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The relationship between chlorophyll *a* fluorescence parameters and yield components in sunflower hybrids

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ABSTRACT:
The sunflower is considered one of the four most important oilseeds globally. The study was conducted on 16 sunflower hybrids in field conditions to link photosynthesis parameters with yield components using chlorophyll *a* fluorescence parameters (ChlF), chlorophyll content, leaf temperature and agronomic traits. By analysing the ChlF parameters in the flowering stage of sunflower hybrids, a statistically significant difference was found between the studied hybrids for all the ChlF parameters except for the photosynthetic efficiency index of energy required from exciton to the reduction of ultimate electron acceptors on photosystem I (PI_{total}). At the same time, the results confirmed the significance of the chlorophyll content, leaf temperature, and agronomic traits for the studied hybrids. The indicators of photosynthetic efficiency showed a significant correlation between the efficiency with which the electron can reduce the final electron acceptors to photosystem I (RE_0/ET_0), PI_{total} and plant height. Also, the number of seeds per head showed a positive and very significant correlation with variable fluorescence in step I (V_I) and a very highly significant negative correlation with the energy flow which reduces electron end acceptors on the acceptor side of photosystem I (RE_0/RC). Using these analyses in sunflower breeding programmes could improve productivity and performance optimisation under changeable growing conditions.

Keywords:
genotype, leaf temperature, photosynthesis, photosynthetic activity, chlorophyll content, agronomic traits.

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INTRODUCTION

Sunflower (*Helianthus annuus* L.) is a high-value oilseed which has become the fourth most important oilseed globally after five centuries of cultivation and is considered one of the main studied crops (Seiler & Gulya 2016). It is a crop of tropical and subtropical regions with semi-arid to arid climates. Therefore, it is often grown in drought-prone countries with additional irrigation (Seghatoleslami *et al.* 2012) despite developing strong roots. Although the sunflower is a highly adaptable crop, depending on the growth and development stage, adverse environmental factors can negatively affect sunflower plants (Hussain *et al.* 2018). Adverse environmental factors limit crop production worldwide, leading to large variations in grain yields or causing a complete lack of grain production. Global climate change has led to an increase in daily, seasonal and annual air temperatures accompanied by high light intensities resulting in drier periods during vegetation (Jug *et al.* 2018). For this reason, crops are exposed to environmental factors which cause stress during vegetation, disrupting physiological and biochemical mechanisms, which lead to reduced plant productivity (Mustafa *et al.* 2017). One of the key physiological processes responsible for plant productivity is photosynthesis. Photosynthesis is the

Table 1. The mean values of the agronomic properties in 16 sunflower hybrids. According to the LSD test ($p \leq 0.05$), significant differences were designated by letters.

Hybrid	Seed weight per head – SWH (g)		Plant height – PH (cm)		Head diameter – HD (cm)		Number of head seeds – NHS		1000-grain weight – TGW (g)	
H1	68.82	bc	206.4	b	19.35	ab	1208.6	bcde	53.12	cd
H2	73.35	ab	191.1	cd	18.25	abcd	1173.4	cde	60.84	ab
H3	72.32	ab	191.2	cd	20.10	a	1269.7	bcd	55.46	bc
H4	79.10	ab	177.3	f	17.93	bcde	1215.5	bcde	56.92	abc
H5	63.80	bc	190.0	cd	19.50	ab	1323.1	bcd	44.70	ef
H6	64.73	bc	191.3	cd	16.75	cde	1171.7	cde	55.18	bc
H7	70.85	abc	186.5	de	18.60	abc	1304.7	bcd	54.36	bc
H8	66.40	bc	193.7	cd	18.30	abcd	1105.8	de	56.12	bc
H9	55.79	c	192.4	cd	14.40	f	1167.3	cde	39.78	f
H10	73.20	ab	211.0	b	19.35	ab	1428.8	ab	50.88	cde
H11	76.06	ab	189.3	cde	18.21	abcd	1598.3	a	44.16	ef
H12	63.10	bc	182.2	ef	16.34	def	1096.6	de	55.32	bc
H13	75.67	ab	196.6	c	17.70	bcde	1258.2	bcd	60.66	ab
H14	66.39	bc	207.0	b	16.44	def	1280.3	bcd	46.90	de
H15	55.91	c	212.1	b	16.05	ef	989.0	e	55.02	ef
H16	86.78	a	226.1	a	18.95	ab	1344.3	bc	63.44	a

