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GRAIN YIELD, YIELD COMPONENTS AND MALTING QUALITY TRAITS OF SPRING BARLEY ON ACIDIC SOILS

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Abstract

A varietal trial involving six genotypes of spring barley (‘Jastrebac’, ’Dinarac’, ’Dunavac’, ’NS-404’, ’Jaran’ and ’Lider’) was conducted over a three-year period at the farm estate of the Secondary School of Agriculture and Chemistry, Kraljevo (Serbia) (the experimental field of the Faculty of Agronomy, Čačak) on an acidic soil (pH_{H2O} 4.5). The following traits were analysed: stem height, spike length, grain number per spike, thousand-kernel weight, grain yield, total germination capacity, grain protein content and extract content. Regardless of year, stem height was significantly higher in ’Dunavac’ and ’Jaran’ than in the other cultivars. The highest stem height in all cultivars was obtained in the second year. Spike length, grain number per spike and 1000-kernel weight were significantly higher in ‘NS-404’ compared to the other cultivars. Variations in grain yield across years were the lowest in ‘Jaran’ and ‘Dinarac’. Total germination capacity was significantly higher in 'Jastrebac' than in the other cultivars in the first and second years. The significant increase in protein content in both years on average for all cultivars was accompanied by a significant decrease in malt extract, and vice versa. The high protein content in some cultivars along with the high malt extract content suggests that the strength of correlation between the traits is dependent on environmental conditions. Although the soil had poor physical and chemical properties, all cultivars had their 1000-kernel weight, total germination capacity, protein content and malt extract content within the standardised limits.

Key words: *barley, grain yield, yield components, malting quality traits*

Introduction

The proper choice of cultivar is of special importance in obtaining high grain yields in good-quality malt barley. In addition, different soil and climate conditions, notably temperature and moisture content during grain fill (Passarella et al., 2005) can largely contribute to variations in major yield components and, hence, total yield and grain quality of malting barley (Atlin et al., 2000; Paunović et al., 2007; Madić et al., 2009). Pržulj et al. (2014) stressed that temperature and rainfall do not play the leading role in determining grain yield and quality of malting barley since grain quality is often poor when these factors approach optimal values. Moreover, grain yield and quality attributes in barley are affected by certain cultural practices such as nitrogen fertilisation (Pržulj and Momčilović, 2008; Marconi et al., 2010). As stressed by Pržulj and Momčilović (2002), realising the full yield and quality potential in barley necessitates strict adherence to production technology, given the precise quality requirements of the brewing industry for barley grain and malt. To ensure high quality of raw materials, new cultivars should be analysed for their traits and introduced into the production system, and cultivar choice made for a specific region. Grain quality i.e. malt extract content is largely dependent on growing conditions (temperature, available moisture, available N, fertilisation) mostly indirectly through grain traits, primarily starch and protein content and composition (Collins et al., 2003). Grain quality attributes are quantitative in nature and greatly affected by environmental factors such as temperature, available moisture, N fertilisation and soil type (Zhang et al., 2006; Petterson and Eckersten, 2007). Some 30-40 % of the world’s arable land is acidic, with a pH below 5.5 (von Uexkull and Mutert, 1995). On acidic soils, a range of chemical limitations and interactions between chemical compounds have a depressive effect on plant growth. Apart from the activity of hydrogen ions, plant growth is largely limited by toxic elements, particularly aluminium and manganese, as well as by the deficiency of P, N, K, Ca, Mg, S, Zn and Mo (Rao et al., 1993, Samac and Tesfaye, 2003). There is high variability in plant resistance to Al toxicity across species and across cultivars within species. Among small grains, barley exhibits the highest susceptibility to Al toxicity (Zhao et al., 2003). From among 600 barley strains, Ma et al. (1997) singled out 19 medium susceptible strains, 39 very susceptible strains, and many strains susceptible to Al toxicity.

The objective of this study was to examine the effect of genotype and growing conditions (year) on yield components, yield and major grain quality traits of spring malting barley grown on an acidic soil in Central Serbia.

