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SPRING BARLEY PERFORMANCES IN THE PANNONIAN ZONE

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Environmental conditions in the Pannonian zone can be characterized with moderate high temperature and partially water deficit during grain filling of spring barley, although low temperature and water deficit are possible also in period till anthesis. This study was conducted to evaluate the variation of the duration of the period from emergence to anthesis (VP), duration of grain filling period (GFP), plant height (PH), spikes number m^{-2} (SN), grains number $spike^{-1}$ (GN), thousand grains weight (GW) and yield (YIL) in spring two-rowed barley in conditions of the Pannonian zone. All three factors; genotype, environment and the interaction GxY affected the studied traits. Average VP was 777 GDD, GFP 782 GDD, PH 78 cm, SN 523, GN 28.2, GW 43.2 g and YIL 6.26 t ha^{-1}. Variation across varieties was higher than across growing seasons. Heritability varied from 0.66 for YIL to 0.94 for VP and GFP. This study confirmed that a sufficiently large genetic variability must be base for

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selecting appropriate varieties for the Pannonian zone conditions. In order to determine high yielding and quality barley extensive research in relation to breeding, variety choice for production and growing practice must be done.

Key words: Barley (*Hordeum vulgare* L.), Pannonian zone, variability, yield, yield components

INTRODUCTION

Spring barley occupied larger growing area than winter barley in most of the European countries and some continents, first of all Australia, North and South America and Asia (SPUNAR *et al*., 2010). Spring barley is important crop in this region as raw material for malt production and feed. Two environmental phenomena frequently occurring in the Pannonian zone during spring barley vegetation, especially during grain filling, are high temperatures and drought. High temperatures and drought make spring barley production more risky comparing to winter barley production. (METZGER *et al*., 2005; OLESEN *et al*., 2011). Marked demand indicates that the spring barley will continue to have high importance in the Pannonian zone, especially due to great progress in quality breeding of spring malting barley.

The main environmental factors determining agronomic properties and grain quality of spring barley are temperature, water and nutrition supplies (ZHANG *et al*., 2006; PETTERSSON and ECKERSTEN, 2007). Barley yield and grain characteristics are determined in both periods from planting to anthesis (VP) and grain filling period (GFP) (SLAFER *et al*., 2005; PRŽULJ and MOMČILOVIĆ, 2011). Heat stress in VP and GFP can significantly decrease grain yield and quality of barley (CATTIVELLI *et al*., 2008). Timing of the stress relative to the stage of grain growth and development has a different effect on yield. Savin and Nicolas (1999) found higher reduction in grain weight, test weight and yield when heat and drought stress occurred in early phase of grain filling. The effects of moderately high temperature are difficult to compare with effects of very high temperature since the responses to each of these thermal regimes may be substantially different. The negative effect of draught on grain weight was smaller than that of heat stress. Stress during grain filling has a stronger effect on starch synthesis than to protein accumulation, which is major reason for lower starch concentration and elevated protein concentration (PASSARELLA *et al*., 2002; and references quoted therein). Protein concentration in the grain is influenced by both actual level of yield and nitrogen use efficiency (PRŽULJ and MOMČILOVIĆ, 2001; GOODING *et al*., 2003; MASCLAUX-DAUBRESSE *et al*., 2010).

Barley produced in regions with appropriate temperature and favorable water supply, such as most of the countries in central and western Europe, will give more-less good malt but not necessarily always better than in Mediterranean conditions (MOLINA-CANO *et al*., 2004). There are many papers related to quality of malting barley grown in western and central Europe as well as Mediterranean-type climates but to the best of our knowledge very few data are published related to either spring or winter malting barley in the Pannonic climate region (GRAUSGRUBER *et al*., 2002; PRŽULJ and MOMČILOVIĆ, 2008). This study was undertaken to (i) evaluate the range of the variation in some agronomic traits in spring two-rowed barley varieties and (ii) indicate the feasibility of using such variation in barley breeding and growing.

