

The Interdependence of Productive and Technological Traits in Two-Rowed Spring Barley

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Abstract: Five two-rowed spring barley cultivars were studied at the Small Grains Research Centre in Kragujevac over a three-year period. Three planting densities, of 300, 400 and 500 germinating grains m⁻², were chosen. The rates of 30 and 60 kg ha⁻¹ N were applied in nitrogen fertilisation of plants and the control variant without fertilisation was used. Eight parameters were analysed, being as follows: plant number per m², spike number per m², spike length (cm), grain number per spike, grain weight per spike (g), grain yield (kg), first-class grain content (%) and protein content (%).

Highly significant positive correlation was determined between the plant number, on the one side, and the spike number and grain protein content, on the other. Highly significant positive correlations were established between the grain weight per spike and the grain number per spike, between the spike length and the first-class grain content, as well as between the spike number and the protein content in the grain. A significant positive correlation effect was determined between the spike length and the grain number per spike, and the grain yield was significantly positively correlated with the spike number and significantly negatively correlated with the spike length and the first-class grain content.

The plant number and spike number were highly negatively correlated with the spike length and the first-class grain content and significantly negative correlation was determined between the grain protein content and the first-class grain content and the spike length.

Key words: Spring barley, productive traits, technological traits, correlations.

Introduction

Spring malting barley grain is a basic raw material in high-quality malt and beer production. The yield and quality of spring barley grain are determined by the effect of different factors, the genotype trait being one of the most important elements. Apart from the impact of cultivar characteristics, special importance is attributed to the effect of climatic and soil conditions which have a considerable effect on both yield and quality variations in malting barley (Atlin, McRac, Lu, 2000). Also, the use of different production technology measures is of great significance for achieving high and profitable yield of grain with good technological traits. In malting barley production technology, plant nitrogen nutrition and planting density have a large effect (Becker, 1981, Malesevic, 1985, Prochazkova, Malek, Dovrtei, 2002, Koutna, Cerkal, Zimolka, 2003).

Malting barley must satisfy strict brewing industry standards. A genotype should be characterised by long and loose spike on which large plump grains of uniform size and shape and over 2.50 mm width may be formed. The grain should have a high germinating capacity and uniform germination energy (Gacesa, Grujic, Klasnja, 1992). Malting barley is expected to have 1000-grain weight of 40 and 46 g and hectolitre grain weight of 68 to 75 kg (Malcev, 1967). Grain chaff should be thin, with fine structure and narrow cross wrinkles. Maximum chaff content should be 12% (from 9% to 12 %). The produced barley grain should have 9% to 11% protein, 60 to 70% of starch, in dry matter, and the extract share in the grain should exceed 80% (Maksimovic et al. 2001).

In order to meet the demands and requirements of malting industry it is necessary to examine all the elements which have a direct effect on the yield and quality of malting barley grain. The more pronounced effect of certain measures often gives rise to undesirable plant reaction in terms of stem elongation, lodging, accumulation of greater nitrogen amounts or proteins in the grain, resulting in undesirable grain traits for malting industry. For this reason, it is necessary to find a compromise between different production technology factors which would by their interaction contribute to achieving high and profitable yield and good malt quality of malting barley cultivars in certain soil and climatic conditions (Paunovic, 2001).

The aim of the investigation was to determine the interdependence of productive and technological traits of spring malting barley in conditions of different planting densities and nitrogen nutrition.

Material and Method

The trial was set up in four replications in a randomised block design at the Small Grains Research Centre farm in Kragujevac. Over a three-year period, five spring malting barley cultivars were investigated, being as follows: Kraguj, Dinarac, Dunavac, Jastrebac and Novosadski-294. The elementary plot surface was 5 m². Pure nitrogen, phosphorus and potassium fertilisers at the rate of 52.50 kg ha⁻¹ each were introduced into the soil by basic fertilisation. Nitrogen dressing was carried out at the rate of 30 kg ha⁻¹ and 60 kg ha⁻¹, and the control variant without fertilisation was

used. Three planting densities, of 300, 400 and 500 germinating grains m⁻² were applied. 30 plants from each individual plot were examined.