process whereby light energy is converted into chemical energy, which plants use, making the study of photosynthesis important for crop production. Many researchers have used the method of measuring photosynthetic efficiency to quantify the influence of environmental factors and determine the degree of tolerance of tested cultivars and genotypes (Viljevac Vuletić *et al.* 2019; Galić *et al.* 2020; Mihaljević *et al.* 2020), but fewer studies have focused on the link between photosynthesis efficiencies and yield.

Furthermore, it is well known that photosynthesis depends on photosynthetic chlorophylls *a* and *b* in the antenna complex of the chloroplasts, which capture the light to be transformed into carbohydrates during photosynthesis. The use of chlorophyll content as a trait could contribute to maintaining/increasing the yield of crops under stress by increasing light interception and conversion efficiency (Kapoor *et al.* 2020). The traditional method of determining the chlorophyll content in plants is destructive, requiring extraction by solvent followed by spectrophotometric determination of absorbance and recalculation. In recent years, researchers eager to obtain results as quickly as possible, without the complexity of the translated analysis and data processing, have created techniques for the non-destructive analysis of chlorophyll. Such a method is based on the absorption and reflection by the intact leaf to obtain chlorophyll index values which express the relative chlorophyll content, rather than on the absorption of chlorophyll content per unit area or leaf tissue mass. The advantage of this method is the speed of implementation and the possibility of it being used in the field, which is why such analysis is accepted and used in research. Sunflower is an important oilseed in agriculture, but there is a lack of information about the interactive effects of photosynthetic efficiency and agronomic traits of this crop.

This study aims to estimate the response of sunflower hybrids to environmental conditions with chlorophyll *a* fluorescence (ChlF) parameters and investigate their association with yield components. It was assumed that ChlF, relative chlorophyll content and leaf temperature would be useful to assess the condition of the plants in the flowering stage, serving as an additional indicator of the correlations between the tested parameters so as to gain insight into the physiological state of the plants. The obtained results will enable the observation of differences in commercially available germplasm, further serving as a guideline in sunflower breeding programmes.

MATERIALS AND METHODS

Experimental materials and design. The experiment was set up at the Tenja Experimental field of the Faculty of Agrobiotechnical Sciences in Osijek. In terms of the chemical analysis of the soil, the pH in KCl was determined as 7.27, followed by 2.56% humus and 12.60 mg/kg phosphorus (according to the Olsen method) and 21.68 mg/kg potassium (according to the Al method).

Table 2. The correlation coefficients among the analysed traits and environmental conditions in the sunflower hybrids. Correlations are significant at $p < 0.05$ (N = 16).