MATERIAL AND METHODS

Field trial. The eight spring two-rowed barley varieties (Novosadski 294, Novosadski 450, Novosadski 454, Novosadski 460, Novosadski 462, NS 466, Scarlett and Viktor) were studied during a seven-year period (1998-2004) in the location of Novi Sad (45°20'N, 15°51'E, 86 m asl). In regard to duration of the period from emergence to anthesis the variety Novosadski 460 was supposed to be early, the varieties Novosadski 454, Novosadski 462, NS 466 and Viktor medium early and the varieties Novosadski 294, Novosadski 450 and Scarlett medium late. A complete randomized block design with three replications was used. Plots 5m x 1m in size with 10cm between rows were sown at the rate of 400 germinable grains m^{-2}. The growing practices applied were those regularly used for large-scale spring barley production. The duration of GFP was defined as the time between anthesis and the loss of green color of the peduncle and spike (Zadoks stage 91). The spikes number m^{-2} (SN) was calculated by counting the spikes contained in 3 m of one of the inner rows in each plot. Grain number $spike^{-1}$ (GN) was determined by counting grains of 10 spikes taken random from inner rows from each plot before harvest.

Grain analysis. Grain yield (YIL) was determined from the combine-harvested plots in each of the three replications corrected to 130g kg^{-1} moisture. After that grains were sieved on Sortimat machine (Pfeuffer) and used for physical grain property determination. Thousand grain weight (GW) was determined from the grading sample by measuring three sets of 300 grains per plot and expressed as weight of 1000 grains.

Statistical analysis. Two-way analysis of variance and estimates of the components of variance due to genotype, year, and genotype x year interaction were made. A mixed model was used, with genotypes considered as fixed and years as random effects (ZAR, 1996). The Genstat v10 procedures and programs were used for the data processing.

Narrow-sense heritability was estimated according BORRÀS *et al*. (2009) using the variance components. Accumulated growing degree days (GDD) were calculated by summing up daily degree-days with base temperature of 0°C (Calderini et al., 2006). Daily degree-days were calculated according (PRŽULJ, 2001).

Weather conditions. Weather conditions during 1998-2004 growing seasons period are described elsewhere (PRŽULJ *et al*., 2012).

RESULTS

Components of variance. Variation in VP was mainly due to genotype and year (Tables 1, 2). In the further text year will be designated as growing season. The ranges of genotype and annual mean values show that almost twofold variation for VP was due to growing season than variety. Low values of the GxY interaction for VP indicated a similar order of the varieties in the seven growing seasons. GFP was mostly determined by the growing season and genotype (Table 2). Heritability for VP and GFP was very high (Table 1).

Table 1. Ranges of variety and growing season mean values for the tested traits of 8 spring two-rowed barley varieties grown in 7 growing season (1998-2004) period

Traits	Varieties (n=8)			Growing seasons (n=7)			Mean
	Min	Max	Diff.	Min	Max	Diff.	
Vegetative period (GDD)	707	825	118	635	860	225	777
Grain filling period (GDD)	734	852	118	750	821	71	782
Plant height (cm)	71	83	12	58	93	35	78
Spikes number per square meter	498	551	53	317	634	317	523
Grains number per spike	26.6	30.5	3.9	26.3	31.3	5.0	28.2
Thousand grains weight (g)	39.6	46.1	6.5	37.7	49.5	11.9	43.2
Yield (t ha^{-1})	5.41	6.74	1.33	3.71	7.25	3.54	6.26

Variation in PH was affected by similar amount of all three factors; genotype, growing season and interaction (Table 2). Range of variation was higher among growing seasons than varieties (Table 1). The average of PH across varieties and growing seasons was 78 cm. High value of heritability indicated importance of genetic factors in plant height variation.

Across varieties and growing seasons SN was 523 and GN 28.2 (Table 1). Variation for both traits was mainly under control of the interaction GxY and growing season (Table 2). Genotype participation in total variance was about one fifth for both SN and GN. Heritability was 0.80 and 0.88 for SN and GN, respectively.

According to the EBC methodology, the GW was determined from the barley sieved with 2.5 mm sieve, because this fraction is used for malting (Analytica EBC 1998). Variation in GW was under significant effect of all three factors, genotype, growing season and interaction, with the highest contribution of growing season (Table 2). Heritability for GW was high, 0.88.

