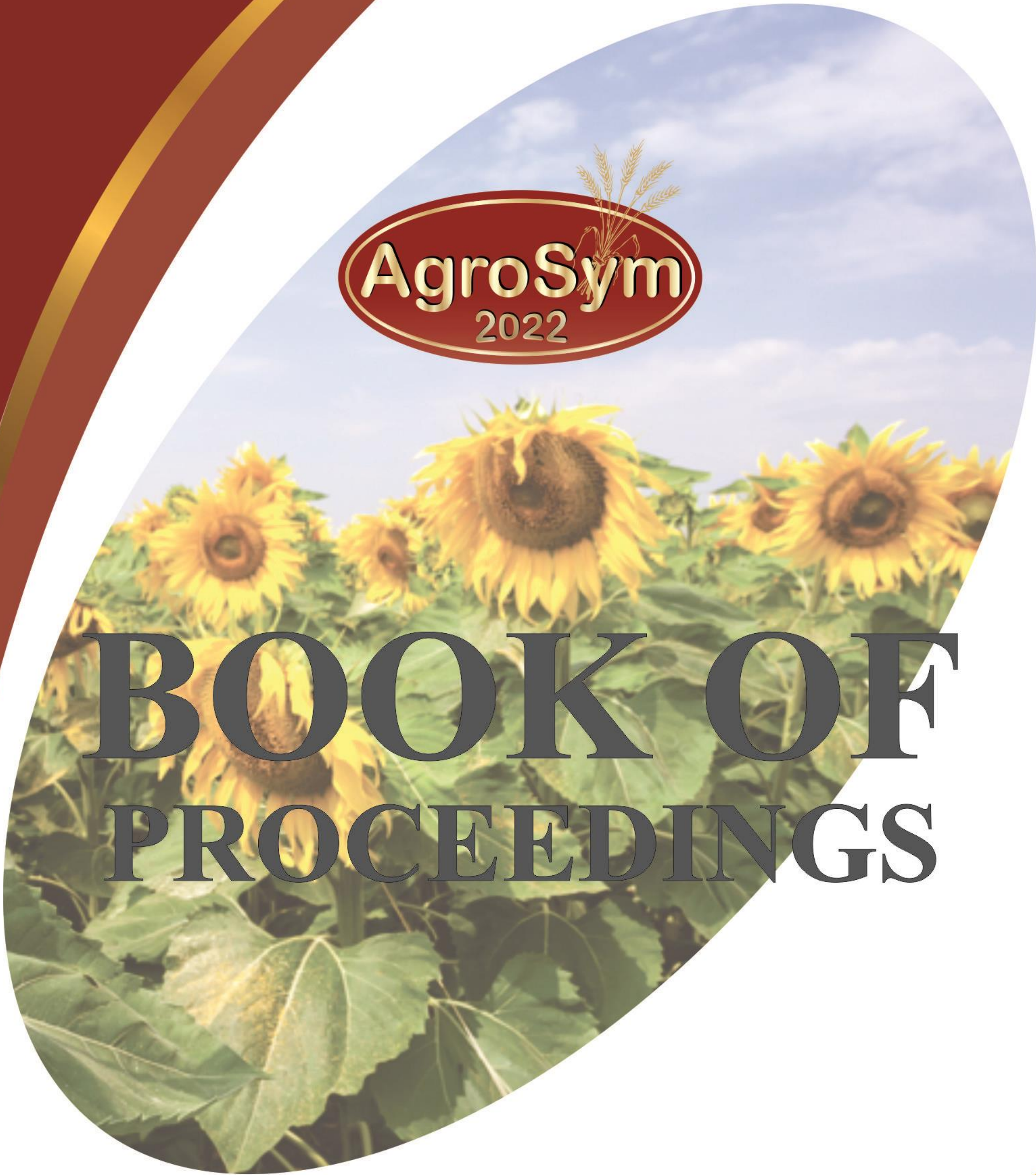

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FERTILITY PARAMETERS AND GRAIN QUALITY OF WINTER BARLEY

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Abstract

The experiments were performed on samples of biomass and grains of winter barley varieties (Rekord and Zlatnik) for two years. The parameters of fertility and quality (yield, mass of 1000 grains and hectoliter mass, moisture, starch, lipids, ash, cellulose and β-glucan) were monitored. The average grain yield ranged from 3,933 t ha-1 to 5,065 t ha-1. Grain yield differed significantly between years and for all genotypes and on average was higher in the first year compared to the second year of cultivation. Average mass values of 1000 grains ranged from 41.60 to 54.83 g. It was found that there are very significant differences in grain yield compared to the year of testing, while the differences between the studied barley varieties were not significant. The results of the chemical composition of barley grains have shown that the tested parameters deviated between cultivars and years. The starch composition varied from 48.8% to 50.1%, while the composition of the crude protein varied from 10.5% to 11.3%. The average composition of the lipids per dry matter was 1.68% for cultivar Rekord and 1.77% for cultivar Zlatnik, respectively. In all tested samples, the composition of the crude cellulose varied from 3.27% to 3.82%. The obtained results showed that the lowest composition of the crude ashes was recorded in the sample of cultivar Rekord (1.58%), while the highest was detected in the sample of cultivar Zlatnik (1.70%). The composition of moisture ranged from 10.11% to 11.01%, while composition of β-glucan varied from 3.9% to 4.23%.

Key words: *barley, yield, fertility parameters, β-glucan, chemical composition.*

Introduction

The stability of grain yield determined for a certain area is a reliable criterion in the selection and recommendation of varieties because the stability of grain yield established in previous years due to the dynamics of climatic factors does not include risk due to weather conditions in subsequent years. The agronomic value of a variety depends not only on its genetic potential for yield but also on its ability to realize its genetic potential under different production conditions (Malešević et al., 2010). Yield largely depends on genetic potential, which can be defined as the yield of a variety grown in the conditions to which it is adapted, with sufficient water and nutrients and effective control of pests, diseases, weeds and other stresses (Đekić et al., 2012). The mass of 1000 grains in malting barley ranges from 40 to 46 g, while the hectoliter mass ranges from 68 to 75 kg hl^{-1} (Paunovic et al., 2006). The positive impact of fibre on human health from