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Grain Yield of New Malting Barley Cultivars in Different Agroecological Conditions

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Abstract: The basic aim of barley cultivation is yield increase per unit area, where yield as a complex trait is affected by genetic and environmental factors. Malting barley production is of high economic significance because malt is a scarce product in the world market, if it conforms with the quality parameters set by the Brewing Industry Association.

In order to determine the most favourable varieties for malt production in the agroecological conditions of Serbia, a number of spring and winter barley varieties bred at the Small Grains Research Centre in Kragujevac were used in the trial. Comparative variety examinations were carried out in a two-year period at five different sites. Based upon grain yield values obtained it can be concluded that all varieties produced a satisfactory result, with the Jagodinac and Record, two-rowed winter barley varieties, having achieved the highest yield. The Jagodinac variety is a malting barley type and of excellent technological quality, and the Record variety can be used for malt production or livestock nutrition. Spring varieties achieved lower average yield and expressed stronger reaction to variable environmental conditions.

Key words: malting barley, productive traits, technological traits, varieties, sites.

Introduction

The major and overall objective of barley breeding for many countries is production of high-yielding varieties, resistant to lodging, diseases and pests, with good grain quality.

With respect to the total world sown areas of about 80 million hectares, barley ranks fourth following wheat, rice and maize. In the 90s, 100,000-120,000 ha of barley were grown annually in Serbia and Montenegro with an average yield of 2.78 t/ha (Maksimovic et al. 1995), which was a decrease in the cultivated area by more than 30% compared to the seventies. The highest decrease (56%) was recorded in Vojvodina (Malesevic and Starcevic 1992, Przulj et al. 1997). The decrease of that extent could not be compensated for by yield increase per unit area, due to which the total barley grain production decreased, too. This plant species has attracted increasing attention in the last several years, and an increase in its production areas is therefore likely to be expected. The high economic importance of barley indicates that more attention should be given to breeding and creation of new varieties that would meet the standards set for both forage and malting barley.

As regards precipitation sums, greater part of the country belongs to semiarid areas, which generally have less favourable conditions for the production of good malting barley (Malesevic and Starcevic 1992).

Stable malting barley production in the country could not be based on introduced varieties bred for different conditions, therefore a national breeding programme should be established.

Certain breeding methods, primarily special-purpose breeding, can be used to create genotypes which would maintain a low protein content even in less favourable growing conditions, with adequate cultivation practice used (Przulj and Momcilovic, 1998).

The aim of this paper is to examine and outline basic productive traits of the Kragujevac-bred winter and spring barley varieties and determine the most favourable ones for malt production in the agroecological conditions of Serbia.

Material and Method

The trial used a number of barley varieties bred at the Small Grains Research Centre in Kragujevac (tab. 1).

The paper presents the results of macro-trials carried out over the 2003-2005 period at five sites (Vojvodina, Sumadija-the Morava river valley, Eastern Serbia, South Morava, Drina river valley-Kolubara river and the West Morava).

The data for the height, yield, hectolitre mass and 1000-grain weight are two-year average values.

Tab. 1. Barley varieties bred at the Small Grains Research Centre in Kragujevac

Variety	Year of recognition	Hybrid combination
	Winter malting barley	
Jagodinac	1992	NS-313/KG-422
Rekord	1999	SSK1986-13/NS-183
Gigant	2000	Sladoran/NS-293
Šampion	2000	SSK 86/87-8/NS-293
Maksa	2003	Rodnik/NS-307
	Spring malting barley	
Galeb	1990	CGS 44-74/Kraguj
Jastrebac	1993	Georgije/Pirouette
Dinarac	1994	Georgije/Kraguj
Dunavac	1995	Georgije/Pirouette
Dukat	1999	
Đerdan	2000	Cornele/ Georgije
Dragulj	2000	KM-184/NS-301
Horizont	2000	NS-292/Nehaj
Jadran	2000	KM-184/NS-301
Ukras	2000	Dilj/ KM-184
Lider	2001	Georgie/KG 206/5

Results and Discussion

As a direct lodging resistance component and an indirect yield and quality component, stem height is one of the most important breeding criteria in barley. With respect to this trait, breeding is focused on creating optimum-height and strong-stem varieties.

