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PHOTOSYNTHETIC EFFICIENCY IN JUVENILE STAGE AND WINTER BARLEY BREEDING FOR IMPROVED GRAIN YIELD AND STABILITY

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SUMMARY

Photosynthetic efficiency parameters (Fv/Fm, ET0/ABS and PIABS) were investigated at the end of tillering stage of winter barley grown in stress environment (21.3% vol. water content of soil) and control (water content 30.4% vol.) in relation to grain yield per vegetative pot. The trial was conducted in vegetative pots according to the RBD method of two-factorial experiment with 10 winter barley cultivars (7 two-rowed and 3 six-rowed) and 2 treatments in 3 repetitions. The stressed variant was exposed to water reduction three times (end of tillering stage, flag leaf to beginning of heading stage, grain filling stage). From sowing to maturity, the air temperature varied from -3.9°C to 32.9°C and water content from 16.4 % to 39.0 % of soil volume in vegetative pot. Significant differences were found for grain yield among the cultivars. The short-term drought stress caused significant reductions in grain yield per pot. The photosynthetic efficiency parameters were significant between cultivars, but significant effects for treatments and interaction were only detected for the Fv/Fm parameter. Photosynthetic efficiency parameters did not have significant correlation coefficients with grain yield and its stability in both treatments. Stability indexes of the parameters PIABS and Fv/Fm had positive but not significant correlations with grain yield in stressed variant (0.465 and 0.452) and stability index of grain yield (0.337 and 0.481).

Key-words: winter barley cultivar, drought stress, photosynthetic efficiency parameters, grain yield, stability index

INTRODUCTION

Different winter barley cultivars showed various levels of genetic tolerance when they were exposed to different stress conditions. Therefore, investigations of interaction among genotypes (cultivars) and environments give useful information concerning yield stability and quality in barley (Blum, 1989; Ceccarelli et al., 1998, 2000; Lalić et al., 2007, 2009). Drought conditions frequently give characteristic of environments that cause stress effect on plant with unfavorable influence to physiological and morphological characters and to grain yield of agricultural plants. Bray et al. (2006) reported that the abiotic stress can decrease the grain yield of barley up to 75.4 % of record yield in the world. In the period from 1982 to 2009 (data of State Bureau for Statistics, Zagreb), the average grain yield of barley in the Republic of Croatia varied from 2.5 t/ha (2003) to 4.3 t/ha (2008). The lowest grain yield of barley was obtained in 2003, the extremely dry year. This is why

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the program of barley breeding for improved drought tolerance has been given priority.

Many authors (Blum, 1989; Oukarroum, 2007; Arnau et al., 1997; Morgan, 1999; Morgan et al., 2002; Kereša et al., 2009; Lalić et al., 2011) have estimated different methods that make possible to find and select drought tolerant genotypes (cultivars) in early stage of growth. Based on the pollen test, methods were developed and used to detect gene in wheat and barley responsible for the control of osmoregulation (or genes), and higher value of osmoregulation is associated with lower drought susceptibility (Morgan, 1999; Morgan et al., 2002). Oukarroum et al. (2007) pointed out that it is possible to rank barley cultivars with respect to drought tolerance on the base of drought factor index, which represents drought-induced reduction of the performance index (PI) derived from the chlorophyll *a* fluorescence data during drought stress in juvenile stage of plant. However, Kocheva et al. (2005) suggested that photosystem 2 was slightly affected by the osmotic treatment of barley seedlings although dehydration was considerable. The analysis of changes in chlorophyll *a* fluorescence kinetics provides detailed information on the structure and function of the photosynthetic apparatus, especiall PSII (Strasser et al., 1995 and 2004).

Our hypothesis that analysis of photosynthetic efficiency parameters in juvenile stage of barley growth might be successfully used for predicting drought tolerance, what could be useful in winter barley breeding program to improve grain yield and its stability. The aim of the present investigation was to compare some widely used parameters of photosynthetic performance (Fv/Fm, ET_0/ABS and PI_{ABS}) at the end of tillering stage. Agronomic characters were estimated before and after harvest of winter barley challenged by mild short-term drought stress.

