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INFLUENCE OF ORGANIC FERTILIZATION ON THE PHYSIOLOGICAL BEHAVIOR OF FIELD TOMATOES

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Abstract

During the vegetation period of the year 2019 on experimental field at Agricultural University - Plovdiv it was conducted a physiological study of tomato cultivar (Rugby) with determined growth under the treatment with chemical and organic fertilizers. The purpose of this research was to examine changes of the functional activity of the plant photosynthetic apparatus of variants with different fertilization and different planting dates. It was determined more optimal ratio between photosynthetic active radiation (PAR) and quantum yield (qY-Fv/Fm) of the photosystem II (PS II) in dark-adapted leaves for organic and chemical fertilized variants, compared to no fertilized variant. Minimal fluorescence (Fo) in reaction centers of PS II after dark-adapted of leaves was with highest value at chemically fertilized variant, which means that it did not affect the photosynthetic activity. Significant differences were observed for values of chlorophyll content index (CCI) in the different variants, as most stable average result showed organic fertilized variant for three differing planting dates on experimental field.

***Key words**: tomato, organic fertilizer, photosynthesis, chlorophyll content index.*

INTRODUCTION

Climate change is cumulative accepted as a worldwide phenomenon with possibly significant consequences and accompanying with recurrent extreme weather events (Stern, 2006). There has been a strong global awakening during the last few decades regarding the proper management of existing natural resources. Among them, irrigation water is one which becoming costlier due to increasing demand of human population. Simultaneously, the demand for food is also increasing, which has brought more and more land under cultivation and focused the attention on fertilizer and irrigation water. With these certain limitations, one has to turn to non-conventional recourses to meet the irrigation water demand (Khan et al., 2003; Kannan et al., 2005). Organic vegetable production is expanding its area and total production in Bulgaria and many other countries around the world. This growth rate is slower in greenhouse vegetable production due to high investment, operational and production costs. Organic production is regarded as extensive with more manual labour and less productive capacity. There are a number of studies that confirm this view (Van de Venter et al., 1991; Pascale, 2004; Yildirim, 2007; Ünlü and Padem, 2009; Gravel et al., 2012), but most often they are farther in time. Scientific and technological progress has created the conditions and facilitates for the intensification of this specific production area. A wide range of granulated NPK organic fertilizers and liquid fertilizers have been created and are available. Organically produced new varieties have greater biological potential and a greater range of sustainability. All these are prerequisites for intensifying the organic greenhouse vegetable production and making it an alternative to the conventional one. To test this opportunity by applying modern technological solutions with the use of suitable organic fertilizers, we have put in experience the bio-production of field tomatoes during the transition period. The physiological condition of plants and effect of various stressful factors thereon have been studied using chlorophyll fluorescence properties by many researchers (Gomes et al., 2012; Mathur et al., 2014; Kalaji et al., 2016).

Chlorophyll fluorescence is a non-invasive measurement of photosystem II (PSII) activity and is a commonly used technique in plant physiology. The sensitivity of PSII activity to abiotic and biotic factors has made this a key technique not only for understanding the photosynthetic mechanisms but also as a broader indicator of how plants respond to environmental change (Murchie and Lawson, 2013). At physiological temperatures the fluorescence is emitted mainly from chlorophyll *a* of PSII and reflects the primary processes of photosynthesis by light absorption, distribution and transfer of excitation energy and photochemical reactions in PSII. Because of the functional relation of PSII with other components of the photosynthetic apparatus of the chlorophyll fluorescence, it is seen as a proxy for the state of the integral photosynthetic process and the plant organism as a whole (Roháček, 2002). The CCM 200 plus is useful for improving nitrogen and fertilizer management, and is ideal for crop stress, leaf senescence, plant breeding, health determination, and other studies. Furthermore, the affordability and ease of use make it an exceptional teaching tool for botany and plant science courses (Opti-Sciences 2002; Richardson et al., 2002). The purpose of this study was to determine the change in chlorophyll fluorescence and relative chlorophyll content depending on the fertilization applied-organic and mineral, at three planting dates of tomatoes.

MATERIALS AND METHODS

Plant material and growth conditions
Rugby's determinant tomatoes have been planted on three dates: 30/04/2019, 07/05/2019 and 14/05/2019 in the experimental field of the Agricultural University Plovdiv, Bulgaria. The following three variants were envisaged: 1. Controlled-was not apply fertilizer; 2. Fertilizing with mineral fertilizers - ammonium nitrate - 34%, triplesuper-phosphate - 50% and potassium sulphate - 46%; 3. Fertilizing with organic fertilizer - Arkobaleno. Arkobaleno and mineral fertilizers: super-phosphate, potassium sulphate, ammonium nitrate was used in the recommended and optimal doses. The variants were set in 4 replicates with an experimental plot of 20 plants, 16 of which were reported. The fertilizers were introduced with the last tillage before planting. The tomatoes were grown on mulch beds under a planting scheme of 160/50 cm and a plot size of 16 m^2. Irrigation was carried out with a drip system according to the development phase. Organic fertilizer Arkobaleno has the following main characteristics: organic nitrogen (N) - 4.5%, phosphorous anhydrite (P_2O_5) - 3.5%, calcium (CaO) - 5-8%, magnesium (MgO) 0.8-1%, organic carbon of organic origin (C) - 30%, organic substance 55-60%; humified organic matter 12-14%, trace elements Fe, B, Cu, Zn. pH 6-8. Vegetative and phenological manifestations were reported during the growing season. Measurements were taken for the three planting dates, in the fruit maturity phase to determine some leaves physiological parameters.

