Riadi et al., 2015

Volume 1 Issue 1, pp.13-23

Year of Publication: 2015

DOI-https://dx.doi.org/10.20319/mijst.2016.s11.1323

This paper can be cited as: Riadi, M. F., Esyanti, R. R., & Faizal, A. (2015). The Effect of Led Light on Production of Female Flowers in Cucumer (Cucumis Sativus L.). MATTER: International Journal of Science and Technology, 1(1), 13-23.

THE EFFECT OF LED LIGHT ON PRODUCTION OF FEMALE FLOWERS IN CUCUMER (*CUCUMIS SATIVUS* L.)

Muhammad Fahri Riadi
School of Life Science and Technology, Institut Teknologi Bandung, Bandung, Indonesia
fahri.riadi@gmail.com

Rizkita Rachmi Esyanti
School of Life Science and Technology, Institut Teknologi Bandung, Bandung, Indonesia
rizkita@sith.itb.ac.id

Achmad Faizal
School of Life Science and Technology, Institut Teknologi Bandung, Bandung, Indonesia
afaizal@sith.itb.ac.id

Abstract

Light quality is one of the main factors that affect the productivity of cucumber plants, especially in induction of flowers. In this study, two lines of cucumber (Mercy and KE 27187) were treated with red (R), blue (B) and yellow (Y) light provided by LED (light emitting diode) with different compositions; RB (80:20) and RBY (80:10:10) for 8 h. Control plants were incubated under HPS lamps and TLD. The results showed that treatment of RB8 generate higher biomass and growth rate compared with RBY in both cucumber lines. Interestingly, RBY light increased sucrose content in plants, which positively correlate to the number of their female flowers. However, the energy efficiency of plants treated under LED light remains a major obstacle compared with control plants.

Therefore, further research using appropriate PAR and light intensity of LEDs is needed to increase the productivity of female flowers in cucumbers.

Keywords

Cucumber, Female Flowers, LED, Sucrose

1. Introduction

Cucumber (*Cucumis sativus* L.) was one of vegetables from Cucurbitaceae family that widely planted by farmer in Indonesia (Samadi, 2003). Cucumber production in Indonesia is still at low number, about 3, 5-4, 8 ton/ha, whereas it's potential can reach 20 ton/ha. Low productivity in cultivation of cucumbers can caused by disease, pest problem and low production of female flowers (Diana, 2007).

Indoor agriculture technology is a solution to prevent disease and pest problem in cultivation of cucumber. Use of indoor agriculture can provide optimal growing space for plant; reduce use of pesticides, as well as allowing production of plants in various places with optimization of energy and space. In the indoor agriculture, artificial light should be provided for photosynthesis of plants.

Nowadays, light emitting diode (LED) technology has been developed as a source of lighting in controlled room by using monochromatic wavelength (Currey& Lopez, 2013). LED has advantages over other artificial light source, such as high efficiency, longer life time, low temperatures, and environmental friendly (Zukauskas, et al., 2002; Massa, et al., 2008). LED lights can produce a spectrum of light with specific wavelength for plant growth and development, such as blue light with a wavelength of 450 nm and red light with a wavelength of 660 nm. Light with wavelength at 700-800nm is also known useful as a signal for plant photomorphogenesis (Vänninen et al., 2010), for example flowering. Induction of light on photomorphogenesis will also stimulate the development structure of the plant, such as internodes (Danielson, 1944).

Differences in the color of light may give different effect on the cucumber plants. Red light can improve biomass, increase leaf length (Stutteet al., 2009) and increase chlorophyll content (Lefsrud, et al., 2008). Blue light can increase leaves area and the pigment content of photosynthesis, while yellow light can stimulates synthesis of disaccharide (Olle &Viršile, 2013). Combination of blue and yellow light will create green light that can enhance plant growth (Cope & Bugbee, 2013).

Based on concepts, optimum lighting composition for cucumber plants using red, blue, and yellow LED must be optimize to increase production of female flowers to enhance productivity of cucumber crops.