MATERIAL AND METHODS

The trial was set up in vegetative pots according to the two factor RBD method with 10 winter barley cultivars (7 two-rowed and 3 six-rowed) and 2 treatments (B1- control and B2 - water-stress environment) in 3 repetitions during 2008/2009 vegetative season. From sowing to maturity, the air temperature ranged from -3.9°C to 32.9°C, the relative air humidity from 25.8 to 99.0% and water content from 16.4% to 39.0% of soil volume per vegetative pot. The pots were filled with topsoil (0 to 30 cm) from the experimental field of Agricultural Institute Osijek. The soil in all pots had identical mechanical, physical and chemical composition. It contained 29.2% clay, 34.9% silt, 34.7% coarse silt, 1.17% fine sand and 0.03% coarse sand. The pH in 1 M KCl was 6.24. The soil contained 2.73% humus, 0.133 mg/100 g N, 16.4 mg/100 g P_2O_5 and 36.21 mg/100 g K_2O (analyses were conducted in the Institute for Soil in Osijek, the Republic of Croatia). The pore volume was 49%, absolute water capacity 39% and air capacity 10% (Romić et al., 2006). The pots were 20 cm in diameter at the bottom and 30 cm at the top, 25 cm deep. Soil volume per pot was 9800 cm^3, measured ten days after filling and soil saturation with water. Plant material was sown seven days after filling on 29 December 2008 sowing 32 seeds per pot. The sowing depth was 3.5 cm. Seeds were sown in 16 hills arranged in a 20-cm circle, with 3.9 cm apart between the hills. The stress variant (B2) was exposed to three mild short-terms water reduction stress: mild short-terms stress for three times: at the end of the tillering stage (EC 29), during the flag leaf and the beginning of heading stage (EC 49/51) and during the grain filling period (EC 75/85) (Reiner et al., 1992) (Table 1). Water content of the potted soil was approximately monitored daily by a portable *Watermark-soil moisture sensor* (two controls per treatment), by weighting every pot at 39% vol. water content (absolute water capacity of soil) of control treatment (B1) and drought stress treatment (B2) and by weighting every pot once a day between 9 and 11 hours in the morning during inducing of drought stress. Water content was calculated as 39% vol. water content – volume percent of water deficit (Table 1). The photosynthetic efficiency parameters was monitored immediately after inducing maximum drought stress in al three stages of growth, but in this paper only data of the photosynthetic efficiency parameters are presented. They were monitored in juvenile stage of growth (EC 29) (Table 1). Water was added up to 39% vol. in every pot of both treatments immediately after monitoring the photosynthetic efficiency parameters.

Three photosynthetic efficiency parameters (Fv/Fm - maximum quantum yield of primary photochemistry, ET_0/ABS - quantum yield of electron transport and PI_{ABS} - photosynthetic performance index) were observed at the end of the tillering stage (EC 29). Measurements of these parameters were carried out on the second leaf from the top (n=3 plants per pot, 180 plants in total for both treatments) by a portable fluorometer *Handy Plant Efficiecy Analyser (Handy* PEA, *Hansatech Instruments Limited*, King's Lynn, Norfolk, UK) according to Strasser et al. (1995) (Table 1). Strasser et al. (1995 and 2004), Oukarroum et al. (2007), Lin et al. (2009) described in details the photochemical and physiological aspects and methods of the monitoring and calculation of the photosynthetic efficiency parameters Fv/Fm, ET_0/ABS and PI_{ABS} by using the values at the steps OJIP of the polyphasic rising transient (JIP-test).

Agronomic characters of winter barley are listed below:

- Analyses based on ten randomly chosen plants in each pot (n=10 plants per pot, 600 plants in total for both treatments): grain number per primary spike

- Analyses based on vegetative pot (n=1 per pot, 60 pots in total for both treatments): spike number, 1000 grain weight, biomass weight (total weight of air-dry plants without root), harvest index (ratio between grain yield and biomass weight per pot) and grain yield.

The indices of stress tolerance of cultivars were calculated as follows:

Yield stability index (YiSI) for each cultivar (Bouslama and Schapaugh, 1984; cit. Talebi et al., 2009).

The following formulas were used in this paper: YiSI= YiB2/YiB1

YiB1= grain yield of each winter barley cultivar in B1 treatment (control)

YiB2= grain yield of each winter barley cultivar in B2 treatment

i = determinate barley cultivar (1 to 10)

The above formula was used for estimation and application of photosynthetic efficiency parameters for investigation of short-term drought tolerance (grain yield was changed with photosynthetic efficiency parameters).

