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Chlorophyll fluorescence parameters and grain yield of winter wheat genotypes

Valentina Španić[1], Marija Viljevac[2], Georg Drezner[1], Hrvoje Lepeduš[2]

[1]*Department for Breeding & Genetics of Small Cereal Crops, Agricultural Institute Osijek, Juzno Predgradje 17, Osijek, Croatia (valentina.spanic@poljinos.hr)*
[2]*Department of Agrochemical Laboratory, Agricultural Institute Osijek, Juzno Predgradje 17, Osijek, Croatia*

Abstract
Photosynthesis often reduces in plants growing under abiotic and biotic stresses, and due to that winter wheat productivity can be limited. The objective of this study was to assess photosynthetic efficiency and find possible correlations with grain yield of different winter wheat genotypes. Chlorophyll *a* fluorescence of flag leaves was measured by Plant Efficiency Analyser (PEA, Hansatech, UK) during 2011/2012 growing season in order to bring out some biophysical parameters of PSII functioning calculated by JIP test. It was detected that investigated genotypes have significantly different photosynthetic efficiency but significant correlations between grain yield and photosynthetic parameters were not found. In conclusion, the final grain yield of winter wheat does not depend on photosynthesis in optimal conditions, but on another physiological process which may be related with energy usage efficiency or assimilate mobilization. Further efforts to improve grain yield need to be focused on extending the duration of efficient photosynthesis and improving the conversation to grain.

Key words: winter wheat, chlorophyll fluorescence, grain yield

Introduction

Wheat (*Triticum aestivum* L.) is one of the most widely grown crops through the world. Grain yield and quality are the most important quantitative traits of the winter wheat and key objective of wheat breeders, producers and processors, but also they are under the great influence of environmental effects (Drezner et al., 2007). Grain yield in wheat is a polygenic trait and is also influenced by a number of environmental factors including temperature at emergence, vegetative stage, grain filling period and grain formation (Ahmad et al., 2011). Winter wheat productivity is limited by a lot of factors, the most important of which is the ability of the plants to absorb photosynthetically active radiation (Slapakauskas and Ruzgas, 2005). It is a great significance to study the photosynthesis during the senescence of wheat leaves because it contributes greatly to grain yield. The primary expression of leaf senescence is the breakdown of chlorophyll and the decline of photosynthetic activity. It is generally accepted, that the genotypes which are able to sustain photosynthesis in flag leaf for longer time, tend to yield more (Guoth et al., 2009). Many institutions worldwide are trying to develop indirect assessment methods, to find out some correlations between physiological and agronomic characteristics of winter wheat (Somerville, 2001; Long et al., 2006; Aliyev, 2010). Chlorophyll fluorescence analysis has become one of the most powerful and widely used techiques available to plant physiologists and ecophysiologists (Zhang et al., 2010). The objective of this study was to assess chlorophyll fluorescence parameters and possible correlations with grain yield of different winter wheat genotypes.

Material and methods

In the Table 1. the origin and pedigree of tested wheat genotypes is summarized.

Table 1. Origin and pedigree of the ten examined winter wheat genotypes

Nr	Genotype	Origin	Pedigree
1	Antonija	HR, PIO, 2011	Victo 2/Brea
2	Divana	HR, Jost, 1996	Favorit/5/Cirpiz/4/Jang/Kwang/2/A+66/ Comanche/3/Velvet
3	Felix	HR, PIO, 2007	Srpanjka/Kom.Bg.160-86
4	Katarina	HR, PIO, 2006	Osk.5B.4-1-94/Osk.5.140-22-91
5	Lucija	HR, PIO, 2001	Srpanjka/Kutjevcanka
6	Osk.112/11	line	-
7	Rebeka	HR, PIO, 2011	BR442//Renan
8	Srpanjka	HR, PIO[a], 1989	Osk.4.50-1/Zg.2696
9	Vulkan	HR, PIO, 2009	Osk.3.343-1-97/FS811-98//KRH44-99
10	Žitarka	HR, PIO, 1985	Osk.6.30-20/Slavonka// Osk.6.78-1-73/Kavkaz

