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Transpiration dynamics of quinoa for controlled environment agriculture: Interactions of light, salinity and nitrogen

H E M Khairul Mazed[1], Sebastian Heintze[2], Jörn Germer[3], Folkard Asch[4]

[1] *University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*
[2] *University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*
[3] *University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*
[4] *University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*

Abstract

Transpiration rate regulates plant water use, nutrient transport, and evaporative cooling – processes critical for plant growth and air humidity control in controlled environment agriculture (CEA). Complementing water requirements from marginal sources such as municipal or saline groundwater requires high water through-put in plant growing systems. High transpiration rates as well as highly efficient nutrient uptake increase the volume of water that can be potentially purified through plant production in CEA deep water hydroponics. Quinoa (*Chenopodium quinoa* Willd. cv. Titicaca), a stress-tolerant halophyte with growing global importance, remains poorly studied in hydroponic CEA, particularly regarding transpiration responses and nutrient uptake under suboptimal nitrogen nutrition.

In this study, quinoa cv. Titicaca was grown under two light sources (LED and metal halide, MHL) with contrasting spectral PAR, combined with two salinity levels (0 and 150 mM NaCl) and two nitrogen ratios (NO_3^-:NH_4^+ = 50:50 and 100:0) at 3.0 mM total N. Over 30 days, five harvests quantified biomass and leaf area, while daily transpiration and nutrient solution measurements enabled estimation of water flux. The system was nearly sealed, so water loss occurred only via transpiration. Daily water loss was recorded at a fixed time, calculated per plant, and normalised by leaf area to derive transpiration rates (mmol cm ^{2}day ^{1}).

Maximum cumulative transpiration (21.33 L plant^{-1}) occurred under non-saline, no-ammonium conditions with MHL, followed by LED (18.45 L plant^{-1}), corresponding to 17.6–18.0 mmol cm ^{2}day ^{1}. Salinity reduced transpiration by 29.85 % under MHL (18.12 to 12.71) but only 1.52 % under LED. Without ammonium, transpiration declined by 28.62 % with salt, while cumulative loss decreased by 53.60 % under MHL and 61.65 % under LED. Overall, 150 mM NaCl reduced transpiration by 16.38 % and stomatal conductance by 44.36 %.

Under LED without ammonium, stomatal conductance increased by 172 % and shoot biomass by 36.87 % compared to MHL. Salinity reduced leaf area by 51 % under LED and 36 % under MHL. Under salinity, transpiration was 47 % higher under LED than MHL, whereas under non-saline conditions, MHL showed 39 % higher transpiration. Quinoa transpiration is strongly influenced by light, salinity, and nitrogen form, offering opportunities to optimise water use and system efficiency in hydroponic CEA.

Contact Address: H E M Khairul Mazed, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Gerstenstrasse 5, 70599 Stuttgart, Germany, e-mail: hemkhairul.mazed@uni-hohenheim.de

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