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Winter Wheat Yields as Affected by Year and Nitrogen Rate Applied

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Abstract: A 10-year study was conducted over 1995-2004 in order to study the effects of different N rates on grain yields of three winter wheat varieties having different yield and quality potentials. The study was part of a larger stationary trial carried out at the Rimski Sancevi site near Novi Sad.

The experiment included four N fertilization treatments. The study years were divided into three groups depending on the yield levels they produced: 1) favorable, or high-yielding years (average yields of over 6 tha^{-1}), intermediate ones (5-6 tha^{-1} on average), and unfavorable or low-yielding ones (yields of less than 5 tha^{-1}). The study determined the effect of three study factors (year, N fertilizer, and cultivar) and their interactions on yield levels in wheat.

In each N treatment individually as well as on average, the highest grain yield was produced by the variety Pobeda and the lowest by the variety Sremica. The highest average grain yield was achieved with the highest N rate (180 kg ha^{-1}), but this yield did not differ significantly from that obtained using 120 kg N ha^{-1} . Yield levels were affected the most by year, N rate and year x N rate interaction, while cultivar produced a significantly lower effect.

Key words: wheat, nitrogen, grain yield, favorableness of year.

Introduction

Wheat yield formation is a result of a whole series of reactions and processes taking place in plants within the climate-soil-plant complex and may be regarded as a function of time. Knowledge of a plant response to changes in environmental conditions is advantageous, because it is these responses that the extent of utilization of the genetic potential for grain yield largely depends on. Conscious adaptation to climatic conditions must involve efforts to mitigate climate effects, most notably the harmful effect of climatic excesses. Zentner *et al.* (1990) report that wheat yields and grain quality are dependent on interactions among many factors, including cultivar, soil, climatic conditions, and growing conditions.

As the main goal of wheat growing is to obtain maximum yields of appropriate quality, economically and agronomically sustainable wheat production can only be achieved by intensive fertilization and adequate crop rotation, tillage, and crop protection (Berzsenyi *et al.*, 2000; Carlson *et al.*, 2004).

When it comes to the use of NPK nutrients, especially nitrogen as the largest contributor to yield, it has long been known that an excess or deficiency of these elements hinders yield formation under such conditions (Kastori, 2005). With uncontrolled N nutrient use, yield fluctuations may become higher when more recent cultivars are used as compared to older ones, the reason being that increased yield potential results in increased cultivar-specificity with respect to N nutrition (Spasojević and Malešević, 1988). An adjusted fertilization system can be used to mitigate the negative effects of year and climatic factors (Bedo *et al.*, 2001, Marinković *et al.*, 2006).

Without going into a detailed analysis of the weather conditions during the ten years of our study (1995-2004), the present paper offers a brief overview of how wheat grain yields are affected by the favorableness of the year and nitrogen fertilizer use.

The analysis was made on a set of data from an ongoing long-term ISDV (*Internationale Stickstoff Dauer Versuche*) trial established as far back as 1971 that is part of a series of trials of the International Commission for the Study of Soil Fertility. Multi-year experiments and long-term stationary field trials play the key role in an effort to understand the complex interactions among plants, the soil, climatic factors, and agronomic practices and are therefore of great importance in the advancement of qualitative and quantitative traits in wheat (Leigh and Johnston, 1994).

Materials and Methods

A ten-year study was carried out at the Rimski Sancevi Experiment Field of the Institute of Field and Vegetable Crops in Novi Sad as part of a larger long-term international field trial (*ISDV - Internationale Stickstoff Dauer Versuche*). The study covered all years between 1995 and 2004 except for 1999, in which there was no harvest due to the NATO bombing of Serbia. Three winter wheat cultivars (Sremica, Lasta and Pobeda) differing in their biological characteristics, genetic yield potentials, and technological grain quality were studied. The cultivars were selected as representatives of three different periods in domestic

wheat production (Sremica: 1970-1975., Lasta: 1980-1985. and Pobeda: 1990-1995) and the objective was to compare these varieties and determine the cultivar specificity of N nutrition.

The study included four N treatments: 0, 60, 120 and 180 kgN ha⁻¹. The N was incorporated by means of split application (50% in the autumn, 50% in the spring). Phosphorus and potassium rates (80 kg ha⁻¹ per treatment) were applied in the autumn. The crop was sown on optimal planting dates using 500-600 germinable seeds per m² depending on cultivar.

The trial employed a randomized block design with four replicates and the experimental units were 57 m² in size (6 m x 9.5 m). The samples were taken from an area of 5 m² and analyzed for grain yield (reduced to 13% moisture), protein content, volume weight, and 1000-grain weight. The present paper discusses only the measurements of yield. To make the analysis more exact, the study years were divided into three groups depending on the yield levels they produced: 1) favorable, or high-yielding years (with average yields of over 6 tha⁻¹), intermediate ones (5-6 tha⁻¹ on average), and unfavorable, or low-yielding ones (yields of less than 5 tha⁻¹).