Chlorophyll fluorescence imaging
Chlorophyll fluorescence transients of tomato leaves were measured using a portable device. PAR-FluorPen FP 110/D manufactured by Photon Systems Instruments Ltd., Czech Republic. The fluorescence measurement protocol uses short (30 μs) measuring flashes to measure zero level fluorescence (F_0) followed by a strong saturating flash [duration 0.8 s, intensity about 3000 μmol m^{-2} s^{-1}] to measure the maximum fluorescence (Fm). After a short dark adaptation, the leaf was exposed to actinic light [1000 μmol m^{-2} s^{-1}] for 4 min. Photosynthetically Active Radiation (PAR) is measured as Photosynthetic Photon Flux Density (PPFD), which is indicated by units of quanta (photons) per unit time per unit surface area. Three strong flashes of saturating light probed the effective quantum yield of PSII during the actinic light exposure (Maxwell & Johnson, 2000; Nedbal et al., 2000). The chlorophyll fluorescence transients were measured on the same day in the morning. The dates of measurement were 14/08/2019 and 10/09/2019 when the tomato plants had reached fruit maturity growth stage. The nine leaves from each variant were dark adapted for about 30 min by detachable leaf-clips prior each measurement. The numeric value of each ChlF parameter (Fv/Fm, PSII, PAR) was determined by integrating it over the measured leaf area.

Physiological estimate of chlorophyll content index (CCI)

Chlorophyll content index of the leaves was measured using a portable apparatus CCM 200 plus, a Chlorophyll Content Meter manufactured by Opti-Sciences, Inc., NH, USA.

The physiological assessment was carried out *in vivo* on the field. Measurements have been made in two dates of a sample of leaves when the tomato plants had reached fruit maturity growth stage.

The dates of measurement were 12/07/2019 and 18/09/2019. Plant measurements were made of each replication of a variants. From each plant there were analyzed 20 leaves by readings on the central part of the leaf.

Statistical analysis

Data are presented as mean values ± Standard error and Student t -test has been used for comparison of mean values from two independent numeric samples. For mathematical data processing it was used Data Analysis tool by program Excel for Windows 10.

RESULTS AND DISCUSSIONS

At the first date of measurement-14/08/2019 the highest average values of quantum yield (Fv/Fm) of dark adaptation leaves were read in third variant-organic fertilizer.

Respectively, the average ratio Fv/Fm which was measured for second variant was e similar with the third variant of treatment. The lowest photosynthetic activity (Fv/Fm = 0.78) was measured for the first variant, as this value indicated for light heat stress (Table 1).

The average values of ratio Fv/Fm of the other variants are close to optimal value for healthy leaves-0.83 (Demmig and Björkman, 1987). Initial fluorescence (F_0) in oxidized reaction centers of PSII after dark adaptation has had the highest value for the second variant.

The heat or low temperature stress increase F_0 (Zlatev & Kolev, 2012; Chen et al., 2018), but in this case it did not affect the photosynthetic activity of the second variant (Table 1).

Measured photosynthetically active radiation (PAR) was higher at two fertilizer variants compare to no fertilizer variant, as ratio between photosynthetically active radiation and quantum yield of dark adaptation leaves was more optimal at the third variant-organic fertilizer.

More effective photosynthetically activity was expressed in the case of the variant - first sow date in all fertilize treatment variants, while more stressed photosynthetically activity (Fv/Fm = 0.71 and F_0 = 4450) was measured at subvariant- no apply fertilizer and second sow date interaction (Table 1).

High temperature reduced the Fv/Fm ratio, indicating that an important portion of the PSII reaction centre was damaged, according to Asada et al., 1998.

Table 1. Results for chlorophyll fluorescence of tomatoes leaves reported at the first date 14/08/2019

Indices	Variant of treatment	First planting date	Second planting date	Third planting date	Average ± SE
Ft=Fo	1. No fertilizer (control)	2840±257.3	4450±398.2	3220±358.2	3503±343.8
Qy=Fv/Fm		0.82±0.009	0.71±0.04	0.80±0.01	0.78±0.03
PAR		108±19.0	60±10.2	108±15.9	92.0±10.2
Ft=Fo	2. Chemical fertilizer	3811±300.2	3932±289.3	4915±411.1	4219±349.5
Qy=Fv/Fm		0.82±0.01	0.79±0.008	0.78±0.009	0.80±0.01
PAR		120±20.0	95±10.2	152±24.3	122.3±11.5
Ft=Fo	3. Organic fertilizer Arkobaleno	3920±273.3	3280±200.2	2990±185.6	3397±274.4
Qy=Fv/Fm		0.82±0.007	0.80±0.009	0.80±0.008	0.81±0.007
PAR		117±13.2	86±8.9	96±12.3	99.7±9.13

