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EVALUATION OF YIELD AND YIELD RELATED COMPONENTS OF SPRING BARLEY VARIETIES BASED ON MULTIVARIATE ANALYSES

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Abstract

The aim of this study was to evaluate the yield and yield components of spring barley varieties cultivated in the Republic of North Macedonia using multivariate analyses. Five spring barley varieties (Makedo, Xanadu, Josefin Variety, Gladys Variety and Scarlet Variety) were used as an experimental material. Makedo is Macedonian variety and the other barley cultivars were introduced. The experiment design was randomized complete block with three replications, carried out on the field areas in Probistip, Republic of North Macedonia. Makedo variety showed the highest value for grain yield (6 844 kg/ha), number of spikes per m^2 (668), number of grains per spike (22) and hectoliter weight (68.5 kg/hl). Using Principal Component Analysis two main components were extracted, accounted for 82.46% of the entire variability among the barley varieties for all investigated traits. The first principal component explained 59.92% of the variance and factor loading for number of spikes per m^2 (0.49), grain yield (0.48) and number of grains per spike (0.47) were the most important traits positively contributing to the PC1. The second PC accounted 22.53% of the variation and the factor loading for 1 000 grain weight (0.84) was the main highly positively trait contributing to the PC2. From all spring barley varieties only Makedo had positive values by both major components. Grain yield was positively correlated with the number of spikes per m^2 ($r = 0.795$), from the one side and from the other side, with the number of grains per spike ($r = 0.632$).

Key words: *barley, grain yield, principal component analysis, correlation*

INTRODUCTION

As one of the oldest plant species, barley has undergone substantial genetic change during its domestication. Over many thousand years of cultivation, the intended use of barley has moved from staple food to an important feed. Among the cereal crop barley is a species with the greatest adaptability to a wide range of environments. Barley is cultivated from arctic latitudes to tropical areas, grown at the highest altitudes and adapted to specific sets of agro-ecological areas (Alemayehu & Parlevliet, 1997). Most of the world's barley is used for fee, followed by malting, 2-3% as food and about 5% as a seed commodity (Ullrich, 2011). In Republic of North Macedonia wheat and barley are the major cereal crops. According to the data from the Statical Office of the Republic of North Macedonia (2023), barley production in Republic of North Macedonia in the last ten years tends to increase. On the National variety list in the Republic of North Macedonia, besides autumn forms of barley, only one variety (Makedo) is registered as a spring domestic variety (MAFWE, 2008).

A priority for global food security is insuring the yield potential and stability of small-grain cereals, such as wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.) and barley (*Hordeum vulgare* L.) (Zoltán et al., 2020). Successful growing of spring barley depends on many factors. Productivity is the final result of the effect and interaction of several yield related traits, which are basically polygenetic (Madić et al., 2014). Grain yield in barley is a trait that is affected by an interaction

of many factors like environment, physiology and morphology of the genotype (Mousavi et al., 2012). The most basic components of yield are grain weight, plant height, number of grains per spike and grain/kernel weight (Madić et al., 2009). Grain yield is dependent on combined and well-balanced effects of these yield components (Turk et al., 2003). Environmental factors like drought affect the yield components and consequently the grain yield of a genotype (Soleymani & Shahrajabian, 2013). Also, many authors studied the environmental effect and the influence of variety on barley grain yield (Helm, 1992; Paynter and Young, 2004; Petkovski et al., 2018). The most important traits in barley plants are grain yield and quality of product, number of spikes per unit area, number of grains per spike and grain weight (Turk et al., 2003; Kavitha et al., 2009; Sukram et al., 2010). To be able to breed for a high yielding genotype, the relationship between yield and yield components and the correlation among yield components need to be well studied and understood (Dofing et al., 1992). Coefficient analysis and Principal Component Analysis are widely applied in the breeding researches of many authors (Dyulgerova, 2012; Gocheva, 2014; Markova Ruzdik et al., 2015) and those tools report the interdependencies between the yield formation elements.

The objective in this study was to evaluate the yield and yield formation elements of spring barley varieties cultivated in the Republic of North Macedonia, using multivariate analyses.

MATERIAL AND METHODS

Plant material and field trial

Five spring barley varieties (Makedo, Xanadu, Josefin Variety, Gladys Variety and Scarlet Variety) were used as an experimental material for this study. Only Makedo was domestic variety and the other cultivars were introduced (Tab. 1). Macedo variety is registered as a Macedonian variety on the National variety list in the Republic of North Macedonia (MAFWE, 2008).