Variation in YIL was mostly under control of interaction GxY and growing season (Table 2). The absence of prominent effect of the varieties in yield variation could be partially explained by a close genetic base of the tested varieties and by a very strong effect of the environment that prevented genotype variation expression. YIL had one of the lowest heritability of all tested traits. Indeed, genetic determination of YIL in this trial was expressed through the interaction GxY, i.e., the specific behavior of the varieties in the tested growing seasons.

Interactions. Across the varieties, the shortest VP was in 2003 growing season- 635 GDD, and the longest in 2001, 860 GDD (Table 3). Across the growing seasons, the variety Novosadski 460 had the shortest and the variety Novosadski 294 the longest VP, 707 and 825 GDD, respectively. All varieties without exception had the shortest VP in 2003 growing season and 6 of the 8 varieties had the longest VP in

2001. Briefly, 2003 was very dry and hot and 2001 warm and wet during entire growing period.

Table 2. Mean squares from the ANOVA, percentage of variance components and heritability of vegetative period duration (VP), grain filling period duration (GFP), plant height (PH), spikes number m^{-2} (SN), grains number $spike^{-1}$ (GN), thousand grains weight (GW) and yield (YIL) in 8 spring two-rowed barley varieties in 7 growing seasons (1998-2004) period

Source	df	VP (GDD)	GFP (GDD)	PH (cm)	SN m^{-2}	GN $spike^{-1}$	GW (g)	YIL ($t\ ha^{-1}$)
Genotype (G)	7	36217.0*	36217.0**	331.6**	13018.0**	51.0**	139.2**	3.9*
Year (Y)	6	136233.6	16578.2**	4076.3**	253390.5**	57.8**	462.7**	36.4**
G x Y	42	2024.6**	2024.6**	52.6**	3473.8**	10.4**	20.2**	1.3**
Pooled error	110	228.1	228.1	4.9	238.6	0.8	5.7	0.1
		% of variance components						
σ_G^2		38.9	39.0	26.6	19.0	23.2	30.9	15.7
σ_Y^2		41.3	41.3	31.7	25.9	29.1	35.2	24.0
σ_{GY}^2		14.3	14.3	31.9	45.1	38.0	28.4	53.8
σ_E^2		5.5	5.5	9.8	10.0	9.7	5.5	6.5
h_b^2		0.94	0.94	0.84	0.73	0.80	0,88	0.66

*Significant at the 0.05 probability level, ** Significant at the 0.01 probability level

Table 3. Vegetative period duration (GDD) of 8 spring two-rowed barley varieties across 7 growing seasons (1998-2004) period

Variety (A)	Growing season (B)							Average
	1998	1999	2000	2001	2002	2003	2004	
NS 294	780	852	877	919	896	681	768	825
Scarlett	769	846	859	911	851	664	799	814
NS 450	763	804	877	911	839	675	799	810
NS 454	718	787	724	837	788	608	758	746
Viktor	705	778	756	824	801	608	716	741
NS 460	692	800	724	748	747	547	660	707
NS 462	769	870	799	828	820	664	743	785
NS 466	736	817	859	906	839	608	740	786
Average	741	819	809	860	822	635	748	777
	A	B	AB					
LSD 0.05	9	9	24					
0.01	12	11	32					

Time of planting, weather conditions and genotype of the tested varieties determined the duration of VP and GFP. In 2003 growing season the shortest GFP was recorded across varieties, due to extremely unfavorable weather conditions and generally much shortened total barley life cycle. The longest GFP across varieties was recorded in 1998. Indeed, during 1998 growing season VP was shorter due to high temperatures, while GFP increased due to moderate temperatures and sufficient amount of water (Tables 2, 4). The shortest GFP was recorded for one variety in growing season 2000, for 2 varieties in 1999 and 2003, and for 3 varieties in 2004. The longest GFP was recorded for one variety in growing season 2000, for 2 varieties in 2001, and for 5 varieties in 1998.