Table 1. Description of the trial method

Tablica 1. Opis metode pokusa

Factor A: Ten winter barley cultivars: *Faktor A: Deset kultivara ozimoga ječma*	Two-rowed *(Dvoredni)*: Barun, Bingo, Zlatko, Vanessa, Rex, Tiffany and Bravo Six-rowed *(Višeredni)*: Lord, Favorit and Titan	
Stage of growth *Stadij razvoja*	Factor B (water regime): Maintaining soil moisture content, % vol. *Faktor B (Vodni režim): Održavanje sadržaja vlage u tlu, % vol.*	
	B1=control *B1= kontrola*	B2= short-term stress condition – water not supplied three times *B2=kratkotrajni stres uslijed suše – tri puta nije dodana voda*
a) end of tillering stage (EC29)*: 7 - 12 March 2009 a) Kraj busanja (EC 29)*: 7. do 12. ožujaka	30.4 - 38.4	21.3 – 28.7
b) from the appearance of flag leaf to the beginning of ear emergence (EC49/51): 22 - 25 April 2009 *b) Od pojave lista zastavičara do početka klasanja (EC49/51): 22. do 25. travnja*	27.2 - 35.5	16.4 - 20.0
c) during grain filling period (EC75/85): 19 - 21 May 2009 *c) U vrijeme nalijevanja zrna (EC75/85): 19. do 21. svibnja*	26.1 - 31.9	20.8 - 24.2
From sowing to the harvest *Od sjetve do žetve*	22.2 - 39.0	16.4 - 39.0

* Eucarpia Code (EC) Reiner et al. (1992)

Shortcuts for next comments:

PI_{ABS} – Photosynthetic performance index *(indeks fotosintetske učinkovitosti);* Fv/Fm – maximum quantum yield of primary photochemistry II *(maksimalni kvantni prinos fotosistema II);* ET_0/ABS – quantum yield of electron transport *(kvantni prinos elektronskoga transporta);* GNS- grain number per spike *(broj zrna po klasu);* SNP - spike number per pot (*broj klasova po loncu);* BWP - biomass weight per pot, g *(biomasa po loncu, g);* TGW - 1000 grain weight, g (*masa 1000 zrna, g);* HI - harvest index (*žetveni indeks);* GYP - grain yield per pot, g *(prinos zrna po loncu, g);* SI-PI_{ABS}, SI-Fv/Fm and SI-ET_0/ABS-stability index of PI_{ABS}, Fv/Fm and ET_0/ABS- respectively *(indeksi stabilnosti parametara PI_{ABS}, Fv/Fm i ET_0/ABS - istim slijedom);* YiSI - Stability index of grain yield *(indeks stabilnosti prinosa zrna)*

RESULTS AND DISCUSSION

Variance analysis of the examined photosynthetic efficiency parameters of winter barley showed that effects of cultivar, treatment and interaction were highly significant for the Fv/Fm parameter ($P<0.01$) (Table 2).

Table 2. Variance and F-test for differences between cultivars, treatments and interactions in the trial of winter barley under control treatment (B1) and short-term water stress condition treatment (B2) in the end of tillering stage (EC29)

Tablica 2. Varijanca i F - test razlika između kultivara, tretmana i interakcije u pokusu ozimoga ječma s kontrolnim tretmanom (B1) i u tretmanu kratkotrajnoga stresa zbog nedostatka vode (B2) u fazi kraja busanja (EC29)

Source of variability/ *Izvor varijabiliteta*	df	Fv/Fm		ET_0/ABS		PI_{ABS}	
		MS	F-test	MS	F-test	MS	F-test
B1 and B2 treatment (n=180)/*B1 i B2 tretman (n=180)*							
Block/*Blok*	2	0.0001015	1.571	0.003070	8.940**	0.11443	3.901*
Combination/*Komb*	19	0.0003784	5.856**	0.000788	2.296**	0.07606	2.593**
Error/*Ostatak*	158	0.0000646		0.000343		0.02933	
Cultivar/*Kultivar*	9	0.0004050	6.269**	0.001369	3.985**	0.11249	3.835**
Treatment/*Tretman*	1	0.0018538	28.693**	0.000184	0.536	0.26075	8.890**
Interaction/*Interakcija*	9	0.0001876	2.903**	0.000276	0.805	0.01911	0.652
B1 treatment (n=90)/*B1 tretman (n=90)*							
Block/*Blok*	2	0.0011512	41.311**	0.003100	7.208**	0.15647	4.182*
Cultivar/*Kultivar*	9	0.0004320	11.789**	0.001022	2.377*	0.08517	2.276*
Error/*Ostatak*	78	0.0000366		0.000430		0.03742	
B2 treatment (n=90)/*B2 tretman (n=90)*							
Block/*Blok*	2	0.0000375	0.512	0.000511	1.726	0.02360	0.980
Cultivar/*Kultivar*	9	0.0001612	2.199*	0.000622	2.103*	0.04643	1.928
Error/*Ostatak*	78	0.0000733		0.000296		0.02408	

