Effects of blue photoconversion film on tomato young plants under controlled environmental conditions

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Abstract

Photoconversion film technology is one of the solutions to increase food production for the growing global population. This technology optimises the use of the solar spectrum through redirection of the wavelengths toward the most beneficial ones for the plant, such as blue. Previous studies about the effects of blue light on tomatoes have shown a reduction in stem elongation and an increase in plants' defence capacity. This study is a proof of concept of the LitePlus® DR Tomato greenhouse foils effects, which enrich the solar spectrum with blue radiation, on tomatoes in comparison to conventional one. Six trials were conducted with two tunnels, each corresponding to a film modality (Blue and Reference) in phytotron. Under each tunnel were placed 30 'Ventero' tomato seedlings from their germination to the 7-8 leaf stage. The growing conditions were precisely controlled at 70% humidity and 22°C/18°C for day/night. Tunnels were placed under plasma lights, which deliver a spectrum close to the solar spectrum, at a light intensity of 250 µmol m-2 s-1 for a 16 h/day photoperiod. The measured variables were non-destructive kinetic variables on phenotypic characteristics, namely tomato plant height, growth rate, and third leaf length of the plants. LitePlus® DR Tomato films impact the growth and development of young tomato plants during vegetative phase by reducing growth speed and leaf area, and does not affect the appearance of the flowering. These observations fit very well with the well-described blue LEDS-related effects on young tomato plants.

Keywords: greenhouse, sunlight, blue light, plant growth, *Lycopersicon esculentum,* vegetative phase

INTRODUCTION

Light is one of the main environmental factors affecting both productivity and performance of the plant during their life span, through its quantity and quality (Smith, 1982). One of the powerful environmental factors to modulate the light quality is the use of blue light. Indeed, blue light is considered as a powerful growth regulator that modulates several responses of plant. Indeed tomato exposure to blue light results in a reduction of stem length, plants are more compact with shorter internodes (Kim et al., 2004; Ouzounis et al., 2016). Moreover, blue light exposition reduce leaf area, both by the reduction of the number of leaves on tomato plants and by reducing their area (Mortensen and Strømme 1987; Ménard et al., 2006). These effects have been described as being causes, among other things, by cell elongation inhibition (Javanmardi and Emami, 2013; Huché-Thélier et al., 2016). This environmental factor has already been used by the innovative lighting sources based on light-emitting diodes (LEDs) to ensure annual productivity, regular yields and high product quality for diverse crop cultivations in a context of a growing global population (Bantis et al., 2018; Paradiso and Proietti, 2022). However, this technology is only applicable to indoor conditions. Consequently, to transpose it to the outdoor conditions, one approach is based on the conversion of certain wavelengths into those of interest, called the photoconversion. The LIGHT CASCADE® film use photoconversion by fluorophores, chemical substances that emit light by external excitation, which absorb UV wavelengths and re-emit them into the blue region.

Tomato is known to be highly sensitive to quality and quantity of light (Fan et al., 2013; Snowden et al., 2016). More precisely, the effects of blue light have been documented in several studies, such as plant height reduction (Kim et al., 2004; Javanmardi and Emami, 2013; Ouzounis et al., 2016), leaf area reduction (Mortensen and Strømme 1987; Ménard et al., 2006), or to stimulate the secondary metabolites production and the disease resistance (Kook, 2013; Ntagkas et al., 2020).

The aim of this study is to evaluate the effects of the blue LIGHT CASCADE® film specifically developed for tomatoes the LitePlus® DR Tomato (LP Blue) on young plant in vegetative phase, and to compare them to the blue LEDs effects, as a proof of concept of the transposition of the blue light application from indoor conditions (LED) to outdoors conditions (Foil).

MATERIALS AND METHODS

Six independent trials have been led for this proof of concept, from 13 November 2020 to 13 July 2021 in the same experimental conditions.