Table 4. Grain filling period duration (GDD) of 8 spring two-rowed barley varieties across 7 growing seasons (1998-2004) period

Variety (A)	Growing season (B)							Average
	1998	1999	2000	2001	2002	2003	2004	
NS 294	783	736	719	735	730	705	733	734
Scarlett	794	742	736	743	775	722	702	745
NS 450	800	784	719	743	788	711	702	749
NS 454	845	801	871	816	838	777	743	813
Viktor	858	810	839	829	826	778	785	818
NS 460	870	788	871	905	879	812	841	852
NS 462	794	719	796	825	807	722	758	774
NS 466	827	771	736	747	788	777	761	772
Average	821	769	786	793	804	750	753	782
	A	B	AB					
LSD 0.05	9	9	24					
0.01	12	11	32					

Lodging resistance is important trait of small cereals. PH was negatively correlated with lodging resistance, where higher plants are generally more susceptible to lodging. Due to that PH is in some sense a measure of lodging resistance. Lodging susceptibility decreases both YIL and quality. One third of the total variation for PH belonged to the interaction genotype x variety (Table 2). Across growing seasons Scarlett had the shortest and Viktor the highest plants (Table 4). Without exception all varieties were the shortest in very unfavorable 2003 and the highest in warm and wet 2001.

SN is one of the components of YIL that has strong relationships with other yield components. Although there was a significant difference among mean values of SN across growing seasons, SN variation was generally moderately expressed, ranged from 498 for Novosadski 294 to 551 for Novosadski 450 (Table 6). SN varied much more among growing seasons. Across varieties the highest SN was in 1999 growing season, 634, and the least in 2003, 317. Studied varieties had the highest SN in one of the following growing seasons: 1998, 1999 and 2001 (Table 6).

Table 5. Plant height (cm) of 8 spring two-rowed barley varieties across 7 growing seasons (1998-2004) period

Variety (A)	Growing season (B)							Average
	1998	1999	2000	2001	2002	2003	2004	
NS 294	83	97	60	94	81	60	84	80
Scarlett	70	89	67	85	67	52	67	71
NS 450	75	96	68	97	82	60	89	81
NS 454	86	92	67	96	76	58	83	80
Viktor	91	93	71	100	78	58	90	83
NS 460	85	92	61	93	74	54	82	77
NS 462	93	94	71	99	75	59	83	82
NS 466	81	84	63	83	71	59	83	75
Average	83	92	66	93	75	58	82	79
	A	B	AB					
LSD 0.05	0.14	0.13	0.36					
0.01	0.18	0.17	0.48					

Table 6. Spike number m^{-2} of 8 spring two-rowed barley varieties across 7 growing seasons (1998-2004) period

Variety (A)	Growing season (B)							Average
	1998	1999	2000	2001	2002	2003	2004	
NS 294	659	582	505	434	543	328	433	498
Scarlett	508	636	552	605	553	328	489	525
NS 450	628	619	533	614	546	349	567	551
NS 454	669	634	477	575	594	323	492	538
Viktor	556	693	416	572	468	323	498	504
NS 460	594	652	533	591	463	305	558	528
NS 462	597	573	484	603	537	291	485	510
NS 466	565	686	570	645	480	290	488	532
Average	597	634	509	580	523	317	501	523
	A	B	AB					
LSD 0.05	10	9	25					
0.01	13	12	33					

Varieties Novosadski 294 and Novosadski 460 had the highest and the variety Novosadski 454 the lowest GN, 30 and 26, respectively (Table 7). Growing season 2003 with low density had the highest GN, 31, while in other growing seasons GN varied from 26 to 29. In all varieties variation in GN from growing season to growing season was highly significant. Some authors determine grain yield m^{-2} by multiplying total grains number m^{-2} and average GW, and suppose GN as indirect yield component.