F - test is significant *P<0.05; **P<0.01 / *F - test je značajan *P<0,05;**P<0,01*

Also, cultivar and treatment had highly significant effects on the PI_{ABS} parameter, while only cultivar had a highly significant effect on the ET_0/ABS parameter (Table 2). Separately in treatment B1 highly significant ($P<0.01$) differences between cultivars were estimated for Fv/Fm parameter while for parameters ET_0/ABS and PI_{ABS} significant differences were estimated at the level $P<0.05$. Significant differences ($P<0.05$) between barley cultivars were estimated for Fv/Fm and ET_0/ABS parameters in B2 treatment (Table 2).

On the base of the same trial with winter barley (Kovačević et al., 2010), significant differences among cultivars were found for nine agronomic characters. Furthermore, the results showed that water stress caused significant reductions in most of the examined characters except spike length and grain number per spike. Significant interaction between cultivars and treatments were found out for plant height and culm length, grain number per spike and 1000 grain weight. The other characters including grain yield showed no significant interaction. In both treatments (B1 and B2) the 2-rowed cultivars Zlatko, Barun and Bingo had better results for grain yield per pot compared to the 6-rowed cultivars Lord, Favorit and Titan and the remaining 2-rowed cultivars Bravo, Rex, Vanessa and Tiffany (Kovačević et al., 2010).

Values of three photosynthetic efficiency parameters (Fv/Fm - maximum quantum yield of primary photochemistry, ET_0/ABS - quantum yield of electron transport and PI_{ABS} - photosynthetic performance index) and their stability index, which were estimated at the end of the tillering stage, are shown in Table 3 and 4. Values of the agronomic characters including grain yield per pot and its stability are also shown in Table 3 and 4. The highest value of PI_{ABS} was estimated for the six-rowed barley cultivar Lord in B1 treatment, but this cultivar had an unfavorable stability index of this parameter and stability index of grain yield. Better stability indices of photosynthetic efficiency parameters were found out for the two-rowed barley cultivars Barun, Bingo and Zlatko which had high grain yield in both treatments (Table 3 and 4). Favorable stability of grain yield and higher grain yield of the above two-rowed cultivars in relation to six-rowed barley cultivars were observed in the field trials in several years and locations (Lalić et al., 2007 and 2009).

The photosynthetic efficiency parameters $PI_{ABS,}$ Fv/Fm and ET_0/ABS were not significantly correlated with grain yield and its stability in both treatments (Table 5). Direct components of grain yield (grain number per spike, spike number per pot and 1000-grain weight) were not significantly correlated with grain yield either in B1 treatment or B2 treatment. However grain number per spike was negative significant correlated in B1 treatment (-0.770) and B2 treatment (-0.626) with stability index of grain yield, while 1000-grain weight was positive significant correlated in B1 treatment (0.798) and B2 treatment (0.717) with stability index of grain yield (Table 5). This confirmed that two-rowed barley cultivars with less grain number per spike and higher 1000 grain weight have better grain yield stability.

Table 3. Photosynthetic efficiency parameters, agronomic characters and grain yield of winter barley cultivars in B1 and B2 treatments

Tablica 3. Parametri učinkovitosti fotosinteze, agronomska svojstva i prinos zrna Kultivara ozimoga ječma u tretmanima B1 i B2

