

SHORT COMMUNICATION

EFFECT OF HEAT STRESS ON GAS EXCHANGE CHARACTERISTICS
IN TOMATO¹

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The effect of high temperature on CO₂ fixation was studied in four tomato genotypes, viz. Ailsa craig, Suncherry extra, UCA 204A and CLN 2026E. High temperature adversely affected the CO₂ gas exchange characteristics at the onset of flowering in all the four genotypes but magnitude of response differed. Photosynthetic rate was reduced significantly by heat-stress in genotypes UC 204A and Suncherry extra at early flowering stage (75 DAS) but it did not change in Ailsa craig and CLN 2026E. Significant reduction in photosynthetic rate due to heat-stress was observed during late flowering and ripening stage. The magnitude of reduction, however, was higher in genotypes Suncherry extra and UC 204A. Transpiration rate increased significantly in all the four genotypes at early flowering stage during heat-stress. However, we observed significant decrease in transpiration rate at later growth stages in Suncherry extra and UC 204A and this could be the possible reason for lesser adaptability of these genotypes at high temperature. The stomatal conductance followed same pattern, as of transpiration at flowering stage; however, stomatal conductance was not affected by heat-stress at ripening stage. The internal CO₂ concentration increased in all the four genotypes at flowering stage, however, no significant change in internal CO₂ concentration was noticed during ripening stage at high temperature.

Key words: Heat stress, photosynthesis, stomatal conductance, tomato, transpiration.

High temperature stress is one of the most important limiting factors for crop productivity, besides drought and salinity, under tropical and sub-tropical conditions. Inhibition of growth under supra-optimal temperature can result from thermal effects on many physiological and developmental processes (Fitter and Hay 1987). Photosynthesis, in particular is one of the most heat sensitive functions of the plant cell (Bjorkman *et al.* 1980). Temperature in the range of 35-45°C tends to inhibit photosynthesis in C₃ plants (Weis and Berry 1988). The photosynthetic rate increases with rise in temperature until an optima, after which an increase in temperature results in a decrease in rate of photosynthesis (Raschke 1970). Among the photosynthetic components, high temperature affects Calvin cycle, photosystem-II activity

(Camejo *et al.* 2005), photophosphorylation (Al-Khatib and Paulsen 1989, Havaux 1992) and Rubisco activity (Berry and Bjorkman 1980, Weis and Berry 1988, Karim *et al.* 1999). In the present study, four tomato genotypes were evaluated for the response of their gas exchange characteristics to heat-stress at reproductive phase.

Four tomato (*Lycopersicon esculentum* Mill.) genotypes, viz. Ailsa craig, Suncherry extra, CLN 2026E[†] and UC 204A[†] ([†]Seed material kind courtesy of Asian Vegetable Research and Development Center, Taiwan.) were used in this study. Seedlings were raised in small plastic pots (9-cm top diam.) filled with 200 g of sand, vermiculite and FYM (2:1:1) with five seeds per pot in a greenhouse under natural day light and 25/20°C day-night

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temperatures at JIRCAS, Okinawa, Japan. When the seedlings were three weeks old, they were transplanted to large wagner plastic pots (16-cm top diam.). Two seedlings per pot were transplanted, while upon establishment were thinned to one per pot. The plants were irrigated daily and 2 g of fertilizer (NPK, 14:14:14) was applied to each pot at fortnight interval. The pots were arranged in completely randomized design in triplicate of two sets and were kept in a greenhouse maintained at 25/20°C day-night temperatures (control) under natural illumination until initiation of flowering (60DAS). Thereafter, one set of pots was then moved to another greenhouse with 35/27°C (heat-stress) day-night temperatures.

The net photosynthetic rate (P_n), stomatal conductance (g_s), transpiration rate (E) and internal CO_2 conc. (C_i) were recorded at early flowering (75 DAS), late flowering (105 DAS) and ripening (120DAS) stages on fully developed youngest leaf from both greenhouses with an infrared gas analyzer (Model LCA-4, ADC, Hertz, UK) equipped with air supply unit and Parkinson

broad leaf chamber (aperture area 6.25 cm²). Measurements were made within one minute after enclosing the leaf into the chamber between 1100 to 1300 hours. The data was analyzed statistically as per the procedure described by Panse and Sukhatme (1985).

Heat-stress when imposed at the onset of flowering stage, adversely affected the gas exchange characteristics in all the four genotypes but magnitude of response differed. The net photosynthetic rate was reduced significantly by heat stress in genotypes UC 204A and Suncherry extra at early flowering stage (75 DAS) but there was no significant effect of heat stress on net photosynthetic rate in genotypes Ailsa craig and CLN 2026E (Fig. 1). However, significant reduction in photosynthetic rate due to heat stress was observed during late flowering and ripening stages in all the four genotypes (Fig. 1), though the magnitude of reduction was higher in Suncherry extra and UC 204A.

