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Kosobrukhov, A. A.
Institute of Soil Science and Photosynthesis USSR Academy of Sciences

Tsonev, Ts.
Institute of Plant Physiology Bulgaria Academy of Sciences

Velichkov, D.
Institute of Plant Physiology Bulgaria Academy of Sciences

Stanev, V.
Institute of Plant Physiology Bulgaria Academy of Sciences

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EFFECT OF VARIOUS TEMPERATURES IN THE ROOT ZONE AND LIGHT INTENSITIES ON PHOTOSYNTHESIS AND TRANSPIRATION OF TOMATO PLANTS

A. A. KOSOBRUKHOV,* TS. TSONEV,** D. VELICHKOV** and V. STANEV**

**Institute of Soil Science and Photosynthesis, USSR Academy of Sciences, Pushchino, Moscow Region, USSR*
***Institute of Plant Physiology, Bulgaria Academy of Sciences, Sofia, Bulgaria*

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KOSOBRUKHOV A. A., TSONEV TS., VELICHKOV D. and STANEV V. *Effect of various temperatures in the root zone and light intensities on photosynthesis and transpiration of tomato plants.* BIOTRONICS **19**, 1–6, 1990. Photosynthetic intensity, transpiration and stomatal resistance (R_s) of tomato plant leaves were studied at various light intensities and temperatures in the root zone. Temperature regime had an insignificant effect on a gas exchange of plants at an irradiation of 900 μmol m^{-2} s^{-1}. Less irradiation, 180 μmol m^{-2} s^{-1}, resulted in a relatively greater effect of temperature on CO_2 uptake. Transpiration rate and stomatal resistance to CO_2 varied slightly within a wide range of temperature changes. An increase and decrease of R_s were observed only at low (<14) and high (>28°C) temperatures, respectively. Reverse dependence was found for the process of transpiration. The highest transpiration coefficient Ph/T was observed at 20°C. The results indicate that it is necessary to take all the aspects of plant activity into account for determining optimal growth conditions.

Key words: *Lycopersicum esculentum* Mill; tomato; photosynthesis; transpiration; stomatal resistance; light intensities; temperature.

INTRODUCTION

Temperature regime in the root zone had a considerable effect on the rate of physiological processes determining plant productivity. Unfavourable conditions result in the decrease of CO_2 assimilation by leaves (*1*), growth rate, dry matter accumulation and plant productivity (*4*).

CO_2 assimilation is decreased due to the decrease of photosynthetic apparatus activity as well as to a change in the degree of stomatal aperture. It has been shown (*6*) that at low temperatures in the root zone the stomatal resistance (R_s) is increased, whereas transpiration and water uptake by plants are decreased. The increase of R_s leads to the decrease of CO_2 assimilation and the final result depends on the character of photosynthesis and transpiration relationship.

To understand temperature effects on photosynthetic activity it is very important to examine the effects of the environmental factors on photosynthesis and stomatal movement especially under the controlled conditions of sheltered ground. This is necessary for subsequent regulation of microclimate in accordance with plant requirements at various irradiation levels.

The aim of the present paper was to study CO_2 assimilation, transpiration and stomatal resistance of individual tomato plant leaves as well as gas exchange of intact plants under various temperatures in the root zone and light intensities.

MATERIALS AND METHODS

Tomato plants (*Lycopersicum esculentum* Mill), cv. Angela, were grown in hydroponics and soil under controlled conditions of a climate chamber. In the hydroponics irradiation was 510 μmol m^{-2} s^{-1} (PPFD), photoperiod—12 h, air temperature day/night—25/20°C, humidity—60%RH. At 5–7 leaves stage the plants were inserted into assimilation chamber of a gasometric device of an open type (*3*) to measure gas exchange. Gas exchange temperature curves were plotted at the irradiation levels of 180, 510 and 900 μmol m^{-2} s^{-1}. The temperature in the root zone was increased from 16–18°C to 40–45°C at a rate of 0.1–0.2°C per minute (*2*).

The potted plants were grown in Mitcherlich's 5 l vessel at 180 and 240 μmol m^{-2} s^{-1}, air temperatures of 25 and 30°C, respectively, and 40%RH. A gasometric device Li-6000 (Li-Cor) was used for measuring photosynthesis, transpiration and stomatal resistance of intact plant leaves.

