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Positive role of melatonin on photosynthetic performance in tomato seedling under high temperature stress

Mohammad Shah Jahan and Shirong Guo*

College of Horticulture, Nanjing Agricultural University

Photosynthesis is a fundamental biosynthetic process in plants that can enhance carbon absorption and increase crop productivity. Heat stress severely inhibits photosynthetic efficiency. Melatonin has been established as a ubiquitous phytohormone capable of regulating diverse abiotic stress tolerances. However, the underlying mechanisms by which melatonin stimulates photosynthetic capacity and the understanding of melatonin-mediated photosynthesis in plants exposed to heat stress largely remain to be elucidated. Here, we revealed the putative functions of melatonin (100 μM) in the regulation of photosynthesis under heat stress (42°C for 24 h) in tomato. Our results revealed that melatonin treatment increased/enhanced the endogenous melatonin content along with its biosynthesis gene expression, resulting in an increased chlorophyll content and biosynthesis transcript abundance under high-temperature stress, whereas heat stress significantly decreased the values of gas exchange parameters. Under heat stress, melatonin boosted CO_2 assimilation, i.e., Vc,max (maximum rate of ribulose-1,5-bisphosphate carboxylase, Rubisco), and Jmax (electron transport of Rubisco generation). Moreover, melatonin application increased Rubisco and FBPase activities, which resulted in upregulated expression of the transcripts of photosynthetic related genes under the same stress conditions. In addition, heat stress profoundly reduced the photochemical properties of photosystem II (PSII) and photosystem I (PSI), particularly the maximum quantum efficiency of PSII (Fv/Fm) and PSI (Pm). Conversely, supplementation with melatonin significantly increased the chlorophyll a fluorescence parameters. Heat stress decreased the actual PSII efficiency (ΦPSII), electron transport rate (ETR) and photochemical quenching coefficient (qP) while increasing nonphotochemical quenching (NPQ); however, melatonin reversed these values, which helps to protect the photosynthetic apparatus, resulting in the dissipation of excess excitation energy. These findings indicated that melatonin protected the PSII and PSI reaction centers and increased the electron transport efficiency. Taken together, our results provide profound insight into the efficacy of melatonin-mediated photosynthesis in a high-temperature regime.

Results

Fig. 1 Effects of melatonin treatment and heat stress on phenotyping appearance of tomato plants

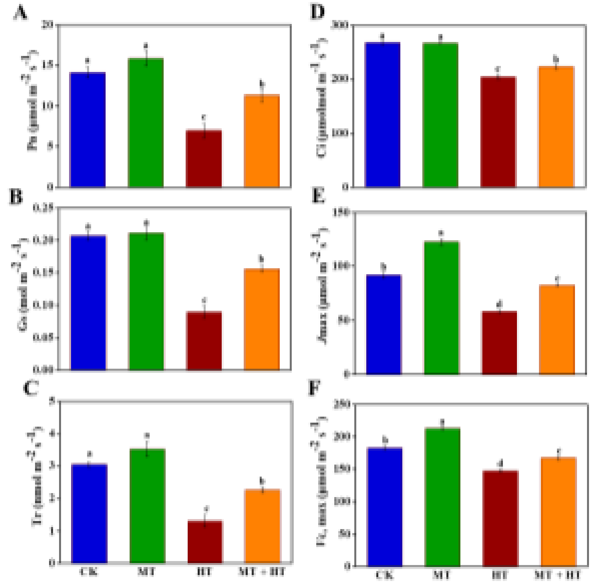

Fig. 2 Effects of melatonin treatment gas exchange and CO_2 assimilation of tomato plants under heat stress