Material and method

Parallel varietal trials were conducted over a period of three years at the experimental field of the Secondary School of Agriculture and Chemistry, Kraljevo (the experimental field of the Faculty of Agronomy, Čačak) on an acidic soil (pH_{H2O} 4.5, humus 2.18%, P2O5 7.50 mg 100^{-1} g i K2O 15.5 mg 100^{-1} g soil), during 2010, 2011 and 2012. The experiment included six genotypes of two-rowed spring barley: ’Jastrebac’, ’Dinarac’, ’Dunavac’, ’NS-404’, ’Jaran’ and ’Lider’. The experiment was laid out as a randomised block design in five replications, with plot size 5 m^2 (5x1m). The total amount of the complex mineral fertiliser N:P:K (15:15:15), 400 kg ha^{-1}, was applied manually over the soil surface prior to seedbed preparation. Sowing was performed by a grain drill suitable for microtrials, with 500 germinating grains m^{-2}, at a spacing of 10 cm between the rows and 3 cm within the row. Sowing dates were 3^{rd} of March 2010, 12^{th} of March 2011 and 7^{th} of March 2012.

At grain maturity, a sample of 30 plants was collected from each plot for the analysis of stem height, spike length and grain number per spike. After harvest, grain yield obtained from each plot was measured and calculated as kg ha^{-1}. Total germination capacity (%) was determined after a seven-day germination period in a thermostat at a temperature of 20^0C. Grain protein content (% on a dry-matter basis) was determined by the Kjeldahl method, and extract content was calculated by Bishop’s formula. The results were subjected to an analysis of variance using the SPSS software (1995). The significance of differences in means was evaluated by LSD testing.

Results and discussion

There is a tendency in breeding malting barley to create low-stem cultivars to eliminate plant lodging as a negative phenomenon, which occurs due to the weak mechanical tissue of the stem (Pržulj et al., 2010). Regardless of year, stem height was significantly higher in ‘Dunavac’ and ‘Jaran’ than in the other varieties, and the lowest in ‘Dinarac’ (Tabela 1). In all cultivars, stem height was the highest in the second year, significantly lower in the first year and the lowest in the third year. Cv. ‘NS-404’ produced significantly higher spike length compared to the other cultivars (Table 1). In all cultivars, the spike was the longest in the first year, significantly shorter in the second year and the shortest in the third year, although spike length showed different variations in the second and third years (cultivar/year interaction). Grain number per spike was the highest and significantly higher in ‘NS-404’ than in ‘Jastrebac’, ‘Dinarac’ and ‘Dunavac’ (Table 1). Regardless of cultivar, grain number per spike was significantly lower in the third year compared to the first and second years. Contrary to the other varieties, ‘Jastrebac’ and ‘Jaran’ had a significantly higher number of grains per spike in the first year compared to the second year (cultivar/year interaction) (Table 1). Grain yield in all cultivars was the highest in the second year, significantly lower in the second, and the lowest in the third year. ‘Jaran’ and ‘Dinarac’ proved to be the most stable since their yield showed significantly lower variations across years compared to the other cultivars (Table 1).

Table 1. Means for stem height (SH), spike length (SL), grain number per spike (GNS), grain yield (GY), 1000-kernel weight (KW), total germination capacity (TGC), protein content (PC) and malt extract content (MEC) in the grain of spring barley cultivars in 2010, 2011 and 2012