The data were processed by two-factor analysis of variance (Factor A – N rate, Factor B – cultivar) and presented in tables and figures.

Results and Discussion

Across the study years, increasing N rates increased both the grain yields of each variety studied and the overall average grain yield of all the varieties (Tab. 1). The highest grain yield was achieved with the highest N rate (180 kg ha⁻¹). However, the average grain yield produced by this treatment (6.25 tha⁻¹) did not differ significantly from that obtained using 120 kg N ha⁻¹.

Table 1. Effect of cultivar and N fertilization on wheat grain yield (t ha⁻¹)

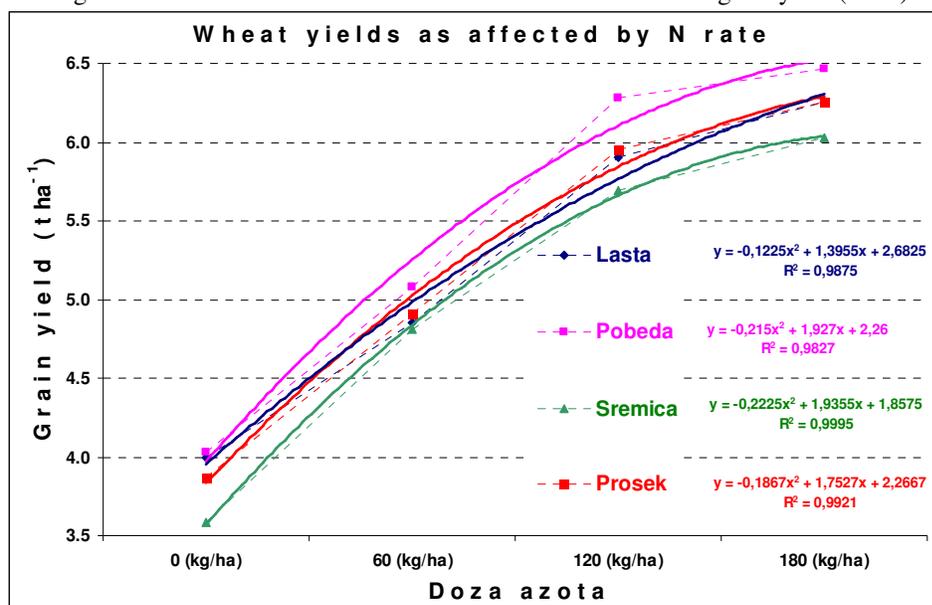
N rate (kg ha ⁻¹) (A)	Cultivar (B)						Average (A)	
	Sremica	Δ	Lasta	Δ	Pobeda	Δ		
0	3.58	-	4.00	-	4.03	-	3.87	-
60	4.81	1.23**	4.85	0.85**	5.08	1.05**	4.91	1.04**
120	5.69	0.88**	5.90	1.05**	6.28	1.20**	5.96	1.05**
180	6.03	0.34	6.26	0.36	6.47	0.19	6.25	0.29
Average (B)	5.03		5.25		5.47		-	
	A		B		BxA		AxB	
LSD 0.05	0.38		0.14		0.36		0.28	
LSD 0.01	0.55		0.19		0.51		0.39	

For each individual cultivar as well as for the cultivars considered collectively, the increase of grain yield induced by increasing N rates had the shape of a least squares regression line (Figure 1). The theoretical maximum

grain yield was calculated to be achievable using $198 \text{ kg ha}^{-1} \text{ N}$, resulting in a yield of 6.35 t ha^{-1} ($r^2=0.992$).

The increases of N rate from 0 to 60 kg ha^{-1} and from 60 to 120 kg N ha^{-1} increased the grain yield by an almost identical rate (1.04 and 1.05 t ha^{-1} , respectively) that was highly statistically significant. The third increase of 60 kg ha^{-1} increased the grain yield by only 290 kg ha^{-1} on average, which was not significant in statistical terms. The response of individual varieties to the increases was almost identical, the only difference being that the highest increase of grain yield in the variety Sremica was achieved with the first N rate, while with Lasta and Pobeda the second rate produced the highest increase. These results suggest that it is statistically and economically justified not to fertilize wheat with more than 120 kg N ha^{-1} . This is in agreement with the findings of many domestic authors, including Starčević *et al.* (1982) and Malešević *et al.* (1996).