2. Material and Methods

Cucumber Plants Preparation

Cucumber plants used in this experiment were obtained from PT. East West Seed Indonesia. Two lines, Mercy and KE 27187 were used in the experiments. Plants was cultivated in growth chamber with controlled temperature at 24-26^{o}C and soil moisture contents at 5-6% in each treatments.

Media Preparation

Media for pre-sowing treatment was straw paper with water. Charcoal husks were used as media for sowing. In greenhouse cultivation, the growing media used a mixture of charcoal husks (30, 7 kg), cocopeat (21, 5 kg), and soil (148 kg) for 66 polybags. Growing media with fertilizer had pH value 5-5, 5.

Treatment

The light source used in this study was LED, HPS and TLD lamps. Two set of LED's used in the treatment was assembled with a composition of **(1)** 80% red light (34 red light, λ = 630 nm) and 20% blue light (8 blue light, λ = 460 nm) and **(2)** 80% red light (34 red light, λ = 630 nm), 10% blue light (4 blue light, λ = 460 nm), and 10% yellow light (4 yellow light, λ = 510 nm). PAR that excited from LED was 44 µmol.m-2.s-1 with average intensity 820 lux. Power input for each LED was 1 watt and each treatment had 12 circuit LED with 44x10 cm circuit board size. Control treatment used light source from 2 HPS lamps and 12 TLD lamps with average PAR 120 µmol.m-2.s-1 and average intensity 3787 lux. Power input for TLD lamp was 36 watt and 400 watt for HPS lamp.

Control and LED treatment were performed in growth chamber. LED treatment were divided into two treatments. First treatment was conducted with 80% red LED and 20% blue LED (RB) for 8 hours whilst in second treatment with 80% red LED, 10% blue LED and 10% yellow LED (RBY) for 8 hours. This treatment run for 28 days. Measurement of plants height and flower was conducted two times a week. Plants were watered 500 ml/day until 3 weeks after planted, then increased 1000 ml/day. First fertilizer (NPK with 16:16:16) was given 7 days after transplantation, with 10g/plant. On the second week, they were given Grow more N fertilizer 1g/plant and third week plants was given 1g/plant of Grow more PK fertilizer.

Quantification of Mass Balance and Growth Rate

Mass balance modelling was constructed based on the equation below (Saterbak, et al., 2007).

$$aC_{12}H_{22}O_{11} + bNH_4NO_3 + cO_2 \rightarrow dCH_{1.27}O_{0.43}N_{0.45} + eH_2O + fCO_2 \quad (1)$$

Reaction coefficient number for each component was obtained using element balance from carbon (C), hydrogen (H), oxygen (O), and nitrogen (N).Growth rate was quantified using data from growth curve with derivative from first order growth rate (Shuler & Kargi, 1992).

$$\mu = (\ln(X_2)-\ln(X_1))/(t_2-t_1) \quad (2)$$

Growth rate was used to create logistic model equation which was expected to model growth for each treatment. The modelling was based on logistic equation by fitting data to actual data. Kinetic modelling for growth rate was based on the logistic equation below (Shuler &Kargi, 1992).

$$dX/dt = \mu X(1-X/Xmax) \quad (3)$$

Actual dry weight obtained was compare with hypothetical dry weight to evaluate the quality of the model. The hypothetical dry weight was obtained from a given amount of fertilizer with assumption that all fertilizer was converted to NH4NO3 and reacted perfectly.

Quantification Average Distance of Internodes

The length of internodes on each crop was measured to see the growth of plants.

Observation and measurement were done manually with tape ruler.

Flower Calculation

Observation and calculation of flowers for all treatments were conducted manually. Flowers was calculated for male and female flowers.

Measurement of Sugar Content

Sugar content was measured by ferricyanide method using a spectrometer (Englis & Becker, 1943). Sample used in the measurement was apical leaf in the last day of cultivation from all lines.

This sampling collection was a modification method from Yamasaki (Yamasaki, et al., 2003).

