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PHOTOSYNTHESIS AND ABSORPTION OF MINERAL NUTRIENT IN TOMATO PLANTS UNDER VARIOUS ROOT ZONE TEMPERATURE AND LIGHT CONDITIONS

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KOSOBRUKHOV A. A., BAGNAVETS E. A., SEMENOVA N. A. and CHERMNYKH L. N. *Photosynthesis and absorption of mineral nutrients in tomato plants under various root zone temperature and light conditions.* BIOTRONICS **17**, 21–28, 1988. Effect of various light and temperature regimes in the root zone on the light stage of photosynthesis, gas exchange, growth processes and absorption of mineral nutrients by tomato plants were studied. Optimum temperatures for dry matter accumulation and absorption of mineral nutrients were found to be shifted when the irradiation condition were changed. A shift of optimum temperatures for dry matter accumulation and absorption of mineral nutrients was found to be due to a change in irradiation conditions. It was 1.6°C per 70 Wm^{-2} within the range of 50–175 Wm^{-2}. The maximum absorption of mineral nutrients did not always coinside with the optimums of dry matter accumulation. For example, at 50 Wm^{-2} the maximum amounts of P, Ca and Mg were absorbed at higher temperatures as compared with the optimum temperatures for dry matter accumulation. Only for N and K these temperatures coinsided. At 175 Wm^{-2} the maximum absorption of N, P, K, Ca, Mg was at the temperatures corresponding to those optimal for dry matter accumulation. These data are of particular importance for precise regulation of temperatures and concentrations of mineral nutrients under controlled conditions of the hydroponic green houses.

Key words: tomato plant, *Lycopersicum esculentum* Mill.; photosynthesis; dry matter accumulation; mineral nutrient; root zone temperature; light intensity; NADPH; ATP.

INTRODUCTION

Great attention is devoted to the problem of determination of optimum condition for growing plants in the hydroponic green houses under conditions of changing irradiation (*4*, *6*, *16*). By regulating air and soil temperatures and maintaining optimal levels of mineral nutrition it is possible to increase plant productivity and to decrease the amount of energy spent on plant growth.

The maintenance of the temperature values in accordance with the maximum of photosynthesis increases plant productivity. Similar studies on different plants were carried out by numerous authors (*8*, *9*, *13*). Furthermore, a multi-factor dependence of gas exchange and plant productivity was obtained (*11*), the optimum growth temperatures were found (*7*). It is also possible to regulate mineral nutrition process in the hydroponic green houses. Accordingly, it is necessary to elucidate the correlation between the plant growth and absorption of mineral nutrients as well as the dependence of these processes on the environmental factors.

The aim of our investigations was to study photosynthetic activity, respiration, growth processes of the tomato plants and absorption of mineral nutrients depending on the level of irradiation and temperature in the root zone.

MATERIALS AND METHODS

Tomato seeds, *Lycopersicum esculentum* Mill. "Ukrainsky teplichnyi 285" variety, were germinated in cuvettes with peat at 105 Wm^{-2} irradiation and 25/20°C day/night air temperature. In 15–20 days the tomato seedlings were planted in Phytotron chambers with light intensities of 50, 105 and 175 Wm^{-2}, and a photoperiod of 12 h. The plants were illuminated with DRLF-400 lamps. The irradiance was measured with Kozyrev's pyranometer calibrated in the institute of Soil Science and Photosynthesis, USSR Academy of Sciences. Day/night air temperature was constant at 25/20°C. The temperature of the nutrient solution was 15, 18, 22, 25, 28, 30°C according to the experimental treatments. The investigations were carried out on water culture with Knop's nutrient mixture. The solution was changed every 3–4 days. The plants were grown at natural CO_2 concentration in the air. During the whole vegetation period every 3–4 days, 4–5 plants at the same growth stage were sampled to determine gas exchange, leaf area, dry matter accumulation and absorption of mineral nutrients. Temperature dependence of CO_2 gas exchange were calculated on the plant of 3–5 leaves stage at 50, 105 and 175 Wm^{-2} that corresponded to the levels of irradiation during the plant growth (*3*). The medium consisting of 0.4 M sucrose, 0.35 M NaCl, 0.1% bovine albumin and Tris-HCl buffer, pH 7.8, was used to isolate and suspend chloroplasts. The rates of non-cyclic electron transport and coupled phosphorylation were measured according to Mukhin and Chermnykh (*10*).