Transpiration rate increased significantly in all the four genotypes at early flowering stage during heat stress.

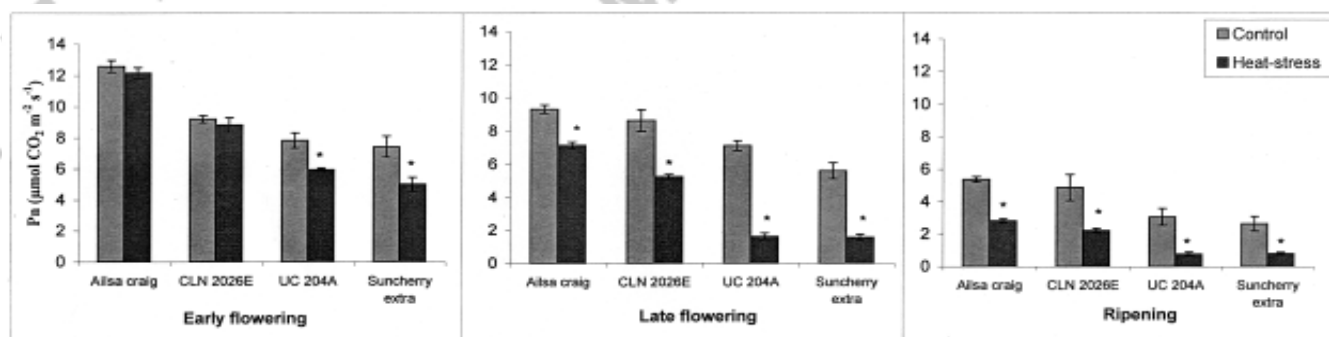


Fig. 1. Effect of heat-stress on net photodynamic rate (P_n) during flowering and ripening stage of four tomato genotypes. Each bar represents mean \pm SEM of three replicates.

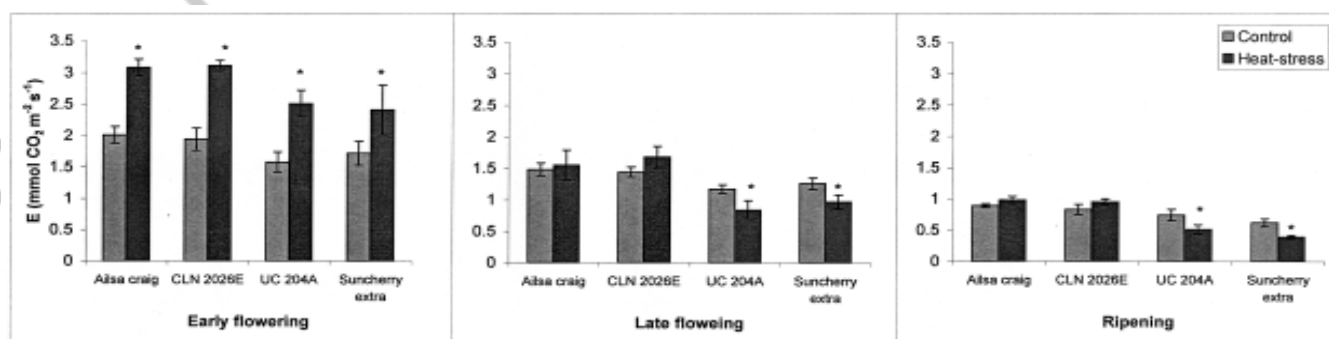


Fig. 2. Effect of heat-stress on transpiration rate (E) during flowering and ripening stage of four tomato genotypes. Each bar represents mean \pm SEM of three replicates.

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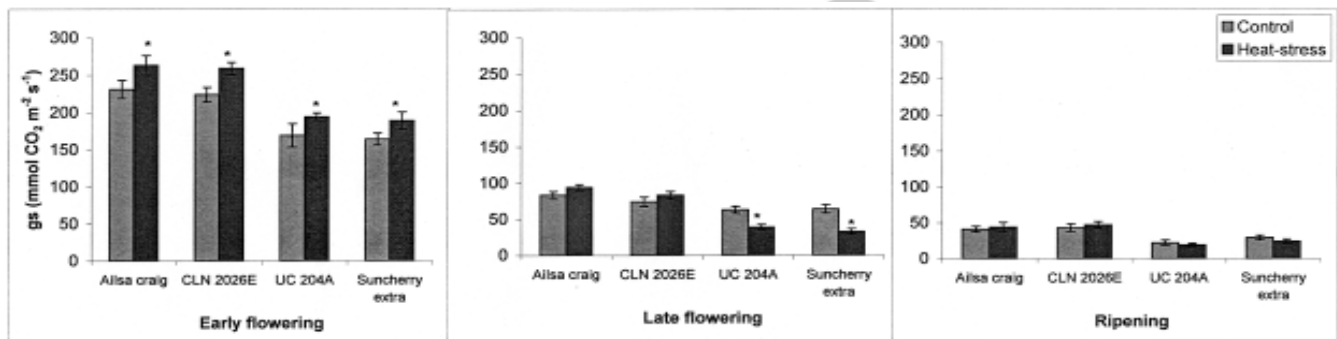