		SH	SL	GNS	GY	KW	TGC	PC	MEC
Cultivars	Jastrebac	75.9bc	6.8b	19.8c	5027	42.1cd	98.5a	11.5ab	78.9ab
(C)	Dinarac	72.6c	6.6b	20.3bc	5140	41.6d	95.9b	11.6ab	78.8ab
	Dunavac	84.3a	6.7b	20.2bc	5084	42.9bc	96.3b	11.8ab	79.0a
	NS-404	76.1bc	7.4a	21.7a	5310	48.3a	95.3b	11.2b	79.5a
	Jaran	83.7a	6.9b	21.2ab	5213	43.7b	96.5b	11.9a	78.9b
	Lider	76.2b	6.8b	21.8a	5072	42.5bcd	95.6b	12.0a	78.3b
Years	2010	73.8b	7.3a	21.3a	5030b	43.5	96.2	11.9a	78.0b
(Y)	2011	98.6a	6.8b	21.3a	6067a	43.4	96.4	11.3b	79.8a
	2012	61.9c	6.4c	19.9b	4332c	43.6	96.3		
Jastrebac	2010	70.6fg	7.3abc	19.4e-i	4512de	40.0h	99.2a	11.7bcd	78.2cd
	2011	93.9cd	6.8def	18.2i	6080a	43.7ef	98.4ab	11.2de	79.7ab
	2012	60.6hi	6.3fg	18.8ghi	4488de	42.6efg	98.0abc		
Dinarac	2010	68.7fg	6.9b-e	18.8ghi	5160bcd	40.0h	95.8de	11,8bcd	77.9cd
	2011	89.2d	6.7def	20.8b-e	5640abc	42.7efg	96.2cde	11.3cde	79.7ab
	2012	57.2i	6.0g	18.4hi	4620de	42.0g	95.6de		
Dunavac	2010	78.5i	7.0bcd	19.4e-i	5072bcd	44.0de	96.4cd	11.6cd	78.5cd
	2011	105.5a	6.9cde	20.3c-g	6400a	42.5efg	96.4cd	12.0abc	79.5b
	2012	65.6gh	6.0g	18.0i	3780e	42.3fg	96.2cde		
NS-404	2010	71.2f	7.8a	21.1a-d	5660abc	51.0a	94.4e	11.5cd	78.6cd
	2011	97.1c	7.4ab	21.9ab	6420a	47.6b	95.2de	10.8e	80.4a
	2012	56.6i	7.1bcd	19.1f-i	3824e	46.3bc	96.2cde		
Jaran	2010	78.3l	7.6a	22.5a	4980bcd	44.0de	96.0de	12.2ab	77.9d
	2011	102.5ab	6.5efg	18.7ghi	5760ab	41.6gh	96.4cd	11.5cd	79.9ab
	2012	67.2fg	6.5efg	19.4e-i	4900bcd	45.5cd	97.0bcd		
Lider	2010	69.9fg	7.0bcd	20.5b-f	4796cd	42.0g	95.4de	12.4a	77.0e
	2011	97.5bc	6.7def	21.8abc	6100a	42.5efg	95.8de	11.5cd	79.9ab
	2012	58.1i	6.6def	20.0d-h	4320de	43.2efg	95.6de		
ANOVA C		**	**	**	ns	**	**	*	*
Y		**	**	**	**	ns	ns	**	**
C x Y		*	**	**	**	**	**	**	*

Means within the columns for cultivars, years and the cultivar/year interaction followed by the same lowercase letter do not show significant differences at 95% on the basis of the LSD test
** F –test significant at 0.01; * F –test significant at 0.05; ns non-significant

The increase in the yield potential of new spring barley cultivars is generally associated with higher total dry matter production, reduced plant height and increased resistance to lodging, along with slight increases in harvest index, 1000-kernel weight and number of grains per spike (Grausgruber et al., 2002; Abeledo et al., 2003). In their comparative studies of two-rowed barley cultivars released over a period of 150 years in Argentina, Abeledo et al. (2003) found that the main component associated with genetic gains in yield in the last several decades has been the number of grains per m^2, reached largely through the increase in the number of spikes m^{-2}, regardless of the number of florets per spike. New cultivars have a higher number of spikes m^{-2} compared to old cultivars, with no decrease in the average number of grains per spike observed. The authors also reported that kernel weight changed slightly during breeding. Kernel weight is an important quality indicator in malting barley due to the positive correlation between grain weight and the content of starch as the main source of malt extract. Also, grain size is important in terms of ensuring uniform germination (Passarella et al. 2003). For malting barley, thousand-kernel weight should preferably be 41-44g, since this kernel germinates uniformly and rapidly (Fox at al., 2003). Significantly higher 1000-kernel weight regardless of year, compared to the other cultivars, was obtained by 'NS-404', which also showed the highest variation in this trait (Table 1). The lowest variation across years was observed in 'Lider' (cultivar/year interaction). In their analysis of grain and malt quality indicators in eight spring malting barley cultivars over a period of seven years, Pržulj et al. (2014) reported that the highest percent of variance for 1000-kernel weight is due to growing season, whereas genotype and the genotype/year interaction account for a similar percentage of variance. Grausgruber et al. (2002) found that the priority in breeding programmes given to the increase in grain fill led to an increase in 1000-kernel weight and to a very slight increase in the number of kernels per spike.

