A water saving approach by using the light effect on tomato plants grown in a controlled environment

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Abstract

The agriculture sector consumes more than two-thirds of world's limited freshwater resources. However, only a small part of the water (less than 5%) that is taken up by roots is used for plant growth, while the rest (above 95%) is lost due to transpiration through the stomatal apertures. Therefore, reducing the transpiration of agricultural plants will contribute to the preservation of precious water resources. However, reducing the transpiration rate artificially is difficult because most plants react delicately and negatively, resulting in water-stressed conditions that often cause different physiological disorders. The present study investigated the transpiration light response in tomato plants (Solanum lycopersicum) grown under LED lights and assessed different irradiation techniques' ability to reduce transpiration and maintained proper plant growth in a controlled environment. Tomato plants were grown in three enclosed hydroponic units under blue (460 nm) and red (630 nm) LEDs inside an air-conditioned glasshouse. The test plants and multiple replicates were grown five consecutive times, and the irradiation intensity (photosynthetic photon flux density (PPFD)), irradiation pattern (simultaneous/alternate irradiation for red/blue LEDs) and LED combination (number/ratio of red/blue LEDs) were changed each time. The plants' physiological parameters (transpiration, stomatal conductance, stem-diameter, stem height, and number of leaves) and daily transpiration rates were recorded periodically and analyzed. The results show that a typical photoperiod of 12 hours with simultaneous irradiation of red/blue LEDs produced balanced physiological growth for plants in general. However, when normalized against water use efficiency (transpiration), an alternate irradiation pattern (6 hours: blue LED on/off repeatedly for 15-minute intervals + 6 hours: red LED on/off repeatedly for 15-minute intervals) was the most suitable for tomato cultivation in controlled environments.

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A WATER SAVING APPROACH BY USING THE LIGHT EFFECT ON TOMATO PLANTS GROWN IN A CONTROLLED ENVIRONMENT

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1. Introduction

Reducing the transpirational loss of water from agricultural plants will contribute to the preservation of precious water resource. However, it is still difficult to reduce the transpiration rate artificially (e.g., by using different antitranspirants) and thus to adopt in general agricultural practices because most plants react delicately and negatively, resulting in water-stressed conditions that often cause different physiological disorders and yield shortage. The present study investigated the transpiration light response in tomato plants (*Solanum lycopersicum*) grown under LED lights and assessed different irradiation techniques' ability to reduce transpiration and maintained proper plant growth in a controlled environment.

2. Methods

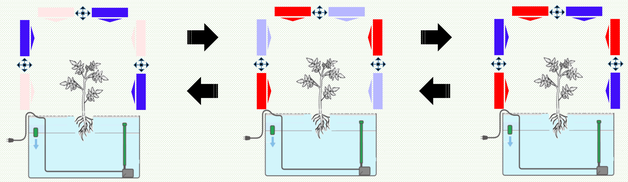
- Test plant: *Solanum lycopersicum*
- Growing Condition: Glass House (CEA), hydroponic culture, LED
- Irradtion Condition (Experiment Design)
  - LED types — Blue (460nm), Red(630nm)
  - LED ratio — red:blue=11:4(approx.)
  - Photoperiod (daily) — 12 hours (with different patterns*)
  - Intensity(PPFD) range — 29.87 ～130 µmol m^{-2} s^{-1}
  - Irradiation patterns* — Simultaneous/alternate red/blue lights (5 consecutive expts.)
    - a) Individual(red[1], blue[2], red+blue[3])
    - b) red(6h)+blue(6h) [1], transplanting to flowering (50 days): blue + flowering to harvest(20-50days) : red[2], red+blue[3]
    - c) blue(75µmol m^{-2} s^{-1}, 6h)+ red(6h) [1], blue(39µmol m^{-2} s^{-1}, 6h)+ red(6h) [2], red+ blue[3]
    - d) blue(6h)+red(6h):10min on/off [1], blue(6h)+red(6h) 60min on/off[2], red+ blue[3]
    - e) blue(6h)+red(6h):15min on/off [1], blue(6h)+red(6h) 15min on/off[2], red+ blue[3]

    1, 2, 3 denotes irradiation protocol

Glass house (CEA)

