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GENOTYPE VARIATIONS IN GRAIN YIELD OF SPRING BARLEY DEPENDING ON SOWING DENSITY

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A three-year study was carried out for grain yield in five cultivars of the spring brewer's barley at the Small Grains Research Centre of in Kragujevac from 1996 to 1998. The effect of three sowing densities on the number of spikes, grain number per spike and grain yield was studied for each cultivar. Research results have shown that the cultivars displayed a highly significant effect on the grain number per spike and grain yield. It has also been noticed that, in the course of every research year, sowing density induced increases in spike number and grain yield. In contrast, the higher sowing density brought about a decrease in the grain number per spike.

Key words: spring barley, genotypes, sowing density, yield

INTRODUCTION

Barley (*Hordeum sativum* Jessen.) is one of the most important field crops. It ranks fourth in the world in terms of the growing area, after wheat, rice and maize. According to MAKSIMOVIĆ (1997), the total growing area of barley in the world is over 80 million ha, and the average grain yield is about 2,217 kg/ha. Its growing area in our country is about 100,000 ha (60,000 ha for spring barley and

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40,000 ha for winter barley) and average grain yield achieved is about 2,775 kg/ha. There are numerous reasons for such modest average grain yields. The most frequent issues associated with barley production method which directly manifest themselves in achieving good yields are the choice of an adequate cultivar, determination of optimum sowing time, plant nutrition, especially nitrogen nutrition and determination of the most adequate sowing density, to enable the achievement of optimum spike number in the harvest season for the cultivar concerned.

Based upon cultivar specificities, the effect of climatic conditions in the study years and the impact of sowing density, the aim of the paper was to determine the optimum combination among the factors and their effects and identify which variant, in the given growing conditions in all genotypes investigated enabled high grain yields in agroecological conditions of Kragujevac.

MATERIAL AND METHOD

In accordance with the aim of the scientific paper, we chose five spring brewer's barley cultivars, four of which were bred at the Small Grains Research Centre in Kragujevac, and the remaining one was the valid standard of the Yugoslav Commission for the Release of Two-Rowed Spring Barley Cultivars, the cv. Novosadski 294 (NS-294). Of the Kragujevac cultivars, the following ones were investigated: Kraguj, Dinarac, Dunavac and Jastrebac.

The investigations were carried out over a three-year period, during 1996, 1997 and 1998 at the Small Grains Research Centre in Kragujevac. The experiment was set up in four replications according to a randomized "block" design. The elementary plot size was 5.0 m^2. Spring field pea was used as the preceding crop in all study years. Standard production method was used. Three sowing densities were determined, being of 300, 400 and 500 germinating grains per m^2. In all study years the sowing was performed at optimum dates. Prior to harvesting, experimental plant samples from each elementary plot were taken, and 30 plants from each separate plot were examined. The spike number was determined by counting the total number of spikes per plant, and the grain number per spike was determined manually. Grain yield was established for each separate plot and the total grain yield was adjusted for grain moisture content of 14 %.

Adequate statistical parameters of the variance analysis for a two-factorial experiment (cultivar x sowing density; 5 x 3) were used for experimental data analysis and the significance of differences was determined by the LSD test. Statistical analysis of the experimental data was performed by study years.

RESULTS AND DISCUSSION

Examining genotype variations in grain yield of spring barley depending on the sowing density we studied some of the most important yield components being the spike number, grain number per spike and grain yield.

The average number of spikes for all cultivars investigated and all densities in the three-year period was 948.1. (Table 1.).

Table 1. - Spike number per 1 m²

Cultivar (A)	Density (grains/m²) (B)	Year 1996	1997	1998	Average for cultivars
Kraguj	300	759.5	741.0	785.3	761.9
	400	850.4	943.8	1028.9	941.0
	500	1155.1	980.5	1199.7	1111.7
	Average	921.6	888.4	1004.6	938.2
Dinarac	300	696.4	772.5	756.9	741.9
	400	1009.3	977.2	1083.7	1023.4
	500	1131.6	1160.3	1140.2	1144.0
	Average	945.7	970.0	993.6	969.7
Dunavac	300	750.1	666.0	767.6	727.9
	400	1058.6	993.6	1121.7	1057.9
	500	1127.0	1217.7	1144.5	1163.0
	Average	978.5	959.1	1011.2	982.9
Jastrebac	300	811.9	705.5	776.0	764.4
	400	1100.0	952.9	1080.5	1044.4
	500	1161.5	1054.1	1153.1	1122.9
	Average	1024.4	904.1	1003.2	977.2
NS-294 (standard)	300	661.9	648.0	721.3	677.0
	400	753.7	820.3	1001.4	858.4
	500	1017.7	1013.3	1218.6	1083.2
	Average	811.1	827.2	980.4	872.9
Average for densities and cultivars	300	735.9	757.8	761.4	734.6
	400	954.4	937.5	1063.2	985.0
	500	1118.5	1085.1	1171.2	1124.9
	Average	936.2	926.8	998.6	948.1