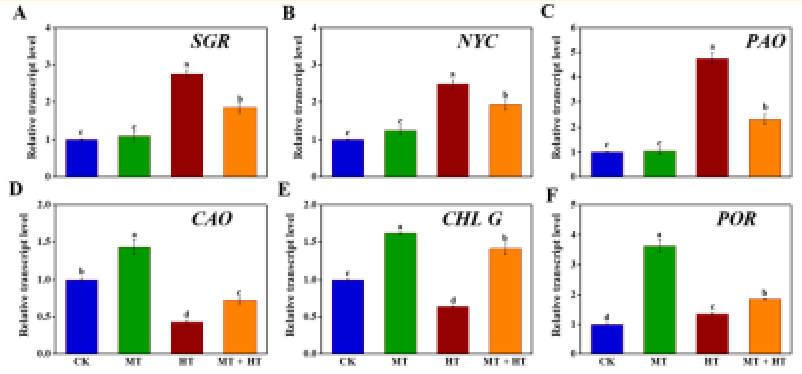

Fig. 3 Interactive effects of melatonin treatment and high temperature on chlorophyll related gene expression

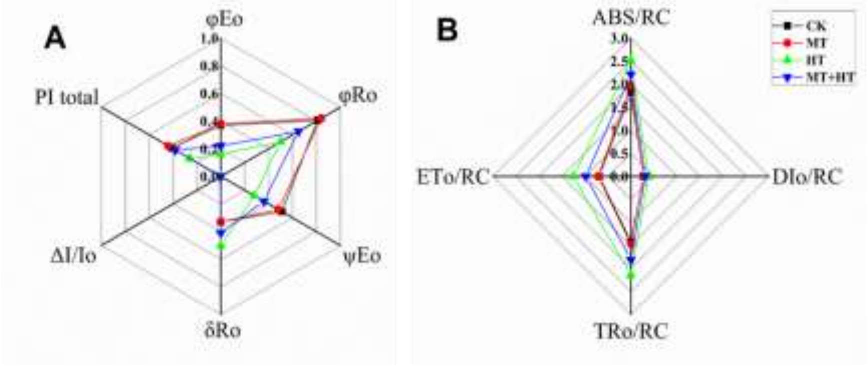

Fig. 4 Radar plots shows the chlorophyll a fluorescence parameters

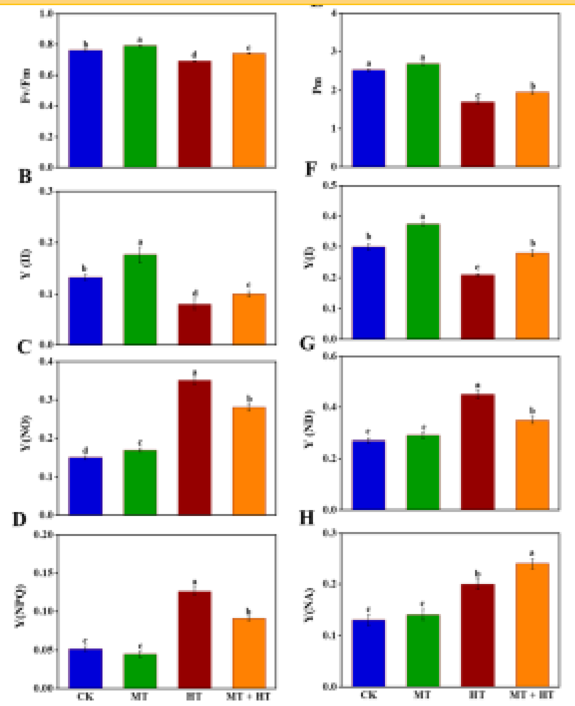

Fig. 5 Effects of melatonin treatment photochemistry properties of (A-D) photosystem II and (E-H) photosystem I

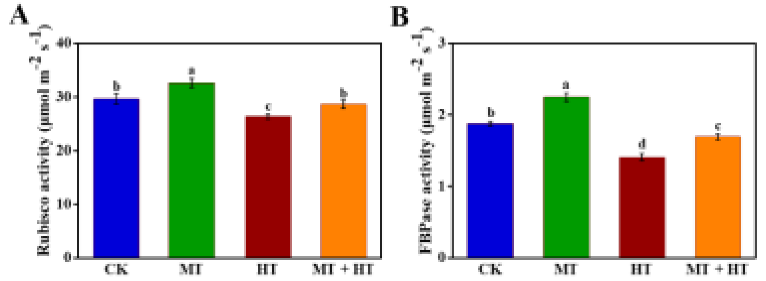

Fig. 6 Effects of melatonin treatment on (A) Rubisco And (B) FBPase enzyme activity under heat stress