Figure 1: Effect of cultivar and N fertilization on winter wheat grain yield (t ha^{-1})



Among the cultivars studied, there were highly significant differences in grain yield. As regards individual treatments as well as the average of the four N rates, the highest yield was achieved with the cultivar Pobeda (5.47 t ha^{-1}), while Sremica and Lasta produced significantly lower yields of grain. The lowest grain yield (5.03 t ha^{-1}), that of the variety Sremica, was significantly lower than the yield of the second highest yielding cultivar, Lasta.

Table 2 shows the effects of the studied factors: type of year (favorable, intermediate or unfavorable), N rate, cultivar, and N rate x cultivar interaction.

Analysis of variance showed that yield levels were affected the most by year, N rate and year x N rate interaction (F-ratio <0.01), with cultivar having a

significantly lower effect ($F = 0.099$). These results are in agreement with those of Malešević *et al.* (2005).

Table 2: Effects of N fertilization and cultivar on wheat grain yields ($t\ ha^{-1}$) in favorable, intermediate and unfavorable years

N rate ($kg\ ha^{-1}$)	Type of year												Average (A)
	Favorable				Intermediate				Unfavorable				
	Lasta	Pobeda	Sremica	Mean	Lasta	Pobeda	Sremica	Mean	Lasta	Pobeda	Sremica	Mean	
0	4.4	4.3	3.4	4.1	4.4	4.2	3.8	4.2	3.2	3.5	3.5	3.4	3.9
60	6.1	6.3	5.7	6.1	4.4	4.8	4.7	4.6	4.1	4.2	4.1	4.1	4.9
120	7.6	7.9	7.1	7.6	5.7	6.2	5.8	5.9	4.4	4.6	4.2	4.4	5.9
180	8.2	8.0	7.6	7.9	5.9	6.5	5.8	6.1	4.7	4.9	4.6	4.7	6.3
Cultivar mean	6.6	6.7	6.0	-	5.1	5.4	5.0	-	4.1	4.3	4.1	-	-
Annual mean	6.4				5.2				4.2				-

LSD values for individual factors and their interactions at significance level of 5%:

Type of year :	0.41
N rate:	0.47
Cultivar:	0.40
Year x N rate interaction:	0.81
Year x cultivar interaction:	0.71
N rate x cultivar:	0.82
Year x N rate x cultivar:	1.41

Yield levels in all fertilization treatments were recorded to be higher in favorable years than in intermediate or unfavorable ones. In the control treatment (no N), there were no significant differences in yield between the favorable and unfavorable years regardless of the cultivar used. In the check, the lowest yield variation by year was recorded in the variety Sremica.

N effects on grain yield were the highest in favorable years and the lowest in unfavorable ones. The unfavorable conditions for N mineralization and microbial activity in unfavorable years were the most likely cause of reduced effect of N incorporation. The stated years had a reduced capacity to express yield potential, being the reason for the smallest differences recorded in them. Similar findings have been reported by Malešević *et al.* (2005).

Conclusions

In each individual N treatment as well as on average, the highest grain yield was produced by the variety Pobeda and the lowest by the variety Sremica.

The highest average grain yield was achieved with the highest N rate (180 kg ha^{-1}). However, the difference between the stated yield and the one obtained with 120 kg Nha^{-1} was not statistically significant.

Yield levels were affected the most by type of year, N rate, and year x N interaction, while the effect of cultivar was significantly lower.

Increased N rates cannot compensate for unfavorable weather conditions in a given year.

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PRINOS OZIME PŠENICE U ZAVISNOSTI OD USLOVA GODINE I NIVOVA ĐUBRENJA AZOTOM

- originalni naučni rad -

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Rezime

Desetogodišnja istraživanja (1995-2004) uticaja različitih doza azota na prinos zrna izvedena su sa tri ozime sorte pšenice, različitog potencijala za prinos i kvalitet, na stacionarnom poljskom ogledu na Rimskim Šančevima, Novi Sad.

Primenjene su četiri varijante đubrenja azotom. Sve ispitivane godine grupisane su na osnovu visine prinosa u tri grupe: povoljne ili rodne godine (sa prosečnim prinosima preko 6 tha^{-1}), srednje (5-6 tha^{-1}) i nepovoljne (nerodne godine, sa prinosima ispod 5 tha^{-1} u ogledu). Utvrđen je uticaj ispitivanih faktora (godine, đubrenje azotom i sorte), kao i njihove interakcije na visinu prinosa.

Najviši prinos zrna na svim dozama azota i u proseku, postignut je kod sorte Pobeda, a najniži kod sorte Sremica. Najveći prosečan prinos zrna dobijen je sa najvišom dozom azota od 180 kg ha^{-1} , međutim nije se statistički značajno razlikovao od prinosa dobijenog sa 120 kg N ha^{-1} . Na visinu prinosa pšenice najjače su uticali tip godine, doze N i interakcija tip godine x doze azota, dok je uticaj sorte bio značajno manji.