various types of cereals and their functional properties have recently attracted significant attention from the scientific and professional public (Ronda et al., 2015; Sarteshnizi et al., 2015). Grain β-glucan is a soluble fibre that lowers blood cholesterol, postprandial glucose and insulin levels (EFSA, 2011), and affects the technological properties of the drought (Ahmed, 2015; Ahmed and Thomas, 2015). According to the FDA, products having 0.75 g of β-glucan per serving size may be characterized as functional (FDA, 1997 and 2008). The natural grain coating and difficulty in grinding as well as the lack of gluten narrow down the usability of barley in the fabrication of food for humans. The content of β-glucan in barley grain varies depending on the genotype and agroecological growing conditions. Its role in human nutrition is multifunctional - medicinal, which is why there is a trend of its increased market demand (Dickin et al., 2011; Hetherington et al., 2013; Pentikäinen et al., 2014).

Materials and methods

During the two growing seasons, two varieties of winter barley (Rekord and Zlatnik) were tested. The experiments were set up according to a random block system in three replications. The usual technology for barley production was applied. Sowing was done at the optimal time. Before sowing 400 kg ha^{-1} of NPK fertilizer (15:15:15) was added, while 250 kg ha^{-1} (KAN) was added with spring fertilization. The land on which the experiment was set up belongs to the type vertisol in the process of degradation, with heavy mechanical composition and rough unstable structure. Soil fertility is moderate, with low pH values (pH in H_2O = 5.66 and KCl <4.28), with a humus content of about 2.85% and total nitrogen from 0.12 to 0.15%. The easily accessible phosphorus content was low (below 10 mg 100 g^{-1} P_2O_5 soil), while the easily accessible potassium content was high (25.65 mg 100 g^{-1} K_2O soil). The research was conducted during two consecutive seasons in the Kragujevac, region of Šumadija, Republic of Serbia. Data on the average monthly air temperature and precipitation for the studied vegetation period are shown in Table 1.

Table 1. Average monthly air temperatures and amount of precipitation (Kragujevac).

Months	**Average monthly air temperatures (^{0}C)**			**Amount of precipitation (mm)**		
	Period I	**Period II**	**Multi-year average**	**Period I**	**Period II**	**Multi-year average**
X	10.0	13.5	12.5	33.3	56.2	57.6
XI	3.1	9.5	6.9	1.3	17.7	70.4
XII	4.6	1.7	1.9	43.3	16.4	71.5
I	0.7	2.9	0.5	117.2	62.4	58.5
II	-3.7	4.0	2.4	60.1	84.3	62.7
III	8.1	6.5	7.1	5.7	102.0	45.4
IV	12.9	13.4	11.6	74.5	41.2	48.9
V	16.1	18.2	16.9	87.3	70.8	56.6
VI	23.0	19.9	20.0	57.8	30.3	58.2
VII	25.8	23.1	22.0	35.4	34.4	46.4
VIII	24.0	22.3	22.7	10.1	33.3	32.4
Average/sum	11.37	12.28	10.41	526.0	549.0	608.1

