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Effect of nutrition and water regime on the photosynthesis in tomato grown in plastic greenhouses

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Abstract

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Photosynthesis is the main physiological process and its speed and efficiency determines the tomato productivity. The speed of photosynthesis is strongly related to the irrigation and activity of plants. In order to trace the photosynthetic nutrition of plants under different add fertilization and fertilization regimes, add was a survey to grow tomatoes in plastic greenhouses. The polar regime has been shown to exert a greater influence on the rate of photosynthesis, intracellular CO_2 concentration and transpiration intensity compared to fertilization. The highest efficiency of the photosynthesis is observed in 100% irrigation regime without fertilization during the vegetation period. Tomato plants grown with 50% of the fertilizer rate and at irrigated regime reduced to a half water rates are distinguished for good gas exchange efficiency.

Keywords: tomato; photosynthesis; transpiration; irrigation regime; fertilization
Abbreviations: A (speed of photosynthesis), E (intensity of transpiration), Ci (intercellular concentration of CO_2), A/E (photosynthesis efficiency)

Introduction

Tomato is a major vegetable crop widespread throughout the world. The yield and quality of tomato fruits are influenced by many factors related to the genetics of the variety, the climatic and soil conditions of the region, the growing technology. Photosynthesis is the main physiological process and the speed and efficiency of photosynthesis have an effect on the tomato productivity. The speed of photosynthesis is significantly related to the irrigation and nutrition of tomato plants.

Photosynthesis rate was more influenced by water than fertilizer, however the yield was opposite. The water-fertilizer combination and yield were positive related. A significant increasing trend of photosynthesis occurred with the increase of irrigation maximum, and it began to decrease when the irrigation maximum reached a certain amount. Moreover, disregarding the amount of irrigation water, the photosynthesis increased first and then decreased slowly. The most suitable combination of irrigation and fertilizer was irrigation 80%-82% of field capacity, and the fertilizer 313.75-439.75 kg/hm^2 of N, 156.55-219.19 kg/hm^2 of P_2O_5 and 313.75-439.75 kg/hm^2 K_2O (Li et al., 2014).There were significant interactive effects of soil moisture and fertilization rates in tomato plants. Soil moisture had greater effects on fruit yield, plant biomass, and root/shoot ratio than did fertilizer rates. The high fertilizer rate decreased leaf photosynthetic pigment contents, gas exchange, and chlorophyll fluorescence when soil moisture was 55% of field capacity, but it increased those values when soil moisture was 95% of field capacity. When soil moisture was 75% of field capacity, the high fertilizer rate increased leaf photosynthetic pigment contents, decreased gas exchange, and had little effect on chlorophyll fluorescence (Zhu et al., 2012; Velichkova, 2019).