Table 7. Grain number spike^{-1} of 8 spring two-rowed barley varieties across 7 growing seasons (1998-2004) period

Variety (A)	Growing season (B)							Average
	1998	1999	2000	2001	2002	2003	2004	
NS 294	33	29	33	29	29	34	27	30
Scarlett	23	26	25	28	29	28	28	27
NS 450	27	26	30	26	27	29	24	27
NS 454	22	25	26	29	24	30	27	26
Viktor	29	26	31	27	30	32	28	29
NS 460	30	28	30	30	29	35	27	30
NS 462	31	29	28	28	27	31	24	28
NS 466	31	27	26	27	28	31	26	28
Average	28	27	29	28	28	31	26	28

		A	B	AB
LSD	0.05	0.57	0.53	1.50
	0.01	0.75	0.70	2.00

Across growing seasons, the varieties significantly differed (P<0.01) in GW (Table 8). The variety Viktor had the largest grains (46 g) and the variety Novosadski 450 the smallest (39 g). The largest GW across varieties was in 2000 and the lowest in 1998. Six varieties had the largest grains in 2000, one in each 2001 and 2002. The low average of GW in 1998 was supported by 5 varieties that had the smallest grain in that growing season. In regard to GW, 1999 was the most unfavorable for three varieties, Novosadski 454, Viktor and Novosadski 462.

Table 8. Thousand grain weight of 8 spring two-rowed barley varieties across 7 growing seasons (1998-2004) period

Variety (A)	Growing season (B)							Average
	1998	1999	2000	2001	2002	2003	2004	
NS 294	28	37	47	44	47	36	42	40
Scarlett	39	45	51	47	51	40	45	45
NS 450	34	37	44	41	45	35	41	39
NS 454	40	39	50	43	46	41	43	43
Viktor	41	39	53	48	50	45	47	46
NS 460	38	39	50	46	48	44	42	44
NS 462	43	41	52	48	47	43	41	45
NS 466	38	39	48	41	48	45	44	43
Average	38	39	50	45	47	41	43	43

		A	*B*	*AB*
LSD	0.05	0.57	0.53	1.51
	0.01	0.75	0.71	2.00

Across growing seasons there was no significant difference in YIL among the tested varieties and mean YIL varied from 5.39 t ha^{-1} in Novosadski 294 to 6.73 t ha^{-1} in Scarlett (Table 9). The lowest YIL of 3.68 t ha^{-1} was in less favorable 2003. The highest YIL of 7.18 t ha^{-1} was in 2000, which was characterized as warm but not hot and with water deficit but not as drought growing season. Three varieties (Novosadski 454, Viktor, NS 466) had the highest YIL in 1999, three varieties (Novosadski 294, Novosadski 450, Novosadski 460) in 2000, and one variety in each 2001 (Novosadski 462) and 2002 (Scarlett).

In 2003, temperatures and precipitation were extremely unfavorable for barley development. During the entire life cycle (March-June), total precipitation was three times lower than average, while temperatures were lower than average from emergence to anthesis and very high from anthesis to ripeness, i.e., during GFP. In that growing season, the YIL across varieties was 41% lower in relation to the total 7- growing season average yield.

Table 9. Yield (t ha^{-1}) of 8 spring two-rowed barley varieties across 7 growing seasons (1998-2004) period

Variety (A)	Growing season (B)							Average
	1998	1999	2000	2001	2002	2003	2004	
NS 294	5.66	5.73	7.03	4.67	6.28	3.67	4.69	5.39
Scarlett	5.07	7.89	7.60	7.93	8.57	3.93	6.12	6.73
NS 450	6.49	5.97	7.03	6.10	6.61	3.59	5.50	5.90
NS 454	6.66	7.71	6.82	7.31	7.04	3.18	5.95	6.38
Viktor	6.61	7.89	7.22	7.13	6.95	4.06	6.50	6.62
NS 460	6.35	6.71	7.45	7.35	5.80	3.84	5.85	6.19
NS 462	7.81	6.75	7.11	7.89	6.80	3.64	4.65	6.38
NS 466	6.75	7.49	7.18	6.93	6.40	3.52	5.63	6.27
Average	6.42	7.02	7.18	6.91	6.81	3.68	5.61	6.23

	B	AB
LSD 0.05	0.13	0.36
0.01	0.17	0.48

DISCUSSION

In regions with suitable environments for growing malting barley, variety is the most important prerequisite for high yield and quality. In regions with less favorable environments as southern and eastern Europe, the Pannonian zone and other regions with similar environments, it is more difficult to produce high quality malting barley (OLESEN *et al*., 2011). In these regions, barley yield and quality are limited by water availability, heat stress and the duration of grain filling period. It has been realized that crop yield and quality are not determined by a single ecological factor but rather by several stress factors whose combined effect is more severe than their sum.