RESULTS AND DISCUSSION

Photosynthetic light curves of plants grown at low light intensities have a similar dip angle of a linear part and saturation plateau at various irradiation (Fig. 1). The stomatal resistance (R_s) to CO_2 flow within a range of 105–180 μmol m^{-2} s^{-1} (a linear part of a light curve) was decreased from 6.0 to 2.0 s cm^{-1} and then it was insignificantly changed. Simultaneously with the decrease of R_s the transpiration rate was increased. With the increase of light intensity from 180 to 240 μmol m^{-2} s^{-1} during plant growth CO_2 assimilation on the saturation plateau was increased more than by one third. The stomatal resistance slightly varied. It should be also noted that the most efficient utilization of light by plants was observed at the intensities which corresponded to the irradiation levels used for plant growth. Similar results were obtained for intact tomato plants grown at 510 μmol m^{-2} s^{-1} (Fig. 2A). The light curve of gas exchange of a whole plant is characterized by a gradual transition from a linear part to a saturation plateau and by a high rate of CO_2 uptake on the plateau. This provides high efficiency of plant photosynthetic apparatus functioning within a wide range of light intensities (*11*).

On the basis of the results obtained, literature data and green house irradiation conditions (*7*), further experiments were carried out with the plants grown at 540

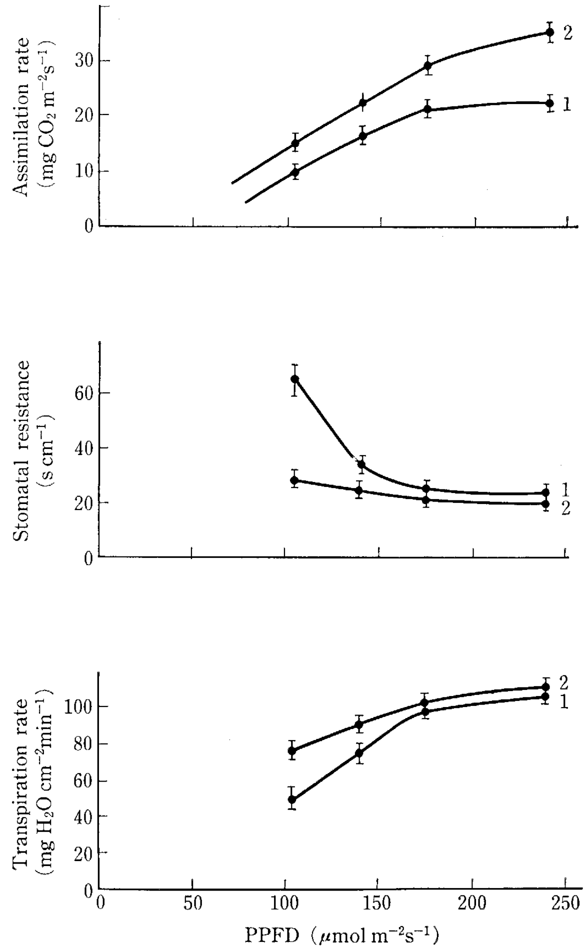

Fig. 1. Light curves of CO_2 uptake, transpiration and stomatal resistance of tomato leaves grown at 180 μmol m^{-2} s^{-1} (1) and 240 μmol m^{-2} s^{-1} (2).

μmol m^{-2} s^{-1}. The temperature of nutrient solution insignificantly affected plant gas exchange at a high light intensity of 900 μmol m^{-2} s^{-1}. At a lower irradiation level, 180 μmol m^{-2} s^{-1}, CO_2 uptake was affected to some extent by the temperature. This results in a more rapid decrease of CO_2 uptake rate with the deviation of temperature from the optimal value (Fig. 2B).

To examine the regulatory mechanisms of plant photosynthetic activity, CO_2 uptake, transpiration and stomatal resistance of individual plant leaves were studied under various temperature conditions (Fig. 3). Transpiration rate and stomatal resistance to CO_2 insignificantly varied within a wide range of soil temperature. The increase and decrease of R_s were observed only at low and high temperatures, respectively. Reverse dependence was found for plant transpiration.

Differences in temperature optimums of CO_2 uptake of individual leaves and whole plant probably result either from growth conditions on soil or nutrient solution or various temperature effect on a leaf and plant foliage. Complication of organization of photosynthetic apparatus leads to the decrease in the optimum

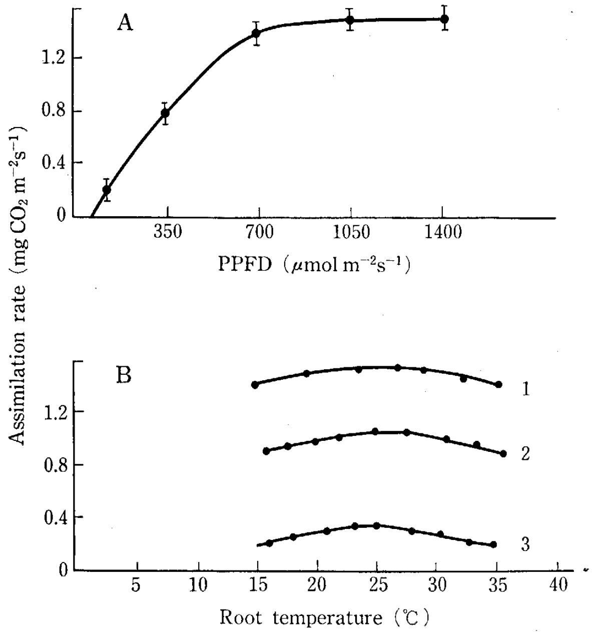

Fig. 2. A: light curves of CO_2 uptake by intact tomato plants grown at 510 μmol m^{-2} s^{-1}; B: temperature curves of CO_2 uptake at 180 (1), 510 (2) and 900 (3) μmol m^{-2} s^{-1}. The plants were grown at 510 μmol m^{-2} s^{-1}.

