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Quality Preservation of Tomato Seedlings Affected by Different Wavelengths of LED-Low Light during Storage

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Summary

We investigated the effects of different wavelengths of photosynthetically active radiation generated by blue, green, yellow or red light-emitting diodes (LEDs) (peak wavelength: 470, 525, 590 or 625 nm, respectively) on quality preservation of tomato (*Lycopersicon esculentum*) seedlings during low light irradiation storage. The photosynthetic photon flux (PPF) at the plant canopy level was automatically controlled using a proportional-integral-derivative controller in order to maintain the CO_2 exchange rate of seedlings at zero. Nine seedlings were stored for 28 d in a storage case at 10±0.5 °C and greater than 95 % RH. There was no significant difference in seedling dry weight before or after storage under any light irradiation (LI). The mean PPFs required for maintaining the CO_2 exchange rate of seedlings at zero under the blue, green, yellow and red LIs for the last 2 weeks of storage were 3.5, 5.6, 5.2 and 4.1 μmol m^{-2} s^{-1}, respectively. Green light may help seedlings preserve their quality better than blue or red light; providing a vigorous and compact appearance with upright morphology and higher visual quality score.

Key words. CO_2 exchange rate – light-emitting diode – PID control – PPF – transplant – visual quality

Introduction

Low light irradiation can preserve seedling quality during low temperature storage of tomato and 18 other species of bedding plants (Heins et al. 1992). Maintaining light intensity such that CO_2 exchange rate is maintained at zero (light compensation point) is optimal for suppressing changes in dry weight and for preserving quality in eggplant (*Solanum melongena*) plug seedling (Kozai et al. 1996), *in vitro* broccoli (*Brassica oleracea*) plantlets (Kubota and Kozai 1995), and tomato (*Lycopersicon esculentum*) seedlings (Fujiwara et al. 2001). An automatic PPF control during storage has been developed to make the best use of storage (Fujiwara et al. 2005). Although mixed light irradiated from fluorescent lamps can be used for storage of tomato seedlings and will be better for plant than monochromatic light, PPF can not be controlled during storage for maintaining PPF with light compensation point because this can differ according to plant species, growth stage and other conditions. On the condition of maintaining the PPF with light compensation point during storage, this study was carried out to examine the effects of different wavelengths of LED low light on quality preservation of tomato seedlings during storage.

Materials and Methods

Seedlings and storage conditions

Grafted tomato (*Lycopersicon esculentum* Mill., scion: 'Momotaro Haruka' and rootstock: 'B-barrier') seedlings (sown on 27 Apr. and grafted on 14 May) were obtained on 25 May, 2007 for replication 1 and they (sown on 4 July and grafted on 21 July) were obtained on 2 Aug. 2007 for replication 2 from a commercial seedling supplier (Berg Earth Co., Ltd., Ehime, Japan). They were grown in a 128-plug tray filled with peat, vermiculite, bark, and perlite mix (4:4:1:1). After arriving in laboratory, they were placed in a chamber (MIR 153; Sanyo Co., Ltd. Tokyo, Japan) at 20±1 °C under a PPF of 235±15 μmol m^{-2} s^{-1} for 1 d prior to storage. Each of five groups (4 colours + a before storage group) contained nine seedlings each. Forty-five out of 128 seedlings were carefully selected with totally expanded third leaf and same stem length. They evenly split into four different lights wavelengths groups and a before storage group for determination of growth parameters and colour-based visual quality scoring of the seedlings before storage. Each group of nine seedlings was subirrigated for 1 h before setting in each storage case.

The seedlings were stored under the continuous light condition for 28 d in a transparent acryl-resin case (200 mm wide×200 mm long×250 mm high), covered with aluminium foil on the four lateral surfaces to prevent light transmission, at 10±0.5 °C and over 95 % RH. Two storage cases were placed in a chamber (MIR 553; Sanyo Co., Ltd. Tokyo, Japan) that was divided into two parts with black drawing paper and an aluminium foil-wrapped board to prevent incident light from the other part. All trays containing the seedlings were rotated by 90 ° every week. Two chambers used in this experiment were in a room controlled at 18 to 20 °C.

