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Full Length Research Paper

Effects of light quality and photoperiod of light emitting LED on growth and biomass accumulation of shallot

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In the present investigation, effects of light quality emitted by light emitting light emitting diodes (LED), and selected photoperiods on the growth and biomass accumulation of shallot (*Allium cepa* var. *aggregatum*) have been studied. Two ratios of red and blue light namely, 2:1 and 1:1 and two photoperiods 16 h dark and 8 h light cycle and 12 h each alternating light and dark cycle were tested. The results showed that the growth of spring shallots and the accumulation of biomass were associated with the ratio of red and blue light as well as on the photoperiod. The plant height growth, growth rate and the accumulation of chlorophyll a were the fastest under an experimental condition of 16 h of illumination with a red and blue light ratio of 2:1. The synthesis of chlorophyll b was the fastest under an experimental condition of 12 h of illumination with a red and blue light ratio of 2:1.

Key words: Shallots, light emitting diodes (LED), light, red and blue light quality, biomass.

INTRODUCTION

Light imposes a wide range of regulatory effects on plants, particularly on their morphological variations, various physiological processes and growth and quality of the final products (Lin et al., 2017). It is considered not only as a source of energy but also an important environmental signal. The growth and development of plants and their morphological and physiological adaptations can be mediated through morphogenetic responses and through light-dependent regulatory mechanisms present in the photosynthesis (Abidi et al., 2013). Recently, following the rapid development of semiconductor technology, a variety of light emitting diodes (LED) has been developed and widely used in various industrial establishments throughout the world. When the quality of light is considered, the effects of red (R) and blue parts of light (B) on the growth and development of plants draw much attention to the scientists. These wavelengths are predominantly absorbed by photosynthetic pigments of plants and have the greatest impact on plant growth and development (Pfündel and Baake, 1990; Massa et al., 2008; Chen et al., 2017). In recent years, the use of LED as a source of light has opened a new era in the field of artificial plant cultivation. Light from a LED source has a lot of advantages which the traditional electric sources such as halogen light cannot meet. LEDs are relatively small, easy to handle, long life, produces less heat and can be precisely modulated (Liu et al., 2012). So their uses are highly recommended in the closed-type and climate-controlled plant factories. In the recent time, this technique has gained significant interest because plant-factories adopting this provide a clean and non-toxic

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environment and thus becomes eco-friendly. Increase in the food productivity with controlled operating conditions and multi-stack growth platforms are also possible (Lam et al., 2016).

With a rapid development and availability of technical facilities, in the modern days, horticultural plants have been heading towards large-scale productions. In this progress, it is an important task to improve the yield of crops by controlling environmental factors such as light source, temperature and humidity (Liu and Yang, 2014; Yu and liu, 2014). In plants, the content and distribution of chlorophyll have been considered as an important indicator for plant nutrition (Zou et al., 2014b). Therefore, by measuring the content of chlorophyll in plants, it is possible to infer their status of growth. This information can also be used to conclude the relationship between plant growth and light and to make a guiding contribution based on the results obtained from the actual production. Onion (*Allium cepa* L.) is a common edible vegetable, the plant height is suitable for artificial plant cultivation, and the high-quality plant products are conducive for farmers to get higher returns. Onion plant has a tremendous economic and medicinal value throughout the whole world. Research on the effect of light intensity in the artificial culture system of onion is still meager. The present research has therefore been undertaken to study the growth of onion in respect to their photoperiod and environmentally sound artificial light quality.

MATERIALS AND METHODS

In the present study, the crop plant used is shallot (*Allium cepa* var. aggregatum), "farm red onion" assortment, produced in Shandong, China; soft sponge containing equally dug 0.40 mm diameter; plastic tray (26.3×15.0×9.5 cm); nutrient solution (concentrated liquid fertilizer diluted with distilled water at a ratio of 1:100). Other equipment used was one ten thousandth balance: LED lamp tube (9w) and the wavelength of red light is 670 nm, FA2204 balance (Shanghai Hengping Instrument and Meter Factory), UV-Visible Photometer (Shimadzu UV-2450) and a Constant Temperature Incubation.

Experimental design

The light source used in the present investigation is light emitting diodes (LED). To study the effect of light quality on shallot, two groups of different red and blue light treatments were designed. Another two groups, having same sources of light as described before, were used to study the effect of photoperiod on shallot. So there were altogether four groups of treatments with the same light intensity, hereinafter designated as A, B, C and D. The treatment of group A contained red and blue light quality 2:1 having 16 h light and 8 h dark cycle. The treatment of group B was red and blue light quality 2:1 having equal duration of alternating light and dark cycle that is,12 h each. The treatment C was red and blue light quality 1:1 having 16 h light and 8 h dark cycle. The treatment D contained red and blue light quality at a ratio of 1:1, having equal 12 h light and 12h dark cycle. LED red and blue panel light specifications for the 24×16 were used in the experiment. The light and dark cycle followed: at every 7:00 AM black shade was put on groups A and C to ensure complete dark, while exposure of LED continued on groups B and D. The shade was removed from the experimental groups A and C at 15:00 h every day, while the group B and D were kept exposed to the LED light. Keeping group A and C exposed to the LED light but shading B and D completely at 19:00 h every day. The nutrient medium of the culture trays was changed by adding 200 ml of fresh solution at 2 days interval regularly.