Table 1. The origin of spring barley varieties used in the experiment.

No.	Spring barley varieties	Breeder/Maintainer
1	Makedo	North Macedonia
2	Xanadu	Germany
3	Josefin Variety	France
4	Gladys Variety	Czech Republic
5	Scarlet Variety	Germany

The field trial was carried out on the experimental field area in Probištip, Republic of North Macedonia, during two growing seasons. Probištip is a town nestled in the southwest corner of the Osogovo Mountains, in northeastern Macedonia, located at 42°00'N and 22°09'E, with an elevation above sea level of 589 m (Fig. 1).

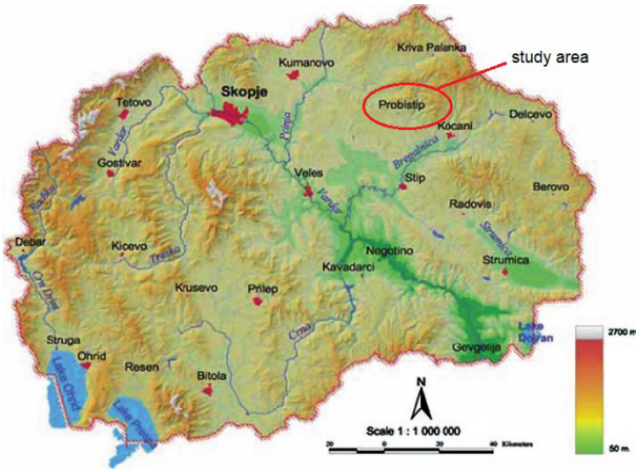

Figure 1. The investigated area on the territory of the Republic of North Macedonia.

Two row spring barley cultivars were arranged in a randomized complete block design with three replications. The size of experimental plot for each variety and replication was 5 m^2. Row to row distance was maintained at 20 cm and all recommended agronomic practices were followed for growing the crop. The sowing and the harvest were done manual.

Data collection

The number of spikes per m^2 was determinate by counting the plants from m^2 of each repetition. In maturity period, grain yield and its components were measured. According to descriptors for barley (IPGRI, 1994), 30 plants were randomly were sampled from each plot to determine plant height (cm). Plant height was measured from the base of the plant to the tip of the spike. Grains per spike were manually counted and the 1 000-grain weight has been determinate to measure 1 000 grains of each repetition and variety. For hectolitre weight was used hectolitre measuring system. Grain yield was obtained from 5 m^2 and was calculated in kg/ha.

Statistical data analysis

To evaluate the yield and yielding components of tested barley varieties and to analyse the contribution of each trait on total variation, multivariate analyses were applied. Least significant differences were calculated using Statistical analysis software JMP (2002). Principal Component Analysis was done by StatGraph 2.1 (Mohammadi & Prasanna, 2003) and components with Eigen values greater than one were considered. Linear correlation was calculated according Singh & Chaudhary (1985), with significance levels of 0.05 and 0.01, using SPSS 19 (2010) software.

RESULTS AND DISCUSSION

In Table 1 the average values for grain yield and yield components of tested barley varieties are given. Number of spikes per m^2 is one of the important traits and play significant role in yield formation. LSD test show that all tested varieties significantly differ. Makedo variety showed the largest number of spikes per m^2 (668) and the lowest was notes by Josefin Variety (517). The tallest plants were registered by Josefin Variety (76.3 cm), followed by Scarlet Variety (69.8 cm). Number of grains per spike is also one of the main yield related components. According to LSD test, there were no significant differences between tested barley varieties except Makedo variety. Makedo variety had the highest value for number of grains per spike (22). 1 000 grain weight is a quality trait and it is indicator for the seed size. This property depends of genetic variety but also of environmental conditions. In our study, this trait ranges from 43.5 g to 50.1 g, with average value of 47.1 g. Hectolitre weight (or weight per unit volume) is the weight of 100 litres of the cultivar and is the simplest criteria of grain quality. It gives us a rough index of flour yield. Higher hectolitre weight, means better flour yield. The factors affecting the hectolitre weight are kernel shape and uniformity of kernel size, orientation of kernels in container when it is filled, density of the grain influenced by structure of grain and its chemical composition. In our research, the highest value for hectolitre weight was observed by Makedo variety (68.5 hg/hl). Macedonian variety also showed the highest value for grain yield (6 844 kg/ha), followed by Xanadu Variety (6 638 kg/ha).