Different irrigation regime and structure of the nitrogen fertilizer exerts influence on the photosynthesis in tomato. Alternate partial root-zone irrigation(APRI) controlled at >60% of the water-holding capacity enhanced root growth and increased leaf instantaneous water use efficiency with a slight yield reduction compared with conventional irrigation regardless of the N form supplied. In contrast, APRI controlled at 40% significantly decreased root growth and inhibited photosynthesis, thereby resulting in a significant yield loss. At the fruit expansion stage and maturity stage, the tomato plants had a higher biomass accumulation and yield with nitrate-N than ammonium-N supply (Chen et al., 2015).The combination of the potassium fertilizer and alternative methods of irrigation also could change the intensity of photosynthesis. Partial root-zone irrigation reduced more transpiration rate than photosynthetic rate, which led to higher leaf water use efficiency. Suitable concentration of Ca fertilizer can increase photosynthetic rate, fresh fruit yield, water use efficiency on fresh yield and fruit quality (Yang et al., 2012. In hydroponic tomato growing the potassium deficiency stress decreased photosynthesis, expansion and transport of ^{14}C assimilates of the source leaf (Kanai et al., 2011). Sulphate concentration(0.1 mM) significantly decreased photosynthetic capacity by reducing the amount of both Rubisco and chlorophyll and by causing an inactivation of Rubisco (Xu et al., 1996).In greenhouse cucumber growing the lack of fertilization resulted in the reduction of netto photosynthesis and leaf chlorophyll content. The lowest rates of photosynthesis and leaf chlorophyll content were observed in the non-fertilized cucumber plants. Foliar application of fertilizer had a pronounced effect on photosynthesis and growth of cucumber plants (Klamkowski et al., 2011). In cotton the speed of photosynthesis depends on the potassium fertilization. Under drought conditions without potassium fertilization cotton cultivars Sahin 2000 had a higher photosynthesis speed and stomata conductance than Nazilli 84-S. Potassium fertilization to a great extent compensated for the inhibitory effect of drought on photosynthesis (Tsonev et al., 2011). Water-stressed plants under K_o application exhibited significant decline in netto photosynthesis, stomata conductance, intercellular CO_2 concentration and ribulose-1,5-bisphosphate carboxylase (Rubisco) activity and resulting in reduced photo-assimilates synthesis and partitioning towards reproductive organs. Conversely, Kapplication decreased the decline in photosynthesis, Rubisco activity and biomass accumulation and partitioning (Zahoor et al., 2017).Nutrition with microelement also makes a change in the plant photosynthesis speed (Velichkova & Sirakov, 2018).The omission of boron, copper, iron, manganese and zinc on *Jatrophacurcas L*. reduced the dry matter yield, chlorophyll content and photosynthetic rate of the plants differently for each omitted nutrient (Santos et al., 2013). The application of Selenium enhanced photosynthesis by increasing the photosynthesis rate, the intercellular CO_2concentration and the transpiration efficiency of rice (Zhang et al., 2014). The individual effect of the irrigation regime is also of great importance for the photosynthesis of the plants. Stomata conductance and leaf growth of tomatoes were significantly reduced by partial root-zone drying and regulated deficit irrigation. Rubisco efficiency was significantly decreased in regulated deficit irrigation plants with respect to control ones (Tahi et al., 2007). Leaves of the irrigated apple trees were lower content of assimilation pigments in leaves that non-irrigated ones. Leaves of late cultivars showed higher photosynthesis activity and pigment content than early cultivars (Podsiadlo & Jaroszewska, 2017).The water deficit significantly reduced the leaf water potential, netto photosynthetic rate and stomata conductance in the cotton. The extent of the decline was greater in moderate water stress from early flowering to full flowering stage (Luo et al., 2016).

The purpose of the study is to establish the photosynthesis response of the plants in different regimes of fertilization and irrigation.

Material and Methods

The experiment was conducted at the beginning of April with tomato variety *Vitelio* by block method in four replications under unheated plastic greenhouses in the region of Plovdiv. We have tested the following treatments:

1. Optimal irrigation regime without fertilization - control
2. Irrigation regime – 50 percentages from the watering rate and 50 percentages – fertilization.
3. Optimal irrigation regime with 50 percentages fertilization.
4. Irrigation regime – 50 percentages from the watering rate and 100 percentages fertilization.
5. Optimal irrigation regime and 100 percentages fertilization

Two measurements were performed for each leaf gas exchange to assess the functional activity of the photosynthesis apparatus using LCA-4 and LCpro apparatus. The measurements were carried out in blossoming and fruitage. Indexes of leaf interchange of gas are determined on the top, completely developed leaves of plants, on sunny days in optimal for photosynthesis time between 10 and 12 hours.

It was established:

• A: speed of photosynthesis (μmol $CO_2 m^{-2} s^{-1}$)

- E: intensity of transpiration (mmol H_2O $m^{-2}s^{-1}$)
- ci: intercellular concentration of CO_2 (vpm).

