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GENOTYPE SPECIFICITY IN NITROGEN NUTRITION OF MALTING BARLEY

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A three-year trial (2003-2005) was conducted under agro ecological conditions of Timočka Krajina (the experiment farm of Technological Research Center in Zaječar). Research object were six malting barley genotypes, which were top-dressed with the following amounts of nitrogen in the course of growing season: 40, 60, 80 and 100 kg ha^{-1}. A non-fertilized variant served as a control. The obtained results indicated that the tested genotypes reacted to increased amounts of nitrogen by changing their morphological and biological characteristics as well as

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the technological values of grain. The effectiveness of the applied nitrogen depended significantly on the distribution of rainfall in periods of highest water uptake by malting barley.

Key words: genotype, grain quality, malting barley, morphological and biological characteristics, nitrogen fertilization

INTRODUCTION

The economic importance of malting barley is due to the use of barley grain in the industries of beer and hard liquors. Quality barley for malting industry should contain more than 60% of starch and less then 12% of total proteins. Bulk weight should be over 65 kg, and 1000-grain weight above 40 g. Modern barley breeding is aimed at the development of genotypes that meet the requirements of processing industry (DJURIĆ *et al.,* 2009). In addition to genotype, has a major impact and properly balanced nutrition, adapted to actual soil fertility and barley requirement for nitrogen, determine the quality of grain (GLAMOČLIJA *et al.,* 1998). The effect of nitrogen on barley characteristics depends on N amount applied and weather conditions in the growing year. Increased amounts of nitrogen curtail its positive effects on spike length, number of grains per spike, 1000-grain weight and yield level. However, the protein content in grain keeps increasing with nitrogen dose, which lowers the quality of malting barley (Malešević *et al.,* 2010). Conversely, PRŽULJ and MOMČILOVIĆ (2001) claimed that intensive nitrogen fertilization significantly increases crop yield, while grain quality and its utility depend on the genotype. The rate of utilization of applied nitrogen depends also on environmental conditions. In years with less rainfall in the spring, plants better utilize the top-dressed nitrogen (PAGOLA *et al.,* 2009). Many authors (KENDALL, 1996; PRŽULJ *et al.,* 1998; GLAMOČLIJA *et al.*, 1999; PAUNOVIĆ *et al.,* 2006, 2008; MADIĆ *et al.,* 2009) reported that an increased number of spikes increasses the yield of malting barley. The chemical composition of vegetative biomass depends on the variety and intensity of plant nutrition, but also from dynamics of individual phenological phases (UZUN, 2010).

GRANT *et al* (1991) clamed that, on soils with low N supplies, malting barley responds well to N fertilizer, exhibiting increases in yield and protein content. However, too much nitrogen can increase protein beyond levels acceptable to the malting industry's standards. New barley genotypes have a high genetic yield potential, getting close to wheat in productivity. Therefore, the barley is considered a prospective crop for Serbia, especially from the point of the global climate change which has not avoided the agricultural regions of Serbia. It is obvious that the impact of drought on the agricultural crops keeps intensifying. Therefore, it is recommended to rely on small grains in the agricultural production because they are tolerant to drought. Barley is highly tolerant to drought and high temperature and it belongs to the crops capable of mitigating the harmful effects of the climate change.

The objectives of this study were to find the most suitable assortment of barley cultivars and determine their genetic yield potential when grown under the agroecological conditions of eastern Serbia.

MATERIALS AND METHODS

The three-year trial (2003-2005) was carried out in the agroecological conditions of Timočka Krajina (the experiment farm of Technological Research Center in Zaječar), on the limeless smonitza soil. Agrochemical analyses showed that the chemical reaction of the soil was slightly acidic (pH - 5.80), and that the soil was provided with phosphorus (P_2O_5) and potassium (K_2O) (17.5% and 29.95%, respectively), medium provided the nitrogen (N) (0.12%), and rich in humus (3.08%).

The research object were genotypes of winter malting barley *Kristal* (G_1), *Premijum* (G_2), *NS -519* (G_3), *NS-525* (G_4), and two lines, *ZA-82/1* (G_5) and *ZA -12/1* (G_6). The experimental plants received the following amounts of mineral fertilizers. During seedbed preparation, 30 kg ha^{-1} of N, 80 kg ha^{-1} of P_2O_5 and 60 kg ha^{-1} of K_2O were applied. Top dressing was performed in the course of the winter season, applying 40, 60, 80 and 100 kg ha^{-1} of N (variants N_1, N_2, N_3 and N_4, respectively).The control variant was not fertilized (N_0).