	PH	HD	NHS	TGW	SWH	CC	LT	F_0	F_m	V_J	V_I	F_V	F_v/F_m	ABS/RC	DI_0/RC	TR_0/RC	ET_0/RC	RE_0/RC	RE_0/ET_0	RC/ABS	TR_0/DI_0	$ET_0/(TR_0$-ET0)	PI_{ABS}
HD	0.06																						
NHS	0.05	0.32																					
TGW	0.12	0.13	0.27																				
SWH	0.16	**0.61**	0.49	0.48																			
CC	0.29	-0.07	0.18	-0.16	0.30																		
LT	0.37	-0.31	0.12	-0.09	0.03	0.16																	
F_0	0.29	-0.41	-0.11	-0.20	-0.03	0.43	0.42																
F_m	-0.28	0.00	0.35	-0.03	-0.08	-0.25	-0.18	-0.20															
V_J	0.21	-0.06	-0.08	-0.16	0.12	0.34	0.11	**0.67**	-0.41														
V_I	**-0.64**	0.15	**0.57**	0.24	0.17	-0.30	-0.22	-0.42	0.47	-0.14													
F_V	-0.32	0.08	0.35	0.01	-0.07	-0.32	-0.25	-0.39	**0.98**	**-0.51**	**0.52**												
F_v/F_m	-0.36	0.30	0.25	0.13	-0.04	-0.47	-0.40	**-0.85**	**0.68**	**-0.72**	**0.55**	**0.81**											
ABS/RC	-0.25	-0.28	-0.18	-0.25	-0.05	0.01	0.34	0.21	**-0.52**	0.26	0.04	**-0.53**	-0.44										
DI_0/RC	0.16	-0.38	-0.35	-0.23	-0.09	0.31	0.40	**0.68**	**-0.74**	**0.71**	-0.38	**-0.84**	**-0.91**	**0.72**									
TR_0/RC	-0.36	-0.22	-0.12	-0.24	-0.06	-0.10	0.27	0.01	-0.39	0.09	0.19	-0.36	-0.21	**0.97**	**0.55**								
ET_0/RC	-0.37	-0.19	-0.14	-0.06	-0.24	-0.34	0.13	**-0.50**	-0.03	**-0.70**	0.16	0.07	0.37	0.48	-0.11	**0.62**							
RE_0/RC	0.33	-0.32	**-0.64**	-0.39	-0.26	0.17	0.37	0.38	**-0.68**	**0.25**	**-0.76**	**-0.72**	**-0.64**	**0.60**	**0.73**	0.48	0.24						
RE_0/ET_0	**0.54**	-0.14	-0.40	-0.26	-0.02	0.42	0.22	**0.74**	**-0.56**	**0.80**	**-0.71**	**-0.68**	**-0.85**	0.15	**0.73**	-0.06	**-0.60**	**0.63**					
RC/ABS	0.21	0.25	0.16	0.24	0.04	0.01	-0.38	-0.19	**0.50**	-0.18	0.00	**0.51**	0.41	**-0.99**	**-0.68**	**-0.97**	**-0.54**	**-0.62**	-0.11				
TR_0/DI_0	-0.38	0.30	0.28	0.10	-0.02	-0.46	-0.40	**-0.80**	**0.74**	**-0.66**	**0.58**	**0.86**	**0.99**	-0.46	**-0.91**	-0.24	0.30	**-0.68**	**-0.83**	0.44			
$ET_0/(TR_0-ET_0)$	-0.19	-0.05	-0.05	0.11	-0.26	-0.31	-0.05	**-0.57**	0.33	**-0.96**	0.04	0.43	**0.61**	-0.30	**-0.62**	-0.16	**0.66**	-0.17	**-0.69**	0.23	0.55		
PI_{ABS}	-0.23	0.16	0.15	0.17	-0.14	-0.35	-0.31	**-0.70**	**0.64**	**-0.88**	0.28	**0.74**	**0.87**	**-0.62**	**-0.92**	-0.44	0.36	**-0.56**	**-0.79**	**0.57**	**0.85**	0.86	
PI_{total}	**0.54**	0.00	-0.40	-0.11	-0.23	0.18	-0.09	0.11	-0.02	-0.10	**-0.76**	-0.04	-0.07	**-0.65**	-0.18	**-0.72**	-0.35	0.21	0.40	**0.62**	-0.09	0.23	0.23

Sowing was done on April 22, 2020, with a distance between the rows of 70 cm and within the rows of 23 cm. Sixteen commercially available sunflower hybrids were sown in 10 rows each. Harvesting was carried out by hand on September 8, 2020. All the necessary agrotechnical measures were performed during the sunflower vegetation according to the recommendations for sunflower cultivation.