Collection and measurement

The plant height, quality and the content of chlorophyll *a* (chl*a*) and chlorophyll *b* (chl*b*) were measured on 8, 12 and 16 days of plant growth period and the mean values were used for evaluation. The plant height was measured from growth point to the distal end of the leaf in the millimeter scale. The bulb diameter of the shallot was measured with the help of a screw gauge. The weight was measured by using a balance up to one ten thousandth of the scale. The chlorophyll content was extracted from the plant and the absorbance was measured by a spectrophotometer. The extraction of chlorophyll was followed via collecting 0.20 g of freshly grown shallot leaf from the top of each plant. After collection, the sample was cleaned by washing with water and then air dried. The portion was then placed in a mortar and appropriate amount of quartz sand and calcium carbonate powder and 2-3 ml 95% ethanol were poured in it. Grinding was done to convert the sample into homogeneous slurry. To it 10 ml of 95% ethanol was added and the ginding was continued until the slurry turns white, which was kept standing for 3-5 min.

The slurry was transferred to a clean and dry brown volumetric flask of 25 ml capacity. The mortar bowl and pestle all were rinsed 2-3 times with 95% ethanol and the rinsed quantity was added to the sample of the volumetric flask. A filter paper moistened with ethanol was fitted with the filtration device and the slurry was poured onto it and the filtration was performed. After filtration, the final volume for all samples was adjusted to an equal amount by adding extra 95% ethanol. The absorbance was measured in a UV-spectrophotometer (U-5100UV/VIS) at wave lengths 665 and 649 nm by using quartz glass cuvettes (1 cm path length) against 95% ethanol as blank. Since the maximum absorption peak of chlorophyll *a* and *b* in 95% ethanol occurs at 665 nm and 649 nm, respectively, the following relationships were used to calculate their concentrations in the sample.

$$Chl\textit{a} = 13.95A665 - 6.88A649$$
$$Chl\textit{b} = 24.96A649 - 7.32A665(A)$$

A665 and A649 are the absorbance values for the wavelengths at 665 and 649 nm, respectively.

Data statistics and analysis

In this experiment, the absorbance of seed nucleic acids, proteins, vitamins and seedling chlorophyll was measured by UV-spectrophotometer, and then the absorbance was processed by Graph Pad Prism5 data processing software. The concentration was further calculated and the data were processed by Graph Pad Prism5 data processing software.

RESULTS

Effects of LED red and blue light quality and photoperiod on the shallots plant height

The ratio of red and blue light quality in both the A and B

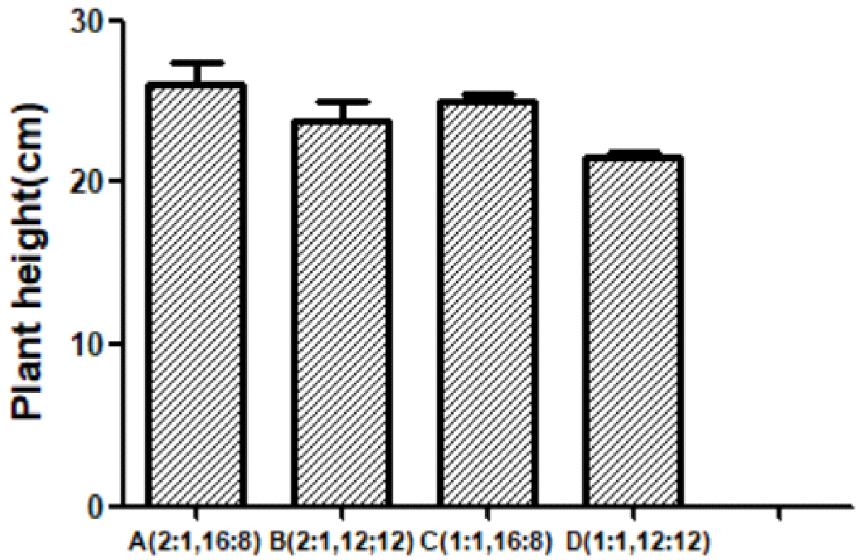

Figure 1. Plant height (cm) of shallot after the 8th days of cultivation in the four different treatments (A, B, C and D).