Absorption of N, P, K, Ca and Mg was calculated by their decrease in the nutrient solution. The analyses were carried out once a week. The following methods were applied: $N\text{-}NO_3$ was determined calorimetrically by its reduction to ammonia, P—according to Merfy and Raily (*1*), K—on a flame photometer, Ca and Mg—by a complexometric method (*12*). The experiments were replicated 4–6 times.

RESULTS AND DISCUSSION

Figure 1 shows the dependences of dry matter accumulation by the tomato plants on the 20th day after their planting on various levels of irradiation and temperature in the root zone.

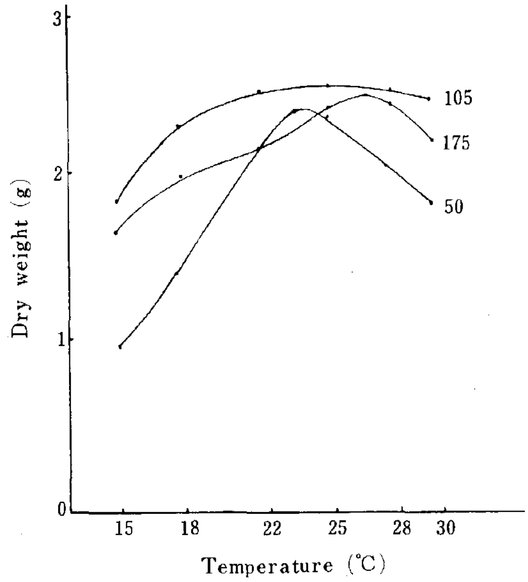

Fig. 1. Accumulation of dry matter by the tomato plants grown for 20 days at various levels of irradiation and temperature in the root zone.

Temperature rise from 15 to the range of 23–24°C at 50 Wm^{-2} resulted in more than a two-fold increase of dry matter accumulation. Further temperature rise led to a decrease in a plant growth rate, however, the negative effect of a higher temperature on the process of dry matter accumulation was less than that of a lower one (15°C).

The enhancement of plant irradiation up to 105 Wm^{-2} contributed to greater dry matter accumulation independently of temperature in the root zone. It should be noted as well that within the range of 18–30°C the temperature had no considerable effect on the process of dry matter accumulation. Only at 15°C a decrease in the accumulation rate is observed.

Under conditions of high irradiation (175 Wm^{-2}) the temperature rise from 15 to 26–27°C led to the increase of dry matter accumulation from 1.6 to 2.4 g per a plant. The further temperature rise (up to 30°C) resulted in the decrease of plant productivity.

Together with the various effect of temperature on the growth processes at different levels of irradiation, there is a shift of the optimum temperature for dry matter accumulation. In our experiments an increase in irradiation from 50 to 175 Wm^{-2} led to a shift of the optimum temperature for dry matter accumulation from 23.5 to 26.6°C. Thus, this shift was equal to 1.6°C per 70 Wm^{-2}. This fact indicates that it is necessary to maintain optimum temperature regimes in the root zone in accordance with the level of irradiation and it can be used under controlled conditions.

The obtained results can be compared with those the other works concerning an insignificant effect on one factor—light, temperature on the optimum temperature. However, the authors considered, as a rule, the effect of the preceding growth conditions on the optimum temperature of photosynthesis (*2*, *8*). The present

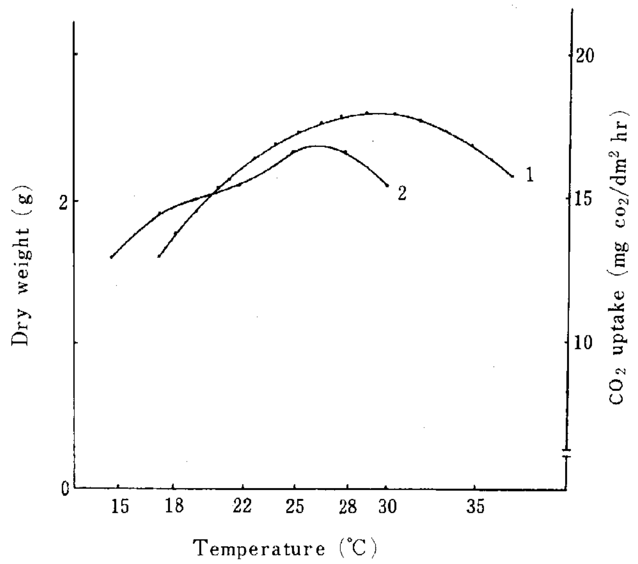

Fig. 2. Accumulation of dry matter (2) and CO_2 absorption (1) by the tomato plants grown for 20 days at 175 Wm^{-2} and various temperatures in the root zone.