Sunflower leaf analysis. ChlF was determined on 16 hybrids in the flowering stage (Schneiter & Miller 1981) with the help of the Handy PEA portable device (Hansatech UK). ChlF was measured between 8-10 am, 45 min after placing the clips on the third well-developed leaf under the sunflower head on ten plants per hybrid. The leaf is considered well-developed if larger than 4 cm (Schneiter & Miller 1981). The leaves were exposed to a pulse of saturating red light of 3200 μmol/m²/s. Using the OJIP test, ChlF was calculated according to Strasser *et al.* (2004) and Yusuf *et al.* (2010). The parameters analysed in this study were: F_0 (minimal fluorescence), F_m (maximal fluorescence), V_J (relative variable fluorescence at 2 ms), V_I (relative variable fluorescence at 30 ms), F_V (variable fluorescence), F_v/F_m (maximum quantum yield of photosystem II), ABS/RC (absorption per active reaction centre), TR_0/RC (trapping per active reaction centre), ET_0/RC (electron transport per active reaction centre), DI_0/RC (dissipation per active reaction centre), RE_0/RC (electron flux reducing end electron acceptors at the PSI acceptor side per RC), RE_0/ET_0 (probability that an electron from the electron transport chain is transferred to reduce end electron acceptors at the PSI acceptor side), RC/ABS (quantum yield for the reduction of end electron acceptors at the PSI acceptor side), TR_0/DI_0 (flux ratio trapping per dissipation), $ET_0/(TR_0-ET_0)$ (electron transport further than primary acceptor Q_A), PI_{ABS} (performance index), and PI_{total} (performance index for energy conservation from exciton to the reduction of PSI end acceptors).

A CL-01 chlorophyll content meter (Hansatech, UK) was used to measure the relative chlorophyll content of the leaf samples. Leaf temperature was measured using a dual focus infrared thermometer (B+B Thermo-Technik GmbH, Germany). The measurements were made on ten leaves per sunflower hybrid, on which ChlF was determined. Three separate measurements were made on each leaf. The arithmetic mean of these measurements was used for the analyses.

Yield components. During harvesting, ten plants were collected to analyse the yield components (seed weight per head – SWH, plant height – PH, head diameter – HD, number of head seeds – NHS and 1000-grain weight – TGW). A total of 160 individual plants were analysed. The stem height and head diameter were determined separately for each plant and hybrid. Seed harvesting and threshing were done by hand, the impurities were removed, and the seeds of individual heads were weighed. After weighing, the number of seeds for each head was determined individually. The same procedure was used to determine the mass of a thousand seeds.

Data analysis. Statistical data processing was performed using the Statistica 12.1 programme. Fisher's LSD test was used to examine the differences between the mean values at $p < 0.05$. The differences between the mean hybrid values were indicated by letters. Correlation analysis was performed using Pearson's correlation coefficient. Significance was marked at the level of $p < 0.05$ (*), $p < 0.01$ (**), or $p < 0.001$ (***).

RESULTS AND DISCUSSION

Chlorophyll *a* fluorescence (ChlF). ChlF is an efficient, fast, simple and non-destructive method which assesses the effects of agroecological environmental conditions on the photosynthetic apparatus of plants (Maxwell & Johnson 2000). The significance ($p < 0.05$) of all the ChlF parameters with the exception of the PI_{total} for all the studied hybrids was confirmed (Fig. 1). F_0 is the first ChlF parameter detected after tissue adaptation to darkness, when all the reaction centres are open, resulting in the complete oxidation of plastoquinone (Q_A) (Kalaji & Guo 2008). In this study, hybrids 13 and 14 had the highest F_0 values compared to the other hybrids whose values were statistically similar. F_m relative to F_0 is an indicator of the performance of the oxygen-evolving centre (OEC). Hybrids 7 and 14 stood out with the highest F_m, while hybrid 15 had the lowest value but did not differ significantly from the other tested hybrids. The F_0 and F_m values (Fig. 1) correspond to conditions without the influence of stress, which is in line with the results of Markulj Kulundžić *et al.* (2022a) in the morning measurements. F_V indicates the difference between F_m and F_0 intensity, where hybrid 15 had the lowest F_V while hybrid 7 had the highest F_V values. Also, the parameter F_v/F_m was determined from parameters F_0 and F_m and described the efficiency of the primary photochemistry of photosystem II (Strasser *et al.* 2004). In this study, the F_v/F_m values ranged from 0.806 (H13) to 0.854 (H7), confirming the functionality of the photosynthetic apparatus in all the sunflower hybrids. This high F_v/F_m value in sunflowers was also confirmed in the investigation carried out by Markulj Kulundžić *et al.* (2021, 2022a) in conditions without stress. According to Björkman & Demmig (1987) and Bolhar-Nordenkampf *et al.* (1991), values of F_v/F_m in the range between 0.75–0.85 are considered to show that plants have an effectively functioning photosynthetic apparatus. Furthermore, V_J is approximately 2 ms relative to V_I, which is approximately 30 ms. The V_J step values were the highest in hybrid 13 and the lowest in hybrid 12, representing their