Cultivars in treatment B1	PI_{ABS}	Fv/Fm	ET_0/ABS	GNS	SNP	BWP g	TGW g	HI	GYP g
Barun	1.395	0.832	0.391	25.7	36.3	76.65	48.94	0.489	37.30
Bingo	1.262	0.815	0.403	23.7	37.0	81.86	50.22	0.451	36.90
Zlatko	1.387	0.824	0.410	25.5	43.3	90.64	47.60	0.464	42.09
Vanessa	1.423	0.824	0.407	20.2	36.7	82.78	52.31	0.400	33.08
Rex	1.396	0.820	0.409	24.6	41.0	88.09	47.91	0.417	36.80
Tiffany	1.433	0.831	0.393	21.7	36.3	76.03	44.28	0.341	25.93
Bravo	1.336	0.828	0.387	26.5	39.7	97.23	45.62	0.397	38.60
Lord	1.633	0.831	0.422	32.7	29.3	84.77	43.04	0.441	37.40
Favorit	1.464	0.831	0.404	32.6	31.3	88.81	40.91	0.421	37.52
Titan	1.350	0.822	0.398	33.0	28.7	70.05	43.20	0.496	34.56
Average/*Prosjek*	1.408	0.826	0.402	26.6	36.0	83.69	46.40	0.432	36.02
$LSD_{0.05}$	0.182	0.0057	0.0196	1.96	4.02	7.08	1.85	0.048	4.82
$LSD_{0.01}$	n.s.	0.0076	n.s.	2.58	5.51	9.70	2.88	0.066	6.61
Cultivars in treatment B2	PI_{ABS}	Fv/Fm	ET_0/ABS	GNS	SNP	BWP g	TGW g	HI	GYP g
Barun	1.399	0.824	0.401	25.7	31.3	72.29	51.05	0.494	35.72
Bingo	1.230	0.814	0.396	23.7	37.7	81.62	50.01	0.436	35.61
Zlatko	1.354	0.825	0.402	24.9	39.3	86.69	47.72	0.459	39.76
Vanessa	1.369	0.822	0.403	20.3	34.3	73.39	51.66	0.454	33.26
Rex	1.266	0.815	0.398	23.7	40.3	82.37	47.44	0.418	34.43
Tiffany	1.309	0.822	0.395	23.9	33.0	68.90	41.57	0.361	24.87
Bravo	1.258	0.819	0.397	26.2	40.7	92.35	44.28	0.374	34.52
Lord	1.415	0.817	0.420	32.6	29.0	79.39	42.74	0.407	32.29
Favorit	1.433	0.827	0.404	31.6	29.3	76.14	37.89	0.42	31.96
Titan	1.284	0.822	0.388	36.3	30.0	65.78	41.25	0.497	32.71
Average/*Prosjek*	1.332	0.822	0.400	26.9	34.5	77.89	45.56	0.432	33.51
$LSD_{0.05}$	n.s.	0.0081	0.0162	1.73	3.36	2.40	1.62	0.050	3.60
$LSD_{0.01}$		n.s.	n.s.	2.28	4.60	3.28	2.22	0.069	4.94

n.s. = differences are not significant / *razlike nisu značajne*

Stability indices of the parameters PI_{ABS} and Fv/Fm in B1 treatment showed favorable positive correlation coefficients with 1000-grain weight (0.352 and 0.338, respectively), harvest index (0.415 and 0.363, respectively) and grain yield (0.287 and 0.211, respectively) (Table 6). However, these correlation coefficients were not significant. Also, stability indices of the parameters PI_{ABS} and Fv/Fm had positive but no significant correlations with 1000-grain weight (0.354 and 0.244, respectively), harvest index (0.584 and 0.565, respectively) and grain yield (0.465 and 0.452, respectively) in the water stress variant (B2 treatment, Table 6). The above stability indices of photosynthetic efficiency parameters had positive but no significant correlations with the stability index of grain yield (0.337 and 0.481, respectively, Table 6).

Table 4. Stability indices of photosynthetic efficiency parameters and grain yield stability indices of winter barley cultivars

Tablica 4. Indeksi stabilnosti parametara učinkovitosti fotosinteze i stabilnosti prinosa zrna kultivara ozimoga ječma

Cultivars/*Kultivar*	SI-PI_{ABS}	SI-Fv/Fm	SI-ET_0/ABS	YiSI
Barun	1.0029	0.9904	1.0254	0.9576
Bingo	0.9746	0.9988	0.9821	0.9650
Zlatko	0.9762	1.0012	0.9792	0.9446
Vanessa	0.9621	0.9976	0.9914	1.0054
Rex	0.9069	0.9939	0.9724	0.9356
Tiffany	0.9135	0.9892	1.0059	0.9591
Bravo	0.9416	0.9891	1.0278	0.8943
Lord	0.8665	0.9832	0.9949	0.8634
Favorit	0.9788	0.9952	0.9991	0.8518
Titan	0.9511	1.0000	0.9745	0.9465

Table 5. Correlation coefficients between photosynthetic efficiency parameters, stability indices of photosynthetic efficiency parameters, agronomic characters, grain yield and yield stability in B1 treatment (above diagonal) and B2 treatment (below diagonal) of winter barley cultivars