[a]PIO-Agricultural Institute Osijek, Croatia

The field trial was set up at the Agricultural Institute Osijek (45º32’N, 18º44’E). The soil type is eutric cambisol. Standard agro-technical measures were made. Genotypes were sown in plots of 2.5 m length and width 1.08 m. The experimental layout was a randomized complete block design with four replications. Chlorophyll fluorescence measurements were carried out by Plant Efficiency Analyser (PEA, Hansatech, UK) at the flowering stage (30th and 31st May 2012) of winter wheat genotypes (Zadok's et al., 1974). Measurements were taken in the morning on six flag leaves per plot which were adapted to the dark for about 30 min before measurements. Changes in fluorescence were measured for 1 s, starting from 50 ms after the onset of illumination. The obtained data were used in OJIP test (Strasser et al., 2004) in order to calculate several biophysical parameters of PSII functioning such as maximum quantum yield of PSII (F_v/F_m) and photosynthetic performance index (PI_{ABS}). After harvest, grain yield was measured.

Analyses of variance were calculated by using the GLM procedure of SAS/STAT 9.1. (Sas Institute Inc. 2004) with a level of significance threshold set at α= 0.05. The mean values of investigated parameters were compared using *post hoc* LSD test.

Results and discussion

Analysis of variance revealed highly significant differences in grain yield, F_v/F_m and PI_{ABS} between investigated genotypes (Table 2).

Table 2. Analysis of variance for grain yield, F_v/F_m and PI_{ABS}

Source	Df	Sum of squares		
		Grain yield	F_v/F_m	PI_{ABS}
Model	9	3189.0**	0.00141*	4.9179**
Error	18	1303.2	0.00092	2.0833

***,**,*=significant at *P*<0.001, 0.01 and 0.05, respectively; ns=not significant (*P*>0.05)

The highest grain yield had cultivar Vulkan (102.43 dt ha^{-1}) and line Osk.112/11 (100.44 dt ha^{-1}) (Figure 1.).

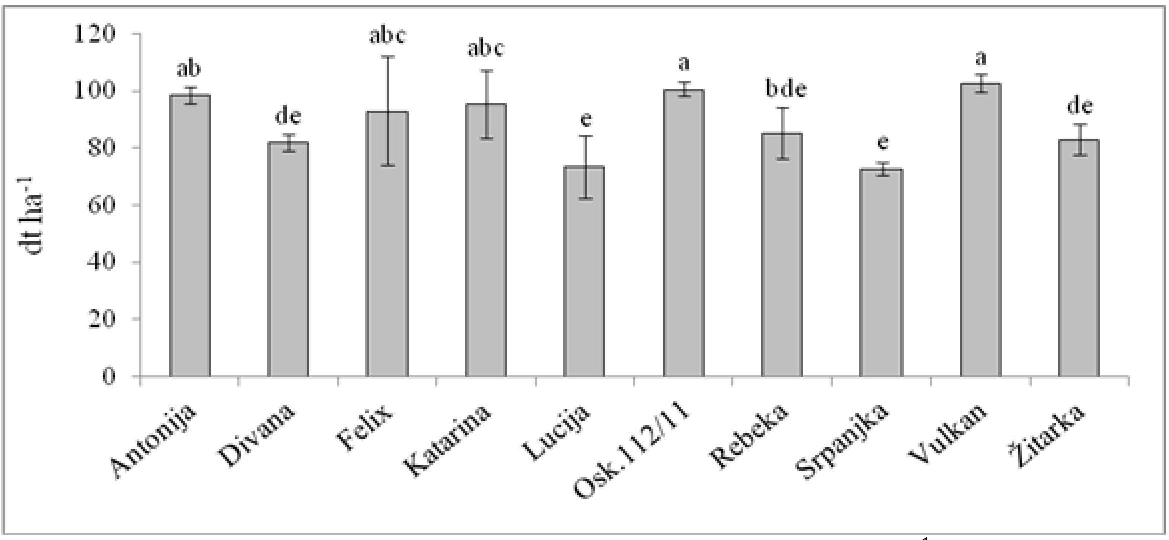

Figure 1. Grain yield of investigated genotypes (dt ha^{-1})