Statistical Analysis

Statistical analysis used SPSS software. Analysis used in this experiment was Duncan test (ANOVA) with significance value p < 0,005.

3. Result and Discussion

Growth Rate and Growth Modelling

Comparison of hypothetical growth rate with actual growth rate between Mercy and KE 27187 lines was provided in Table 3.1 and 3.2.

Table 3.1: *Comparison of Hypothetical and Actual Growth Rate from Mercy Line*

Mercy (cm/weeks)	**RB8**	**RBY8**	**Control**
Hypothetical	0,089	0,068	0,107
Actual	0,0121	0,0041	0,0507

Table 3.2: *Comparison of Hypothetical and Actual Growth Rate from KE 27187 LINES*

KE 27187 (cm/weeks)	**RB8**	**RBY8**	**Control**
Hypothetical	0,083	0,069	0,102
Actual	0,0139	0,0104	0,0442

The actual growth rate from RB8 treatments was greater than RBY8. Blue light composition on RB8 was 10% greater than RBY8. Blue light on the plants might activate cryptochromes system that induced stomata to open which could increase rate of transpiration.

High rate of transpiration might increase root activity in absorption nutrient such as water and mineral that would lead to faster growth rate (Olle & Viršile, 2013).

Modelling was performed based on logistic equation by fitting with actual data. The model showed that closest actual growth rate to hypothetical growth rate from line Mercy and KE 27187 was from control treatments with higher PAR and light intensity which affected growth rate (Olle & Viršile, 2013). PAR and light intensity produced from RB8 and RBY8 treatments was 44 μmol.m^{-2}.s^{-1} and 820 LUX. Meanwhile, PAR and light intensity produced from control was 120 μmol.m^{-2}.s^{-1} and 3787 LUX. Therefore, growth rate of control plants was greater than RB8 and RBY8 treatments.

Plants Dry Weight

Final dry weight from RB8, RBY8 and control was shown in Table 3.3.

Table 3.3: *Final Dry Weight from Mercy and KE 27187 Lines*

Treatment	**Dry Weight (g)**	
	Mercy	**KE 27187**
RB8	4,8 ± 0,47^{c}	6,43 ± 1,21^{c}
RBY8	3,00 ± 0.05^{b}	2,22 ± 0,05^{b}
Control	46,78 ± 1,34^{a}	48,34 ± 2,13^{a}

Dry weight value calculated from average dry weight + Standard Error of Mean (SEM) Different letter showed difference in significance based on Duncan Test (p < 0, 005)

Hypothetical dry weight was obtained from mass balance equation below:

$$0,39\ C_{12}H_{22}O_{11} + 0,23\ NH_4NO_3 + 3,43\ O_2 \rightarrow CH_{1,27}O_{0,43}N_{0,45} + 4,07\ H_2O + 3,64\ CO_2 \qquad (4)$$

Table 3.4: *Mass Balance Equation*

	$C_{12}H_{22}O_{11}$	NH_4NO_3	O_2	$CH_{1,27}O_{0,43}N_{0,45}$	H_2O	CO_2
Initial (mole)	-	0,55	-		-	-
Reaction (mole)	0,93	0,55	8,20	2,39	9,73	8,70
Final (Mole)	-	0	-	2,39	9,73	8,70

Fertilizer given along cultivation was 44g, thus the initial mole of NH_4NO_3 was 0,55. All fertilizer were considered to react and act as limiting reactant that gave final biomass mole 2,3919 with 63,25g final biomass (MW biomass : 63,25).

The actual dry weight from RB8 treatment was higher than RBY8, which might be done to blue light composition in RB8 was higher than RBY8. Blue light can enhance chlorophyll content that will increase photosynthetic activity in plants (Olle &Viršile, 2013). Biomass formed in RB8 could be more than RBY8 that caused RB8 treatment had higher dry weight than RBY8. However, when compared with control plants, the dry weight from RB8 and RBY8 treatment were much smaller compared to the dry weight of control plants.