The lower stem height trait is determined by the recessive genes carried by the first, second and third (Milohnic, 1972) and the seventh chromosome (Thomas et al., 1984). Sears et al. (1981) point to the fact that four recessive alleles bring about the shorter stem trait and according to Mickelson and Rasmusson (1994) the trait is determined by one, two or three recessive genes the most distributed one being the *sdw* gene. The other two are present in a small number of genotypes and they are not defined. Hellewell et al. (2000) also record that the short-stem and spike-length traits of barley are affected by the *sdw* and *denso* alleles mapped in the same region of the long 3H chromosome arm and that stem height is reduced by the *sdw* alleles by 10-20 cm. Stem-height-reducing genes have a different phenotypic effect in barley compared to the *Rht* genes of wheat; the *dwarf* barley genotypes actually have an easily breakable stem, they are disease-sensitive and their malt is of lower quality (Przulj et al. 2000).

The Jagodinac variety achieved the highest average height value of 100 cm, and the stem height of the other ones ranged from 80-90 cm. New winter malting barley varieties were characterised by good lodging resistance. Further winter barley breeding should concentrate on reducing the stem height by about 10 cm.

Tab. 2. Productive-technological and biological traits of barley varieties bred at the Small Grains Research Centre in Kragujevac

Variety	Height (cm)	Lodging resistance	Gen. yield potential (t/ha)	Hectolitre mass (kg ha^{-1})	1000-grain weight (g)	% protein
Winter malting barley						
Jagodinac	100	resistant	11	80	45	11
Rekord	80	resistant	11	72	39	11.9
Šampion	90	resistant	11	76	48	12
Gigant	87	resistant	11	74	43	13.1
Maksa	80	resistant	11	77	42	11
LSD 0.05	3.84			2.56	3.93	
0.01	5.58			3.73	5.71	
Spring malting barley						
Galeb	80	good	8	68	41	14.3
Jastrebac	75	good	8	70	40	13.3
Dinarac	77	good	9	73	43	19-12
Dunavac	70	excellent	9	76	42	10-12.5
Dukat	72	good	8	71	34	13.8
Đerdan	76	good	9	74	41	12.7
Dragulj	70	good	9	73	39	13.2
Horizont	80	good	9	72	45	13.4
Jadran	73	excellent	9	74	47	13
Ukras	80	good	9	73	42	13.2
Lider	78	v. good	9	74	40	13.9
LSD 0.05	8.09			2.12	3.17	
0.01	11.15			2.92	4.37	

The height of spring varieties ranged from 70-80 cm and there was no statistically highly significant difference for the trait between the varieties. With the optimum spring barley stem height achieved, further changes should be focused on the improvement of stem traits such as stem thickness or creation of an anatomic structure which would provide sufficient strength (Tab. 2).

Hectolitre mass is a major quality parameter in barley as a raw material for malt production. The trait depends primarily on grain filling degree, shape and moisture. Hectolitre mass is mostly affected by the starch content which is why hectolitre mass is an indirect indicator of the extract malt content. Hectolitre mass of good malting barley varieties is over 66 kg hl^{-1}.

The Kragujevac-bred winter barley varieties had higher hectolitre mass than the spring ones. The highest mass was recorded with the Jagodinac variety, 80 kg hl^{-1}.

1000-grain weight is a good indicator of malting barley quality because extract malt amount is positively correlated with the grain size (Madic et al., 2005). The Kragujevac-bred varieties, both winter and spring ones, were large-grained. Depending on the growing conditions 1000-grain weight of winter and spring barley varieties ranged from 39 to 48 gr and from 34 and 47 gr, respectively. The highest

grain weight was recorded with the Sampion (48 gr) in the winter and with the Jadran (47 gr) in the spring varieties (tab. 2).

