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YIELD COMPONENTS AND GRAIN QUALITY OF WINTER BARLEY CULTIVARS GROWN ON PSEUDOGLEY

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Abstract

Four two-row winter barley cultivars Premium, Jagodinac, Record and Crystal were evaluated for grain yield components and grain quality. Parallel trials were conducted over a three-year period (2008-2011) at an experimental field of the Secondary School of Agriculture in Kraljevo. Data were subjected to a two-factor analysis of variance. The significance of differences between individual means was assessed using the LSD test. The cultivars showed significant differences in yield, stem length, grain weight per spike and germination energy, whereas no significant differences were observed in protein content. Yield, grain weight per spike and germination energy were significantly affected by growing conditions (year), as well as by genotype x year interaction. Barley cvs. Premium, Jagodinac and Crystal gave a significantly lower grain weight per spike in the first year of the study, and a tendency to increase grain weight in the second and third years, as compared to Record.

Key words: barley, cultivar, yield, protein content, acid soils

Introduction

Choice of cultivar, mineral nutrition and weather conditions during the growing season play an important role in achieving high grain yields and quality of barley. Bogdanović et al. (1994) underline that the absence of mineral fertilisation leads to a reduction in crop yield, the highest being in barley (49%).

Increased amounts of mineral nutrients, nitrogen in particular, induce intensification of vegetative growth, an increase in spike number m^{-2}, a decline in grain number per spike and a variable effect on grain weight (Christensen and Killoran, 1981; Gonzales Ponce et al., 1993; Paunović et al. 2006.). Gonzales Ponce et al. (1993) define the soil moisture x nitrogen level interaction as the major factor determining grain yield in barley.

Approximately 30-40% of the world's arable land is acidic, with a pH below 5.5 (von Uexkull and Mutert, 1995). In acid soils, a number of chemical limitations and interactions between chemical compounds have a depressive effect on plant growth. Apart from hydrogen ion activity, plant growth is also largely limited by the presence of 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 among and within species in their resistance to Al toxicity. Barley has the highest susceptibility to Al toxicity of all small grains (Zhao et al. 2003). Among 600 barley lines, Ma et al. (1997) determined moderate susceptibility to Al toxicity in 19 lines, high susceptibility in 39 and susceptibility in the majority of lines.

Certain breeding methods, primarily directional selection, can be used to create genotypes that can retain a low protein content even under unfavourable growing conditions, with adequate cultural operations applied (Pržulj and Momčilović, 1998).

The objective of this study was to evaluate the effect of mineral fertilisers and liming on yield, yield components and grain quality in four two-row winter barley cultivars grown on acid soil.

Material and method

The study was conducted at the experimental field of the Secondary School of Agriculture in Kraljevo during 2008-2011. The soil used in the experiment was pseudogley, having poor physical properties (a high degree of compaction, a high percentage of silt and clay particles, low water permeability), acid reaction (pH_{H2O} < 4.5) and a humus content of 2.16%. The experiment involved four cultivars of two-row winter barley, viz. Premium, Jagodinac, Record, and Crystall.

The experiment was laid out as a randomised block design in three replications with a plot size of 5 x 1 m (5m^2). Seeding was performed using a small mechanical seed drill in mid-October at a row spacing of 12.5 cm and an intrarow spacing of 3 cm. Prior to seedbed preparation, 5000 kg ha^{-1} of "Njival Ca" lime fertiliser was manually broadcast on the surface of the field. The experiment also involved the use of complex NPK fertilisers (8:24:16), superphosphate (17% P_2O_5) (120 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1} and 53 kg K_2O ha^{-1}) and ammonium nitrate containing 34.4% N used for top-dressing.

At full maturity, a sample consisting of 30 plants was collected from each plot for analysis of stem length (cm) and grain weight per spike. Grain yield was determined for each plot and calculated in t/ha at 14% moisture. Germination energy (%) and protein content were assessed four months after harvest. Grain protein content (% d.m.) was determined by the Kjeldahl method. The results were subjected to analysis of variance, using SPSS software (1995). Individual differences between means were assessed by the LSD test.

Results and discussion

Grain yield in barley is a complex economically important trait resulting from the effect of genotype and the environment throughout the life cycle of a plant. It is particularly difficult to develop cultivars that would carry positive traits under different growing conditions and show resistance to biotic and abiotic stress factors (Pržulj et al. 1998.; Knežević et al. 2007). The analysis of variance for the average yield showed significant differences among cultivars, with cv. Record producing the highest yield, and cv. Crystal the lowest. Grain yield was significantly affected by growing conditions (year) as well as by the genotype x year interaction (Table 1). The analysis of the genotype x year interactions revealed that cvs. Jagodinac and Record exhibited a similar tendency in their response to growing conditions, in contrast to cv. Crystal. The significance of the interactions resulted from the different behaviour of cv. Crystal, whose yield in the third year was comparable to that in the second year, as induced by its unresponsiveness to improved environmental conditions.