Coefficients for testing the least significant difference for spike number per 1 m²

		A	B	AB
1996	Lsd 0,05	96.48	74.74	167.11
	Lsd 0,01	127.18	98.53	220.28
1997	Lsd 0,05	92.07	71.32	159.45
	Lsd 0,01	121.36	94.01	210.18
1998	Lsd 0,05	58.98	45.70	102.19
	Lsd 0,01	77.75	60.24	134.70

The highest average spike number as to the study years was determined in 1998 (998.6) and the lowest one in 1997 (926.8). The sowing density had a statistically very significant effect on the difference between the average spike number in all three study years. The highest and the lowest spike number in the study period was determined in the cultivar Dunavac (982.9) and Novosadski 294 (872.9), respectively.

An analysis of variance of the spike number in 1996 showed that there were statistically very significant differences between the cultivars investigated in spike number. The Novosadski 294 cultivar had a statistically very significantly lower spike number compared to all other cultivars studied. A statistically very significant difference in the spike number was also determined between the cultivars Kraguj and Jastrebac. The differences between other cultivars were not statistically justifiable.

In 1997, statistically very significant difference between the cultivars Dinarac and Dunavac, on the one hand, and the standard cultivar, on the other, was determined. The differences in the average spike number in other cultivars were not statistically justifiable.

The analysis of variance of the spike number in the cultivars investigated in 1998 did not show statistically significant differences.

Grain number per spike is considered an extremely significant genetic component of grain yield. The study results showed that the average grain number per spike for all cultivars investigated and all densities in the three-year period was 18.69. (Table 2.).

Table 2. - Grain number per spike

Cultivar (A)	Density (grains/m^2) (B)	Year 1996	1997	1998	Average for cultivars
Kraguj	300	20.53	18.19	23.63	20.78
	400	19.27	17.05	22.98	19.76
	500	19.18	16.88	22.56	19.54
	Average	19.66	17.37	23.05	20.02
Dinarac	300	19.39	18.49	22.98	20.28
	400	19.23	17.20	21.88	19.43
	500	17.93	16.98	21.76	18.87
	Average	18.85	17.53	22.20	19.52
Dunavac	300	17.20	15.94	21.79	18.31
	400	16.65	15.04	20.99	17.86
	500	15.73	15.67	21.26	17.55
	Average	16.52	15.85	21.34	17.90
Jastrebac	300	18.88	16.31	22.16	19.11
	400	18.56	15.15	21.05	18.25
	500	16.64	14.80	20.68	17.37
	Average	18.02	15.42	21.29	18.24
NS-294 (standard)	300	16.58	16.77	22.27	18.54
	400	15.40	15.82	21.85	17.69
	500	14.43	15.33	21.80	17.18
	Average	15.42	15.97	21.97	17.80
Average for densities and cultivars	300	18.51	17.02	22.56	19.40
	400	17.82	16.05	21.75	18.59
	500	16.78	15.92	21.61	18.10
	Average	17.70	16.33	21.97	18.69

Coefficients for testing the least significant difference for grain number per spike

		A	B	AB
1996	Lsd 0,05	1.13	0.40	1.96
	Lsd 0,01	1.32	0.52	2.58
1997	Lsd 0,05	0.93	0.71	1.62
	Lsd 0,01	1.23	0.94	2.14
1998	Lsd 0,05	0.83	0.65	1.05
	Lsd 0,01	1.10	0.86	1.38

The average grain number per spike varied over the years. The highest grain number was recorded in 1998 (21.97) and the lowest one in 1997 (16.33). The sowing density increase induced a decrease in the grain number per spike in all study years. The highest and the lowest grain number in all three years was recorded with the cultivar Kraguj (20.02) and the cv. Novosadski 294 (17.80), respectively.