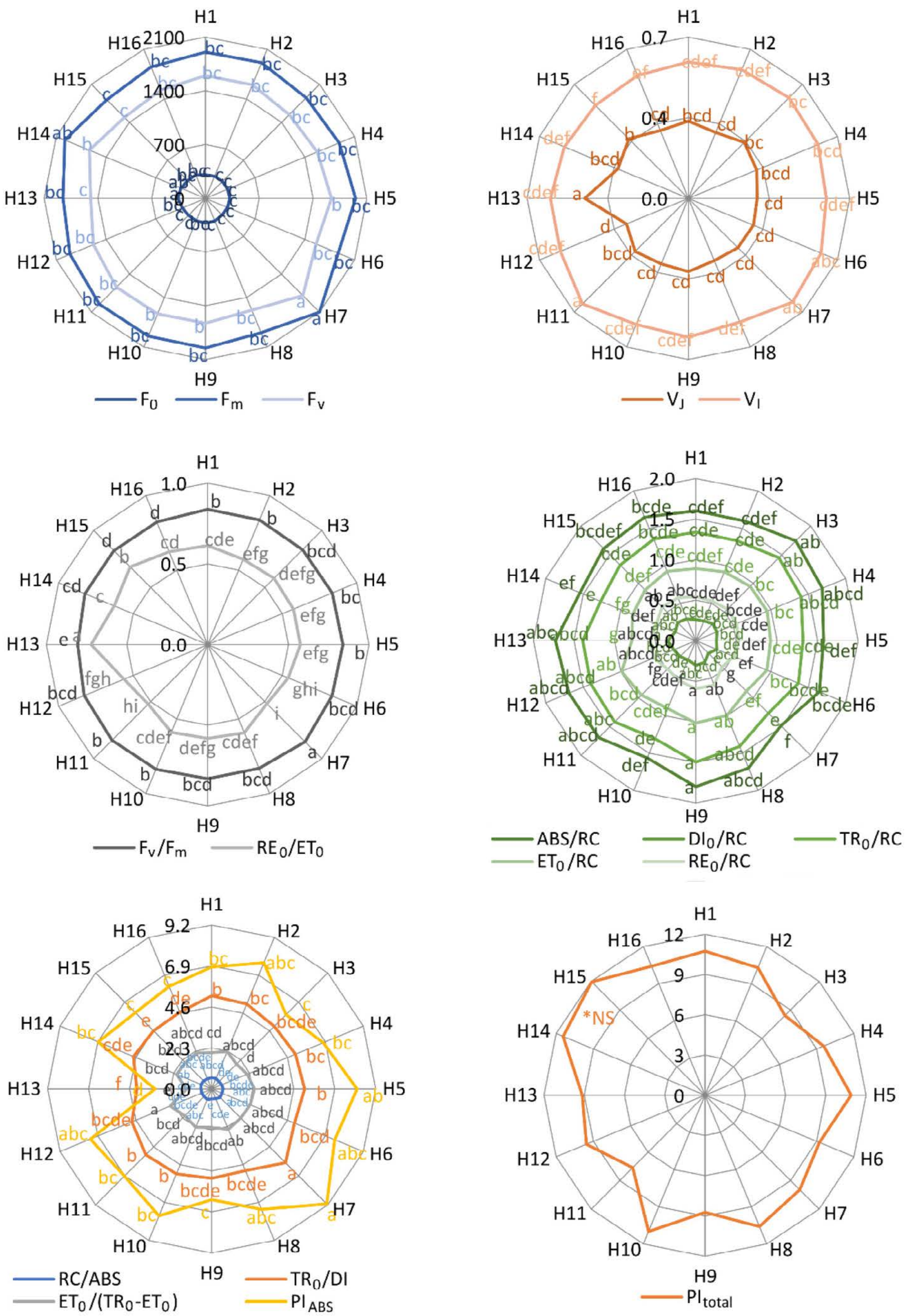

Fig. 1. The mean values of the JIP parameters in 16 sunflower hybrids. According to the LSD test ($p \leq 0.05$), significant differences were designated by letters. NS – no significance