Fig. 3. Effect of heat-stress on stomatal conductance (gs) during flowering and ripening stage of four tomato genotypes. Each bar represents mean \pm SEM of three replicates.

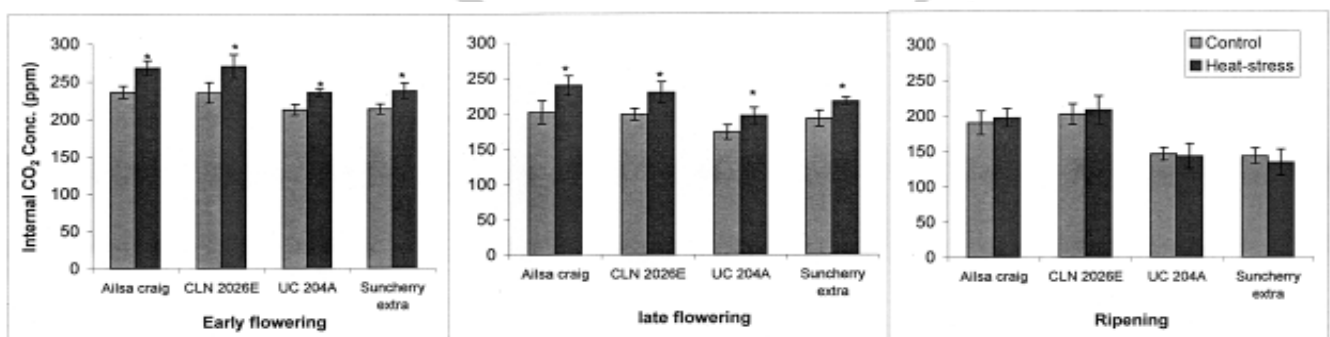


Fig. 4. Effect of heat-stress on internal CO₂ conc. (Ci) during flowering and ripening stage of four tomato genotypes. Each bar represents mean \pm SEM of three replicates.

However, we observed significant decrease in transpiration rate during the flowering and ripening stages in Suncherry extra and UC 204A (Fig. 2) and this could be the possible reason for lesser adaptability of these genotypes at high temperature. The stomatal conductance followed same pattern, as of transpiration at early and late flowering stages (Fig. 3); however, stomatal conductance was not affected by heat stress at ripening stage. The internal CO₂ concentration increased in all the four genotypes at early and late flowering stages (Fig. 4), however, no significant change in internal CO₂ concentration was noticed during ripening stage at high temperature.

Photosynthesis, in particular is one of the heat sensitive functions of the plant cell (Bjorkman *et al.* 1980). Temperature in the range of 35–45°C tends to inhibit photosynthesis in C₃ plants (Weis and Berry 1988). We observed significant reduction in photosynthetic rate of heat sensitive genotypes (UC 204A, Suncherry extra), when the heat stress was imposed at the on set of

flowering stage (Fig. 1), however, there was not much change in the net photosynthetic rate of heat tolerant genotypes. The transpiration rate, stomatal conductance and internal CO₂ concentration increased during heat stress (Fig. 2,3,4). The reduction in photosynthetic efficiency by high temperature has been reported in mungbean (Hamid *et al.* 1991), cabbage (Chauhan and Senboku 1996) and tomato (Bar-Tsur *et al.* 1985, Camejo *et al.* 2005). Heat stabilization of photosynthetic efficiency in tolerant genotypes possibly occurred due to desaturation of lipids in thylakoid membranes (Murakami *et al.* 2000). The reduced level of lipid unsaturation improved the rate of photosynthesis and plant growth at high temperature (Gombos *et al.* 1994). Increased transpiration rate and stomatal conductance enables plants to avoid heat stress by lowering leaf temperature (Hamid *et al.* 1991, Hall 1992). Jin and Shen (1999) noticed that the increase in transpiration rate in heat resistant cultivars was much higher than that in heat susceptible one, under high temperature stress. Higher stomatal conductance may lead to increase in intercellular CO₂ concentration

during heat stress. Therefore, it seems that some non-stomatal factors are responsible for decreased photosynthetic rate in heat sensitive genotypes at early flowering stage.

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