results indicate that the optimum for dry matter accumulation is shifted when the level of irradiation is changed. In this case the optimum temperatures for photosynthesis and productivity do not coinside (Fig. 2). For example, for the plants grown at 175 Wm^{-2} the photosynthetic optimum was found at 30°C with a range of optimal temperatures from 23.6 to 35.6°C as a 10% decrease of the maximal value at 30°C. The optimum temperature for dry matter accumulation is lower, i.e. 26.6°C and the range of the optimum temperatures is narrowed as compared with that of the photosynthetic optimum temperature.

The shift of the optimum temperature observed for dry matter accumulation was also found for the process of absorption of mineral nutrients. Figure 3 shows the dependences characterizing the absorption of mineral nutrients from the nutrient solution at various temperatures in the root zone.

An increase in the level of irradiation led to a shift of the optimum temperature for the absorption of the nutrients towards higher values. In this case the greatest absorption of the elements did not always coinside with the optimums for dry matter accumulation. For example, the greatest absorption of P, Ca, and Mg under low irradiation conditions (50 Wm^{-2}) was observed at higher temperatures as compared with dry matter accumulation. Only for N and K the optimum coinsided. At 175 Wm^{-2} the optimum temperatures for the absorption of the elements and for dry matter accumulation were the same. As a result, the greatest absorption of N, P, K, Ca, Mg was found at high temperatures. High optimum temperature for P and Ca absorption was observed for some other plants, cucumber in particular (*14*). The data obtained at high irradiation are also supported by the results from Turner and Lahav (*18*) concerning the direct dependence of N, P, K, Mg distribution in accordance with that of dry matter.

It should be noted that the level of irradiation has a direct effect on the absorption on the nutrient elements. For example, at 50 Wm^{-2}, K was absorbed from the