Large grain is among the most precise quality indicators due to a high starch content and a low protein content, which ensure sufficient energy for germination (Fox et al. 2006). In the first and second years, total germination capacity was significantly higher in 'Jastrebac' than in the other cultivars, whereas no significant difference among the cultivars was observed in the third year (cultivar/year interaction) (Table 1). Malt extract yield largely determines grain quality of barley during malting (Molina-Cano et al. 2000, Fox et al. 2003). The cultivars producing a higher protein content ('Jaran' and 'Lider') had a lower grain extract content (Table 1). In both years, the low protein content on avarega in all cultivars was associated with the high extract content, and vice versa. Extract content in cvs. 'Dunavac' and 'NS-404', which also had a lower protein content, was significantly higher compared to 'Jaran' and 'Lider'. As opposed to the other cultivars, 'Dunavac' gave a significantly higher protein content in the second year (cultivar/year interaction), but its extract content was comparable to that of the other cultivars. Fox et al. (2003) reported that protein content is negatively correlated with starch and extract contents. New barley cultivars have a low protein content mostly due to a decrease in grain N content which is the result of increased yield i.e. the “dilution effect“ under which the nitrogen available to a given plant is distributed among greater grain yields in new cultivars (Calderini et al., 1999; Grausgruber et al., 2002; Abeledo et al., 2003; Gianinetti et al., 2005). Pržulj et al. (2014) observed that variation in % protein is mostly due to the genotype/year interaction, whereas the percent variance for year is higher than the genotype variance. The same authors found that all cultivars had a low protein content during the years that favoured grain fill, whereas under unfavourable conditions the differences between the test cultivars were much higher. Pržulj et al. (2014) also reported that variation in extract content is equally due to genotype and year, with a much lower percentage of the genotype/year variance. Molina-Cano et al. (2000) and Pržulj et al. (2013) found that the strength of the negative correlation between protein content and extract content is dependent on growing conditions and that a high protein content does not always suggest a low malt extract content. Garcia del Moral et al. (2003) specified that the correlation between quality attributes can be absent, present to a higher or lesser extent, sometimes even functional, often having compensatory effects. The same authors observed that the strength of a particular correlation is also largely dependent on the environment.

Conclusion

Genotype, growing conditions and their interaction had a significant effect on the traits analysed. Regardless of year, cvs. ’Dunavac’ and ’Jaran’ had a significantly higher stem compared to the other cultivars. Spike length and number of kernels per spike were significantly higher in cv. ’NS-404’ than in the other cultivars, regardless of year. In the second and third years, the cultivars showed different variations in these traits. Grain yield exhibited the lowest variation across years in ’Jaran’ and ’Dinarac’. Thousand-kernel weight was the highest in ’NS-404’ and it also exhibited the highest variation across years. Total germination capacity in the first and second years was significantly higher in 'Jastrebac' compared to the other cultivars. 'Jaran' and 'Lider', which gave a higher grain protein content, had a lower malt extract content. The significant increase in protein content in both years on average for all cultivars was accompanied by a significant decrease in malt extract, and vice versa. The high protein content in some cultivars along with the high malt extract content suggests that the strength of correlation between the traits is dependent on environmental conditions. Although the soil had poor physical and chemical properties, 1000-kernel weight, total germination capacity, protein content and malt extract content were within the standardised range in all cultivars, suggesting that the barley grain provided satisfactory malting quality.

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