Promotive effects of 5-aminolevulinic acid on photosynthesis and chlorophyll fluorescence of tomato seedlings under suboptimal low temperature and suboptimal photon flux density stress – Short communication

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Abstract

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Effects of 5-aminolevulinic acid (ALA) on photosynthetic characteristics of tomato grown under suboptimal conditions were investigated to evaluate the potential value of ALA spraying in vegetables. The net photosynthetic rate (Pn), stomatal conductance (Gs), maximum quantum efficiency of photosystem II (Fv/Fm), coefficient of photochemical quenching (qP), antenna transformation efficiency (Fv'/Fm'), light compensation point (LCP), CO_2 compensation point (CCP) and chlorophyll (chl) contents of tomato stressed by suboptimal temperature (17°C/12°C) and suboptimal photon flux density (250 μmol/m^2s) were decreased, but intercellular CO_2 concentration (Ci) was increased distinctly. Compared with the parameters of tomato pretreated with water, Pn, Gs, Fv/Fm, qP, Fv'/Fm' and chl content of tomato pretreated with ALA were increased, and the Ci, LCP and CCP were decreased obviously. These results indicate that the inhibition of photosynthesis induced by suboptimal stress can be alleviated by ALA spraying.

Keywords: protected culture; *Solanum lycopersicum*; environmental stress; chemical substance; carbon assimilation

Abiotic stresses due to suboptimal photon flux density (PFD) (below 300 μmol/m^2s) and suboptimal temperatures (below 20°C/12°C, day/night) are frequent in sunlight greenhouses in winter world wildly and may last a long time, resulting in a decline in production and quality of vegetable. Unfortunately, only a few of studies focused on effects of suboptimal temperature stress on the growth and development of vegetables (Edelstein, Kigel 1990; Mercado et al. 1997; Liang et al. 2009).

Low concentrations of 5-aminolevulinic acid (ALA), which is a key precursor in the biosynthesis of all porphyrins compounds, can increase tolerance of plants to cold (Wang et al. 2004; Korkmaz et al. 2010), increase crop yield (Hotta et al. 1997; Watanabe et al. 2006). This experiment was aimed to investigate the effects of spraying ALA on photosynthesis and chlorophyll *a* fluorescence of tomato grown under suboptimal stress to evaluate the potential value of spraying ALA on vegetables cultured under suboptimal stress.

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Table 1. Effects of ALA pretreatment on photosynthetic parameters of tomato under suboptimal treatments

Treatment	Pn (μmol/m²s)	Ci (μmol/mol)	Gs (mmol/m²s)	LCP (μmol/m²s)	CCP (μl/l)
Optimal & water	8.70 ± 0.36[a]	235.67 ± 6.81[c]	99.33 ± 6.11[a]	74.76 ± 6.99[a]	87.14 ± 4.49[a]
Suboptimal & water	4.08 ± 0.66[c]	310.67 ± 3.21[a]	64.33 ± 4.04[b]	33.81 ± 2.83[b]	62.24 ± 4.39[b]
Optimal & ALA	9.33 ± 0.99[a]	225.33 ± 8.51[c]	102.67 ± 7.57[a]	72.28 ± 4.65[a]	85.63 ± 4.78[a]
Suboptimal & ALA	5.60 ± 0.72[b]	283.00 ± 18.52[b]	74.67 ± 3.79[b]	19.66 ± 5.61[c]	53.57 ± 5.51[b]

ALA – 5-aminolevulinic acid; Pn – net photosynthetic rate; Ci – intracellular CO_2 concentration; Gs – stomatal conductance; LCP – light compensation point; CCP – CO_2 compensation point