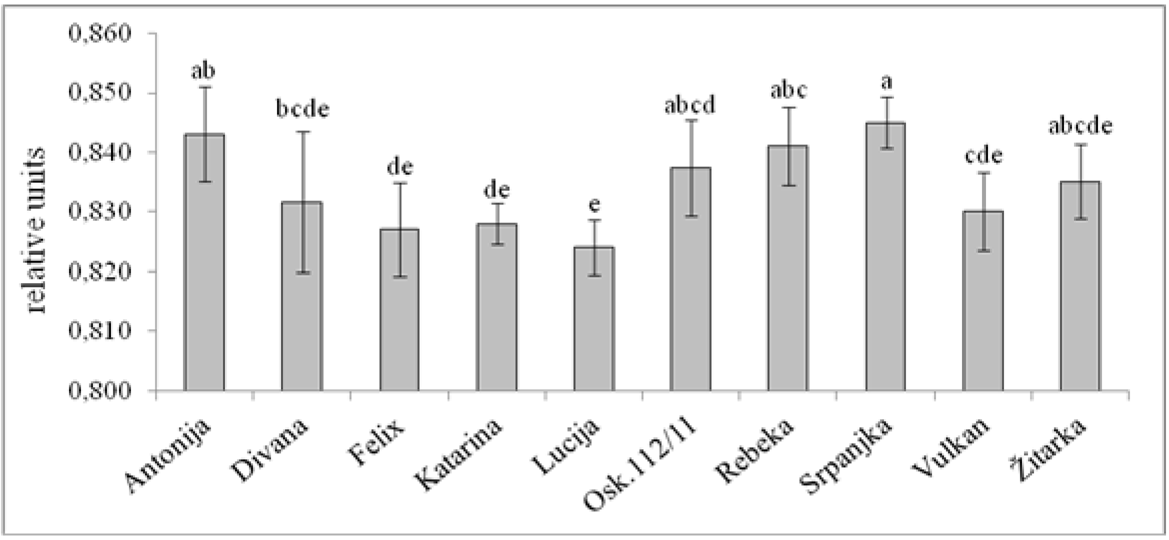

Figure 2. Maximum quantum yield of PSII (F_v/F_m) in investigated genotypes

The so called F_v/F_m parameter which represent a maximum quantum yield of PSII is deduced from F_o and F_m ($F_v/F_m = (F_m-F_o)/F_m$) and reflects the efficiency of electron transfer in the photosystem II complex of the photosynthetic apparatus so it is used as a sensitive indicator of plant photosynthetic performance (Maxwell and Johnson, 2000). Maximum quantum yield of PSII (F_v/F_m) should be a high value around 0.83 in unstressed leaves (Demmig and Björkman, 1987), while 0.75 is the value considered as boundary value for fully functional PSII (Bolhár-Nordenkampf et al., 1989). F_v/F_m was pronounced in Srpanjka (Figure 2), which is the most widely grown cultivar in Croatia, with high stability. Although Cultivars Lucija, Katarina and Felix showed decreased F_v/F_m values, their photosynthetic performance was entirely efficient. In fact, these cultivars had medium yield in relation to other investigated cultivars, and also had well PI_{ABS} values, similar as, for example, cultivars Antonija and Divana, which had higher $F_{v/}F_m$ values then those three cultivars. Cultivar Srpanjka had the highest PI_{ABS} (4.993) (Figure 3) but lower grain yield in comparison to other cultivars. Correlations between grain yield and photosynthetic parameters were not significant.