Eight traits were analysed in the trial, being as follows: plant number per m⁻², spike number per m⁻², spike length (cm), grain number per spike, grain weight per spike (g), grain yield (g), first-class grain content (%) and protein content (%). Experimental data analysis was made using the EBC analysis and protein (nitrogen) content in barley grain was determined by standard Kjeldahl method.

Correlation analysis was used to examine the interdependence of the traits examined. Based on the degree of concordance between the variables in linear interdependence, the coefficient of correlation between the parameters examined was determined, Hadzivukovic, 1991.

The correlation coefficient was determined according to the formula:

$$r = \frac{\sum_{i=1}^n (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^n (X_i - \bar{X})^2 \sum_{i=1}^n (Y_i - \bar{Y})^2}}$$

and the significance for n-2 freedom degrees was compared with the values presented in tables t – distributions.

Results and Discussion

Table 1. Coefficients of correlation between the traits investigated

Traits	Protein content	I-class grain content	Grain yield	Grain weight per spike	Grain number per spike	Spike length	Spike number	Plant number
Plant number	0.71**	- 0.78**	0.43	- 0.32	- 0.49	- 0.83**	0.96**	-
Spike number	0.73**	- 0.80**	0.63*	- 0.30	- 0.44	- 0.87**	-	
Spike length	- 0.61*	0.76**	- 0.63*	0.43	0.55*	-		
Grain number per spike	- 0.22	0.20	0.02	0.81**	-			
Grain weight per spike	- 0.02	0.09	- 0.04	-				
Grain yield	0.45	- 0.56**	-					
I-class grain content	- 0.83**	-						
Protein content	-							

$$r_{0.05} = 0.514 \quad r_{0.01} = 0.641$$

Correlation coefficients for significance thresholds 0.05 and 0.01

The plant number was fully positively correlated with the spike number (0.96) and strongly correlated with the protein content in the grain (0.71). The plant number was very strongly negatively correlated with the spike length (-0.83) and the first-class grain content (-0.78).

The increased spike number had a highly significant effect on the protein content increase in the grain (0.73) and on the grain yield (0.63) (Sinco, 2002). However, the increased spike number was very strongly negatively correlated with the spike length (-0.87) and with the first-class grain content (-0.80).

The spike length had a positive effect on the formation of a greater first-class grain share (0.76) and on the grain number per spike (0.55). Conversely, negative correlation was determined between the spike length and the grain yield (-0.63) and the protein content in the grain (-0.61).

The grain number in the spike was positively correlated with the grain weight per spike (0.81) and the grain yield was negatively correlated with the first-class grain content (-0.65).

The first-class grain content was negatively correlated with the protein share in the grain (-0.83).

Examining the correlations, highly significant negative correlation was determined between the protein content in the grain and first-class grain content (-0.83) and significant negative correlation was recorded between the protein content and the spike length (-0.61). Highly significant correlation was recorded between the protein content, spike number (0.73) and the plant number (0.71) (Table 1).

Based on the significance threshold coefficients $r_{0.05} = 0.514$ and $r_{0.01} = 0.641$ it was determined that other correlations between the traits investigated were of no significance.

In all three study years, planting density increase brought about a higher plant number. At the highest planting rate of 500 grains m^{-2} the highest spike number was recorded. The data are in accordance with the results obtained by a number of authors (Malesevic and Starcevic, 1992, Paunovic, 2001).

At a low planting density with the lowest spike number determined, the lowest grain yield was recorded, too. Conversely, at the highest planting density, with the highest nitrogen rate applied, the highest spike number and highest grain yield were recorded. The spike number was therefore determined to be the most important grain yield component which was also confirmed by positive significant correlation between the grain yield and the spike number (0.63).

The lower spike number determined at the lowest planting density enabled the plants, supplied with sufficient nutrient and necessary water amounts, to achieve longer spike length compared to the higher planting density. At a planting density of 400 grains m^{-2} and 500 grains m^{-2} , both a higher spike number and higher competition between them were determined, which resulted in smaller spike length.