Light treatment

Two modalities of film were tested in one growth chamber (4×2.5 m): the LitePlus® DR Tomato (LP Blue) and the corresponding reference film without the technology. One tunnel (L3.5×l1×H0.9 m) of each film modality were placed in this chamber, on sub-irrigation Tables (3.5×1 m). Three plasma lamps (400 W, Lumartix, Helvetia) were placed above each film to light up the crops, with a 250µmol m-2 s-1 light intensity in photosynthetically active radiation (PAR). The respective two light spectra have been measured (Figure 1), the gain in blue obtained under the LP Blue is significant and at 22% level. Each table were surrounded with light reflectors to increase the percentage of light emitted by the plasma lamps to the culture.

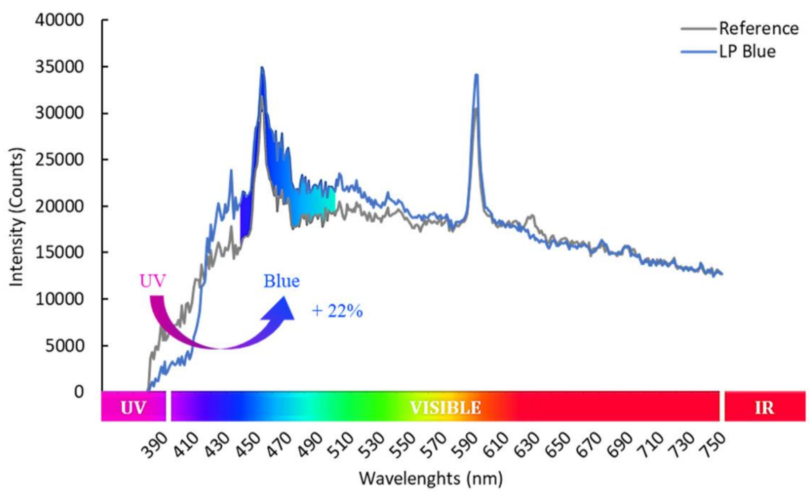

Figure 1. Light spectrum from UV (<400 nm) – IR (>700 nm) of the two film modalities, LP Blue (blue line) and Reference (grey line), measured by MR-16 spectrometer in growth chamber.

Plant material

The tomato plants (Solanum lycopersicum 'Ventero') were sown in seed trays filled with potting soil and germinated under forcing weil P17 (grammage 17 g m-2) in greenhouse. At the stage of two-leaf the seedlings were potted in 1L pots with a draining substrate composed of blond, peat, perlite and coconut fibre (70/20/10, V/V/V) and transferred in growth chamber (4×2.5 m), 30 young plants under each tunnel.

Climatic parameters were controlled as following: day and night temperature were 22 and 18°C respectively, at 70% relative humidity, for a 10-h photoperiod.

The irrigation was planned automatically by sub-irrigation twice a day, at 9 and 18 h, with a fertilized water (15-30-10, N/P2O5/K2O), at 1.2 mS cm-1 of electro-conductivity with recycled system.

Measured variables

Growth parameters were measured twice a week for both modalities of film: plant height and length of the 3rd leaf of tomato young plants.

Statiscal analysis

Data were statistically analysed using R Studio software by comparing the means with the Student test, in the case of compliance with the hypotheses of normality and equality of variances, or the Welch or Wilcoxon tests respectively in the case of non-compliance with the hypothesis of equality of variances or normality.

Means were determined as significantly different at the p_value threshold of less than 0.05.

RESULTS AND DISCUSSION

Plant stem elongation

Upon the exposition to LP Blue film, the tomato young plants were significantly more compact than those exposed to the reference film. Indeed, the average height of the young plants grew under Reference is 70cm, while that of those did under LP Blue film is 56 cm (Figure 2). This corresponded to about a statistically significant reduction of 20% in stem elongation. This result is widely documented as the blue LED light on tomato plants, including fewer internode for plants exposed to blue, leading to smaller plants than under control conditions (da Silva and Debergh 1997; Kim et al., 2004; Javanmardi and Emami, 2013).

Figure 2. Comparison of tomato plants phenotypes between under the Reference (left) and Blue LP (right) films 35 after transfer of the plants in the growth chamber.

This young plant height reduction was more likely due to a tendency of smaller growth rate of the plants grew under LP Blue film, compared to those under reference film (Figure 3), so this light modification technology produces young plants that are more compact and therefore easier to transport. Several studies also measured this effect, especially by observing the length of internodes, which is significantly lower when young tomato plants are exposed to blue light, thus showing the decrease of growth by blue LED light (Mortensen and Strømme, 1987; Ouzounis et al., 2016; Spaninks et al., 2020).