By examination of individual differences between the cultivars investigated in the grain number per spike carried out by the LSD test in 1996, it was determined that the grain number per spike was statistically very significantly higher in the cultivar Kraguj than in the cultivars Novosadski 294, Jastrebac and Dunavac. The Dinarac cultivar had a statistically very significantly higher grain number per spike compared to the standard cultivar and cultivar Dunavac. A statistically very significantly higher grain number was recorded with the Jastrebac cultivar than with the cultivars Novosadski 294 and Dunavac. All other differences were statistically insignificant.

By analysis of the grain number per spike in 1997 it was determined that the cultivars Dinarac and Kraguj had a statistically very significantly higher grain number compared to other cultivars. The differences in grain number per spike in other cultivars were not statistically justifiable.

In the last study year the effect of the factors investigated on the trait remained unchanged. An analysis of variance showed a statistically very significant impact of the cultivar used and the sowing density employed. However, by testing of individual differences, by LSD test, it was established that the cultivar Kraguj, with the highest grain number per spike on the average (23.05), was statistically very significantly different from all other cultivars. The grain number per spike in the cultivar Dinarac was higher on the average compared to the cultivars Jastrebac, Dunavac and Novosadski 294. The difference between the cultivar Dinarac and the first two cultivars was statistically significant and the difference of 0.23 grains per spike compared to the cultivar Novosadski 294 was not statistically justifiable. The differences in the grain number per spike between other cultivars were not statistically justifiable.

New domestic cultivars of spring brewer's barley are characterized by high genetic potential for grain yield ranging from 8,000 to 9,000 kg/ha. The need for producing quality grain is particularly stressed in brewer's barley. Brewer's barley production is therefore especially complex due to the great difficulty of harmonizing quantity and quality traits.

Based on the results of the average grain yield of the spring brewer's barley cultivars investigated, it was determined that the average grain yield for all cultivars in the three-year period was 4,941 kg/ha (Table 3).

With respect to the study years, the highest grain yield on the average was recorded in 1998 (5,653 kg/ha) and the lowest yield in 1996 (3,881 kg/ha). The highest average grain yield in the three-year period was registered with the cultivar Dunavac (5,293 kg/ha) and the lowest yield was recorded with the cultivar Novosadski 294 (4,120 kg/ha).

The sowing density increase induced an increasing grain yield tendency in all study years.

The average grain yield of the cultivar Novosadski 294, in 1996, was statistically very significantly lower compared to all other cultivars. Other yield differences between the cultivars investigated were not significant. In 1996, the highest grain yield on the average was recorded with the sowing density of 400 grains/m^2. The testing of the significance of differences in average grain yield

between sowing densities showed that the difference in the yield between the sowing density of 300 grains/m^2 and that of 500 grains/m^2 was statistically significant, and the difference between the density of 300 grains/m^2 and that of 400 grains/m^2 was statistically very significant. The difference in grain yield of 268 kg/ha between the densities of 400 grains/m^2 and 500 grains/m^2 was not statistically justifiable.

Table 3. - Grain yield, kg/ha

Cultivar (A)	Density (grains/m^2) (B)	Year 1996	1997	1998	Average for cultivars
Kraguj	300	4063	5065	5180	4769
	400	4486	5181	5608	5091
	500	4570	5146	5751	5155
	Average	4373	5130	5513	5005
Dinarac	300	3847	5406	4198	4483
	400	5351	5338	5885	5858
	500	4043	5166	6421	5210
	Average	4413	5303	5501	5072
Dunavac	300	3623	5483	5808	4971
	400	4540	5493	6579	5537
	500	4286	5216	6613	5371
	Average	4149	5397	6333	5293
Jastrebac	300	3698	5075	5616	4796
	400	4513	5375	5768	5218
	500	4363	5543	6000	5302
	Average	4191	5331	5794	5105
NS-294 (standard)	300	2248	4356	5265	3956
	400	2150	4343	5320	3937
	500	2930	4753	5718	4467
	Average	2442	4484	5434	4120
Average for densities and cultivars	300	3495	5077	5213	4595
	400	4208	5146	5832	5128
	500	3940	5164	5916	5101
	Average	3881	5129	5653	4941

Coefficients for testing the least significant difference for grain yield

		A	B	AB
1996	Lsd 0,05	470	380	830
	Lsd 0,01	630	490	1100
1997	Lsd 0,05	320	260	550
	Lsd 0,01	420	340	730
1998	Lsd 0,05	320	260	550
	Lsd 0,01	420	340	730

An analysis of variance of the average grain yield in 1997 indicated statistically very significant differences between the cultivars investigated. The cultivar Novosadski 294 had a statistically very significantly lower grain yield compared to all other cultivars investigated. Other differences in grain yield were not statistically justifiable. In this year, the sowing density effect did not exhibit statistically justifiable differences in grain yield.