Tablica 5. Koeficijenti korelacije između parametara učinkovitosti fotosinteze, indeksa stabilnosti parametara učinkovitosti fotosinteze, agronomskih svojstava, prinosa zrna i stabilnosti prinosa zrna za tretman B1 (iznad dijagonale) i tretman B2 (ispod dijagonale) kod kultivara ozimoga ječma

	PI_{ABS}	Fv/Fm	ET_0/ABS	GNS	SNP	BWP	TGW	HI	GYP	YiSI
PI_{ABS}		0.643	0.589	0.396	-0.459	0.043	-0.451	-0.160	-0.076	-0.516
Fv/Fm	0.639		-0.188	0.266	-0.295	0.033	-0.505	-0.236	-0.173	-0.461
ET_0/ABS	0.678	-0.050		0.248	-0.171	0.138	-0.027	0.157	0.292	-0.222
GNS	0.245	0.189	0.081		-0.704	-0.038	-0.792	0.482	0.361	-0.770
SNP	-0.669	-0.416	-0.297	-0.630		0.524	0.590	-0.224	0.258	0.380
BWP	-0.256	-0.331	0.241	-0.284	0.749		0.009	-0.281	0.583	-0.463
TGW	-0.182	-0.283	-0.009	-0.721	0.455	0.186		0.059	0.064	0.798
HI	0.190	0.288	-0.184	0.208	-0.255	-0.375	0.397		0.612	0.007
GYP	-0.038	-0.032	0.078	-0.116	0.457	0.567	0.544	0.545		-0.370
YiSI	-0.360	-0.075	-0.478	-0.626	0.270	-0.324	0.717	0.381	0.069	

$r=0.6021$ $p<0.05$; $r=0.7348$ $p<0.01$

Conversely, Kovačević et. al. (2011) applied the same procedureon ten cultivars of winter wheat in juvenile stage and obtained significant correlation coefficients between stability indices of the photosynthetic efficiency parameters and important agronomic characters of mature plants, such as the number of grain per spike, 1000-grain weight, harvest index, biomass yield and grain yield per pot.

Table 6. Correlation coefficients between stability indices of photosynthetic efficiency parameters, photosynthetic efficiency parameters, agronomic characters, grain yield and yield stability of winter barley cultivars in B1 and B2 treatments

Tablica 6. Koeficijenti korelacije između indeksa stabilnosti parametara učinkovitosti fotosinteze, parametara učinkovitosti fotosinteze, agronomskih svojstava, prinosa zrna i stabilnosti prinosa zrna kultivara ozimoga ječma za B1 i B2

Stability index/*Indeks stabilnosti*	Treatment/*Tretman*	PI_{ABS}	Fv/Fm	ET_0/ABS	GNS	SNP
SI-PI_{ABS}	B1	-0.602	-0.120	-0.443	-0.168	0.220
	B2	0.086	0.526	-0.405	-0.191	0.052
SI-Fv/Fm	B1	-0.638	-0.674	0.011	-0.156	0.244
	B2	-0.274	0.220	-0.557	-0.118	0.262
SI-ET_0/ABS	B1	0.078	0.710	-0.633	-0.083	0.025
	B2	0.242	0.263	0.129	-0.110	-0.104
Stability index/*Indeks stabilnosti*	Treatment/*Tretman*	BWP	TGW	HI	GYP	YiSI
SI-PI_{ABS}	B1	-0.077	0.352	0.415	0.287	0.337
	B2	-0.067	0.354	0.584	0.465	
SI-Fv/Fm	B1	-0.127	0.338	0.363	0.211	0.481
	B2	-0.077	0.244	0.565	0.452	
SI-ET_0/ABS	B1	0.187	-0.081	-0.248	-0.085	-0.206
	B2	0.121	-0.020	-0.298	-0.191	

$r=0.6021$ $p<0.05$

On the base of this research it is possible to suggest that stronger drought stress in juvenile stage of winter barley growth can result in higher benefit while applying of photosynthetic efficiency parameters in breeding of winter barley to improve grain yield and its stability.

CONCLUSION

Photosynthetic efficiency parameters (Fv/Fm, ET_0/ABS and PI_{ABS}) which were investigated at the end of tillering stage of winter barley growth in stressful and control variant of trial did not have significant correlations with grain yield and its stability.

Stability indexes of parameters PI_{ABS} and Fv/Fm had positive but not significant correlations with grain yield in stressful variant (0.465 and 0.452) and stability index of grain yield (0.337 and 0.481). Also, direct components of grain yield (grain number per spike, spike number per pot and 1000 grain weight) had not significant correlations with grain yield in both control variant (from 0.064 to 0.361) and (from -0.116 to 0.544) stressful variant.

