PLOS One

RESEARCH ARTICLE

Use of spectral indices and photosynthetic parameters to evaluate the growth performance of hydroponic tomato at different salinity levels

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Citation: Al-Gaadi KA, Zeyada AM, Tola E, Madugundu R, Edrris MK, Mahjoop O (2025) Use of spectral indices and photosynthetic parameters to evaluate the growth performance of hydroponic tomato at different salinity levels. PLoS One 20(6): e0325839. https://doi.org/10.1371/journal.pone.0325839

Editor: Mayank Anand Gururani, United Arab Emirates University, UNITED ARAB EMIRATES

Received: December 30, 2024

Accepted: May 19, 2025

Published: June 6, 2025

Data availability statement: All relevant data are within the manuscript and its Supporting Information files.

Abstract

Conventional methods for measuring plant physiological parameters are expensive and time-consuming, and this has promoted the use of optical and sensing techniques. Therefore, this study was conducted to investigate the effect of salinity on the performance of hydroponic tomato plants, based on optical and sensing techniques (i.e., spectral indices and photosynthetic parameters), as well as fruit yield. Four spectral vegetation indices-VIs (Moisture Stress Index "MSI", Canopy Response Salinity Index "CRSI", Normalized Difference Nitrogen Index "NDNI" and Green Leaf Index "GLI") were calculated using spectral measurements collected from tomato plant leaves. Also, four photosynthetic parameters (Net photosynthetic rate "P_N", Water use efficiency "WUE", Transpiration rate "Tr" and Total stomatal conductance "Gs") were measured from the same tomato plant leaves. Measurements were recorded for tomato plants grown under three salinity levels (Salinity-1; 2.5 dS m^{-1}), (Salinity-2; 4.0 dS m^{-1}), and (Salinity-3; 6.5 dS m^{-1}) at different growth stages represented by days after transplantation (DAT), as 35 DAT (vegetative stage), 50 DAT (1st cluster flower stage), 60 DAT (3rd cluster flower stage), 75 DAT (fruit development stage) and 85 DAT (fruit ripening stage). Results showed that tomato plants were significantly affected by the imposed salinity treatments. Where, tomato plants treated with salinity-1 was healthier compared to salinily-3 treated plants. This has been concluded from the results of the studied VIs, where the highest mean values of MSI (0.543) and CRSI (0.779) were associated with salinity-3, along with low values of GLI (0.353) and NDNI (0.220), indicating high salinity stress. However, the highest mean values of both NDNI (0.232) and GLI (0.386) were observed for salinity-1, indicated healthy condition. It also proven with the studied photosynthetic parameters, with the highest mean values of P_N (9.8 µmol CO_2 m^{-2} s^{-1}),Gs (0.117 mmol H_2O m^{-2}

Funding: This study was funded by the Deanship of Scientific Research, King Saud University, for funding this study through the Vice Deanship of Scientific Research Chairs.

Competing interests: No authors have competing interests

s^{-1}) and Tr (2.236 mmol H_2O m^{-2} s^{-1}) were associated with salinity-1, While the lowest mean values of P_N (8.3 µmol CO_2 m^{-2} s^{-1}), Gs (0.102 mmol H_2O m^{-2} s^{-1}) and Tr (1.902 mmol H_2O m^{-2} s^{-1}) were recorded for the plants treated with salinity-1. Moreover, the total tomato fruit yield also decreased significantly at salinity-3 compared to salinity-1.

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the major fresh and healthy crops worldwide and the second most important agricultural crop after potato [1]. Hernández-Pérezet al. [2] stated that tomato production will become insufficient in the near future, due to increasing demand as a result of population growth and scarcity of land and some abiotic stress factors. Salinity stress is among the most important factors causing a decrease in tomato yield [3]. However, hydroponics, an advanced system for growing plants in greenhouses, has been used to control nutrition, irrigation, and environmental factors [4], control salt concentrations for plants [5], and achieve high productivity and economic returns [6].

Tomatoes are among the most important plants grown under hydroponic systems in greenhouses in Saudi Arabia, as greenhouse tomato cultivation constitutes about 50% of the total tomato production [7]. Saudi Arabia is located in a dry desert environment with very low rainfall, with an average annual rainfall of less than 100 mm and no other water resources for freshwater supplies, such as lakes or rivers [8]. However, using saline water to irrigate crops is an effective solution to overcome the shortage of freshwater [9]. Tomatoes are plants that tolerate moderate salinity, while high salinity concentrations have a negative effect on plant growth and fruit development [10]. Tomatoes can tolerate salinity within an electrical conductivity (EC) range of 1.3 to 6.0 dS m^{-1} [11]. However various studies have reported a reduction in tomato fruit weight of about 10% at an EC of 5.0–6.0 dS m^{-1}, and 30% at an EC of 8.0 dS m^{-1} [11]. In fact, the ability of plants to tolerate salinity stress varies based on different growth stages [12], as tolerance to salt stress at a certain stage of plant growth does not mean tolerance at other growth stages [13].

Spectroscopy, which relies on the absorption and reflection of light energy, has become a rapid and non-destructive alternative method for detecting plant stress [11]. Spectral vegetation indices can be described as a mathematical analysis of multiple spectral bands of the electromagnetic spectrum [14]. The spectral vegetation indices can also be used to determine the spatial variability of crops within a field based on crop water availability and variations in soil parameters [15]. The concept of plant spectral reflectance is that healthy plants absorb more light in the visible part of the electromagnetic spectrum with less reflectance, while reflecting more light in the near-infrared part of the spectrum than plants under stress [16]. Roman and Ursu [17], noted that healthy plant leaves absorb about 70–90% of the visible light and reflect green light so that these leaves become visible to the naked eye. However, green light, when absorbed by leaves, activates photosynthesis very efficiently [18]. These different wavelengths of light can directly regulate photosynthesis by affecting stomata, chloroplast development, pigment content, and the activity of photosystems