In 1998, the analysis of variance of the average grain yield of the cultivars investigated showed that the cultivars statistically very significantly differed and that the sowing density induced statistically very significant differences. The grain yield of the cultivar Dunavac in 1998 was statistically very significantly higher compared to all cultivars investigated. The cultivar Jastrebac had a statistically significantly higher yield compared to the cultivar Novosadski 294. Other differences in grain yield between the cultivars were not statistically justifiable. The effect of sowing density of 300 grains/m^2 in 1998 induced yield differences and the effect was statistically very significantly lower than the effects of other two densities. The difference in grain yield of 84 kg/ha between the densities of 400 grains/m^2 and 500 grains/m^2 was not statistically significant.

In all study years, with the sowing density increase, the spike number increased, too, which is in accordance with JEVTIĆ (1971), LALIĆ (1977), MALEŠEVIĆ (1985), PAUNOVIĆ (1994). Furthermore, with the spike number increase, the grain yield was raised too, which is in accordance with the results of a number of authors (PERIĆ, 1978, 1982, MALEŠEVIĆ, 1983, 1985). By a sowing density increase, the grain number per spike decreased. In all three years a statistically very significant difference in grain number per spike was determined between the lowest and highest sowing density in all cultivars investigated. Identical results were obtained by JEVTIĆ (1971), PAUNOVIĆ (1994). The highest average grain yield was recorded in the cultivar Dunavac (5,293 kg/ha), followed by the cultivars Jastrebac (5,105 kg/ha), Dinarac (5,072 kg/ha) and Kraguj (5,005 kg/ha). Similar research results on the average grain yield of the cultivars mentioned were also obtained by MAKSIMOVIĆ and POPOVIĆ (1978), PERIĆ (1982), MAKSIMOVIĆ (1994, 1996, 2000), PAUNOVIĆ (1994).

CONCLUSION

Three-year investigations were carried out from 1996 to 1998 at the Small Grains Research Centre in Kragujevac. Examinations were made of the spike number, grain number per spike and grain yield in five cultivars of spring brewer's barley depending on three sowing densities. Based on the results presented, the following conclusions were drawn:

A statistically very significant cultivar effect, in all three study years, was produced with respect to the spike number, grain number per spike and grain yield.

The sowing density effect, in the study period, was determined in terms of the spike number increase and grain yield. Increased sowing density induced a decrease in the grain number per spike.

The investigated cultivars Dinarac, Dunavac, Kraguj and Jastrebac produced 750 to 850 spikes/m^2 at the sowing density of 300 to 400 grains/m^2. The cultivar Dunavac achieved the highest average grain yield of 5,293 kg/ha for three study years. The average three-year grain yield of the cultivar Jastrebac was 5,105 kg/ha. The cultivar Dinarac was characterized by high and stable grain yield (5,072 kg/ha). The average grain yield, in the old cultivar Kraguj, was 5,005 kg/ha. The cultivar Novosadski 294 achieved on average the lowest grain yield of 4,120 kg/ha in the study

period. With the aim of achieving the highest possible grain yield, in this cultivar, the sowing density of 500 grains/m^2 could be applied. Owing to lower coefficient of productive tillering on an average this cultivar allows higher sowing density.

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GENOTIPSKA VARIRANJA PRINOSA ZRNA PROLEĆNOG JEČMA U ZAVISNOSTI OD GUSTINE SETVE

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I z v o d

Ispitivanje prinosa zrna kod pet sorti jarog pivarskog ječma obavljeno je u trogodišnjem periodu, od 1996 do 1998. godine, na imanju Centra za strna žita u Kragujevcu. U okviru svake sorte, proučavan je uticaj tri gustine setve na broj klasova, broj zrna po klasu i prinos zrna. Na osnovu rezultata istraživanja utvrđeno je da ispitivane sorte pokazuju visoko značajan uticaj u odnosu na broj zrna po klasu i prinos zrna. Gustina setve, u svim godinama ispitivanja, delovala je na povećanje broja klasova i prinosa zrna. Suprotno tome, povećana gustina setve uticala je na smanjenje broja zrna po klasu.

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