current maximum of reduced Q_A. The V_I values ranged from 0.572 (hybrid 15) to 0.650 (hybrid 11) and suggested a further reduction in Q_A and Q_B (Strasser *et al.* 2004). ABS/RC represents the total amount of light chlorophyll molecules can absorb divided by the number of active reaction centres (Strasser *et al.* 2004). Higher ABS/RC values follow lower F_v/F_m values under stress study conditions (Mihaljević *et al.* 2020). In contrast, in this study conducted in the morning, when there was no indication of stressful conditions, hybrid 7 had the highest F_v/F_m value and the lowest ABS/RC. Furthermore, the decrease in ABS/RC in hybrid 7 was accompanied by a decrease in TR_0/RC, resulting in Q_A reduction. At the same time, there was also a decrease in DI_0/RC, RE_0/RC and RE_0/ET_0 in hybrid 7. DI_0/RC denotes the ratio of the total dissipation of untrapped excitation energy from all the reaction centres in relation to the total number of active reaction centres. At the same time, RE_0/RC and $RE_0/$

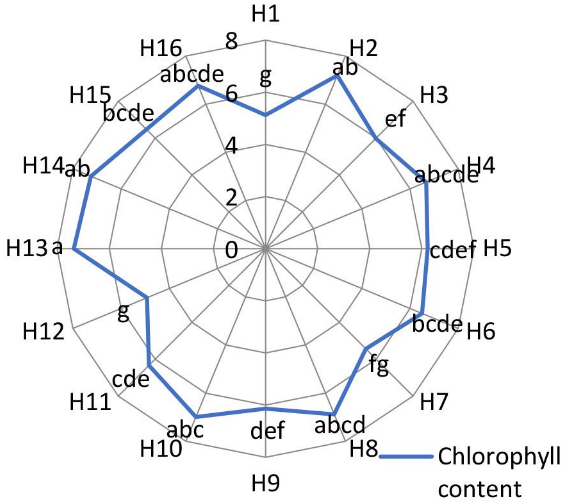

Fig. 2. The mean values of the chlorophyll content (CC) in 16 sunflower hybrids. According to the LSD test ($p \leq 0.05$), significant differences were designated by letters.

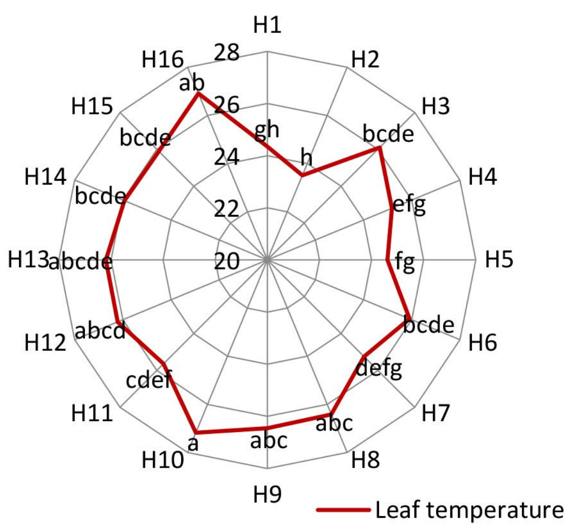

Fig. 3. The mean values of the leaf temperature (LT) in 16 sunflower hybrids. According to the LSD test ($p \leq 0.05$), significant differences were designated by letters.