The average air temperature in the second year of the study was higher by 1.87 ^{0}C compared to the multi-year average, while the amount of precipitation was lower by 59.1 mm. In the second year of the research, higher amounts of precipitation were recorded in February and March, which led to a higher grain yield compared to the first year of the research. Based on the obtained results, the parameters of descriptive statistics were calculated. Statistical data processing was performed in the Analyst module of the SAS/STAT program (SAS Institute, 2000). Moisture concentration in the analyzed samples was determined according to the AACC International (2000). Starch, total lipids and total ash were determined according to Kaluđerski and Filipović (1998). For determination of starch concentration, a CARL ZEISS polarimeter of 24/60 Hz was used, with a specific angle of rotation of 181.3. Protein concentration was determined according to the Kjedahl method with a conversion factor of 6.25 (ISO 20483:2006). Crude cellulose (crude fibre) concentration was determined according to Veender, using “Fibertec 2010” and the instructions from the manual: Fibertec 2010 system, User Manual, 1009 9130/rev. 1.3, FOOS Tecator, Sweden. The samples were ground in a laboratory mill (Knifetec 1096). All the samples were tested in three replications, and the results were expressed on a dry matter basis. Nitrogen-free extract (NFE) was calculated as follows: %NFE = 1000 % (crude protein + lipid + ash + crude fibre). The total β-glucan concentration was analysed by the spectroscopic method 32–23.01 (AACC, 2003) using Megazyme β-glucan mixed linkage assay kit (Megazyme International Ireland Ltd., Wicklow, Ireland).

Results and Discussion

The average values of yield and mass of 1000 grains in the studied winter barley cultivars grown during the two growing seasons are shown in Table 2. The yield of the examined barley cultivars differed depending on the year of research. In the first year of research, the Zlatnik variety achieved a slightly higher grain yield (4,100 t ha^{-1}), while the Rekord variety achieved a slightly lower yield (3,933 t ha^{-1}). In the second year of research, the Rekord variety achieved a yield of 5,650 t ha^{-1}, which is 0.530 t ha^{-1} more than the Zlatnik variety. The average grain yield in the observed two-year period was slightly higher in the cultivar Rekord and amounted to 4,792 t ha^{-1}. Đekić et al. (2012b) point out that grain yield and fertility parameters are mainly influenced by climatic and genetic factors. Also, Dumlupinar et al. (2011) state that differences between years occur due to environmental conditions.

Table 2. Average values of the analyzed traits of winter barley.

Variety	I year			II year			Average		
	$\bar{x}$	S	$S_{\bar{x}}$	$\bar{x}$	S	$S_{\bar{x}}$	$\bar{x}$	S	$S_{\bar{x}}$
Grain yield (t ha^{-1})									
Rekord	3.933	0.076	0.44	5.650	0.150	0.087	4.792	0.946	0.386
Zlatnik	4.100	0.218	0.126	5.120	0.207	0.119	4.610	0.590	0.241
Average	4.017	0.172	0.070	5.385	0.332	0.136	4.701	0.758	0.219
1000 grains mass (g)									
Rekord	46.10	1.153	0.666	49.83	1.258	0.726	47.97	2.312	0.944
Zlatnik	54.83	2.255	1.302	51.60	1.442	0.833	53.22	2.450	1.000
Average	50.47	5.044	2.059	50.72	1.550	0.633	50.59	3.560	1.028
Hectolitre mass (kg hl^{-1})									
Rekord	68.47	0.839	0.484	68.20	0.436	0.252	68.33	0.615	0.251

Zlatnik	71.48	1.353	0.781	71.53	0.551	0.318	71.51	0.924	0.377
Average	69.97	1.935	0.790	69.87	1.879	0.767	69.92	1.819	0.525

Starting from the fact that there was a sufficient amount of precipitation in the spring months (Table 1), especially during May, which is very important for the successful production of small grains, it can be concluded that the distribution and amount of precipitation during the second growing season was much more favourable which resulted in a higher yield in this year compared to the first one. In both research years, the Zlatnik variety achieved a higher average mass of 1000 grains (54.83 g and 51.60 g, respectively). A slightly lower average value of 1000 grains mass in both the first and the second year of research was achieved by the variety Rekord (46.10 g and 49.83 g, respectively). Some authors (Jelić et al., 2002; Đekić et al., 2010) point out that the mass of 1000 grains is a varietal characteristic and that there is significantly greater variation between different genotypes than between environmental factors. Hectolitre mass is an indicator of grain quality, especially its monetary value. It is generally considered that grain with a higher hectoliter mass is of better quality compared to one with lower mass values. The value of hectoliter mass in both years of research was slightly higher in the winter barley cultivar Zlatnik (71.48 kg hl^{-1} and 71.53 kg hl^{-1}, respectively).