Phenological stages were observed in the course of the growing season and plant samples for analyses were taken at the stage of full maturity. The following parameters were measured: plant height, number of spikes per m^2, spike length, 1000-grain weight and hectolitre weight. All variants were sampled for determination of germinability and germination energy.

The obtained data were processed by the analysis of variance.

The annual amounts of rainfall in the three years (638 mm, 665 mm and 672 mm) were above the long-term average (586 mm). The distribution of rainfall in the first year of study was unfavourable. Long periods of drought at the stages of tillering, shooting and heading significantly affected the development of plants. The highest rainfall during growing season occurred in the second year. Most favourable distribution of rainfall was in the third year. The temperature regime was within the long-term average values for the studied region.

RESULTS AND DISCUSSION

Barley stem height was affected by increased nitrogen and genotype in all three years of study. The effect of the treatments depended on the weather conditions during the barley growing season (Table 1). PECIO and BICHONSKI (2002) emphasize the high effect of nitrogen on the total growth of barley plants. TAMM and TAMM (2000) reported significant correlation between varieties and environmental conditions.

The number of spikes per meter square, or intensity of tillering, was lowest in the first year (318). In the third year, the tillering was 2 times higher, and in the second year 2.5 times higher than in the first year. Nitrogen fertilizers affected the intensity of tillering in all three years, with differences among genotypes being significant only in the second year (Table 2). VEIGH and RAJKAI (2006) emphasize an optimal nitrogen rate to be applied in barley nutrition should be identified.

Table 1. Stem height, cm

Genotype	2002/3						2003/4						2004/5						
	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	$\bar{X}$
G_1	33	38	41	44	46	40.4	66	77	82	85	83	78.6	57	64	69	72	73	67.0	62.0
G_2	32	38	41	44	46	40.2	67	73	77	78	80	75.0	58	62	66	69	70	65.0	60.1
G_3	32	42	44	45	45	41.6	68	76	79	81	81	77.0	59	64	66	70	70	65.9	61.5
G_4	34	43	44	46	46	42.6	68	76	80	83	84	78.2	57	65	70	74	75	68.2	63.0
G_5	33	37	41	42	44	39.4	64	76	77	79	80	75.2	56	61	66	67	68	63.6	59.4
G_6	35	41	44	45	46	42.2	67	76	84	83	84	78.8	57	65	71	75	76	68.8	62.3
Average	33.2	39.8	42.5	44.3	45.5	41.1	66.7	75.7	79.8	81.5	82.0	77.1	57.3	63.5	68.0	70.5	72.0	66.3	61.5

Characteristic tested	Test	2002/3			2003/4			2004/5		
		Genotype	Nitrogen	AxB	Genotype	Nitrogen	AxB	Genotype	Nitrogen	AxB
	F test	**	**	**	**	**	NS	**	**	*
Stem	LSD 5%	1.1603	0.8560	2.2438	3.6093	1.6044	5.1384	1.4038	1.1094	2.8532
height	1%	1.6503	1.1268	3.0493	5.1337	2.1178	7.1178	1.9967	1.4603	3.8677

Table 2. Spike number per m^2

Genotype	2002/3						2003/4						2004/5						
	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	$\bar{X}$
G_1	253	283	345	347	349	315	652	787	847	861	860	801	560	655	679	699	695	658	591
G_2	243	285	349	352	352	316	652	833	860	880	881	821	568	656	685	695	697	660	599
G_3	248	281	348	352	352	316	633	795	860	878	884	810	555	663	688	700	700	661	596
G_4	246	295	351	352	355	320	652	790	855	872	881	810	557	651	689	695	701	659	596
G_5	257	289	352	360	357	323	648	801	855	887	889	815	546	652	691	701	696	657	598
G_6	253	288	348	355	353	319	662	779	845	864	873	805	550	660	688	696	702	659	594
Average	250	287	349	353	353	318	649	797	853	873	878	810	556	656	686	697	698	659	596

Characteristic tested	Test	2002/3			2003/4			2004/5		
		Genotype	Nitrogen	AxB	Genotype	Nitrogen	AxB	Genotype	Nitrogen	AxB
	F test	NS	**	NS	**	**	*	NS	**	NS
Spike	LSD 5%	12.0048	9.4283	24.2884	10.6032	8.7004	22.3140	10.9456	9.3269	23.5391
number	1%	17.0750	12.4107	32.9314	15.0815	11.5578	30.1967	15.5685	12.2772	31.8224

Spike length was found to depend in all three years on the genotype and the amount of nitrogen, while the interaction of these two factors was significant only in the third year (Table 3).

