Effects of different ratio of red and blue light on flowering and fruiting of tomato

Xiaoxue Fan¹ *, Yana Yang² and Zhigang Xu³

¹Institute of Vegetables, Jiangsu Academy of Agriculture Sciences & Institute of Vegetable Crops, Jiangsu Academy of Agricultural Sciences & Jiangsu Key Laboratory for Horticultural Crop Genetic Improvement, Nanjing 210014, China
²College of Horticulture, Shanxi Agricultural University, Taigu 030801, China
³College of Agronomy, Nanjing Agricultural University, Nanjing 210095, China

*Corresponding author: fxx600@163.com

Abstract. In this study, the effects of red and blue Light Emitting Diodes (LED) light on flowering and fruiting in the facility cultivation of tomato plants were investigated, tomato plants were subjected to 4 light treatments, dysprosium lamp (as the control, CK) and another three LEDs light with different ratios of red and blue light (RB1, RB2, RB3, R, B). The results showed that under the light with the ratio of red and blue 1:1, the time of first flower and first fruit appeared significantly earlier. The pollen viability and the content of soluble solids sucrose were the highest, and the ratio of sugar to acid is high, which made tomatoes taste great. This study is expected to provide theoretical basis for the high-quality cultivation of tomato seedlings.

1. Introduction

Tomato is one of the main vegetable types cultivated in facility in China. Tomatoes is photophilous, which requires a higher light environment. However, it is easy to cause weak light environment in facility cultivation, which is not conducive to the normal production of tomato, resulting in the decline of yield and quality. Therefore, the research on the control technology of the light environment in the facility is a key issue that needs to be solved urgently in actual production at this stage.

Spectral energy distribution, light quality and light intensity have regulatory effects on plant morphogenesis, photosynthesis, carbon and nitrogen metabolism and gene expression [1-4]. Light Emitting Diodes (LED) lights with different light quality ratios were used as light source for the whole growth period of tomatoes, to investigate the effects on the growth and development of tomatoes. The results showed that the different ratio of red to blue light could significantly affect the plant morphogenesis, biomass allocation, flowering and fruit quality [5-9].

In this study, LED lights with different red and blue ratios were used as light source to study their effects on cherry tomato flowering and fruiting, and to provide reference on optimal light ratio for related research.
2. Materials and methods

2.1. Experimental design and materials

In this experiment, cherry tomato ‘Qianxi’ was used as the experimental material, the substrate of vermiculite: peat = 1:3 (V / V) was used for seedling cultivation, and natural light was used as the light source. When the seedlings grew to 3 leaves and 1 leaf heart, they were planted in a nutrition bowl (18 cm × 14 cm), and the culture medium was Peat: Perlite: vermiculite (volume ratio 3:1:1). Six treatments were set up in the experiment, with dysprosium lamp (white light) as control (CK), red / blue = 1:1 (RB1), red / blue = 7:3 (RB2), red / blue = 3:7 (RB3), single red light (R) and single blue light (B). The light intensity of all the LED lights were 300 ± 10 μmol·m⁻²·s⁻¹, the light period was set to 12 h·d⁻¹, and the temperature was 25 ± 1 °C in bright period and 17 ± 1 °C in dark period. Pour the nutrient solution (AB fertilizer, provided by Shanghai Yongtong Chemical Co., Ltd.) every 4 days. The spectral distributions of each treatment were shown in Table 1.

| Table 1. The spectrum details of different LED light qualities |
|-------------------|-----------------|-----------------|-----------------|------------------|
| Treatment | Light spectral distribution | Light intensity (μmol·m⁻²·s⁻¹) | Red light intensity (μmol·m⁻²·s⁻¹) | Blue light intensity (μmol·m⁻²·s⁻¹) |
| CK | Dysprosium light | 300 | - | - |
| RB1 | R:B=1:1 | 300 | 150 | 150 |
| RB2 | R:B=7:3 | 300 | 210 | 90 |
| RB3 | R:B=3:7 | 300 | 90 | 210 |

2.2. Florescence statistics and pollen vigor determination

The first flower time: the average time of 50% flower bud opening of the first inflorescence of all plants in each treatment. Observation of Pollen Vigor: the flowers with fully expanded petals were sampled at 9:00 a.m. and determined by 0.5% TTC staining method.

Place a small amount of the collected pollen on a glass slide, add 1-2 drops of TTC solution, cover with a cover glass, and place it in 35°C incubator for 15 minutes in the dark, and observe under a microscope. All pollens dyed red have strong vigor, followed by light red, and colorless pollens are inactive or sterile. The total number of pollen in each field was more than 50. The staining rate of pollen was counted, and the staining rate was used to express the vigor of pollen. Pollen vigor = red pollen number / total pollen number × 100%.

2.3. Statistics of initial fruit period and determination of fruit quality

The first fruits time: the average time of 50% of the first spike fruiting of all plants in each treatment. Determination of fruit quality: soluble solids and titratable acid were determined by digital sugar acid meter; soluble sugar was determined by anthrone method, sucrose was determined by m-diphenol method [10]; sugar acid ratio was the ratio of soluble sugar and titratable acid.

2.4. Data Statistics and Analysis

Excel was used to process the data, and SPSS 22 software was used for significant analysis of differences.