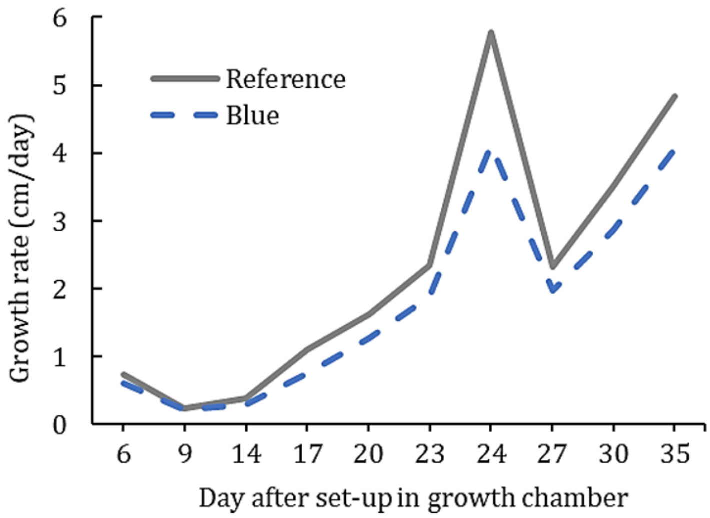

Figure 3. Growth rate evolution (height) of the young tomato plants growing under LP Blue and Reference film over time, from day 6 to day 35 after setting up the tomato seedlings in growth chamber, under Reference or LP Blue tunnel.

Leaf length

Third leaf length measurements for each modality over time, indicated that this leaf was significantly shorter in plants exposed to LP Blue film than the reference one (Figure 4). Studies have shown that the use of blue light has the effect of reducing the size of tomato leaves, and more broadly has significantly reduced the total leaf area of the plant (Kaiser et al., 2019; Kalaitzoglou et al., 2021).

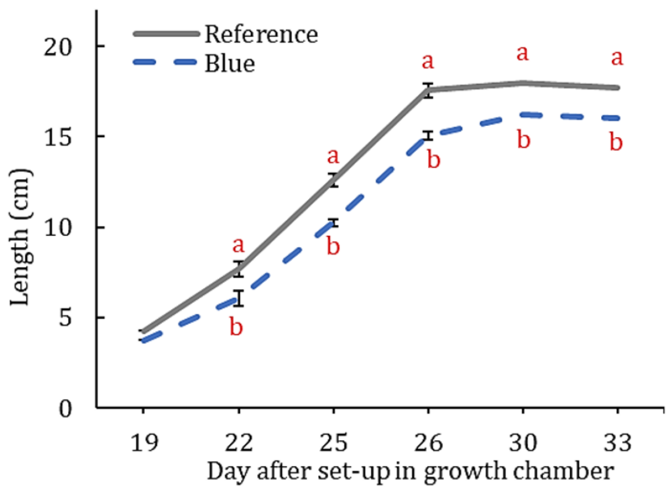

Figure 4. Third leaf length evolution of young tomato plants growing under LP Blue and Reference film over time, from day 19 to day 33 after setting up the tomato seedlings in growth chamber, under Reference or LP Blue tunnel. The letters correspond to statistical groups.

Further analysis on photosynthesis will allow us to study the repercussions on carbon production, knowing that C fixation is increased under blue light.

CONCLUSIONS

LitePlus® DR Tomato film formulation decreases young tomato plant height in comparison to the Reference film just after seedling development, which results in more compact young vegetative plants without impact on the beginning of flowering. This CASCADE LIGHT® film also has the effect of reducing the leaf area.

All these effects match well with the well-known effects of blue LEDs on tomato plants and lay out a solid foundation for further investigations at both the phenotypic and molecular levels. Indeed, the use of a LIGHT CASCADE® photoconversion film seems to be a promising technology to allow transposition of LED technology, only applicable to indoor conditions, to outdoor conditions, by extending its use to other wavelength ranges such as red and green.

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