The optimum temperature range for full expression of agronomic traits and yield potentials of temperate cereals is 15-18°C. In the Pannonian climate zone, the mean temperature during GFP is higher than the optimum, exceeding even 25°C. Increased temperature during grain filling may be defined as (i) moderately high temperatures, when the mean temperature is between 15°C and 25-30°C, with the maximum temperature up to 32°C, and (ii) very high temperatures, defined as heat stress, when maximum daily temperature, ranges from 35°C to 40°C, and lasts for at least several days. In our study heat stress occurred in one of the seven growing seasons, 2003, while the other growing seasons with increased temperatures could be considered to belong to the growing seasons with moderately high temperatures. Drought during GFP tended to decrease GW (SAMARAH *et al*., 2009; RAJALA *et al*., 2011) and increase grain nitrogen concentration (HABERLE *et al*., 2008). ANDERSSON and HOLM (2011) found that temperature rise of 1°C during the whole growing period increased grain nitrogen concentration at maturity by 0.87-1.55 mg g^{-1}.

GRA (grains > 2.5 mm) is very important from the economical point of view. The mean GRA across eight cultivars and seven growing seasons of 85%, obtained in this study, may be supposed as economically acceptable. Heat stress reduces the percentage of maltable grains and the industrial yield. In our study share of the genetic factors in the total variation of GRA was relatively low, with heritability of 0.54, which indicated a necessity to find appropriate genetic resources for improving the grading value.

According to GW the malting barley varieties can be divided into three groups: >45g- big grain, 41-44g- medium grain, 37-40g- small grain (SCHELLING *et al*., 2003). The GW of 40 g will be a threshold for achieving a maximum screening percentage and varieties with a thousand grain weight lower than 36-37 g are not acceptable for malting (SAVIN and MOLINA-CANO, 2002). The varieties with medium size of grain are more suitable for malting because they soak uniformly and rapidly (MOLINA-CANO *et al.*, 2000). In our study, the cultivars of importance in the malting barley production had the GW ranging between 40-50 g, which is acceptable for malting industry.

Potential grain size is sensitive to environmental conditions prevailing before and during grain development, especially after anthesis and pollination (CALDERINI *et al*., 2006; BINGHAM *et al*., 2007). BINGHAM *et al*. (2007) detected the negative association between GW and pre-anthesis temperature in barley. Reduction in GW in barley is generally associated with a reduction of GFP, rather than slower grain filling rate, while grain filling rate is only modified under severe water deficit (PRŽULJ and MOMČILOVIĆ, 2003; PAYNTER and YOUNG, 2004). ANDERSON and HOLM (2011) found that GW was high when high temperature before anthesis were followed by low temperature after anthesis and low when low temperature before anthesis were followed by high temperature after anthesis. Both drought and water surplus reduce the quality and weight of barley grain. In the very dry and hot 2003, GW was 5.4% lower in regard to the 7-growing season period average. That means that the YIL reduction of 41% in that growing season resulted mainly from reduction of SN per unit area. This reduction was expected in sense of the very unfavorable weather conditions during the tillering period. It is known that spring barley in relation to winter barley in the Pannonian conditions had lower density but higher

GN (PRŽULJ and MOMČILOVIĆ, 2011). Low temperature till anthesis caused higher GN but lower GW than high temperature (ANDERSON and HOLM, 2011).

Genotype x environment interaction is referred to differences in reaction of different varieties to the environmental conditions; growing seasons and locations. Some varieties have stabile phenotypic performance in wide range of different environments, while others are characterized by significant variation over environments. Varieties with stable or slightly affected agronomic traits and quality are very valuable for growers and breeders. Due to that determination of the type of reaction of each variety to different environmental conditions as well as finding stabile varieties is of special importance. GW seems to be the most stable trait in our study and may be used in selection of varieties for this area.

