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Analysis of Grain Yield and Cytolytic Degradation of Winter and Spring Barley Cultivars

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Abstract

Six barley cultivars were grown in locations of Osijek and Nova Gradiska (Croatia) for three successive years. Our study included cultivars of different seasonal type. 'Zlatko', 'Barun' and 'Vanessa' are two-rowed winter type barley cultivars and 'Fran', 'Matej' and 'Scarlett' are spring barley cultivars. The results of grain yield and cytolytic degradation showed significant differences among winter and spring cultivars under different growing conditions. Winter type cultivars 'Zlatko' and 'Barun' showed significantly higher grain yield in comparison with other cultivars. Generally, spring barley cultivars when compared with winter cultivars had significantly higher malt extract content, lower malt extract fine-coarse difference, lower malt viscosity, higher β-glucanase activity and lower malt β-glucan content, higher friability.

Keywords: barley cultivars, locations, malt quality, cluster analysis, breeding

Introduction

Barley production for the brewing industry in the Republic of Croatia aims to improve itself, especially in the production of spring varieties (Vincetić *et al*., 2007), through organized production, application of scientific research, breeding achievements and by the overall increase in land sown with barley for brewing. Nowadays, even though the production of spring barley intended for the brewing industry is being encouraged, the production of winter barley varieties for malting use has even larger significance, especially because of its well known production stability under the effects of global warming (Deudon *et al*., 2001).

The ability of degradation of the barley grain, together with disintegration parameters of malt, represents significant criteria in the assessment and selection of barley in terms of its brewing quality. There is a certain trend today, which shows that grain modifications during the malting process tend to be optimal, rather than extreme to certain points. Georg-Kramer *et al*. (2001) point out that enzymes responsible for starch degradation present inside the barley grain are important criteria in breeding, because of their significant role in achieving good malting quality. Production results are firstly dependant on genetics for grain yield and brewing quality parameters, but there is also a significant factor residing in the plants' sole ability to reach those characteristics under various environmental, often stressful conditions (sowing date, sowing rate, soil type and fertility, climate) (Edney *et al*., 2007; Holopainen *et al*., 2005).

Materials and methods

Material and field experiments

Field trials were conducted starting with the 2003/2004 season to 2006/2007 on locations in Nova Gradiska and Osijek with six barley varieties, three of which are winter types, while the other three are spring seasonal types. The varieties from the Agricultural Institute Osijek are 'Zlatko', 'Barun', 'Fran' and 'Matej'. 'Scarlett' and 'Vanessa' originate from Germany (bred by Saatzucht Josef Breun, GDBR-Herzogenaurach, Germany). Varieties 'Zlatko', 'Barun' and 'Vanessa' are winter types with a 2-row spike form. The other three ('Fran', 'Matej' and 'Scarlett') are spring types, also with 2-row spike form.

Every location distinguishes itself with its own type of soil. The selection field of the Agricultural Institute Osijek has been determined as brown lessive soil: pH (KCl) = 6.25, humus = 2.20%; and the location of Nova Gradiska has an alluvial soil type: pH (KCl) = 7.63, humus = 1.83%, the experiment was set in three replications along with a sowing rate of 450 kernels/m^2. The average dimension of the basic parcel was 7.56 m^2. The sowing process was conducted with "Hege 80" spacing drill into seven rows with spacing of about 13.5 cm between them. Micro-malting and malt analysis were conducted at the Research Institute of Brewing and Malting, PLC, Malting Institute Brno, of the Czech Republic. Barley grain protein and starch content (%) were determined with "Infratec 1241" grain analyzer (Foss Tecator AB, Sweden). Grain and malt quality analysis were being done throughout a three year period (2004, 2005, 2006) by using average samples.

Data analysis

The acquired data has been analyzed with SAS Ver. 9.1 software and procedures PROC GLM, PROC MEANS (SAS Institute Inc, 2007). The differences between varieties and environments were tested with LSD-test and Duncan`s Multiple Range Test.

Weather characteristics

Climate data considering average monthly temperatures and total precipitation for the 2003/04 to 2006/07 period in the Osijek and Nova Gradiska locations, as well as average data (from 1981 to 2006) was acquired through the Croatian Meteorology and Hydrology Service (Tab. 1).

Results and discussion

Field trials conducted from the 2003/2004 season to 2006/2007 on locations in Nova Gradiska and Osijek with 3 winter types and 3 spring seasonal types of barley, showed significantly (P≤0.05) higher grain yield for the two winter barley types 'Zlatko' and 'Barun' compared to other varieties results. Variety 'Vanessa' (winter type) has achieved similar grain yield as varieties 'Matej' and 'Scarlett' (spring types) (Tab. 2).