3. Results

3.1. Effect of different ratios of red and blue light on tomato flowering and fruiting time

Different ratio of red and blue light has significant effect on Tomato flowering and fruiting (Table 2). The flowering time of RB1 was the earliest, 5 days earlier than that of CK, followed by RB2 and RB3, 2 days earlier than CK. There was little difference in flowering node and total flower number of the first panicle of tomato under different treatments, and these two characters may be mainly affected by varieties. The first inflorescence of tomato plants bear fruit first in RB1, 7 days earlier than CK. There was no significant difference between RB2 and RB3 in the first fruit date.
Table 2. Effects of different ratio of red and blue light on characteristics of flowering of tomato

| Light treatment | Time of first flower /d | Node order of first flower | Flower number of first inflorescence | Time of first fruit /d |
|-----------------|--------------------------|-----------------------------|--------------------------------------|-----------------------|
| CK              | 66                       | 9                           | 12                                   | 78                    |
| RB1             | 61                       | 9                           | 12                                   | 71                    |
| RB2             | 64                       | 9                           | 12                                   | 78                    |
| RB3             | 64                       | 9                           | 10                                   | 78                    |

3.2. The effect of different ratios of red and blue light on tomato pollen vigor

It can be seen from Fig. 1 that different treatments of red and blue light have significant differences in pollen vigor of tomato. The pollen viability of RB1, RB2 and RB3 were 83.0%, 50.1% and 69.0% respectively, which were 67.7%, 1.2% and 39.4% higher than that of the CK (49.5%). In addition, the pollen activity of RB2 was lower than that of RB3, indicating that the increase ratio of red light may reduce the pollen activity of tomato.

Figure 1. Effects of different ratio of red and blue light on tomato pollen vigor. (a) pollen vigor (%); and (b) pollen observation.
3.3. The effect of different ratios of red and blue light on tomato fruit quality

It can be seen from Table 3 that the soluble solid content in tomato fruit of RB1 is the highest, which is 5.5% higher than the CK, and the lowest in that of RB2, which is 33.4% lower than CK. The titratable acid content under light of each treatment combination is lower than that of the CK, and the lowest under RB1, which is 31.3% less than CK, but the soluble sugar content and sucrose content are significantly higher than the CK, increased by 3.8% and 96.7%, respectively; and its sugar-acid ratio was the best, which increased by 51.0% compared with the CK. After comprehensive comparison, it was found that the tomato fruit quality under RB1 was the best.

| Light treatment | Soluble solid | Titration acid | Soluble sugar | Sucrose | Ratio of sugar and titration |
|-----------------|---------------|---------------|---------------|---------|------------------------------|
| CK              | 8.60a         | 1.15a         | 7.04ab        | 1.28b   | 6.14c                        |
| RB1             | 9.07a         | 0.79c         | 7.31a         | 2.52a   | 9.27a                        |
| RB2             | 5.73b         | 0.89b         | 6.95c         | 0.75c   | 7.80b                        |
| RB3             | 5.80b         | 0.84bc        | 7.21ab        | 2.13a   | 8.68ab                       |

4. Discussion

This study found that different red and blue ratio of light can significantly affect the flowering and fruiting of tomato. The results showed that under RB1, the flowering and fruiting dates of tomato were earlier than that of the control group, and the pollen vigor was the highest, significantly higher than that of the control. The damage to its vigor increased with the increase of the ratio of red light, which was consistent with related study. The quality and flavor of cherry tomato are closely related to soluble solids, and the higher the content of soluble solids, the better the flavor [6]. The content of soluble solid, soluble sugar and sucrose in tomato fruit was higher under the ratio of light with red and blue 1:1, while the content of titratable acid was lower and the ratio of sugar to acid was higher. The suitable sugar acid ratio of tomato fruit was between 7 and 10, and the sugar acid ratio of RB1 treatment was 9.27, which was within the suitable range, so the quality of tomato fruit was higher.

5. Conclusion

In conclusion, different red and blue light ratio of LED lights were used as the light source for cultivation of cherry tomato, and the effects on flowering and fruiting of tomato were studied. It was found that different ratio of red and blue light could significantly affect the flowering date, fruiting date and fruit quality of tomato. The plant grew well under the light with red and blue light at 1:1, which could blossom and fruit earlier and improve the fruit quality.

Acknowledgement

This study was supported by the National Key Research and Development Program of China (No. 2017YFB0403903). We would like to thank Chungui Lu from School of Rural, Animal and Environmental Sciences, Nottingham Trent University for the help, thank Gang Xu and Wenrui Gao for providing laboratory conditions and equipment, also thank Yanjun Sun and Bing Han for their help in data collection.

References

[1] Cao K, Yu J, Ye L, et al. 2016 Transactions of the Chinese Society of Agricultural Engineering 32 180-186
[2] Sun N, Wei M, Li Y, et al. 2016 Acta Horticulturae Sinica 43 80-88
[3] Yang YN, Fan XX, Xu G, et al. 2019 Acta Agriculturae Zhejiangensis 31 737-745
[4] Liu XY, Jiao XL, Xu ZG, et al. 2015 Journal of Nanjing Agricultural University 38 772-779
[5] Fan XX, Yang YN, Xu G, et al. 2019 *Fujian Journal of Agricultural Sciences* **34** 1026-1031
[6] Yang ZB, Liu Y, Jin ZJ, Xu WH, et al. 2020 *Chinese Agricultural Science Bulletin* **36** 134-141
[7] Wu Q, Su NN, Cui J 2013 *Northern Horticulture* **21** 59-63
[8] Wang WL, Li Y, Xin GF, Cui M, Mi QH, Yang QC 2017 *Chinese Journal of Applied Ecology* **28** 1595-1602
[9] Wang LW, Li Y, Xin GF, Wei M, Yang QC 2017 *Acta Horticulturae Sinica* **44** 768-776
[10] Li HS 2000 Principles and techniques of plant physiological and biochemical experiments (Beijing: China Higher Education Press)