Values are means ± Standard errors of mean

At the second date of measurement-10/09/2019 the most optimal ratio between PAR and quantum yield (Fv/Fm) of dark adaptation leaves was read for the second variant, where low PAR value is interacted with high value of quantum yield (Table 2). Initial fluorescense F_0

in oxidized reaction centres of PSII after dark adaptation have again highest value for the second variant, as the obtained result is similar to those reported in the first measurement. Compare to first measurement, in the second measurement there have more significance variations for results of PAR and initial fluorescence. However, the ratio Fv/Fm in all variants is equal (0.82-0.83), as this value indicates for absence of stress (Table 2).

Table 2. Results for chlorophyll fluorescence of tomatoes leaves reported at the second date 10/09/2019

Indices	Variants	First planting date	Second planting date	Third planting date	Average ± SE
Ft=Fo	1. No fertilizer (control)	3790±152.0	4030±133.3	4213±110.3	4011±122.4
Qy=Fv/Fm		0.81±0.008	0.83±0.007	0.83±0.007	0.82±0.007
PAR		455±56.0	574±67.8	676±75.2	568.3± 63.7
Ft=Fo	2. Chemical fertilizer	3751±259.3	5372±489	4380±300.2	4501±333.6
Qy=Fv/Fm		0.83±0.006	0.82±0.007	0.85±0.006	0.83±0.006
PAR		420±65.3	218±35.6	284±42.3	311.7±42.3
Ft=Fo	3. Organic fertilizer Arkobaleno	2820±195.6	3278±237.8	3630±252.3	3243±234
Qy=Fv/Fm		0.81±0.009	0.83±0.008	0.84±0.008	0.82±0.008
PAR		315±20.36	292±15.6	359±25.3	322.0±19.65

Values are means ± SE-standard error of mean.

From the analysis of the results for the reported average values of leaves relative chlorophyll content from the different variants, it can be concluded that there is no significant advantage of planting date variant. An exception is an option organic fertilizer plus second planting date (Table 3). However, the most stable result shows the third variant. In this variant, the amount of chlorophyll pigments is the same at the second and third planting dates, while the other variants had significance lower results in compare to third planting date. This is an indication of a more sustainable development of the plants of organic fertilization variant, differing in the date of planting. Statistical analysis of the average results indicated a significance difference between no fertilized variant and organic fertilized variant to the advantage of the last variant (Table 3). Alves et al. (2018) and Doncean et al. (2013) reported for increase of chlorophyll content at treated with organic fertilizer of tomato plant and tomato seedlings.

Table 3. Results for chlorophyll content index (CCI) of tomatoes leaves reported at the first date 12/07/2019

Variants	First planting date CCI	Second planting date CCI	Third planting date CCI	Average ± SE CCI
No fertilizer (control)	30.5±2.78	31.93±2.43	36.0±2.27	32.81
Chemical fertilizer	33.95±2.63 n.s.	33.93 ±2.45 n.s.	39.34±2.93 n.s.	35.74 n.s.
Organic fertilizer	33.67±2.47 n.s.	38.33±2.96 **	38.26 ±3.01 n.s.	36.75 *

SE-standard error of mean; n.s.-no significance, *-significance at p=0.05; **-very significance at p=0.01

In Table 4 are not present data for first and second sow date subvariants, because of lack off green material for analyse. Compare to the first reading, when the most stable result showed the third option, in the second data of measured there is a significant difference between the results for no fertilize variant and other fertilize variants (Table 4). It can be concluded that the plants of the different fertilized variants of the third planting date have better photosynthetic activity than the plants of the first variant in the later stage of their development, as well. Fertilization delays degradation of chlorophyll pigments. The organic fertilized treatment variant was not advantage over chemical treatment variant (Table 4).

Table 4. Results for chlorophyll content index (CCI) of tomatoes leaves reported at the second date 18/09/2019

Variants	Third planting dates CCI values±SE
No fertilizer	28.19±2.53
Chemical fertilizer	38.06 ±2.24**
Organic fertilizer	38.85±2.58 **

SE-standard error of mean; **-very significance at p=0.01

CONCLUSIONS

It was determined more optimal ratio between photosynthetic active radiation (PAR) and quantum yield (qY-Fv/Fm) of PS II in dark-adapted leaves for organic and chemical fertilized variants, as compared to no fertilized variant.

More effective photosynthetically activity was expressed in first planting date variant in all fertilized treatment variants, while at the second date of measurement it was not established a statistically significance difference of Fv/Fm value at different planting dates.

Minimal fluorescence Fo in reaction centres of PS II after dark-adapted of leaves was with highest value at chemical fertilized variant.

Significance differences were observed for values of chlorophyll content index (CCI) in the different variants, as most stable average result showed the organic fertilized variant for three differing planting dates on experimental field.

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