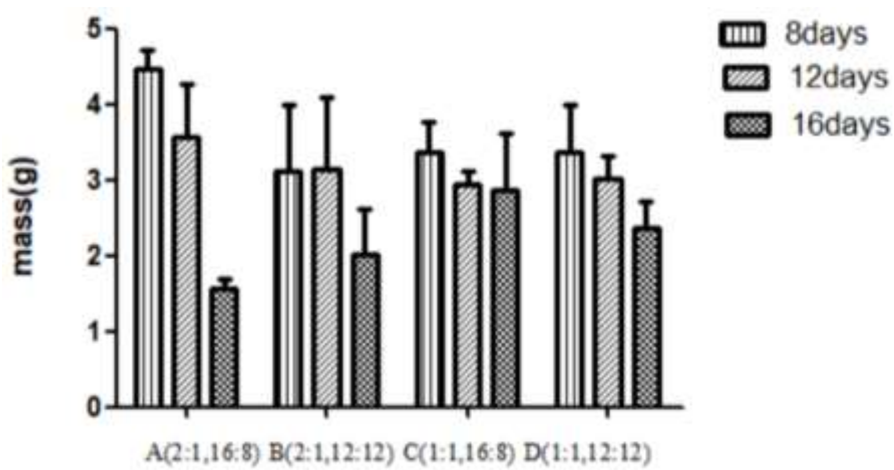

Figure 2. Showing the quality of shallots (weight in g) in four groups of treatments.

groups of experiments is 2:1. But the irradiation time of Group A was longer than that of Group B under the same measurement time. Similarly, when the ratio was 2:1 in Group C and D, the irradiation time of Group C was longer than group D and the value of group C was always larger than group D under the same measurement time. This indicates that the longer the irradiation time, the higher the plant height under the same light quality ration and measurement time (Figure 1). The results of t-test was highly significant ($P < 0.01$) and therefore proved to be highly reliable.

As for Group A and C, the ratio of irradiation time was 16:8. The proportion of red light in Group A was higher than that in group C. It was found that the plant height of Group A was higher than that of Group C and it is 12:12 for Group B and D. The proportion of red light in Group B was higher than that in Group D. It can be found from the figure that the plant height of Group B was higher than that of Group D. It means that the red light was in favor of the increase of plant height under the same irradiation time. The results of t-test was highly significant ($P < 0.01$) and therefore, proved to be highly reliable.

The change of A quality in Group A, B, C and D was the most obvious, the change degree of B, D was the second and the change degree of group C was the smallest according to Figure 2, which showed that a higher ratio of red and blue light and the longer lighting time promoted the growth of shallots. The result of t-test was highly

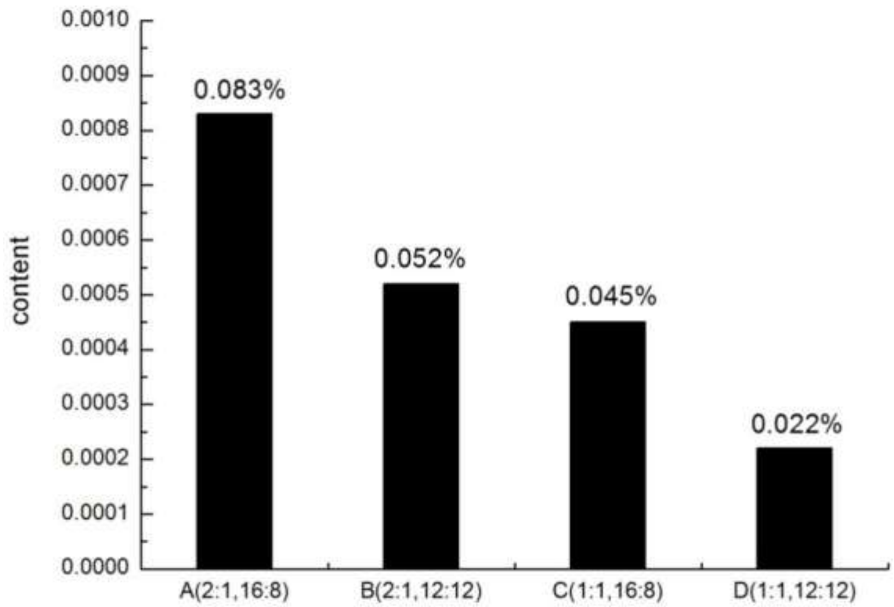

Figure 3. Effects of light quality on the chla content after 8th days of growth.

significant (P <0.01) and therefore, proved to be highly reliable.

Effects of LED red and blue light quality and photoperiod on the quality of shallots

Highest weight of shallot bulb was shown only during the early stages (8 days) in almost all the four groups of experiments (Figure 2). However, with an increase in growing time (12 and 16 days) bulb weight fell in Groups A, C and D. In group B, bulb weights were almost the same at both 8 days and 12 days harvest. A higher ration of red and blue light and the longer lighting time promotes the growth of shallots (Figure 2). The result of t-test was highly significant (P <0.01) and therefore proved to be highly reliable.