The biggest influence to yield stability had grain number per spike (r= -0.770 control variant; r= -0.626 stressful variant) and 1000 grain weight (r= 0.798 control variant; r= 0.717 stressful variant).

Stability indexes of parameters PI_{ABS} and Fv/Fm, which were calculated on the basis of data of measurement at the end of tillering stage of winter barley growth, can be interesting for screening winter barley genotypes before field-testing, because there is a tendency of positive correlation coefficients with grain yield and its stability.

Two-rowed winter barley cultivars Barun, Bingo and Zlatko, which gave very good results regarding yield and its stability in agricultural production of the Republic of Croatia, have good stability indices of PI_{ABS} and Fv/Fm photosynthetic efficiency parameters.

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REFERENCES

1. Arnau, G., Monneveux, P., This, D., Alegre, L. (1997): Photosynthesis of six barley genotypes as affected by water stress. Photosynthetica 34: 67-76.
2. Blum, A. (1989): Osmotic adjustment and growth of barley genotypes under drought stress. Crop Science 29: 230-233.
3. Bray, A.E., Bailey-Serres, J., Weretilnyk, E. (2006): Responses to abiotic stresses. In: Buchanan, B., Gruissem, W., Jones, R. (ed.), Biochemistry and Molecular Biology of Plants. Sixth impression (paperback), Singapore: 1159-1160.
4. Ceccarelli, S., Grando, S., Impiglia, A. (1998): Choice of selection strategy in breeding barley for stress environments. Euphytica 103: 307-318.
5. Ceccarelli, S., Grando, S., Tutwiler, R., Baha, J., Martini, A. M., Salahieh, H., Goodchild, A., Michael, M. (2000): A methodological study on participatory barley breeding I. Selection phase. Euphytica 111: 91-104.
6. Kereša, S., Barić, M., Horvat., M, Habuš Jerčić, I. (2009): Drought tolerance mechanisms in plants and their genetic base in wheat. Sjemenarstvo (Summary is in English) 25: 35-45.
7. Kocheva, K.V., Busheva, M.C., Georgiev, G.I., Lambrev, P.H., Goltsev, V. N. (2005): Influence of short-term osmotic stress on the photosynthetic activity of barley seedlings. Biologia plantarum 49: 145-148.
8. Kovačević, J., Lalić, A., Abičić, I., Cesar, V., Dvojković, K., Kovačević, V., Kovačević, M. (2010): Influence of water deficit stress to agronomic characters of winter barley cultivars. 45th Croatian and 5th International Symposium of Agriculture, Opatia, Croatia, Summary 157.
9. Kovačevič, J., Kovačević, M., Cesar,V., Drezner, G., Lalić, A., Lepeduš, H., Jurković, Z., Dvojković, K., Katanić, Z., Kovačević, V. (2011): Photosynthetic efficiency in juvenile stage of growth and breeding of winter wheat to improve grain yield and its stability. 46th Croatian & 6th International Symposium of Agriculture, Opatia, Croatia, Summary sa 2011-a 0311.
10. Lalić, A., Kovačević, J., Šimić, G., Drezner, G., Guberac, V. (2007): Environmental effects on grain yield and malting quality parameters of winter barley. Cereal Research Communications 35: 709-712.
11. Lalić, A., Kovačević, J., Novoselović, D., Šimić, G., Abičić, I., Guberac, V. (2009): Agronomic and quality traits of winter barley varieties (Hordeum vulgare L,) under growing conditions in the Republic of Croatia. Agriculturae Conspectus Scientificus 74 (4): 283-289.
12. Lalić, A., Guberac, V., Novoselović, D., Goreta, S., Dumančić, G., Urlić, B., Drezner, G., Dvojković, K., Abičić, I., Kovačević, J. (2011.): Učinak dušika i zasušivanja na svojstva biljke kod ozimih sorti ječma. Zbornik radova/ Proceedings 46. hrvatski i 6. međunarodni simpozij agronoma (46tth Croatian & 6th International Symposium on Agriculture), Milan Pospišil (ur.): 596-600 .
13. Lin, Z.H., Chen, L.S., Chen, R.B., Zhang, F.Z., Jiang, H.X., Tang, N. (2009): CO_2 assimilation, ribulose-1,5-bisphosphate carboxylase/oxygenase, carbohydrates and photosynthetic electron transport probed by the JIP-test, of tea leaves in response to phosphorus supply. BMC Plant Biology 9: 43.
14. Morgan, J.M. (1999): Pollen grain expression of a gene controlling differences in osmoregulation in wheat leaves: a simple breeding method. Australian Journal of Agriculture Research 50: 953-962.
15. Morgan, J.M., Holland, J.F., Read, B.J. (2002) Evaluation in barley lines of a simple pollen method for breeding for drought tolerance in wheat. Cereal Research Communications 30: 315-322.