LED characteristics and PPF control system

Thirty-six blue, green, yellow, and red [peak wavelength: 470, 525, 590, 625 nm (OSUB5161A-PQ, OSPG516A-RS, OSYL516A-QR, and OSHR516A-QR; Optosupply Ltd., Hong Kong, China)] were adopted as light sources. The directional half-value angle of the LEDs was 30 °. LEDs of each wavelength were arrayed in a square formation of 6×6 (parallel and series) LEDs, which occupies 16.5×16.5 cm^2 on a rectangular universal circuit board. Each storage case was placed directly below an LED array. An automatic PPF control system during storage was followed as described by FUJIWARA et al. (2005). An optimal combination of proportional band (PB), integral time (T_i), and derivative time (T_d) was newly determined by a series of preliminary storage experiments for 24 h (PB=50 %, T_i=1800, and T_d=0).

Measurement

Stem length, number of fully expanded leaves, leaf area, leaf colour difference (ΔE^*ab), and visual quality score (VQS) were recorded for all seedlings on days 0, 7, 14, 21, and 28 after the start of storage. Visual quality was assigned a score between 4 (in which almost all leaves were green) and 0 (in which most leaves were brown and/or some leaves were showing necrosis) (FUJIWARA et al. 2005). Photos of the top and lateral views of all the seedlings were captured with a digital camera (E-10, Olympus Corporation, Tokyo, Japan) before storage and every week from the start of storage. The leaf colour of all seedlings was determined with a colour reader (CR-13, Konica Minolta Holdings, Inc., Tokyo, Japan) every week during storage. A circle one cm in diameter on the terminal leaflet of the third leaf was used for leaf colour measurements taken at room temperature without direct lighting. ΔE^*ab was calculated with the L^*, a^*, and b^* values on the colour reader. After measurement of the leaf colour and growth parameters at 28 d from the start of experiment, they were separated into leaf, stem, and root. They were placed in a dry oven (DX400, Yamato Scientific Co., Ltd., Tokyo, Japan) at 66 °C for 4 d and the dry weights of each organ were measured.

Experimental design and statistical analysis

The experiment was conducted twice (n=18). Statistical analysis was subjected that four colours treatments were tested against the standard "before storage" with the Dunnett test procedure at P≤0.01 using JMP software (JMP, SAS Institute Inc., Cary, NC, USA).