With an increase in the planting density and nitrogen rates applied during dressing, over the three-year period, the spike number per m^{-2} was increased as well. This is in accordance with the data recorded by Maksimovic et al, 1998. Complete positive correlation between the plant number and spike number (0.96) indicates that the highest planting density with the highest plant number determined resulted in the highest spike number. Furthermore, with the

spike number increase, the grain yield was increased too (significant positive correlation 0.63), which is in accordance with the findings by Malesevic (1985), Paunovic (2001), Madic et al. (2005).

Increasing nitrogen rates had a statistically very significant effect on the spike number. A higher spike number caused a spike length decrease. A very strong negative correlation between these two traits (-0.87) was determined. Higher spike length was very strongly positively correlated with the first-grain content (0.76) and strongly correlated with the grain number per spike (0.55). The spike length was strongly negatively correlated with the protein content in the grain (-0.61).

The planting density increase and nitrogen rate increase pointed to a general grain yield increase tendency in all cultivars investigated.

The grain yield was significantly negatively correlated with the first-class grain share (-0.56) and strongly significantly negatively correlated with the spike length (-0.63). It was determined that grain yield was highly positively correlated with the spike number (0.63). These results are in accordance with the results by Malesevic and Starcevic (1992).

As determined by the analysis of the three-year study results on the protein content in the grain, the cultivars did not express statistically justifiable differences, but the planting density and nitrogen effects had brought about statistically very significant differences. In the cultivars examined, increased planting density and nitrogen nutrition resulted in increased protein content in the grain. The protein increase tendency differed between the years. The complexity of the issue of nitrogen nutrition is fully expressed when the effect of growing conditions is taken into consideration, because the effect of high air temperatures in the maturation period brings about an increase in the protein content in the grain in spring barley.

Conclusion

Based on the study results obtained the following conclusions may be drawn:

Highly significant positive correlation was determined between the plant number, on the one hand, and spike number and protein content, on the other. Equal correlation was determined between the grain weight per spike and grain number per spike, between the spike length and the first-class grain content, as well as between the spike number and the protein content in the grain. Significant positive correlation was recorded between the spike length and the grain number per spike.

Highly negative correlation was determined in the plant number and the spike number compared to the spike length and the first-class grain content. Also, the protein content was significantly negatively correlated with the first-class grain content and the spike length.

The grain yield was significantly positively correlated with the spike number and significantly negatively correlated with the spike length and the first-class grain content.

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MEĐUZAVISNOST PRODUKTIVNIH I TEHNOLOŠKIH OSOBINA JAROG DVOREDNOG JEČMA

- originalni naučni rad -

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Rezime

U trogodišnjem periodu proučavano je pet sorti jarog dvorednog ječma na imanju naučnog Centra za strna Žita u Kragujevcu. Za setvu su odabrane tri gustine od 300, 400 i 500 klijavih zrna m^{-2} . U prihrani biljaka azotom primenjene su količine od 30 i 60 $kg\ ha^{-1}\ N$ i kontrolna varijanta u kojoj je izostavljeno prihranjivanje. Analizirano je osam parametara: broj biljaka po m^{-2} , broj klasova po m^{-2} , dužina klasa (cm), broj zrna po klasu, masa zrna po klasu (g), prinos zrna (kg), sadržaj zrna prve klase (%) i sadržaj proteina (%).

Utvrđen je visoko značajan pozitivan korelacioni odnos broja biljaka prema broju klasova i sadržaju proteina u zrnu. Pozitivna, visoko značajna veza ustanovljena je između mase zrna po klasu i broja zrna po klasu, između dužine klasa i sadržaja zrna prve klase, kao i između broja klasova i sadržaja proteina u zrnu. Značajan pozitivni korelacioni efekat utvrđen je između dužine klasa i broja zrna po klasu, a prinos zrna je u značajnoj pozitivnoj korelaciji sa brojem klasova, a značajno negativnoj korelaciji sa dužinom klasa i sadržajem zrna prve klase.

Broj biljaka i broj klasova ispoljava jako negativan korelacioni odnos prema dužini klasa i sadržaju zrna prve klase, a značajno negativna korelacija utvrđena je između sadržaja proteina u zrnu u odnosu na sadržaj zrna prve klase i dužinu klasa.