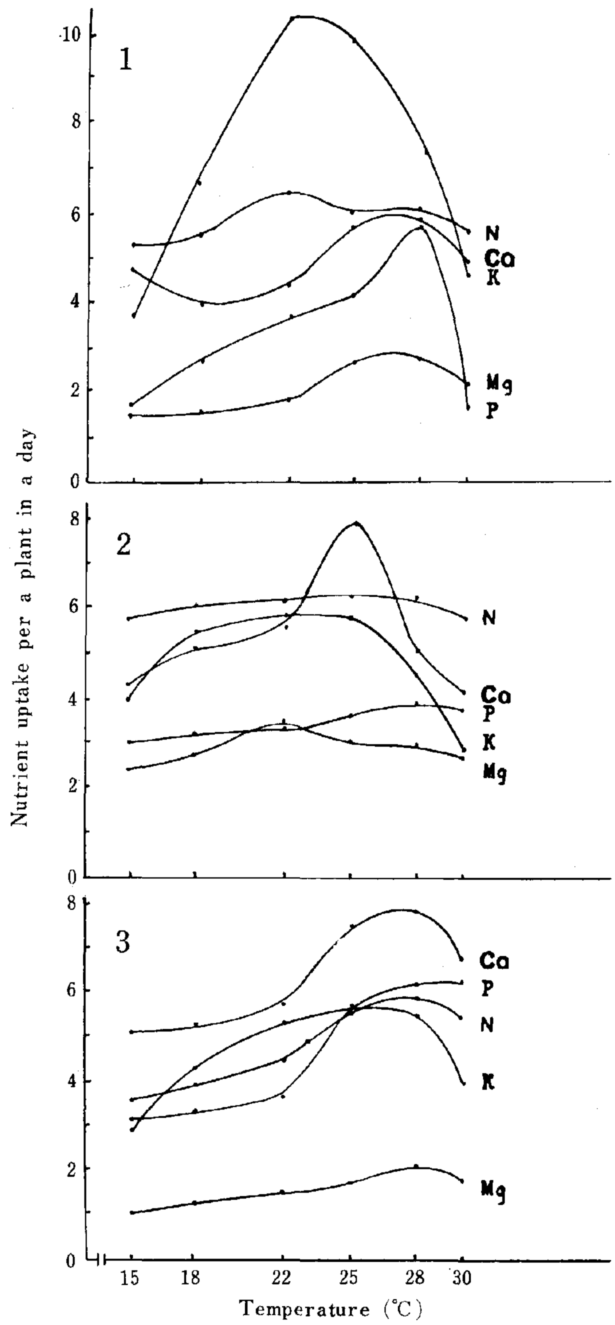

Fig. 3. Absorption of mineral nutrient elements by the tomato plants grown for 20 days at various levels of irradiation and temperature in the root zone. 1–50 Wm^{-2}, 2–105 Wm^{-2}, 3–175 Wm^{-2}.

nutrient solution at a high rate. With an increase in the level of irradiation to 105 Wm^{-2} and, especially, to 175 Wm^{-2} the absorption of potassium by the plants is decreased and that of calcium is increased. As a result, one stabilizing element is substituted for the other. This fact, probably, should be taken into account for regulating the content of the nutrient solution by decreasing potassium content and increasing the amount of calcium nitrate, especially as under conditions of increased temperatures, the plants efficiently use a nitrate form of nitrogen (*5*).

An increase in the absorption of phosphorus observed at high levels of irradiation and temperature characterizes a greater extent of application of this element in the plants. Indeed, a rise in temperature in the root zone to 25°C led to an increase of ATP synthesis and NADP reduction rate (Table 1).

At 30°C a decrease in the activity of photochemical reactions was observed.

It is well known that the chloroplast photochemical activity is increased with an increase in the level of irradiation (*17*). Thus, the plants grown at 175 Wm^{-2} and optimum temperatures are characterized by a high rate of photochemical reactions and, correspondingly, by a greater contribution of photosynthesis in supplying the growing plants with energy.

During our investigations we studied the rate of CO_2 absorption in the day-time and respiration in the night. The plants grown at the temperatures of greater accumulation of dry matter were shown to have a smaller respiration/photosynthesis ratio as compared with the plants grown at other temperatures (Table 2).

It indicates that the growth efficiency of the plants grown under optimum temperature conditions in the root zone is higher.

At high irradiation the temperature had no considerable effect on the value of the respiration/photosynthesis ratio, it can be compared with the results (*15*) obtained on sunflower and mustard plants. On the contrary, at 50 Wm^{-2} a change in the ratio value was significant. The greatest value of the respiration/photosynthesis ratio is characteristic for the plants grown at low levels of irradiation and is connected with a great decrease in the rate of CO_2 absorption and that of respiration with the decrease of light intensity (*19*).

Thus, investigation of the effect of various light regimes and temperature in the root zone on the light stage of photosynthesis, gas exchange, growth processes

Table 1. Rates of NADP reduction and ATP synthesis by the chloroplasts from the leaves of the tomato plants, grown at various temperatures in the root zone

Temperature in the root zone (°C)	NADPH	ATP
30	98.3±2.4*	56.0±2.4
25	114.3±3.8	76.0±1.6
20	98.0±3.2	56.0±1.2
15	56.0±3.2	28.0±2.0

* μmol mg Chl^{-1} h^{-1}. The values shown are means±square error of six independent experiments.

Table 2. Respiration/photosynthesis ratio in the tomato plants on the 20th day of the growth

Irradiation (Wm^{-2})	Temperature in the root zone (°C)					
	15	18	22	25	28	30
50	0.50	0.41	0.25	0.25	0.36	0.30
175	0.18	0.16	0.15	0.12	0.13	0.14

and absorption of mineral nutrients allowed us to find that it is nesessary to regulate temperature and plant nutrition in accordance with the level of irradiation. The shift of the optimum temperatures for dry matter accumulation and various optimums of the absorption of mineral nutrients are very important for correct regulation of temperature and concentration of the nutrient elements under the controlled condition of the hydroponic green houses.

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