Statistical analysis and all chartings were performed within the R program version 3.4.4 (2018-03-15). The data were presented as mean value and standard errors of the mean (SEM). Statistical significance was computed using Pair-Samples T-Test, with a significance level of $p < 0.05$. Comparisons between different treatment options group were performed with Duncan's Multiple Range Test with $p < 0.05$.

Results and Discussion

Results from the leaf gas exchange show the current situation of carbon nutrition and water exchange of plants. The netto photosynthesis (A) values in tomato-flowering phosphophase were in the range of 6.28 µmol CO_2 $m^{-2}s^{-1}$to 9.28 µmol CO_2 $m^{-2}s^{-1}$.Values obtained for the netto photosynthesis (A) in fruitage of tomato were from 4.84 CO_2µmol $m^{-2}s^{-1}$ to 9.50 µmol CO_2 $m^{-2}s^{-1}$ (Figure1 and Figure 2). It was established that in both phases of the tomato development the speed of photosynthesis is higher in the variants with optimal irrigation regime, in equal fertilization, which shows that soil moisture has a greater influence on photosynthesis compared to fertilization.

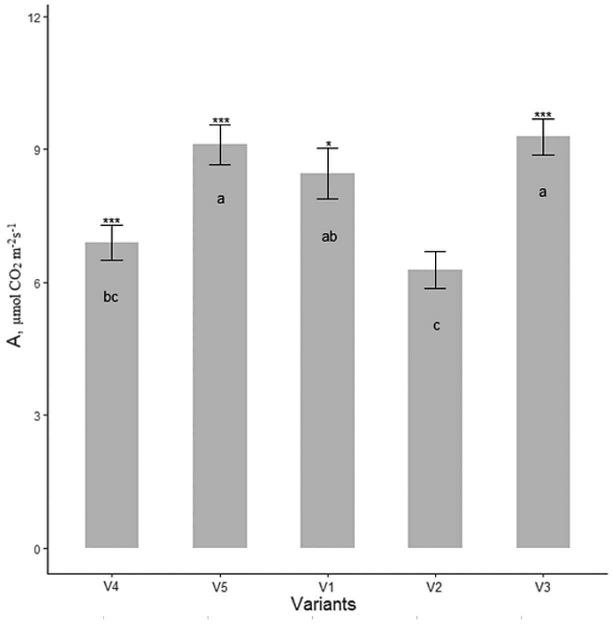

Figure 1. Speed of netto photosynthesis in blossoming of tomato. The error bars indicate the standard deviation while the asterisks indicate significant differences in different variants of growing of tomato, at p < 0.01 (*), p < 0.001 (**) and p < 0.0001 (***), respectively. Different letters indicate significant difference at p < 0.05 levels by Duncan's Multiple Range Test

The values measured for the photosynthesis (A) in blossoming of the tomato demonstrated that in treatments V3, V4 и V5 are significantly higher ($p < 0.0001$) than the values in the remaining two treatments – V1 and V2 (Fig. 1). According to Duncan's Multiple Range Test it is known that means with the same letter are not significantly different. Here, we have that both treatments V3 and V5 belong to the same group, the 'a', and V1, V2, V4 are different from the other two, belongs to the group 'ab', 'c', 'bc', respectively. Speed of the netto photosynthesis) (A, µmol CO_2 $m^{-2}s^{-1}$) in the tomato fruitage shows that the values in the treatments V1, V4 and V5 (fig. 2) are significantly higher ($p < 0.0001$) than the values in the treatments V2 and V3. The results in Figure 2 indicates that the four treatments V1, V2, V3 and V5 belong to the same group, the 'a', and V4 is different from the other quadruple, belong to the group 'b'.