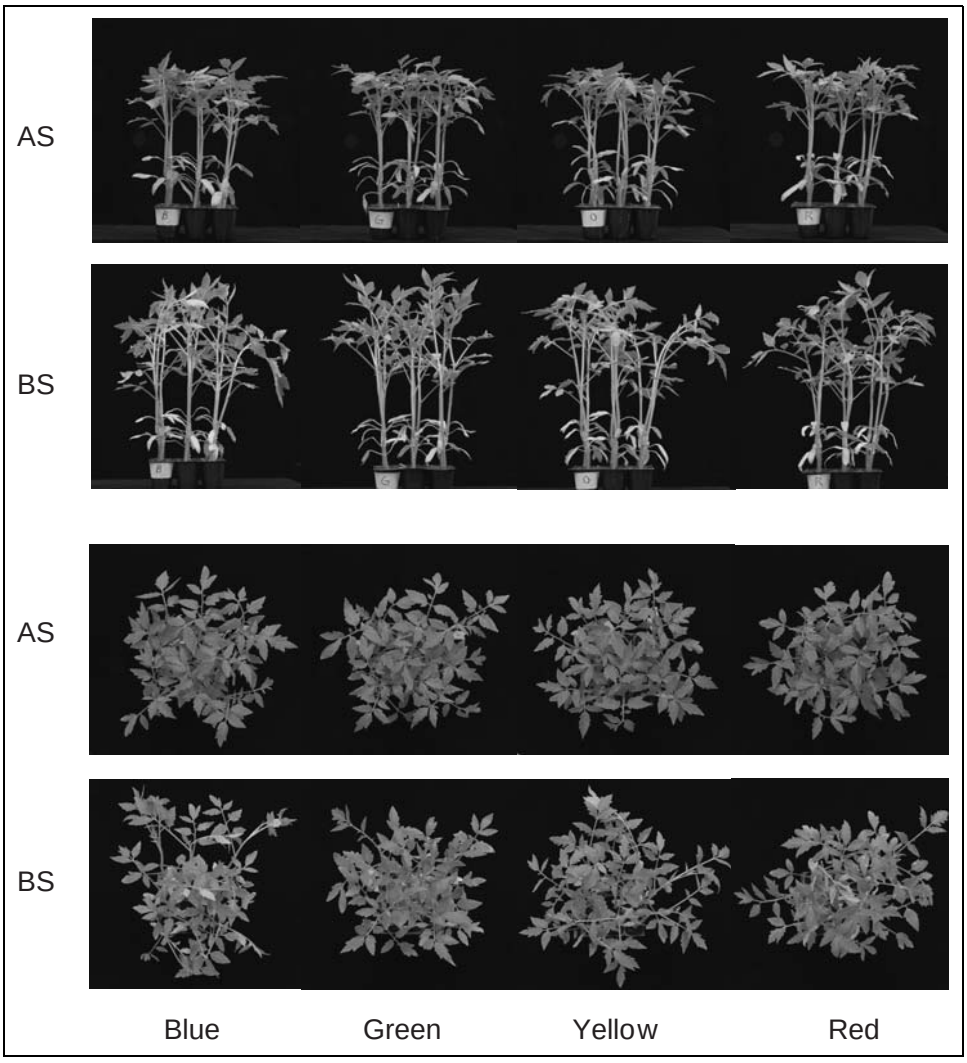


Fig. 1. Tomato plug seedlings before storage (BS) and after storage (AS) irradiated with blue, green, yellow, and red LED (470, 525, 590, and 625 nm, respectively) under automatic PPF control system during 28 d low temperature storage.

Results and Discussion

PPF and Dry weight

The falling-trend of PPF (i.e. light compensation point) each during 28 d storage was overall similar with the previous report (FUJIWARA et al. 2005). The mean PPFs required for maintaining the CO_2 exchange rate of seedlings at zero under the blue, green, yellow, and red light irradiation (LI) for the last 2 weeks of storage were 3.5, 5.6, 5.2 and 4.1 μmol m^{-2} s^{-1}, respectively. Green or yellow LIs required higher PPF for maintaining light compensation point during storage because of row efficacy of photosynthetic rate.

Since the outflow CO_2 concentration (C_{out}) from the all storage cases was satisfactorily maintained at around inflow CO_2 concentration (C_{in}) during storage, stem, root and total dry weights of the seedlings after storage were not significantly different from those before storage. This means the automatic PPF control system worked well during storage. Leaf dry weight of the seedlings stored under the green LI after storage was less than that before storage. Although many studies were reported regarding green light effect on plant growth or morphology (MANDOLI and BRIGGS 1981; DOUGHER and BUGBEE 2001; KIM et al. 2005), they did not use LEDs as a light source. Thus, the effect of green light continues to be controversial. One of the reasons caused to a decrease in leaf dry weight may be higher photosynthate allocation rate to other organs because of no significant difference in total dry weight. Under a PPF of light compensation point and low temperature for 28 d, green LI suppressed leaf dry weight of tomato seedlings.

Morphology and leaf colour

Stem length and ΔE^*ab of all seedlings after storage showed a significant increase compared with those before storage due to an adaptation on the low light conditions. The number of fully expanded leaves and leaf area of the seedlings irradiated with blue increased significantly more than those before storage. Although VQS of all seedlings decreased after 28 d storage, VQS of the seedlings irradiated with green (3.1) was the highest then followed by yellow (2.8) and blue (2.7) and the lowest was red (2.5).

Vigorous looking seedlings that can not survive after transplanting do not have economic value. With a viewpoint of post-storage vitality we previously reported (FUJIWARA et al. 2003) that there was no significant difference in aerial and subterranean dry weight between non-stored seedlings and the high visual quality stored seedlings when the seedlings were grown in a greenhouse for 28 d. Leaves of seedlings stored under the green LI looked vigorous with upright morphology and compact on day 28 due to suppression of rachises elongation (the main axis of the pinnate leaf) during storage whereas those under the others LIs were slightly drooped (Fig. 1).

In conclusion, it is not easy to distinguish the effect of different wavelengths on quality of the seedlings because plant can adapt to different light conditions. Green light itself and its higher PPF for maintaining light compensation point may induce these results because of greater transmitted and reflected percentage of green light through and on leaves relative to that of blue and red lights. On the green plant storage, green light may help seedlings preserve their quality better than blue or red light.

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