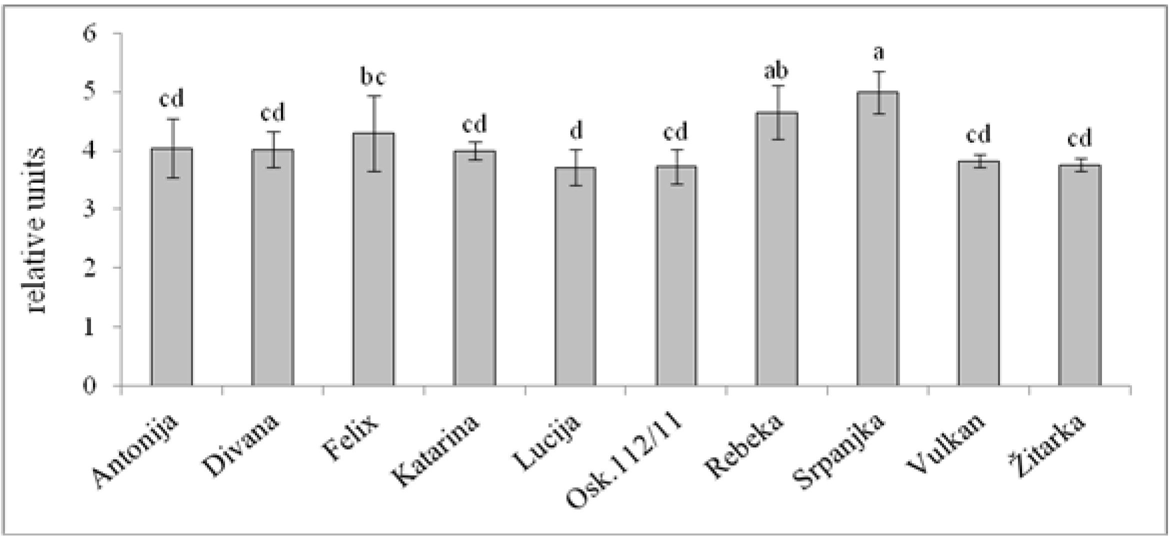

Figure 3. Photosynthetic performance index (PI_{ABS}) in investigated genotypes

For extra photo-assimilates to translate into increased grain yield, reproductive aspects of growth must be tailored to a range of agro-ecosystems to ensure that stable expression of a high harvest index (HI) is achieved (Reynold et al., 2011). This kind of data might be used in monitoring abiotic or biotic stresses in the field and could help breeders to select cultivars which are higher stress resistant. We suggest that the higher productivity of winter wheat cultivars could be more correlated with energy usage efficiency or assimilate mobilization rather than with their light absorption capacity.

Conclusion

All investigated genotypes had optimal photosynthetic rate in the unstressed conditions. Many assays were done, but still there are much to investigate about the role of photosynthetic activity and fluorescence considering wheat grain yield. More detailed studies, coupled with other important agronomic and photosynthetic parameters, could go in chlorophyll fluorescence imaging that can be useful method for the detection and characterization of leaf spot infection in the wheat, which could influence grain yield decrease. We conclude that final grain yield of winter wheat does not depend on photosynthesis in optimal conditions, but on another physiological process.

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Sažetak

Fotosintetska aktivnost biljaka često može biti smanjena uslijed abiotskih i biotskih stresova, a u korelaciji s time opada i produktivnost uroda ozime pšenice. Cilj ovoga istraživanja bio je procijeniti učinkovitost fotosinteze i utvrditi moguće korelacije s urodom zrna različitih genotipova ozime pšenice. Fluoroscencija klorofila *a* lista zastavičara izmjerena je pomoću *Plant Efficiency Analyser* (PEA, Hansatech, UK) tijekom vegetacijske sezone u 2011./2012. godini kako bi se pomoću JIP testa izračunali biofizički parametri koji opisuju funkcioniranje fotosustava II. Dobiveni rezultati ukazuju na to da ispitivani genotipovi imaju značajno različitu fotosintetsku učinkovitost, ali značajne korelacije između uroda zrna i fotosintetskih parametara nisu dobivene. Možemo zaključiti da urod ozime pšenice ne ovisi o fotosintezi u optimalnim uvjetima, već o drugom fiziološkom procesu koji može biti povezan s asimilacijom hranjivih tvari i iskorištenjem energetske učinkovitosti. Daljnja istraživanja, u smislu povećanja uroda zrna trebaju biti usmjerena na dulje trajanje učinkovite fotosinteze.

Ključne riječi: ozima pšenica, fluorescencija klorofila, urod zrna