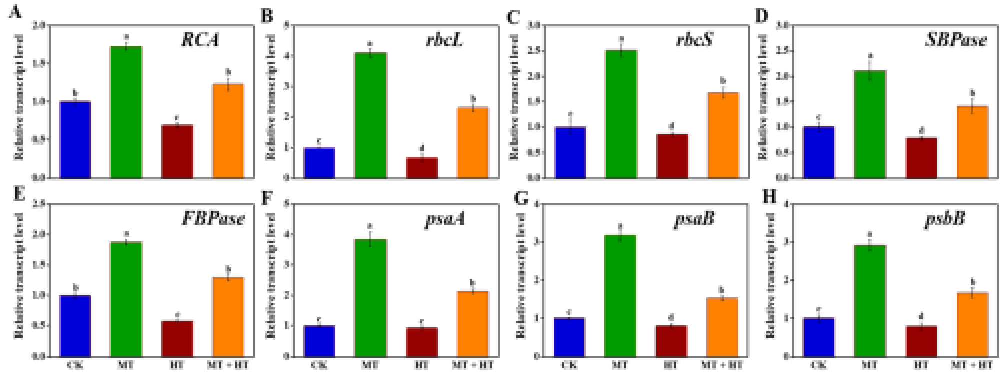

Fig.7 Interactive effects of melatonin treatment and high temperature photosynthesis related gene expression

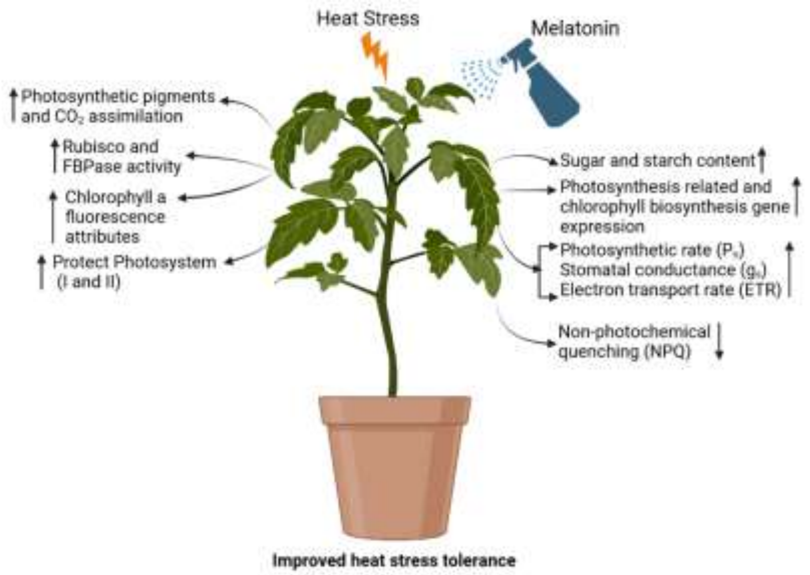

Fig. 8 Schematic summary of melatonin-mediated photosynthesis regulation.

Conclusion: The summary of the interactive functions of melatonin and heat on photosynthetic performance is presented in Figure 3. Melatonin treatments can attenuate heat stress-induced photoinhibition by enhancing sugar metabolism and upregulating melatonin biosynthesis. Melatonin increases CO2 assimilation (Jmax and Vc,max), resulting in the stabilization of gas exchange attributes and restoration of photosynthetic pigment contents under heat stress. In addition, melatonin enhances activity of key photosynthetic enzymes (Rubisco and FBPase). Moreover, the photochemistry of photosystems II and I along with the chlorophyll a fluorescence apparatus was boosted by melatonin application. Overall, melatonin suppressed the heat-induced photosynthetic damage to tomato plants by increasing photosynthesis efficiency and protecting the photosystem.

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