Sugar Content

Sugar analysis was performed using ferricyanide method (Englis& Becker, 1943). Results of sugar analysis was shown in Table 3.5.

Table 3.5: *Total Sugar Content on Apical Leaf*

Treatment		Sugar Content (ppm)
RB8	Mercy	2648,82
	KE27187	5117,67
RBY8	Mercy	7125,06
	KE 27187	6202,12
Control	Mercy	13401,01
	KE 27187	11393,63

Based on the result of sugar content, RBY8 had a higher sugar content than RB8 because RBY8 treatment had yellow light that stimulate disaccharide which result in more photosynthate production in plants. The highest sugar content found in the control plants due to better photosynthesis process.

Average Length of Internodes

Average length of internodes to the first female flower on cucumber plants was shown in Table 3.6.

Table 3.6: *Average Distance Internodes for Mercy and KE 27187 Lines*

Treatment		Average Distance Internodes (cm)
RB8	Mercy	7,41 ± 0,13
	KE 27187	7,8 ± 0,33
RBY8	Mercy	6,3 ± 0,24
	KE 27187	7,25 ± 0,2
Control	Mercy	7,35 ± 0,18
	KE 27187	7,03 ± 0,18

The average distance to internodes was closely related to cucumber flowering. Average distances of RBY8 treatment in both lines was shorter than RB8, because RBY8 treatment had yellow signal that inhibited internodes elongation if the composition didn't match (Brazaitytė et al., 2009). Good cucumber plants should have short internodes, solid stems and green leaves, for high productivity of cucumber plants.

Flower Quantification

Maximum flowers observed in all treatments was shown in Figure 3.1.This figure showed that RBY8 treatment produced more female flowers than RB8. Mercy line from RB8 treatment gave an average of 1 female flower/plant, while RBY8 gave an average of 1, 8 female flower/plant. KE 27187 lines treated with RB8 treatment gave an average 3, 8 female flower/plant, while RBY8 gave an average 4, 2 female flower/plant. This result indicated that yellow light signal had role to stimulate synthesis of disaccharide. The sugar will provide a signal to the synthesis of ethylene which is hormones for female flower induction (Yamasaki et al, 2003).

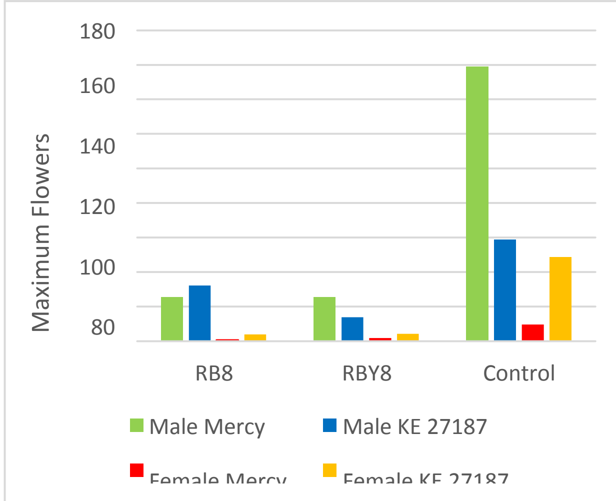

Figure 3.1: *Maximum flowers observed in Mercy and KE 27187 lines*

The highest average of female flowers was from control treatment because PAR and light intensity in control treatment was much better than RB8 and RBY8, resulting more photosynthate production to induce female flower.

Energy Consumption

Energy assessment was performed to calculate energy used to produce each female flower, thereby cost of energy was counted and compared to evaluate the benefit for each treatment. Energy consumption for all treatment was shown in Table 3.7.

Table 3.7: *Consumption Energy from Mercy and KE 27187 Lines*

Treatment		Energy Consumption	Maximum Female Flower/plant
RB8	Mercy	36,228	1
	KE 27187		3,8
RBY8	Mercy		1,8
	KE 27187		4,2
Control	Mercy	177,408	9,6
	KE 27187		48,4

Based on calculation of energy consumption from both lines, RBK8 treatment was more efficient than RB8 treatment because it produced more female flower with same energy consumption. However, control treatment was more efficient than treatment using LED. Control treatment produced more female flowers, although used high energy consumption.