Tab. 3. Yield of some barley varieties in different agroecological conditions (t/ha)

Variety	Sites						
	Vojvodina region	Sumadija-the Morava river valley	Eastern Serbia	the South Morava	the Drina river valley-the Kolubara	the West Morava	$\overline{X}$ t/ha
Jagodinac	6.25	6.90	5.85	5.95	6.10	5.90	6.20
Rekord	6.24	6.38	5.96	6.40	5.77	5.80	6.09
Dunavac	5.29	5.90	4.7	4.98	4.80	4.90	5.10
Dinarac	4.96	5.71	4.01	4.30	4.70	4.90	4.76
Jadran	4.02	4.86	3.90	4.28	4.30	4.02	4.23

Yield is a very complex trait representing genotype realisation in environmental conditions. The yield of the Kragujevac-bred barley varieties in macro-trials, depending on the year, ranged from 4.23-6.20 t/ha. The highest average yield was achieved by the Jagodinac variety, in the Sumadija-Morava river valley region, followed by the Vojvodina region. The Record variety also showed good results and achieved the best yield in the South Morava region, followed by the Sumadija-Morava river valley and Vojvodina regions (Tab. 3).

Owing to its high yield stability and broad biological plasticity, the Jagodinac variety has produced the highest yields in almost all production conditions for more than a decade.

Of the spring varieties, new varieties Dunavac and Dinarac have been the most prominent ones, have produced satisfactory yields even in bad weather conditions and achieved the highest yields in the previous four-year research in Serbia, due to which they should be intensively produced.

Conclusion

The Kragujevac-bred spring and winter malting barley varieties are characterised by 70-100 cm stem height, good lodging and disease resistance, high yield and large and well-filled grain.

Owing to its high yield stability and broad biological plasticity, the Jagodinac variety has achieved the highest yields in almost all production conditions for more than a decade.

Of the spring varieties, new varieties Dunavac and Dinarac have been the most prominent ones, producing satisfactory yields even in bad weather conditions.

When selecting barley varieties for the brewing industry the greatest attention should be paid to genotypes with higher germination energy and lower protein content, as is the case with Jagodinac and Maksa of winter and Dunavac and Dinarac of spring varieties.

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PRINOS ZRNA NOVIH SORTI PIVSKOG JEČMA U RAZLIČITIM AGROEKOLOŠKIM USLOVIMA

- originalni naučni rad -

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Rezime

Osnovni cilj gajenja ječma je povećanje prinosa po jedinici površine, koji se kao složena osobina nalazi pod uticajem genetičkih i ekoloških faktora. Proizvodnja pivskog ječma je od velikog ekonomskog značaja, jer je slad na svetskom tržištu deficitaran proizvod, ukoliko odgovara parametrima kvaliteta propisanih od strane udruženja industrije slada i piva.

Da bi se odredile najpogodnije sorte za proizvodnju slada u agroekološkim uslovima Srbije u ogledu je bio zastupljen veći broj jarih i ozimih sorti ječma, poreklom iz Centra za strna žita Kragujevac. Uporedna sortna ispitivanja obavljena su u dvogodišnjem periodu na pet različitih lokaliteta. Na osnovu dobijenih vrednosti prinosa zrna može se zaključiti da su sve sorte imale zadovoljavajući rezultat, a najbolji prinos su ostvarile sorte ozimog dvoredog ječma Jagodinac i Rekord. Sorta Jagodinac pripada tipu pivskog ječma i odličnog je tehnološkog kvaliteta, dok se sorta Rekord može koristiti za proizvodnju slada ili za ishranu stoke. Jare sorte su ostvarile manji prosečan prinos i ispoljile jaču reakciju na promenljive agroekološke uslove.