MATERIAL AND METHODS

Tomato seedlings (*Solanum lycopersicum*) were cultured in a sunlight greenhouse in the experiment base of Shandong Agricultural University in Tai'an, Shandong Province, China from March 2010 to July 2010. The temperature in the greenhouse was about 26 ± 4°C, the relative humidity (RH) was about 50–60% and the average PFD in the morning (9:00) was 570 ± 10 μmol/m²s and in the afternoon (13:00) it was 1,170 ± 50 μmol/m²s. Half of healthy tomato seedlings with similar height (about 5 to 6 leaves) were sprayed with 10 ml ALA (30 mg/l, Sigma, St. Louis, USA) per plant. The remaining ones were sprayed with equal amount of distilled water. ALA or distilled water was sprayed again after 3 days. After another 3 days, half of the seedlings pretreated with ALA or distilled water were transferred into a phytotron and the environment was controlled as: 700 μmol/m²s PFD, 25°C/20°C (day/night) (labeled as optimal and water or optimal and ALA in the tables), 65–70% RH with 12/12 photoperiod. The remaining ones were transferred into another phytotron with same RH and photoperiod, but the PFD was 250 μmol/m²s and temperature was 17°C/12°C (day/night) (labeled as suboptimal and water or suboptimal and ALA in the tables). After 7 days, the photosynthetic parameters of the fourth leaf were measured at 9:30 a.m. to 11:00 a.m. by a CIRAS-2 portable photosynthesis system (PP-systems, Amesbury, UK) and then chlorophyll fluorescence parameters were measured by a portable fluorometer (FMS-2, Hansatech, King's Lynn, UK) according to the handbook. After that, the chlorophyll contents were determined according to the method of Memon et al. (2009).

Values are means ± one standard deviation (SD) of 4 repetitions. Statistical analyses were carried out using DPS (Refine Information Tech. Co., Ltd., Hangzhou, China) software. Lowercase within columns showed significant difference ($P < 0.05$) between treatments.

RESULTS AND DISCUSSION

No changes were observed in net photosynthetic rate (Pn), stomatal conductance (Gs), intracellular CO_2 concentration (Ci), light compensation point (LCP), CO_2 compensation point (CCP), maximum quantum efficiency of phorosystem II (Fv/Fm), antenna transformation efficiency (Fv'/Fm'), coefficient of photochemical quenching (qP) and chlorophyll (chl) *a* and *b* of tomato seedlings pretreated with water or ALA cultured under optimal condition for 7 days. But the Pn, Gs LCP, CCP, Fv'/Fm', qP and chl *a* and *b* content of seedlings pretreated with water decreased evidently after 7 day's subop-

Table 2. Effects of ALA pretreatment on chlorophylls fluorescence parameters and chlorophyll content of tomato under suboptimal treatments

Treatment	Fv/Fm	Fv'/Fm'	qP	Chl *a* content (mg/g FW)	Chl *b* content (mg/g FW)
Optimal & water	0.880 ± 0.001[b]	0.799 ± 0.021[a]	0.905 ± 0.004[a]	1.226 ± 0.044[a]	0.369 ± 0.009[a]
Suboptimal & water	0.858 ± 0.001[d]	0.587 ± 0.015[c]	0.709 ± 0.011[c]	0.796 ± 0.084[c]	0.191 ± 0.011[c]
Optimal & ALA	0.888 ± 0.004[a]	0.825 ± 0.005[a]	0.916 ± 0.003[a]	1.253 ± 0.046[a]	0.389 ± 0.022[a]
Suboptimal & ALA	0.871 ± 0.002[c]	0.666 ± 0.029[b]	0.748 ± 0.003[b]	0.922 ± 0.067[b]	0.250 ± 0.019[b]

ALA – 5-aminolevulinic acid; Fv/Fm – maximum quantum efficiency of phorosystem II; Fv'/Fm' – antenna transformation efficiency; qP – coefficient of photochemical quenching; chl – chlorophyl timal stress, which was consistent with the results of Al-Qurashi and Awad (2011) from date palm. However, pretreatment with ALA led to a significant alleviation of the decrease in Pn Gs LCP, CCP, Fv'/Fm', qP and chl *a* and *b* content. For example, the Pn of tomato seedlings pretreated with ALA under suboptimal stress was 37% greater than that of seedlings pretreated with water under suboptimal stress, which was consisted with other results (Hotta et al. 1997; Wang et al. 2004; Memon et al. 2009; Naeem et al. 2010).

The Ci of seedlings pretreated with water was increased evidently after 7 days suboptimal stress and pretreatment with ALA can reduce this increase (Tables 1, 2). These results indicated that the electron transferring of PSII reactive centers were partly inhibited by suboptimal stress (Venema et al. 2000), while ALA pretreatment can alleviate this down-regulation and this alleviation may result from relative higher level of chlorophyll contents (Tanaka et al. 1992, 1993; Korkmaz et al. 2010).

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