Varieties 'Zlatko' and 'Barun' had the same significantly higher levels (P≤0.05) of starch content in comparison to other varieties. Variety 'Zlatko' had significantly higher results of hectoliter grain mass compared to other varieties examined. Lalić *et al*. (2006), found out that genotypes in the Republic of Croatia exhibiting a later start of the spiking period and longer vegetation (like 'Tiffany', 'Vanessa', 'Favorit') achieve significantly lower grain yield when compared to early ripen varieties ('Bingo', 'Barun', 'Prometej', 'Gvozd', 'Zlatko'). Temporal differences in spiking through the vegetation period between varieties can last from 6 up to 12 days, depending on the variety and the year of cultivation. The mentioned reaction of variety 'Vanessa' is connected with the interaction of the date of spiking and length of grain filling period, and with stressful production conditions which are usual for Central Europe and the Republic of Croatia. Shakhatreh *et al*. (2001), revealed that the length of grain filling period can have positive effects on grain yield and quality, but only if there is enough moisture available; whereas in other cases (lack of moisture) the varieties with longer vegetation will achieve significantly lower results.

The results of extract content and cytolytic degradation showed significant differences between winter and spring cultivars together with the year of cultivation (Tab. 3 and 4). However, as far as location results are concerned

Tab. 1. Average air temperature and total precipitation during the winter barley vegetation period (X-VI month) according to year and locations and during the spring barley vegetation period (II-VII month)

Average air temperature and precipitation				
	Average air temperature, °C		Average rainfall, mm	
Year	Location		Location	
	Osijek	Nova Gradiska	Osijek	Nova Gradiska
2003	11.3	11.1	516.5	612.6
2004	11.0	10.8	865.4	898.6
2005	10.4	10.1	973.7	797.0
2006	11.5	10.8	632.1	788.1
Average 1981/2006	11.1	10.9	679.7	781.0
The growing season	Air temperature during winter barley vegetation period (X-VI month), °C		Precipitation during winter barley vegetation period (X-VI month), mm	
	Osijek	Nova Gradiska	Osijek	Nova Gradiska
2003/04	7.8	7.7	626.1	699.8
2004/05	7.8	7.6	622.7	544.3
2005/06	8.0	7.5	496.1	581.7
2006/07	10.9	10.4	336.1	470.1
Average 1981/2006	8.2	8.0	490.9	563.9
The growing season	Air temperature during spring barley vegetation period (II-VII month), °C		Precipitation during spring barley vegetation period (II-VII month), mm	
	Osijek	Nova Gradiska	Osijek	Nova Gradiska
2003	13.4	9.85	154.2	190.1
2004	12.5	12.2	415.8	415.2
2005	11.7	11.6	507.0	402.7
2006	13.2	12.4	358.8	394.4
Average 1981/2006	13.0	12.6	341.0	389.0

Tab. 2. Means for grain yield, hectoliter weight and starch content

Variety/Year/ Location/ Seasonal type	Grain Yield (t x ha^{-1})		Hectoliter weight (kg)		Starch content (%)	
'Zlatko'	7.289	a	68.79	a	60.81	a
'Barun'	7.387	a	65.99	c	60.84	a
'Vanessa'	5.955	b	63.29	d	60.10	b
'Fran'	5.517	c	67.43	b	59.72	c
'Matej'	5.938	b	66.96	b	59.25	d
'Scarlett'	5.743	bc	65.62	c	60.43	b
LSD 0.05	0.419		0.93		0.36	
2004	6.257	b	66.29	b	60.13	ab
2005	5.490	c	64.55	c	60.36	a
2006	7.167	a	68.21	a	60.08	b
LSD 0.05	0.296		0.65		0.26	
Osijek	6.600	a	66.27		59.55	b
Nova Gradiska	6.001	b	66.43		60.83	a
LSD 0.05	0.242		ns		0.21	
Winter barley	6.877	a	66.03	b	60.58	a
Spring barley	5.733	b	66.67	a	59.80	b
LSD 0.05	0.242		0.53		0.21	
Average	6.305		66.35		60.19	

Different letters between cultivars denote significant differences (Duncan's Multiple Range test at P≤0.05)

Tab. 3. Means for fine grind extract, malt extract fine-coarse difference, viscosity of malt and Hartong

Variety/Year/ Location/ Seasonal type	Extract fine grind(%)		Malt extract fine-coarse difference (%)		Viscosity of malt (mPa x s)		Hartong (%)	
'Zlatko'	79.13	b	2.65	a	1.788	a	35.17	c
'Barun'	79.73	b	2.20	ab	1.700	a	39.27	ab
'Vanessa'	80.07	ab	1.50	c	1.559	b	35.42	bc
'Fran'	80.62	ab	1.43	c	1.552	b	35.45	bc
'Matej'	80.42	ab	1.77	bc	1.700	a	34.60	c
'Scarlett'	81.32	a	1.27	c	1.512	b	42.45	a
LSD 0.05	1.57		0.55		0.129		4.09	
2004	79.04	c	2.08	a	1.709	a	34.90	b
2005	79.89	b	1.71	b	1.560	c	39.05	a
2006	81.38	a	1.62	b	1.636	b	37.23	ab
LSD 0.05	0.75		0.29		0.072		3.39	
Osijek	80.38		1.78		1.668		36.72	
Nova Gradiska	79.83		1.83		1.602		37.39	
LSD 0.05	ns		ns		ns		ns	
Winter barley	79.64	b	2.12	a	1.682	a	36.62	
Spring barley	80.57	a	1.49	b	1.588	b	37.50	
LSD 0.05	0.91		0.32		0.074		ns	
Average	80.11		1.80		1.635		37.06	

Different letters between cultivars denote significant differences (Duncan's Multiple Range test at P≤0.05)

there was no evidence that would point out the statistically significant difference in terms of extract content together with malt cytolytic degradation parameters.