Table 2. Average values for yield and yield components of tested barley varieties.

Variety	Number of spikes per m^2	Plant height (cm)	Number of grains per spike	1 000 grain weight (g)	Hectolitre weight (kg/hl)	Grain yield (kg/ha)
Makedo	668a	64.8c	22a	49.4a	68.5a	6 844a
Xanadu	617c	64.4c	20b	43.5c	66.0c	6 638a
Gladys Variety	576d	68.8b	20b	50.1a	67.7ab	5 841a
Scarlet Variety	638b	69.8b	20b	46.3b	67.0b	4 949b
Josefin Variety	517e	76.3a	20b	45.8b	64.7d	5 279b
Mean	**604**	**68.8**	**21**	**41.1**	**66.8**	**6 544**
$LSD_{0.05}$	**20.32**	**1.32**	**1.05**	**1.81**	**0.93**	**1 922.3**

Principal Component Analysis (PCA) reflects the importance of the largest contributor to the total variation at each axis of differentiation (Sharma, 1998).

In this study, Principal Component Analysis was utilized to examine the variation and to estimate the relative contribution of tested traits for total variability. Principal Component Analysis was carried out by using five spring barley varieties and six traits. Table 3 presented the results of PCA, viz., percentage, cumulative variances, and Eigen value of the first two principal components. This multivariate tool usually is used to identify the properties that were the main source of variability. The importance of analysed traits to the different principal components can be seen from the corresponding loading factors.

In this research, two main components were extracted with Eigen value greater than one (Tab. 3). The first two principal components accounted for 82.46% of the entire variability among the barley varieties for all investigated traits.

The first principal component (PC) explained 59.92% of the variance. The importance of traits to the different PC can be seen from the corresponding factor loading, presented in Table 3. Factor loading for number of spikes per m^2 (0.49), grain yield (0.48) and number of grains per spike (0.47) were the most important traits positively contributing to the first main component. This comment relates to fact that spike number per m^2 had a high significant correlation with grain yield. On the other hand, the plant height was negative correlated to PC1 (-0.51), which mean that higher plants should have lower grain yield. The second PC accounted 22.53% of the variation and the factor loading for 1 000 grain weight was the main highly positively trait of PC2 (Tab. 3).

Table 3. Principal Component Analysis and factor loading of all tested traits.

Parameter	**PC1**	**PC2**
Eigen value	2.99	1.12
Percentage of variance (%)	59.92	22.53
Cumulative percentage (%)	59.92	82.46
Trait	**Factor loading of tested traits**	
Number of spikes per m^2	0.49	-0.14
Plant height	-0.51	0.34
Number of grains per spike	0.47	0.35
1 000 grain weight	0.12	0.84
Hectolitre weight	0.15	0.25
Grain yield	0.48	-0.20

The similar results were reported by Žáková & Benková (2006). According Žáková & Benková (2006) two main components were extracted, which accounted 72.8% of variability and also, the grain yield had the highest positive factor loading but plant height was negatively correlated by first main component.

Abdullah et al., (2018), also used PC analysis in their experiment, and they reported four main components with 85.5% cumulative variability.

In Table 4 are given the factor loading of tested barley varieties by main components. From all spring barley varieties only Makedo had positive value by both main components. This means that the most suitable for breeding, according to the tested traits and environmental conditions was Makedo variety.

Table 4. Factor loading of tested barley varieties by main components.

Variety	**PC1**	**PC2**
Makedo	**2.54**	**0.71**
Xanadu	0.54	-1.76
Gladys Variety	-0.25	0.87
Scarlet Variety	-0.64	-0.17
Josefin Variety	-2.19	0.34

Correlation explained the degree of association between two traits. The interrelationship of characters determines the response to selection in breeding programs. It also helps to apply indirect selection to improve the target traits of interest (Joshi & Okuno, 2010).

Manu researches had been used linear correlation to determine the interaction between grain yield and yield related components in barley (Žáková & Benková, 2006; Dorostkar et al., 2015; Markova Ruzdik et al., 2015; Abdullah et al., 2018; Kaur et al., 2018; Al-Sayaydeh et al., 2019; Tsige, 2020).