ET_0 reflect the electron flow plastoquinol (PQH_2) to the end electron acceptors of photosystem I. Unlike hybrid 7, hybrid 9 was characterised by the highest values for the parameters ABS/RC, ET_0/RC, TR_0/RC and RE_0/RC. According to previous research, one of the most sensitive parameters is PI_{ABS}, also called the plant vitality index. It is described by three additional parameters: RC/ABS, TR_0/DI_0 and $ET_0/(TR_0/ET_0)$ (Strasser *et al.* 2004). The above parameters distinguished hybrid 13 with low values and hybrid 7 with high values. PI_{total} is the only parameter in this study in which no statistically significant difference was found among the tested sunflower hybrids. Hao *et al.* (2021) proved that the location, i.e. weather conditions (precipitation and the intensity of solar radiation) influence the significance of PI_{total}. On the other hand, PI_{total} proved useful in testing resistance to abiotic stress, especially in the breeding process to exclude material with poor photosynthetic apparatus function, thus increasing the efficiency of the selection process (Matoša Kočar *et al.* 2022). According to the ChlF parameters, when comparing the tested hybrids, it can be concluded that H9 and H14 exhibited the lowest photosynthetic efficiency, while H7 and H13 demonstrated the best photosynthetic efficiency.

Chlorophyll content. Chlorophylls are pigments which permit the transformation of light into carbohydrates, thus helping to maintain crop yields under stressful conditions. Therefore, the chlorophyll content in plants is very important, especially in conditions of stress when various mechanisms can protect chlorophyll from degradation (Monteoliva *et al.* 2021). Using the CL-01 implies obtaining information about the relative chlorophyll content using dual-wavelength optical absorbance at 620 and 940 nm. In this study the significance ($p < 0.05$) of the chlorophyll content between the hybrids was confirmed (Fig. 2). The chlorophyll content values for the sunflower hybrids in the flowering stage ranged between 4.92 and 7.36, indicating the genetic variability of the tested hybrids. Hybrids 1, 12 and 7 had the lowest values, in contrast to hybrids 13, 14 and 2, which stood out with the highest chlorophyll content (Fig. 2). The presented results were partially in accordance with the photosynthetic parameters, which is not in line with the results of the research conducted by Simões *et al.* (2018), who examined the morphological and productive response of sunflower plants to irrigation. Explaining the obtained results, they stated the adaptation of the tested hybrids to local climatic conditions, especially solar radiation and temperature.

Leaf temperature. Solar radiation is the most influential environmental factor which affects foliar anatomical traits and the photosynthesis of leaves (Yang *et al.* 2018). It causes significant changes in plant architecture, changing both the position of the leaves and the inclination of the petioles in response to air temperature (van Zanten *et al.* 2009). Since the sunflower is a heliotropic plant, it changes the position of its leaves by affecting tissues in the pulvinar region (Charzewska 2006). In this study, the significance ($p < 0.05$) of the leaf temperature was confirmed among the studied hybrids (Fig. 3) in response to different adaptations to ambient temperature due to genetic diversity. Markulj Kulundžić *et al.* (2016a, b) confirmed the same when investigating the effect of water content in soil on leaf temperature. This is confirmed by the fact that the average ambient temperature at the time of the leaf temperature measurement was 27.43°C, while the leaf temperature was 25.73°C. The leaf temperature range was 23.51–27.17°C in H2 and H10 (Fig. 3).

Agronomic traits. Plant biomass is mostly derived from photosynthetically captured carbon and is closely related to crop yield (Monteoliva *et al.* 2021). Photosynthesis supplies energy and organic matter for plant growth and development and determines crop yield (Zhou *et al.* 2022). Parry *et al.* (2011) believe that applying natural variations of photosynthesis, including natural populations in breeding, can lead to reasonably short-term (within five years) crop improvements. For that reason, in this study, natural variations in photosynthetic parameters in commercially available sunflower hybrids which may be associated with biomass accumulation, which is considered a surrogate of canopy photosynthesis, were investigated to gain insight into the genetic variability of the tested material and to attempt to establish a link between them. The results confirmed the significance ($p < 0.05$) of all the agronomic traits for the studied hybrids (Table 1). Genetic variability between the hybrids was demonstrated for seed weight per head (SWH), plant height (PH), head diameter (HD), number of head seeds (NHS) and 1000-grain weight (TGW) (Table 1). The results show that H9 had the lowest SWH, HD, NHS, and TGW, as well as lower PH. On the other side, H16 had the highest SWH, PH, and TGW and high HD and NHS. Similar results were confirmed by Markulj Kulundžić *et al.* (2022b). Liović *et al.* (2021) and Mijić *et al.* (2022) also proved the influence of the environment and the genetic variation of hybrids on grain yield and oil content.