Effects of LED light quality on chlorophyll-a content of shallots

As shown by Group A and B, higher proportion of red light is more favorable for the increase of chlorophyll *a* with same photoperiod, and longer photoperiod is more favorable for the accumulation of chlorophyll *a* with same light quality ratio (Figure 3).

Effects of LED light quality ratio and photoperiod on chlorophyll content of shallots

The results showed that Group A and B have same red and blue light quality ratio, and the photoperiod of group A is longer than Group B, chlorophyll *b* content of group B is greater than group A. Under the same condition of red and blue light quality ratio, the longer the photoperiod, the lower the chlorophyll *b* content. From Figure 4, both A and C are shown as the contrast groups; it is seen that under the same condition of the photoperiod, the higher proportion of red light promotes the synthesis of chlorophyll *b* (Figure 4).

DISCUSSION

Red and blue light are not only the main sources absorb light, but also work as the main signal of receiving light. In the study of plant cultivation, the red and blue light have great influence on the growth and development of crops (Yu et al., 2015; Zang et al., 2014; Zou et al., 2014a; Su, 2014). By regulating the ratio of red and blue light quality and application time of LED light, plant growth and development can be promoted as well as the crop quality can also be improved. It was found that higher frequency of LED pulsed light during plant growth cycle could increase the yield of var. Pak-choi (*Brassica chinensis* L.) (Harun et al., 2013). Since there is a big dearth of research on the effects of light intensity and light quality on the onions, the present study was devoted to discuss the growth status of shallot from the aspects of light quality and photoperiod.

The results showed that the growth of the onion and the accumulation of biomass were related to the ratio of red and blue light and the photoperiod. Higher red light ratio and longer illumination time are favorable to

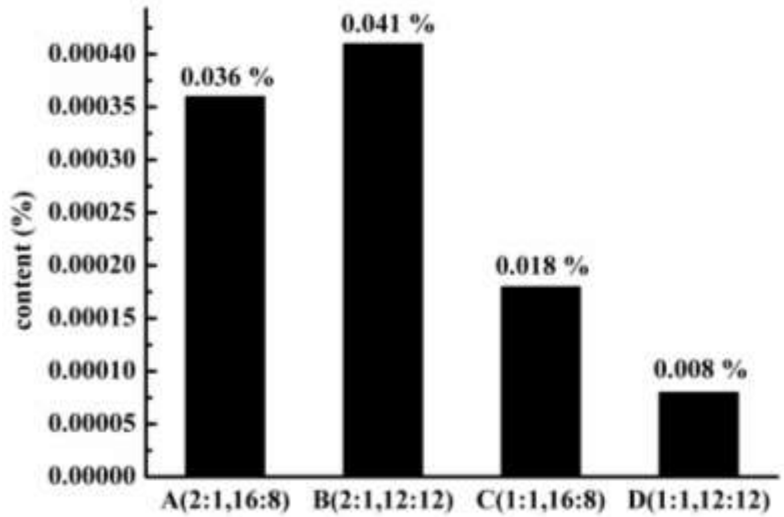

Figure 4. Effects of light on the content of chlb after the 8th days growing period.

promote plant height, growth rate, and synthesis of chlorophyll a. Higher red light ratio and shorter illumination time are favorable to the synthesis of chlorophyll b. Different Light quality may play different roles in regulating the growth of different plants. Longer illumination was beneficial to the growth of brandy, which was consistent with the experimental results. On the contrary, the production of lettuce (*Lactuca sativa* L.) could be increased by reducing the photoperiods. In this experiment, a large ratio of red light is beneficial to the growth of onion. Shen et al. (2017) found that blue light is helpful to improve the growth potential and harvest quality of Chinese cabbage. From this research the growth and quality of shallot bulb can be purposely adjusted by adopting different ratio of red vs. blue light and photoperiod without adding new energy consumption. But because only a small number of indicators were determined in this experiment, other indicators such as protein and crude fiber content were not involved, and only two light quality ratios and two cycles were determined. In addition, LED light had different effects on plants in other bands besides red and blue light. All these need further study.

The study on the environmental attributes of artificial lighting, contributes significantly to the construction and development of controlled artificial light panels for garden facilities. Currently, in the large scale production of crop plants, application of controlled light environment is relatively small. In this respect, there is an ample chance of exploring the relationships between the artificial light source and the culture of many crop plants. The present research put forwarded some methods and suggestions for improving the quality and yield of shallots, and provided technical support for the cultivation of the same crop using artificial light sources in any plant factory. The shallot variety chosen for the present research was "farm red shallot". This variety has a good production phase and higher growth rate and is suitable to achieve commercially feasible production.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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