16. Oukarroum, A., El Madidi, S., Schansker, G., Strasser, R. J. (2007): Probing the responses of barley cultivars (*Hordeum vulgare* L.) by chlorophyll *a* fluorescence OLKJIP under drought stress and re-watering. Environmental and Experimental Botany 60: 438-446.
17. Reiner, L., Buhlmann, V., Graser, S., Heißenhuber, A., Klasen, M., Pfefferkorn, V., Spanakakis, A., Straß, F. (1992.): Weizen Aktuell, Deutsche Landwirtshcaftliche Gesellschaft (DLG) Verlag, Frankfurt am Main.
18. Romić, D., Petošić, D., Stričević, I., Ondrašek, G., Rus, B., Kondres, N., Maurović, N. (2006.): Hidropedološka studija s idejnim rješenjem navodnjavanja proizvodnih površina Poljoprivrednog instituta Osijek. Zagreb: 1-87.
19. Strasser, R.J., Srivastava, A., Govindjee (1995): Polyphasic chlorophyll a fluorescence transient in plants and cyanobacteria. Photochemistry and Photobiology 61:32-42.
20. Strasser, R.J., Tsimilli-Michael, M., Srivastava, A. (2004): Analysis of the chlorophyll *a* fluorescence transient. In: Chlorophyll *a* Fluorescence: A Signature of Photosynthesis. Edited by: Papageorgiou, G.C., Govidjee. Advances in Photosynthesis and Respiration19: Dordrecht, Springer, The Netherlands, 321-362. Talebi, R., Fayaz, F., Naji, A. M. (2009): Effective selection criteria for assessing drought stress tolerance in durum wheat (*Triticum durum* Desf.). General and Applied Plant Physiology 35: 64-74.

FOTOSINTETSKA UČINKOVITOST U MLADOME STADIJU RAZVOJA I OPLEMENJIVANJE OZIMOGA JEČMA NA PRINOS ZRNA I NJEGOVU STABILNOST

SAŽETAK

Istraživana je učinkovitost parametara fotosinteze (Fv/Fm, ET_0/ABS i PI_{ABS}) mjerenih krajem busanja ozimoga ječma u stresnoj varijanti (sadržaj vode od 21,3% vol.) i kontrolnoj varijanti pokusa (30,4%) u odnosu na prinos zrna po vegetacijskoj posudi. Pokus je postavljen u vegetacijskim loncima po metodi RBD s dva činitelja, a to su 10 kultivara ozimoga ječma (7 dvorednih i 3 višeredna) i 2 tretmana u tri ponavljanja. Ispitivani kultivari u jednoj varijanti tretmana izloženi su tri puta umjerenom kratkotrajnom stresu zbog suše i to na kraju busanja, u fazi lista zastavičara i početka klasanja te u fazi nalijevanja zrna. Od sjetve do žetve temperatura zraka varirala je od -3,9°C do 32,9°C, a sadržaj vlage od 16,4% do 39,0% od volumena tla u loncu. Značajne razlike između kultivara utvrđene su za urod zrna. Kratkotrajni višekratni stres zbog suše prouzročio je značajno smanjenje uroda zrna u odnosu na kontrolni tretman. Parametri Fv/Fm, ET_0/ABS i PI_{ABS} bili su značajno različiti između kultivara, ali značajna razlika između tretmana i značajna interakcija utvrđena je samo za parametar Fv/Fm. Parametri fotosintetičke učinkovitosti nisu dali značajne koeficijente korelacije s prinosom zrna i stabilnosti prinosa zrna kultivara u oba tretmana. Indeksi stabilnosti parametara PI_{ABS} i Fv/Fm u pozitivnim su nesignifikantnim korelacijama s prinosom zrna u varijanti stresa (0,465 i 0,452) i s indeksom stabilnosti uroda zrna (0,337 i 0,481).

Ključne riječi: kultivar ozimoga ječma, suša, stres, učinkovitost fotosinteze, urod zrna, indeks stabilnosti

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