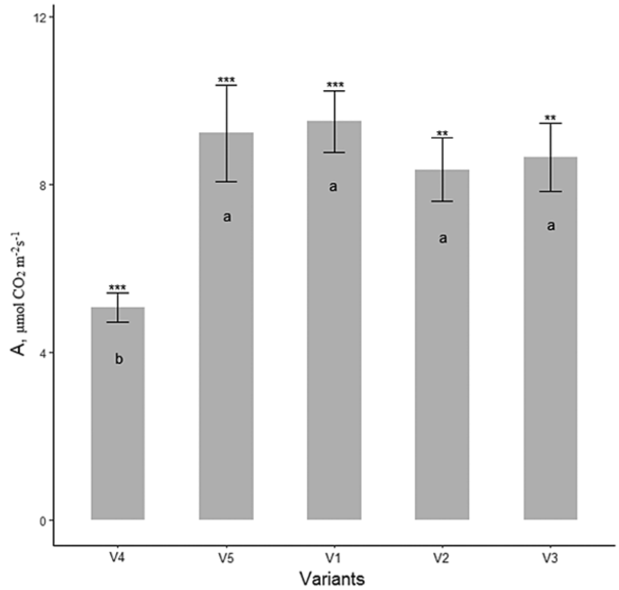

Figure 2. Speed of photosynthesis in fruitage of tomato. The error bars indicate the standard deviation while the asterisks indicate significant differences in different variations of growing, at p < 0.01 (*), p < 0.001 (**) and p < 0.0001 (***), respectively. Different letters indicate significant difference at p < 0.05 levels by Duncan's Multiple Range Test

The intracellular CO_2 concentration in the tomato blossoming ranges from 398.5 vpm to 537 vpm for individual treatments. The highest values were measured in the treatments with optimal irrigation regime V1 and V3 regardless of the fertilizing (Figure 3). In water deficiency (treatment 2 and treatment 4), the intracellular CO_2 concentration is lower as well as the speed of the photosynthesis, which is due to low CO_2 conductivity through the stoma as a result of the broken water exchange. In this case, the plants cannot maintain the necessary moisture of the tissues. Stomata are closed as a result of this the carbon dioxide inflow inside of the leaves is limited although it is necessary for the intensive photosynthesis performance and the effect of the transpiration for plant cooling is significantly decreased. The irrigation regime has a strictly individual effect on the photosynthesis of the plants found by Tahi et al. (2007).

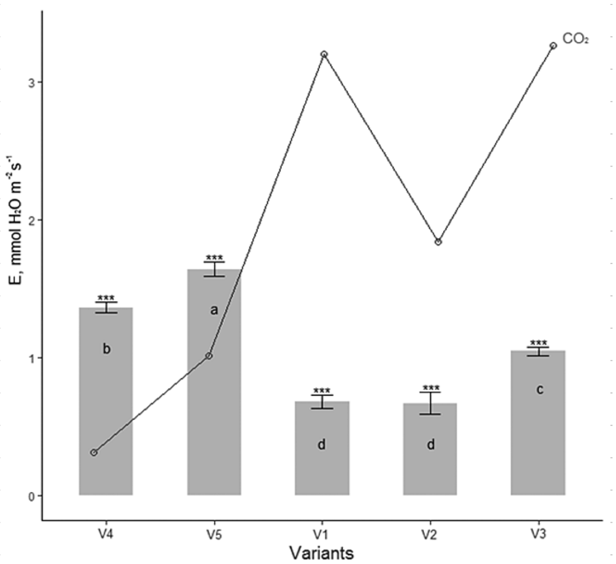

Figure 3. Intensity of transpiration and intercellular concentration of CO_2 in blossoming in tomato. The error bars indicate the standard deviation while the asterisks indicate significant differences in different variations of treatment of tomato, at $p < 0.01$ (*), $p < 0.001$ (**) and $p < 0.0001$ (***), respectively. Different letters indicate significant difference at $p < 0.05$ levels by Duncan's Multiple Range Test

Significant differences in intercellular carbon dioxide concentration depending on the irrigation and nutrient regime of the plants were not observed in the fruiting phase. The values are from 419 vpm to 485.8 vpm for the individual treatments.