Stem length is one of the most important initial selection criteria in barley breeding work, being a direct component of lodging resistance and an indirect component of both yield and quality. The cultivars analysed showed significant differences in stem length (Table 1). Stem length was significantly greater in Record than in Jagodinac and Crystal, which had the shortest stem. The cultivar x year interaction suggested different responses of the cultivars to growing conditions, i.e. a significant effect of year. Premium showed an identical response to a change in environmental conditions. Favourable external factors (effect of year) and increased amounts of mineral nutrients, particularly N, cause vegetative growth intensification, an increase in spike number m^{-2}, a decrease in grain number per spike, and a

variable effect on grain weight (Christensen and Killoran 1981; Gonzales Ponce et al. 1993; Paunović et al. 2008).

Table 1. Grain yield, stem length, grain weight per spike, germination energy and protein content in winter barley cultivars over a three-year period

		Yield tha^{-1}	Stem length (cm)	Grain weight per spike	Germination energy (%)	Protein content (%)
	Premium	5.9ab	66.97ab	0.56ab	94.9b	10.71
cultivars	Jagodinac	5.8ab	66.52b	0.52b	96.8a	10.34
	Record	6.1a	69.69a	0.60ab	94.5b	11.11
	Crystal	5.7ab	58.88c	0.62ab	92.9bc	10.95
years	2009 (I)	4.6c	63.85c	0.57a	94.6	10.83
	2010 (II)	6.0b	67.99b	0.64a	94.3	10.62
	2011 (III)	6.8a	78.40a	0.62a	94.7	
Premium	I	5.2g	67.43bc	0.49cde	91.8fg	10.78
	II	6.1cde	68.90bc	0.61a d	95.3cde	10.55
	III	7.3a	81.27a	0.68abc	97.5a	
Jagodinac	I	5.4g	63.63cd	0.51b e	96.7abc	10.30
	II	6.1cde	71.43b	0.69ab	95.9abc	10.20
	III	7.1a	84.13a	0.54a-d	97.ab	
Record	I	5.3g	64.30cd	0.72a	91.5g	11.42
	II	6.5b e	71.27b	0.64abc	95.3cde	10.85
	III	7.5a	84.37a	0.56a-d	96.9abc	
Crystal	I	5.8fg	60.03d	0.56a-d	96.1abc	11.18
	II	6.6bcd	60.37d	0.64c	91.2g	10.72
	III	6.9bcd	63.83cd	0.71a	91.3g	
ANOVA	Cultivar	*	**	*	**	ns
	Year	**	**	**	Ns	ns
	AxB	**	**	*	**	ns

Mean values designated with the same lowercase letter are not significantly different at the 95% level according to the LSD test

** F-test significant at 0.01; * F-test significant at the 0.05 level; ns non-significant

Similar results were obtained for grain weight per spike which exhibited no marked positive correlation with grain yield in wheat under normal conditions, but the two traits were positively correlated under stress conditions (Dencic et al., 2006).

Significant differences in grain weight per spike were observed only in cvs. Crystal and Jagodinac, regardless of year (Table 1). The effect of year induced a significant increase in grain weight per spike. However, the cultivars showed different responses across years (cultivar/year). In Crystal and Premium, the effect of year on grain weight per spike was not significant. Knezevic et al. (2007) and Paunovic et al. (2007) indicated that increased rates of mineral nutrients lead to a significant increase in grain weight per spike. Previously, Baethgen et al. (1995) reported no significant effect of increased rates of mineral nutrients, particularly

nitrogen, on grain weight in malting barley. The different responses of the test cultivars to liming and P fertilisers are in agreement with the results obtained by Romer and Schenk (1998) and Gahoonia and Nielsen (2004) who found high levels of genetic variability in barley for P uptake and utilisation, particularly on acid soils, which have a low availability of P. Foy (1996) and Huttova et al. (2002) also observed significant differences in barley tolerance to low soil pH.

Since malt is defined as a germinated barley grain, barley suitable for the malting industry should preferably germinate for ten days after harvest to retain viability for 365 days regardless of storage conditions. Some grain traits, such as dormancy and hydrosensibility, are desirable in agronomic terms, but undesirable in technological terms; therefore, breeders are expected to satisfy production and storage requirements, on the one hand, and malting requirements, on the other (Pržulj et al., 2010). The cultivars displayed significant differences in germination energy, whereas the year effect was not significant. Germination energy was highest in cv. Jagodinac and lowest in cv. Crystal. The lowest variation across years was observed in cv. Jagodinac. Conversely, cvs. Record and Premium exhibited significantly higher values in the second and third years. The analysis of the effect of the cultivar x year interaction indicates a specific response of each cultivar to germination energy. All cultivars were found to have the required germination energy of above 90%.

Grain protein content is among key parameters of malting barley. The cultivars tested did not significantly differ in the trait, nor did growing conditions produce any significant effect. This finding suggests that all of the cultivars analysed can be used as equally valuable raw materials in the brewing industry. The choice of the most favourable cultivar can be determined by other production traits.

Conclusion

The three-year study suggests that the genotypes tested gave satisfactory values for the traits analysed.

Yield was significantly affected by growing conditions (year) as well as by the genotype x year interaction. Crystal exhibited the strongest response to variable environmental conditions, whereas the lowest variation was observed in Record and Premium, regardless of growing conditions. The analysis of the cultivar x year interaction effect indicates a specific response of each cultivar in terms of germination energy, with all cultivars having the germination energy of above 90%.

Growing conditions had no significant effect on grain protein content and extract content. This finding suggests that all cultivars can be used as equally valuable raw materials in the brewing industry.

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