The values of phenotypic correlations of yield and yield components are depicted in Table 5. Grain yield was highly and significantly in positive correlation with the number of spikes per m^2 ($r = 0.795$), at level of significance $p<0.01$. Dorostkar et al., (2015), Abdullah et al., (2018) and Madić et al., (2019) also reported positive interaction between spike number per m^2 and grain yield.

Grain number per spike is an important yield component and is usually used as selection trait in barley breeding programmes. In our research, also, significant positive correlation was established between number of grains per spike and grain yield ($r = 0.632$, $P<0.05$). This correlation was also reported by other researches such as Garcia del Moral et al., (1991), Doting & Knight (1992), Saed-Moucheshi et al., (2013), Dorostkar et al., (2015), Madić et al., (2019).

From the other side, grain yield and 1 000 grain weight had no significant correlation (Tab. 5). Same results were reported in Dorostkar et al., (2015) study.

Table 5. Linear phenotypic correlation coefficients between yield and yield related components.

	Plant height	Number of grains per spike	1 000 grain weight	Hectolitre weight	Grain yield
Number of spikes per m^2	-0.823	-0.467	-0.075	-0.660	**0.795****
Plant height		0.636	0.172	0.760	0.492
Number of grains per spike			0.490	0.649	**0.632***
1 000 grain weight				0.748	0.101
Hectolitre weight					0.424

*Statistical significance of differences at $P<0.05$;
**Statistical significance of differences at $P<0.01$

CONCLUDING REMARKS

From the performed research it can be conclude that the highest yield was obtained by Makedo variety. Also, Makedo showed the largest number of spikes per m^2, number of grains per spike and hectolitre weight. The used PCA extracted two major components that accounted 82.46% of the total variability among the barley varieties for all investigated traits. Using linear correlation, grain yield showed highly and significantly positive relationship with the number of spikes per m^2 and with the number of grains per spike. From all spring barley varieties only Makedo had positive value by both main components, which means that this variety is suitable for cultivation and should be more present in barley production. Also, the other varieties can be included in barley production because they showed optimal values for the tested yield related traits and a suitable breeding strategy required to combine most, if not all, of the desired traits into a single genotype in order to come up with superior genotype.

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ЕВАЛУАЦИЈА НА ПРИНОС И КОМПОНЕНТИ НА ПРИНОСОТ КАЈ ПРОЛЕТНИ СОРТИ НА ЈАЧМЕН СО КОРИСТЕЊЕ НА МУЛТИВАРИЈАНТНИ АНАЛИЗИ

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Резиме

Целта на овој труд е да се направи евалуација на приносот и компонентите на принос кај пролетни сорти јачмен одгледувани во Република Северна Македонија со примена на мултиваријантни анализи. Како материјал за работа во овој експеримент беа употребени пет пролетни сорти на јачмен (Makedo, Xanadu, Josefin Variety, Gladys Variety и Scarlet Variety). Makedo е македонска сорта, а останатите се со странско потекло. Опитот беше поставен во рандомизиран блок систем, со три повторувања, спроведен на површините во Пробиштип, Република Северна Македонија. Сортата Makedo покажа највисока вредност за принос на зрно (6.844 kg/ha), број на класови на m^2 (668), број на зрна во клас (22) и хектолитарска маса (68.5 kg/hl). Со помош на компонентна векторска анализа издвоени се две главни компоненти, кои претставуваа 82.46% од целата варијабилност помеѓу сортите и испитуваните својства. Првата главна компонента (ПЦ1) претставува 59.92% од варијабилноста, а вредностите на факторите на оптоварување за бројот на класови на m^2 (0.49), принос на зрно (0.48) и број на зрна во клас (0.47) позитивно влијаат по првата главна компонента. Втората главна компонента (ПЦ2) претставува 22.53% од варијабилноста, а вредноста на факторот на оптоварување за маса на 1.000 зрна позитивно влијае по втората главна компонента. Од сите пролетни сорти кои беа предмет на истражување, само сортата Makedo покажа позитивни вредности по двете главни компоненти. Приносот на зрно покажа позитивна корелација со бројот на класови на m^2 ($r = 0.795$) од една страна и со бројот на зрна во клас ($r = 0.632$) од друга страна.

Клучни зборови: *јачмен, принос на зрно, компонентна векторска анализа, корелација.*