4. Conclusion and Suggestion

Based on the result of study, RB8 treatment produce higher biomass, growth rate, and average distance internodes than RBY8 treatment in both lines. Sugar content analysis showed that sucrose content was positively correlated with the number of female flower produced. Energy assessment indicated that using LED was not optimal for treatment due to low of PAR and intensity of the light. PAR and intensity played a role to generate energy that accommodated production of female flower. Therefore, future research is needed using optimize LED equipment with PAR and intensity needed by plants to increase the productivity of female flowers in cucumber, which reduce energy cost and make indoor agriculture more profitable.

5. Acknowledgment

We thank PT. East West Seed Indonesia for the contribution in this research by facilitating all the plants, cultivation, and equipment.

References

Brazaitytė, A., Duchovskis, P., Urbonavičiūtė, A., Samuolienė, G., Jankauskienė, J., Kasiulevičiūtė-Bonakėrė, A., Bliznikas, Z., Novičkovas, A., Breivė, K., Žukauskas, A. (2009) The effect of light-emitting diodes lighting on cucumber transplants and after- effect on yield. Zemdirbyste–Agriculture 96: 102-118.

Cope, K.R., Bugbee, B. (2013). Spectral effects of three types of white light-emitting diodes on plant growth and development: Absolute versus relative amounts of blue light. HortScience 48: 504-509.

Currey, C.J., Lopez, R.G. (2013, October) Comparing LED Lighting To High-Pressure Sodium Lamps. Greenhouse Grower, 34-40.

Danielson, L. (1944). Effect of day length on growth and reproduction of the cucumber, Plant physiology 19: 638.

Diana, S. (2007). ResponPertumbuhandanProduksiMentimun (CucumisSativus) dengan Mutagen

Kolkhisin, FakultasPertanianUniversitas Sumatera, Medan.

Englis, D., Becker, H. (1943).Sugar Analysis by Alkaline Ferricyanide Method - Determination of Ferrocyanide by Iodometric and Other Procedures.Ind. Eng. Chem. Anal. Ed., 15 (4), 262–264.

Lefsrud, M.G., Kopsell, D.A., Sams, C.E. (2008). Irradiance from distinct wavelength light- emitting diodes affect secondary metabolites in kale. HortScience 43: 2243-2244.

Massa, G.D., Kim, H.H., Wheeler, R.M., Mitchell, C.A. (2008).Plant productivity in response to LED lighting. HortScience 43: 1951-1956.

Olle, M., Viršile, A. (2013). The effects of light-emitting diode lighting on greenhouse plant growth and quality, Agricultural and Food Science 22: 223-234.

Saterbak, A., San, K., McIntire, L,V. (2007).Bioengineering Fundamentals. Pearson Prentice Hall.

Shuler, L, M., Kargi, F. (1992) Bioprocess Engineering.Prentice Hall.

Stutte, G, W., Edney, S., Skerritt, T. (2009).Photoregulation of bioprotectant content of red leaf lettuce with light-emitting diodes. HortScience 44: 79-82.

Vänninen, I., Pinto, D., Nissinen, A., Johansen, N., Shipp, L. (2010). In the light of new greenhouse technologies: 1. Plant-mediated effects of artificial lighting on arthropods and tritrophic interactions, Annals of Applied Biology 157: 393-414.doi: 10.1111/j.1744-7348.2010.00438.x

Yamasaki, S., Fujii, N., Takahashi, H. (2003). Photoperiodic regulation of CS-ACS2, CS-ACS4, and CS-ERS gene expression contributes to the femaleness of cucumber flowers through diurnal ethylene production under short-day conditions, Plant Cell and Environment, 26: 537-546. doi: 10.1046/j.1365-3040.2003.00984.x

Zukauskas, A., Shur, M., Gaska, R. (2002).Introduction to solid-state lighting, J.Wiley.