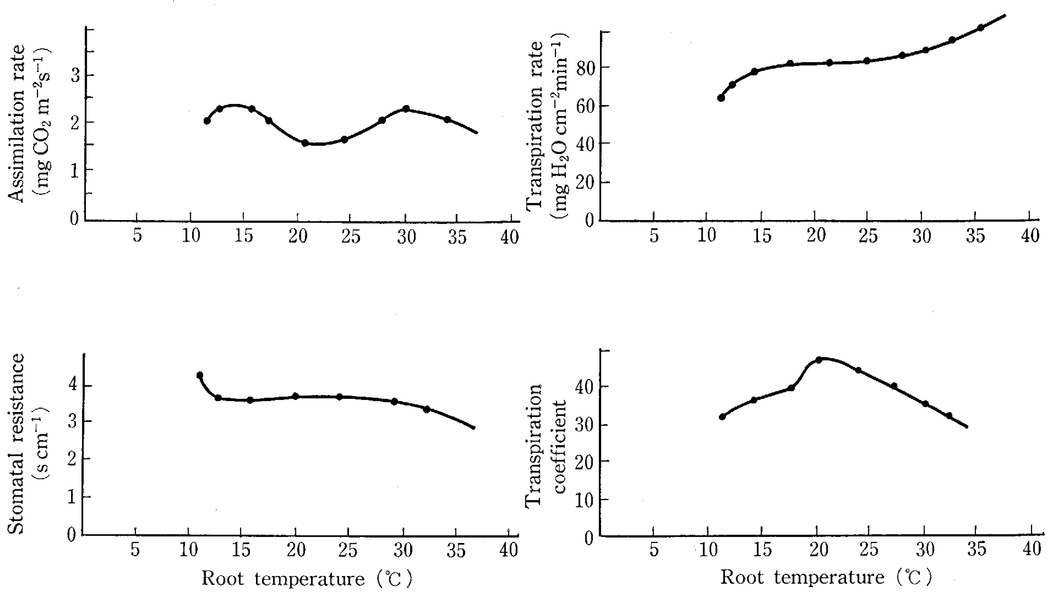

Fig. 3. CO_2 uptake, transpiration rate, stomatal resistance and water use efficiency by tomato plants at various temperatures in the root zone and light intensity of 80 μmol m^{-2} s^{-1}. The plants were grown at 180 μmol m^{-2} s^{-1}.

temperature of CO_2 uptake (*10*). Higher photosynthetic optimum temperatures were reported by Markovskaya and Kurets (*9*) when the measurements were carried out on individual leaves. In our case two peaks of CO_2 uptake by plant leaves were observed at low and high temperatures (Fig. 3). The decrease in a photosynthetic rate at a temperature lower than 14°C was simultaneous with the decrease in transpiration and the increase in stomatal resistance. According to Kramer (*6*) plant damage with a temperature lower than 15°C is due to the direct temperature effect on the root system as well as to water deficiency. At 20°C some decrease of CO_2 assimilation was not accompanied by a change in transpiration and stomatal resistance. This results in the increase of transpiration coefficient (Photosynthesis/Transpiration) within a range of 16–20°C (Fig. 3). A further temperature increase led to the decrease of the transpiration coefficient.

Optimal correlation between the water loss and gas exchange is achieved at moderate aperture of stomata when the transpiration coefficient is minimal. This results in the optimal correlation of gas exchange and transpiration as well as in maximum water use efficiency (*Tr*/*Ph*). The latter can or can not be taken into account during temperature regulation under sheltered ground conditions, since water is not a limiting factor. However, obviously it is necessary to examine all the aspects of temperature effect on physiological processes for optimization of temperature for plant growth.

The necessity to regulate the rates of physiological processes is well known. In particular, optimum temperature for the growth processes can be higher or lower than that of photosynthesis (*3*, *8*) and this should be taken into account if we want to get higher plant productivity. Therefore, it can be suggested that the parameters of transpiration coefficient should be also used while considering all the plant requirements during temperature regulation under sheltered ground. The results obtained confirm once more the necessity to take all the aspects of activity of plants into account for determining their optimum growth conditions.

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