Correlation coefficient. Existing methods to improve yields have been exhausted, so the study of photosynthesis, which plays a very important role in yield determination and is widely researched today, should be linked to agronomic traits to support future demands to increase crop yields (Monteoliva *et al.* 2021). Important factors in crop yields are growth rate and productivity, whose variations can cause variations in the efficiency of photosynthesis (Flood *et al.* 2011). Therefore, correlation coefficient analysis was performed, which confirmed a significant association between PH and V_I, RE_0/ET_0 and PI_{total}. HD correlates with SWH and NHS with V_I and RE_0/RC (Table 2). Qu *et al.* (2017) stated that to date, successes in identifying the photosynthetic parameters positively associated with crop biomass accumulation have been rare. By examining 64 elite wheat varieties (*Triticum aestivum* L.), Driever *et al.* (2014) found that although there were significant variations in photosynthetic capacity, biomass, and yield, there was no correlation between grain yield and photosynthetic capacity.

The chlorophyll meter and leaf temperature did not confirm an association with ChlF parameters and agronomic properties. In contrast, Qu *et al.* (2017) confirmed a positive correlation between F_v/F_m and chlorophyll content with plant height, tiller number and biomass.

CONCLUSIONS

Breeding for resistance and developing resilient varieties remain the most efficient control strategies to combat unfavourable climate changes. Significant variations in ChlF, chlorophyll content, leaf temperature and agronomic traits were observed among the tested hybrids. This shows that sunflower hybrids exhibit significant genotypic variation in ChlF, chlorophyll content, leaf temperature and agronomic traits. In terms of the ChlF parameters, when comparing the tested hybrids, it can be concluded that H9 and H14 exhibited the lowest photosynthetic efficiency, whereas H7 and H13 demonstrated the best photosynthetic efficiency. The agronomic results show that H9 had the lowest SWH, HD, NHS, and TGW, as well as lower PH. On the other hand, H16 had the highest SWH, PH, and TGW as well as high HD and NHS. The correlation coefficient analysis confirmed a significant association between PH and V_I, RE_0/ET_0 and PI_{total}. HD correlates with SWH, and NHS with V_I and RE_0/RC. Using these analyses in sunflower breeding programmes could improve productivity and performance optimisation under changeable growing conditions.

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REZIME

Botanica SERBICA

Odnos parametara fluorescencije hlorofila *a* i komponenti prinosa kod hibrida suncokreta

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Suncokret se smatra jednom od četiri najvažnije uljarice u svijetu. Istraživanje je provedeno na 16 hibrida suncokreta u poljima kako bi se povezali parametri fotosinteze s komponentama prinosa. Analizom fotosintetičkih parametara u fazi cvetanja hibrida suncokreta utvrđena je statistički značajna razlika između ispitivanih hibrida za sve parametre fotosinteze osim indeksa fotosintetske efikasnosti potrebne energije od ekscitona do redukcije krajnjeg akceptora elektrona na fotosistem I (PI_{total}). Ujedno rezultati pokazuju značajnost sadržaja hlorofila, temperature lista i agronomskih karakteristika na svim hibridima. Pokazatelji fotosintetske efikasnosti pokazali su značajnu korelaciju između efikasnosti kojom elektron može redukovati krajnji akceptor elektrona na fotosistem I (RE_0/ET_0), PI_{total} i visine biljke. Takođe, broj semenki po glavi pokazao je pozitivnu i vrlo značajnu korelaciju s varijabilnom fluorescencijom na I koraku (V_I) i vrlo visoku značajnu korelaciju negativnog smera s protokom energije koja redukuje krajnje akceptore elektona na akceptorskoj strani fotosistema I (RE_0/RC). Korišćenje ovih analiza u programu oplemenjivanja suncokreta moglo bi poboljšati produktivnost i optimizaciju učinka u promenljivim uslovima uzgoja.

Ključne reči: genotip, temperatura lista, fotosinteza, fotosintetska aktivnost, sadržaj hlorofila, agronomska svojstva