Table 3. Analysis of variance of the analyzed traits of winter barley.

Effect of years on the traits analyzed				
Traits	**Mean sqr Effect**	**Mean sqr Error**	**F (df1,2) 1.10**	**p-level**
Winter barley				
Grain yield (t ha^{-1})	5.617	0.070	80.233	0.000004
1000 grains mass (g)	0.187	13.924	0.013	0.909916
Hectoliter mass (kg hl^{-1})	0.035	3.637	0.010	0.923569
Effect of cultivar on the traits analyzed				
Trait	**Mean sqr Effect**	**Mean sqr Error**	**F (df1,2) 1.10**	**p-level**
Winter barley				
Grain yield (t ha^{-1})	0.099	0.622	0.159	0.698258
1000 grains mass (g)	82.687	5.674	14.573	0.003388
Hectolitre mass (kg hl^{-1})	30.242	0.616	49.051	0.000037
Effect of the year x cultivar interaction				
Trait	**Mean sqr Effect**	**Mean sqr Error**	**F (df1,2) 1.8**	**p-level**
Winter barley				
Grain yield t ha^{-1})	0.364	0.030	12.284	0.008022
1000 grains mass (g)	36.401	2.519	14.450	0.005227
Hectolitre mass (kg hl^{-1})	0.075	0.757	0.099	0.760656

Based on the analysis of variance, it can be concluded that the interaction of varieties x years very significantly affects the grain yield (Fexp = 12,284 **) and the mass of 1000 grains (Fexp = 14, 450 **). The influence of vegetation year on hectolitre mass in the examined winter barley varieties was not significant, while in the case of yield it was very highly significant. No significant influence of the variety on grain yield was found between the examined barley

genotypes, while significant differences were found at the mass of 1000 grains and hectolitre mass.
The results of the analysis of the chemical composition of the barley are presented in Table 4. Based on the obtained results, it can be seen that there are deviations of the tested parameters between the varieties and the year of production. The starch content varied in the range of 48.8 to 50.1%. The crude protein content in barley grain ranged from 10.5 to 11.3%. This difference can be attributed to the specificity of the variety and agro-ecological conditions of the environment. A previous study (Alijošius et al., 2016) states that the protein content of barley grain has differences depending on growing conditions. The average lipid content is 1.72% on dry matter, with the variety Rekord at 1.68% and Zlatnik at 1.77%. These values in the tested barley grain samples were slightly lower than those established in previous studies (Šterna et al., 2015). Crude cellulose in all tested barley grain samples ranged between 3.27% and 3.82%. The results showed that the lowest content of raw ash was in the sample of the variety Rekord (1.58%), and the highest in Zlatnik (1.7%). The moisture content was in the range between 10.11 and 11.01%.

Table 4. The chemical composition of barley grain.

Variety	**Rekord**		**Zlatnik**	
Year	I	II	I	II
Starch	48.8	49	50	50.1
Proteins	10.8	10.5	11.3	10.9
Lipids	1.66	1.7	1.82	1.73
Cellulose	3.28	3.31	3.82	3.79
Ash	1.58	1.63	1.55	1.7
Moisture	10.11	10.2	11.01	10.82
NFE	23.77	23.66	20.5	20.96
β-glucan	3.91	3.9	4.1	4.23

The content of β-glucan in the seed samples of the cultivar Rekord (3.9%) was slightly lower compared to the samples of the cultivar Zlatnik (4.16%).

Conclusion

Based on the presented results, it can be concluded that the winter barley variety Rekord achieved better results in grain yield, while the variety Zlatnik had a slightly higher mass of 1000 grains and hectolitre mass. Grain yield shows a tendency to increase in years with higher sum and better precipitation distribution during critical phases of plant development. Analysis of variance revealed a very significant effect of the interaction of year x variety on grain yield and mass of 1000 grains in barley, while the influence of the growing season on barley grain yield was statistically justified. Very significant differences were found for the mass of 1000 grains concerning environmental factors. Differences in chemical composition have also been noted, which can be related to the characteristics of varieties.

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