- Measurement
  - Physio-morphology — Number of leaves, shoot length, stem diameter, dry biomass, leaf temperature, transpiration, photosynthesis, yield
  - Growing environment — Ambient temperature, relative humidity

Experiment Design



Changing the irradiation intensities, photoperiod patterns and protocols

3. Results

3.1 Rate of increase in plant growth

In all the 5 consecutive experiments conducted in the present study (as mentioned in section 2. Methods), tomato plants were grown in 3 hydroponic units at different irradiation intensities/patterns/protocols. Experiment a) was a basic experiment which reconfirmed the general tendency/effect of red and blue light on tomato plants' growth (Kato and Roy, 2013) while in other experiments (b)～e)), average plant growth rates(%) were figured out in terms of different physiological parameters (leaf/shoot/stem). Fig. 1 presents the growth rates in terms of specific parameter which had the strongest correlation (R^2>0.85) with average daily transpiration rate in the respective experiment. Comparing with the typical irradiation type (red+blue, 12h), alternate irradiation patterns designed in the study affected the plant growth rates in different levels as shown below.

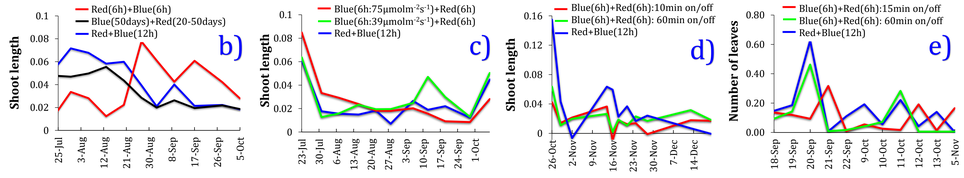


Fig. 1 Status of plant growth rates (rate of increase) at different irradiation intensities, patterns and protocols designed for different experiments in the study

3.2 Water efficiency in term of transpiration

Daily transpiration rate of all replicates (number of replicates: 4 to 6; except expt. e) that was carried out with a single replicate) in each pattern was measured (weight method) from a weeklong observation in four different growing stages for each experiment. Daily average amount of transpiration per replicate throughout the observation period was calculated and the transpired amount of water was normalized against the plant growth in each growth stage and condition.

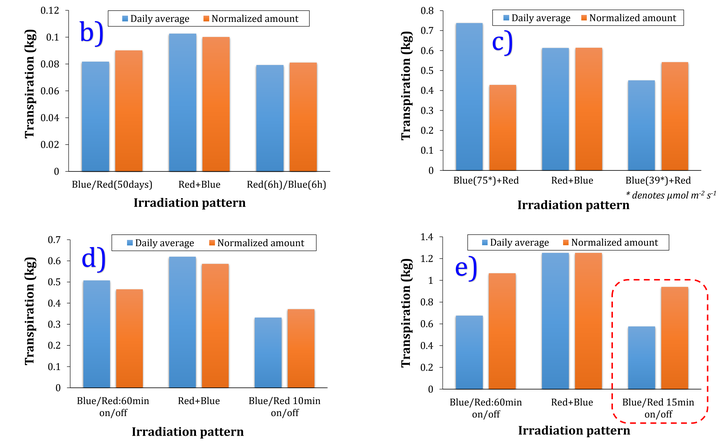


Fig. 2 Status of daily average and normalized amount of transpiration per plant at the flowering stage in different experiments

4. Conclusions

The results show that a typical photoperiod of 12 hours with simultaneous irradiation of red/blue LEDs produced balanced physiological growth for tomato plants in general. However, when normalized against water use efficiency (transpiration), along with the consideration of all other factors measured in the study, an alternate irradiation pattern (6 hours: blue LED on/off repeatedly for 15-minute intervals + 6 hours: red LED on/off repeatedly for 15-minute intervals) was the most suitable for tomato cultivation in controlled environments. The findings of the experimental results provided guidelines to design ongoing research experiments on water saving techniques for controlled environment agriculture.

Reference

Kato, Y and Roy, K., (2013), Effects of light irradiation on physiology and water demand of plants, Journal of Environmental Information Science, 41-4: 67 (*in Japanese*).