Through transpiration, plants move water and nutrients from the root system to the shoot system, and the high transpiration intensity in good water regime of plants makes the leaf temperature lower compared to the ambient air, thus protecting the plants from overheating. The analysis showed that the highest values (1.64 mmol H_2O m^{-2} s^{-1} and 1.37 mmol H_2O m^{-2} s^{-1}) were recorded at transpiration intensity in variant (V5) with optimal irrigation regime in both observations (Figure 3 and Figure 4). The transpiration intensity is higher at 100% of the irrigation rate (V3 and V5) compared to reduced irrigation with half-water rate (V2 and V4) in different fertilization levels.

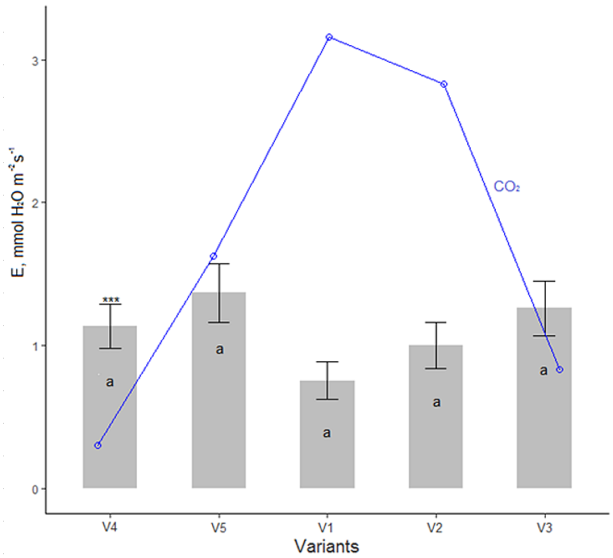

Figure 4. Intensity of transpiration and intercellular concentration of CO_2 in fruitage in tomato. The error bars indicate the standard deviation while the asterisks indicate significant differences in different variations of treatment of tomato, at $p < 0.01$ (*), $p < 0.001$ (**) and $p < 0.0001$ (***), respectively. Different letters indicate significant difference at $p < 0.05$ levels by Duncan's Multiple Range Test

The effectiveness of photosynthesis expressed by the photosynthesis speed to transpiration intensity ratio (A/E) shows the plants response from the different treatments to a different irrigation and fertilization rate. They have good physiological status when the ratio of the assimilated CO_2 to the transpired water (A / E) is high. The results obtained are identical in blossoming and fruitage. The highest photosynthetic efficiency (12.5-12.88) is observed in treatment 1 without fertilization during the vegetation period at 100% irrigation regime which is due to the low transpiration intensity despite the relatively high photosynthesis speed. Good plant status A/E (8.02-11.08) is observed in fertilization with 50% of the fertilizer rate and reduced irrigation regime (Treatment 2). Plants are tolerant to water deficiency. The physiological plant status is deteriorated at the background of a reduced fertilizer rate and optimal irrigation regime. Yang et al. (2012) believe that a suitable concentration of Sucrose may increase the rate of photosynthesis, yield and quality of the fruit. The photosynthetic efficiency values are within the limits of 4.28-5.01 in optimal nutritional and disturbed water regime (treatment 4), while at the optimal nutrient and optimum water regime, (treatment 5) the values are 5.5-6.73, indicating that the efficiency of the gas exchange is increased at 100% irrigation rate.

Conclusion

The irrigation regime has a greater effect on the photosynthesis rate, intracellular CO_2 concentration and transpiration intensity compared to the fertilization in growing of tomatoes under plastics. The highest photosynthesis efficiency is observed at 100% irrigation regime without fertilizing during the vegetation period. Good gas exchange efficiency was established in plants fertilized with 50% of the nutrition rate and irrigated with a half of watering rate.

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