Time of planting, weather conditions and genotype of the tested varieties determined the duration of VP and GFP. Varieties with short VP had long GFP and vice versa. These results are in agreement with our previous study where significant negative correlation was found between VP and GFP (PRŽULJ and MOMČILOVIĆ, 2003). Temperature is supposed to be the main factor determining GFP (PRŽULJ, 2001). Water supply and drought stress are other important factors influencing grain filling (MOLINA-CANO *et al*., 2000). When GFP is shortened as a consequence of high temperature, drought stress, or both, the yield of barley is decreased (CATTIVELLI *et al*., 2008).

YIL of spring barley is in a significant positive correlation with temperature accumulated during VP, while there is no significant relationship with rainfall in that period (PRŽULJ and MOMČILOVIĆ, 2008). These relations are expected due to two facts: (i) tillering of spring barley in the Pannonian zone takes place in spring months when generally there is enough water from winter reserves and current rainfall and (ii) spring months are rather cold and each temperature elevation increases the rate of growth, i.e., increases the tillering capacity. Faster development enables the accumulation of increased quantities of nitrogen needed for translocation during grain filling and earlier completion of the life cycle, before very high temperatures occur in the second half of June (PRŽULJ and MOMČILOVIĆ, 2001).

It could be said that production of malting barley is rather demanding, according to grain quality and biology of spring barley. A large number of traits have been proposed for malting barley assessment (FOX *et al*., 2003). Climatic conditions are not possible to control unlike the majority of factors influencing the production practice. In the analysis of temperature and precipitation effect on spring barley yield and quality in period from 1974 to 1996, on different locations spread across Germany SCHELLING *et al*., (2003) found that yields higher than 23 growing seasons period requires lower mean daily temperature than 18°C. In German environmental conditions to achieve above mentioned yields grain filling period must be at least 42 days. SCHELLING *et al*. (2003) indeed defined the ideal environmental conditions for producing top yielding and quality malting barley, which are not common even for malting barley belt in Europe. Definitely, an environment similar to the German's growing conditions is difficult to meet in the Pannonian zone. So, in order to grow high yielding and quality barley, extensive research in relation to breeding, variety selection and growing practice must be done.

CONCLUSIONS

Less favorable weather conditions; such as high temperatures and drought or cold temperatures and restricted available water during either vegetative or grain filling period reduces grain yield and quality of spring barley. The scope of the present results is limited to a single location and a rather narrow genetic base. To be more general, the research should be extended over a broader range of environmental conditions as well as larger genetic variability. Still, this study provided information that a sufficiently large genetic variability allows the selection of varieties with good agronomic and quality performances in conditions of the Pannonia zone.

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OSOBINE JAROG JEČMA U PANONSKOJ ZONI

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Ekološki uslovi u Panonskoj zoni odlikuju se umereno visokim temperaturama i delimičnim deficitom vode tokom perioda nalivanja zrna jarog ječma, mada su niske temperature i deficit vode mogući i u periodu do cvetanja. U sedmogodišnjim istraživanjima proučavano je variranje nekih fizioloških, morfoloških i produktivnih osobina jarog dvoredog ječma u uslovima Panonske zone, na lokalitetu Novi Sad. Prosečna dužina perioda od nicanja do cvetanja- vegetativni period, iznosila je 777°C sume aktivnih temperatura, perioda nalivanja zrna 782°C, visina stabljike 78 cm, broj klasova po m^{-2} 523, broj zrna po klasu 28,2, masa hiljadu zrna 43,2 g i prinos zrna 6,26 t ha^{-1}. Heritabilnost je varirala od 0,66 za prinos do 0,94 za vegetativni period i period nalivanja zrna. Varijabilnost svih ispitivanih osobina bila je određena genotipom, godinom i interakcijom genotip x godina. Ova istraživanja su potvrdila da je izbor odgovarajućih sorti za agroekološke uslove Panonske zone moguć iz dovoljno široke genetičke varijabilnosti. Intenzivan oplemenjivački rad, testiranje velikog broja sortu radi izbora najpovoljnijih za određeno područje i definisanje adekvatne tehnologije proizvodnje osnova su za postizanje visokog prinosa i dobrog kvaliteta pivskog ječma.

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