The 'Scarlett' variety has the significantly (P≤0.05) largest extract content and the best malt cytolytic degradation (Tab. 3 and 4). Variety 'Fran' (spring type) and 'Vanessa' (winter type) follow this variety. Based on analyzed grain and malt quality parameters for 2004 all varieties had significantly (P≤0.05) lower quality values in comparison to the year 2006. Eagles *et al.* (1995) pointed out in a study conducted in the SE part of Australia (a similar climate as in the Mediterranean), the great influence of the year of cultivation on the barley malting quality parameters, where the greatest impact was related to the amount of extract gained, the percentage of nitrogen contained within the grain and diastatic power.

The malting industry defines certain quantity and reactivity of enzymes in terms of the diastatic power, which irepresents the measure through which malt is able to hydrolyze starch to fermentable sugars (Evans *et al.*, 2009). The diastatic power positively correlates with the amount of the malt extract (Zhang *et al.*, 2006; Evans *et al.*, 2003; MacGregor *et al.*, 2002). Significant differences (P≤0.05) between varieties have been found in terms of the diastatic power, amount of β-glucanase and α-amylase (Tab. 4), which directly points out differences between varieties considering the enzymatic activity within the barley grain, and explains various effects of cytolitic and proteolitic disintegration of malt. Special criteria are to be followed in breeding for malting industry, which focus on the enzymes responsible for starch degradation, which have direct effect on the malting quality (Georg-Kraemer *et al.*, 2001).

In general (Tab. 3 and 4) spring barley varieties had a higher amount of extract, lower difference between the extract produced from fine-coarse grinded malt, lower malt viscosity, higher level of β-glucanase reaction, lower content of β-glucans and higher friability in comparison to winter varieties. The Republic of Croatia is situated in the more Southern part of Europe where winter barley types (especially in lower regions) achieve higher and more stable grain yield (Lalić and Kovačević, 1997), because of the better usage of moisture during fall and winter, and also because of their ability to withstand drought and to ripe early. Lalić and Kovačević (1997.) point out that spring barley grown in the Republic of Croatia has the overall better and more stable results concerning quality of malt than winter types.

Conclusions

In terms of varieties distinctiveness and suitability for growing under different agro-climatic conditions the results from locations showed no evidence, which would point out the statistically significant difference in terms of extract content, together with malt cytolytic degradation parameters. Adaptability of both seasonal types varieties was satisfactory with reference to grain yield and cytolytic

Tab. 4. Means for diastatic power, β-glucanase, α-amylase, malt β-glucan content and friability of malt

Variety/Year/Location/ Seasonal type	Diastatic power U.W.-K		β-glucanase U/kg		α-amylase D.U.		Malt β-glucan content(%)		Friability (%)	
'Zlatko'	331	b	296	c	51.00	b	2.52	a	47.53	c
'Barun'	341	b	333	bc	49.50	b	2.26	abc	50.03	c
'Vanessa'	485	a	343	bc	45.50	b	1.53	bc	60.27	b
'Fran'	183	c	409	b	50.33	b	1.46	c	71.62	a
'Matej'	234	c	316	bc	45.00	b	2.33	ab	55.62	bc
'Scarlett'	370	b	522	a	62.33	a	1.41	c	70.42	a
LSD 0.05	74		99		6.91		0.86		9.80	
2004	359	a	317	b	49.67		2.61	a	51.58	b
2005	344	a	355	b	52.42		1.81	b	59.16	ab
2006	270	b	438	a	49.75		1.33	c	67.00	a
LSD 0.05	39		42		ns		0.39		8.83	
Osijek	337		385		52.17		1.97		61.43	
Nova Gradiska	311		355		49.06		1.86		57.07	
LSD 0.05	ns		ns		ns		ns		ns	
Winter barley	386	a	324	b	48.67		2.10		52.61	b
Spring barley	262	b	416	a	52.56		1.73		65.88	a
LSD 0.05	43		58		ns		ns		16.36	
Average	324		370		50.61		1.92		59.25	

Different letters between cultivars denote significant differences (Duncan's Multiple Range test at P≤0.05)

degradation, with certain distinction for winter cultivars 'Zlatko' and 'Barun' which significantly showed the highest grain yield. Parallel analysis based on homogenous groups pointed out similarities that may be useful in the testing process of advance lines and new varieties under production and specific cultivation conditions.

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