Barley is a kind of small grains with the highest tillering coefficient. It depends on the genotype, nitrogen nutrition of plants, as well as on environmental conditions (MADIĆ *et al.,* 2006). On the other hand, VEIGH and RAIKAI (2006) clamed that optimum soil moisture in the initial stages of growth significantly affects the development of roots. Well-rooted plants are more intense tillering of the increased nitrogen supply.

The weight of 1000 grains is an important indicator of the utility of malting barley. Its value was lowest in the first year and the overall average was below 40 g. In the second and third years, the 1000'grain weight was above 40 g in all six genotypes, which meant that we obtained quality raw materials for the beer industry. Variations of the treatment groups were highly significant per genotype and per nitrogen nutrition of plants (Table 4). According to PRŽULJ and MOMČILOVIĆ (2002) and PRŽULJ *et al.* (1998) the optimal amount of nitrogen for malting barley nutrition, from the standpoint of grain size, is 80 kg ha^{-1}.

Table 3. Spike lenght, cm

Genotype	2002/3						2003/4						2004/5						
	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	$\bar{X}$
G_1	7.1	7.3	8.0	8.3	8.5	7.9	8.7	9.6	10.5	10.6	10.7	10.0	7.7	8.5	8.6	9.1	9.5	8.7	8.9
G_2	7.0	7.7	8.3	8.4	8.6	8.0	8.7	9.8	10.6	10.9	10.9	10.2	7.4	8.4	9.0	9.4	9.4	8.8	9.0
G_3	7.2	8.1	8.7	8.7	9.0	8.3	8.7	10.2	10.8	11.4	11.2	10.5	7.8	9.2	9.8	10.2	10.5	9.5	9.4
G_4	7.1	7.8	8.4	8.8	8.9	8.2	8.3	9.8	10.5	10.9	10.9	10.1	7.7	8.6	9.2	9.4	9.4	8.9	9.1
G_5	7.0	7.6	8.6	8.8	8.9	8.2	8.5	10.0	10.6	10.8	10.7	10.1	7.9	8.6	9.2	9.4	9.4	8.9	9.1
G_6	7.1	8.0	8.9	9.3	9.4	8.5	9.3	10.2	11.3	11.7	11.9	10.9	8.0	9.2	10.0	10.4	10.3	9.6	9.7
Average	7.1	7.8	8.5	8.7	8.9	8.2	8.7	9.9	10.7	11.1	11.1	10.3	7.8	8.8	9.3	9.7	9.8	9.1	9.2

Characteristic tested	Test	2002/3			2003/4			2004/5		
		Genotype	Nitrogen	AxB	Genotype	Nitrogen	AxB	Genotype	Nitrogen	AxB
	F test	**	**	NS	*	**	NS	**	**	*
Spike	LSD 5%	0.2619	0.1661	0.4568	0.4380	0.4121	1.0175	0.2330	0.1820	0.4695
length	1%	0.3724	0.2186	0.6244	0.6229	0.5425	1.3709	0.3314	0.2395	0.6367

