$\hat{Y}$ = 22.164 + 0.0401 N	0.478	0.228
Sremica	$\hat{Y}$ = 22.505 + 0.0646 N	0.706	0.498
NSR-2	$\hat{Y}$ = 20.712 + 0.0555 N	0.801	0.641
Jugoslavija	$\hat{Y}$ = 18.952 + 0.0590 N	0.776	0.602
Somborka	$\hat{Y}$ = 19.300 + 0.0550 N	0.867	0.752
Lasta	$\hat{Y}$ = 14.336 + 0.0525 N	0.773	0.598
Pobeda	$\hat{Y}$ = 19.307 + 0.0613 N	0.795	0.631
Average	$\hat{Y}$ = 19.693 + 0.0549 N	0.744	0.565
$r_{0.05\ (16)} = 0.468$	$r_{0.01\ (16)} = 0.590$		

The highest effect (r^2) of N nutrition on WGC (75,2 %), was registered in the variety Somborka, followed by, NSR-2 (64,1%), Pobeda (63,1%), Yugoslavija (60,2%), Lasta (59,8%) and Libellula (56,9%). The effect was only 22,8 % in the variety Drina (Table 4).

BS varied from 2.9 to 3.5 in 1995, 2.2 to 3.6 in 1996 and 2.2 to 3.8 in 1997 (Table 5). A significant difference was found only between the highest N dose and the control, and even that only for the 3-year averages. The highest loaf volume was achieved by N application [3], while [17] reported significant increases in loaf volume for each additional 60 kgNha^{-1} from 0 to 180 kgNha^{-1}. The quality of a wheat variety depends not only on its genetic potential for particular characters, but also on its ability to realize this potential in actual production and under different environmental conditions [2]. Marking only the percentage content of total protein and gluten in wheat grain does not mean the same as the evaluation of the technological value. The opinion that a high content of both components does not always correspond to a high baking value of flour is confirmed by the results reported by [18]. What is essential is not only the content of these components, but in particular low- and high-molecular gliadins and gluteine sub-units which form it, related with baking value [19]. Besides there are reports [20,21], in which the effect of nitrogen fertilisation on the value of technological parameters of wheat did not run in one direction.

Table 5. Effect of N dose and year on BS

Year	kg N ha^{-1}						Average BS per year
	0	60	90	120	150	180	
1995	2.9	2.9	2.9	3.1	3.3	3.5	3.1
1996	2.2	2.5	2.5	3.1	3.3	3.6	2.9
1997	2.2	2.6	3.2	3.5	3.7	3.8	3.2
Average(BS) (BS)	2.4	2.7	2.9	3.2	3.4	3.6	3.0

LSD (P<0,05) for different years within a N treatments = 0.7; for different N treatments within a year = 1.0; for different years at different N treatments =1.8

The correlations between the N treatments and BS were positive, both on the average and for the individual varieties (Table 6).

Table 6. Regression equations showing the increase of BS per kg of applied N ha^{-1}

Variety	Regression equation	r	r^2
Libellula	$\hat{Y} = 0.6 + 0.0006\ N$	0.047	0.002
Drina	$\hat{Y} = 1.0 + 0.0021\ N$	0.118	0.138
Sremica	$\hat{Y} = 4.8 + 0.0074\ N$	0.634	0.403
NSR-2	$\hat{Y} = 2.5 + 0.0094\ N$	0.651	0.423
Jugoslavija	$\hat{Y} = 3.8 + 0.0082\ N$	0.421	0.177
Somborka	$\hat{Y} = 1.9 + 0.0064\ N$	0.365	0.133
Lasta	$\hat{Y} = 0.7 + 0.0129\ N$	0.752	0.565
Pobeda	$\hat{Y} = 3.3 + 0.0093\ N$	0.603	0.364
Average	$\hat{Y} = 2.3 + 0.0070\ N$	0.449	0.276
$r_{0.05\ (16)} = 0.468$	$r_{0.01\ (16)} = 0.590$		

Although BS increased proportionally with the increases in N dose, the increases were not significant in the varieties Libellula, Drina, Yugoslavija and Somborka. In the other four varieties, the coefficients were highly significant (r >0.468), and so was the average for all varieties. Most intensive increases in BS, by 1,29 and 0,94 per 100kgNha^{-1}, were registered in the Lasta and NSR-2 varieties. Different levels of N fertilization tend to change protein structure in wheat grain, which results in changes in the viscoelastic properties of dough which in turn cause variations in bread quality [9]. The highest effect (r^2) of N nutrition on BS, 56,5% was registered in the variety Lasta (Table 6).

Conclusion

This paper has shown that the applied nitrogen treatments increased the GPC of the tested wheat varieties. Wet gluten content (WGC) kept increasing to the highest N dose in all years. Significant differences in baking score among the varieties were the result of dominance of the genetic factor for this trait. This research shows how we can affect some of the parameters that are important on the market. The results will be used to formulate fertility recommendations for growers interested in producing high protein wheat.

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