Table 4. 1000 - grain weight, g

Genotype	2002/3						2003/4						2004/5						
	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	$\bar{X}$
G_1	36.4	37.7	39.0	39.2	39.9	38.5	40.0	43.5	44.7	45.9	46.0	44.0	41.1	44.5	46.2	46.7	47.1	45.1	42.5
G_2	36.9	37.6	39.2	40.0	40.8	38.9	40.7	41.4	43.4	43.9	43.9	42.6	41.6	43.8	45.3	45.7	46.0	44.5	42.0
G_3	37.6	40.5	42.0	42.3	43.2	41.1	40.6	44.5	46.0	47.3	47.1	45.1	45.7	46.5	48.1	49.5	49.7	47.9	44.7
G_4	36.4	42.2	42.5	43.2	43.6	41.6	40.0	44.8	47.7	47.1	48.2	45.6	41.1	47.2	49.3	50.7	51.8	48.0	45.1
G_5	38.0	38.7	39.6	40.0	40.2	39.3	40.7	43.3	44.4	44.9	45.5	43.8	42.1	46.7	48.0	49.1	49.5	47.1	43.4
G_6	37.3	38.1	38.6	39.1	39.4	38.5	41.2	42.3	43.6	44.1	44.4	43.1	41.2	44.0	46.2	46.4	46.7	44.9	42.2
Average	37.1	39.1	40.2	40.6	41.2	39.7	40.5	43.3	45.0	45.6	45.9	44.0	42.1	45.5	47.2	48.0	48.5	47.8	43.8

Characteristic tested	Test	2002/3			2002/3			2002/3		
		Genotype	Nitrogen	AxB	Genotype	Nitrogen	AxB	Genotype	Nitrogen	AxB
1000-	F test	**	**	**	**	**	**	**	**	*
grain	LSD 5%	0.3801	0.3095	0.7899	0.4558	0.5602	1.3223	0.9658	0.8543	2.1376
weight	1%	0.5406	0.4074	1.0696	0.6483	0.7374	1.7679	1.3737	1.1246	2.8861

Bulk weight is also an important indicator of technological value of grain. In the first year, it was near the lower threshold of the acceptable quality (the overall average value of 64.2 kg). In the second and third years, the grain was of excellent quality, the bulk weights being 69.4 and 72.1 kg, respectively. Highest fluctuations in the values of bulk weight were registered in the first year when significant differences were recorded between the genotypes, the amounts of nitrogen and the interaction of these two factors. There were no significant differences in the second year, while in the third year the genotype x nitrogen interaction was non-significant (Table 5).

The barley seed from the second year had the lowest germination energy (84.9%). The respective values in the third and first years were 89.2% and 92.3%. The three-year overall average value and the annual average values depended to a large measure on the genotype and amount of nitrogen. The interaction genotype x nitrogen was non-significant only in the first year (Table 6). Significant effect of weather conditions on seed quality was also indicated in a study of GLAMOČLIJA *et al*. (1998). According to JACKSON (2000), environmental factors such, as drought stress, that occur late in the season can adversely affect grain yield, and, in particular, quality characteristics. Kernel plumpness characteristics are strongly related to yield potential and available nitrogen.

Table 5. Bulk weight, kg

Geno-type	2002/3						2003/4						2004/5						
	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	$\bar{X}$
G_1	61.4	62.4	63.0	65.5	64.3	62.9	69.0	69.9	72.0	72.7	72.8	71.3	65.1	66.4	68.8	69.5	70.1	68.0	67.4
G_2	62.5	64.5	65.8	67.2	76.5	65.5	68.4	71.1	73.9	74.6	75.1	72.6	66.5	67.9	68.9	70.7	71.6	69.1	69.1
G_3	62.2	64.0	65.4	65.4	65.9	64.6	68.0	74.2	73.5	72.6	73.4	72.3	65.6	66.7	69.5	70.4	70.7	68.6	68.5
G_4	62.1	64.3	65.9	66.9	67.4	65.3	68.2	70.1	73.5	73.9	74.7	72.0	65.8	69.4	72.6	73.6	74.1	71.1	69.5
G_5	62.5	63.9	64.4	64.8	65.8	64.3	68.4	72.6	71.9	74.1	74.0	72.2	67.7	69.5	72.3	71.9	73.6	71.0	69.2
G_6	54.1	61.2	61.8	62.8	63.6	62.7	68.2	73.3	72.9	73.2	73.8	72.3	66.4	67.5	68.2	69.7	70.4	68.4	67.8
Average	60.8	63.4	64.4	65.4	67.3	64.2	68.4	71.9	73.0	73.5	73.9	72.1	66.2	67.9	70.1	71.0	71.8	69.4	68.6

Characteristic tested	Test	2002/3			2003/4			2004/5		
		Genotype	Nitrogen	AxB	Genotype	Nitrogen	AxB	Genotype	Nitrogen	AxB
Bulk	F test	**	**	**	NS	NS	NS	**	**	NS
weight	LSD 5%	0.9102	0.6853	1.7860	1.6928	1.2172	3.2147	0.6484	0.8014	1.8902
	1%	1.2946	0.9021	2.4253	2.4077	1.6022	4.3730	0.9223	1.0550	2.5268

Table 6. Germination energy, %

Genotype	2002/3						2003/4						2004/5						
	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	N_0	N_1	N_2	N_3	N_4	$\bar{X}$	$\bar{X}$
G_1	88.7	90.0	93.7	94.7	95.7	92.5	77.0	78.3	82.0	84.0	85.0	81.3	85.7	87.7	90.0	92.3	94.0	89.9	87.9
G_2	89.7	90.7	93.7	94.7	96.3	93.0	79.7	81.7	86.3	87.7	89.3	84.9	88.3	88.3	91.7	93.0	94.7	91.2	89.7
G_3	90.3	90.0	90.7	92.7	92.7	91.3	78.7	76.0	78.3	81.3	84.0	79.7	85.3	84.0	87.0	89.0	89.3	86.9	86.0
G_4	90.7	90.3	94.0	93.7	94.7	92.7	87.0	85.3	89.0	90.3	91.0	88.5	87.0	85.3	89.0	90.3	91.0	88.5	89.9
G_5	89.0	90.7	93.7	94.7	96.0	92.8	86.7	88.7	90.0	91.3	92.0	89.7	86.7	88.3	90.0	91.3	92.0	89.7	90.7
G_6	88.0	89.0	91.0	94.0	95.3	91.5	87.0	79.7	83.3	87.3	88.3	85.1	88.3	86.0	89.0	90.7	91.0	89.0	88.5
Average	89.4	90.1	92.8	94.1	95.1	92.3	82.7	81.6	84.8	87.0	82.3	84.9	86.9	86.6	89.5	91.1	92.0	89.2	88.8

Characteristic tested	Test	2002/3			2003/4			2004/5		
		Genotype	Nitrogen	AxB	Genotype	Nitrogen	AxB	Genotype	Nitrogen	AxB
	F test	**	*	NS	**	**	**	**	**	**
Germination	LSD 5%	0.9741	0.7622	1.9655	1.1300	0.9143	2.3371	0.8206	0.9149	2.1905
energy	1%	1.3856	1.0033	2.6653	1.6072	1.2035	3.1653	1.1672	1.2043	2.9364

CONCLUSION

The three-year research results of genotypic specificity in nitrogen nutrition of malting barley allow us to draw the following conclusions.

- In the year with the unfavourable distribution of rainfall, nitrogen top dressing increased the average stem height by 29.1%. In the favourable years, the increases were 19.5% and 19.6%.

- The overall average number of spikes per unit area was highest when 100 kg/ha of nitrogen were applied (643). The highest effect was registered in the first, dry year.

- Water regime affected the length of the spike. Under dry conditions and on the overall average, the genotype *NS-519* and the line *12 /1* formed a significantly longer spike.

- The genotypes *NS-519* and *NS-525* had largest grains whose bulk weight exceeded 40 grams even in the dry year.

- Bulk weight of grain was very good on the whole; as it was less dependent on the distribution of rainfall. In the year with the most favourable water regime, the studied factors did not influence this parameter. The line *82/1* was distinguished throughout the study period for highest bulk weight.

- Abundant RAINFALL during the barley maturation in the second year adversely affected the germination energy, which was below the standard value required by the beer industry.

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GENOTIPSKE SPECIFIČNOSTI PIVARSKOG JEČMA U USLOVIMA INTENZIVNE ISHRANE AZOTOM

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I z v o d

Trogodišnji ogledi (2003-2005) su izvedeni u Centru za poljoprivredna i tehnološka istraživanja u Zaječaru. Materijal istraživanja bilo je šest genotipova pivarskog ječma koji su tokom vegetacionog perioda prihranjivani sledećim količinama azota 40, 60, 80 i 100 kg ha^{-1}. Kao kontrola poslužila je varijanta bez prihranjivanja. Dobijeni rezultati pokazali su da genotipovi reaguju na povećane količine azota promenom morfoloških i bioloških osobina, kao i promenama tehnološke vrednosti semena. Efekti upotrebljenog azota značajno zavise od rasporeda padavina u periodima najveće potrošnje vode.

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