Effects of light quality on the growth and essential oil content in Sweet basil

Article *in* Acta horticulturae · September 2011

DOI: 10.17660/ActaHortic.2011.907.9

4 authors, including:

Wakanori Amaki
Tokyo University of Agriculture
43 PUBLICATIONS **230** CITATIONS

SEE PROFILE

Effects of Light Quality on the Growth and Essential Oil Content in Sweet Basil

W. Amaki, N. Yamazaki,
and M. Ichimura
Department of Agriculture
Tokyo University of Agriculture
Funako 1737, Atsugi
Kanagawa 243-0034, Japan
amaki@nodai.ac.jp

H. Watanabe
Graduate School of Agriculture
Tamagawa University
6-1-1 Tamagawa Gakuen, Machida
Tokyo 194-8610, Japan

Keywords: aromatic plant, artificial light, light emitting diodes, *Ocimum basilicum* L., photomorphogenesis

Abstract

Sweet basil seedlings were grown under four monochromatic lights irradiated with blue, blue-green, green and red LEDs that have the peak wavelength of 470, 500, 525 and 660 nm respectively. A combined white light was simultaneously irradiated by white, blue, green and red LEDs (the PPFD ratio was 3:1:1:1). The treatment conditions of the LED lights consisted of 24±2 ºC at 50 µmol m^{-2} s^{-1} PPFD. After 70 days of the light treatment, plants were harvested so as to measure their biometric characteristics and essential oil contents in leaves. The results showed that the top fresh weight, total leaf weight and total leaf area were higher under green monochromatic light than under other lights. However, the total leaf weight and total leaf area of lateral shoots were the largest under blue light. The largest amount of essential oil was observed in leaves under blue light. The essential oil contents of plants grown under blue light were 1.2 – 4.4 times higher than those grown under white light. On the other hand, the contents of plants grown under red light were only 12.7 – 77.0 % of that under white light.

INTRODUCTION

Sweet basil (*Ocimum basilicum* L.) is one of the major aromatic plants. In our previous studies, we have shown that the growth of sweet basil plants and the contents of essential oil in leaves were affected by light intensity, temperature and irrigation levels (Ichimura et al., 1987, 1991). It is known that the light quality affects the secondary metabolites, such as medicinal components (Nishimura et al., 2007) and plant pigments (Ebisawa et al., 2008). However, little has been reported on the effects of light quality on the contents of aromatic compounds and the growth of sweet basil plants. Johnson et al. (1999) and Ioannidis et al. (2002) reported that the supplementary lighting of UV-B light enhanced the level of aromatic volatile compounds in sweet basil leaves. This study aimed to examine the effects of light quality on the growth and the amount of essential oil production in leaves of sweet basil. The content of essential oils were much larger in younger leaves on stems and the major components of fresh flavor were α-pinene, β-pinene, 1,8-cinelol and linalool that have relative low boiling points (Ichimura et al., 2008). Thus, in this report, the sampling position of leaves was determined at the upper part (first, third and fifth nodes) and the head space method for extraction was used for collection of essential oils with low boiling point.

MATERIAL AND METHODS

Plant material and light treatments

Sweet basil seeds (purchased from Fujita Seeds Co., Japan) were sown in 162-cell plug trays and grown in a growth chamber (16-hr photoperiod with white fluorescent lamps at 240 μmol m^{-2} s^{-1} PPFD and 23±1 ºC) up to the stage of having entirely unfolded cotyledons. The seedlings were transplanted to 6 cm pots and transferred under respective monochromatic lights or a combined white light. Four monochromatic lights were irradiated with blue, blue-green, green and red LEDs which have the peak wavelength of 470, 500, 525 and 660 nm respectively. A combined white light was simultaneously irradiated by white, blue, green and red LEDs (the PPFD ratio was 3:1:1:1). The treatment conditions of the LED lights consisted of 16-hr photoperiod at 24±2 ºC and 50 μmol m^{-2} s^{-1} PPFD. After 70 days of the light treatment, plants were harvested so as to measure biometric characteristics and essential oil contents in leaves.

Head space gas chromatography analysis for essential oil contents

After 70 days of the light treatments, pair leaves at the uppermost (first), third and fifth nodes of main stem were collected and weighed the fresh weight (FW). Then each of pair leaves placed in a 20 mL glass vial for headspace GC analysis. A gas chromatograph (GC-14A, Shimazu Co., Ltd., Japan) equipped with FID detector was used. Each sample in vial was retained for 30 min at 40 ºC. The column used a Carbowax 20M (0.25 mm × 30 m, Restek, USA). The carrier gas was He at a velocity of 0.62 mL min^{-1}. The temperatures of the injector and detector were 290 ºC, and the initial column temperature was 55 ºC, increasing at 4 ºC min^{-1} until 210 ºC. The concentrations of the major 7 compounds in sweet basil leaves were expressed as mg kg^{-1} leaf FW calculated by the analysis values using authentic standards. This experiment was repeated three times. Each of values represented in Table 2 was the mean of three replicates.

RESULTS AND DISCUSSION

The sweet basil seedlings under green light condition grew vigorously. The largest values of growth parameters, such as FW of top and roots, leaf FW of main stem and stem diameter were recorded from the plants grown under green light. Blue light promoted the growth of lateral shoots. The largest leaf FW of lateral shoots was obtained from plants under blue light. The root growth of plants grown under blue-green light was poor. As the results of poor root development, the top growth under blue-green light was also limited, compared with those under other lights (Table 1). The leaf lamina under red light rolled up because of marked epinasty. It seems that the rolled leaf shape is unfavorable for intercepting of light irradiated from upside position. The stem of plants grown under red light was obviously thinner (Table 1).

The essential oil contents of respective leaf positions on the main stem were shown in Table 2. The first (uppermost) pair leaves showed the largest value in total contents of the major 7 essential oil components, except for that of plants grown under red light. This result is similar that of plants grown under sun light in field condition (Ichimura et al., 2008). The highest content value among 7 essential oils was 1,8-cineol regardless of light quality. The plants grown under blue light showed the largest value on the sum total content of 7 essential oil components. On the other hand, plants grown under green light produced less amounts of essential oils in spite of its vigorous vegetative growth. Amounts of essential oils in leaves of plants grown under blue light were 1.2 – 4.4 times higher

(depended on the leaf position) than those of plants grown under white light. On the other hand, the amounts of plants grown under red light were only 12.7 – 77.0 % of that under white light.

The essential oil composition of plants grown under blue light was different from those under other light sources. The second and third major compounds under blue light were myrcene and linalool. However, those were α-pinene and β-pinene under green and red lights. Those under white and blue-green lights showed the intermidate response, that is, the second and third major compounds were myrcene and β-pinene. Blue light irradiation could enhance the metabolism of aromatic compounds and improve the composition of essential oils in leaves of sweet basil.

Literature Cited

Ebisawa, M., Shoji, K., Kato, M., Shimomura, K. Goto, F. and Yoshihara, T. 2008. Effects of supplementary lighting of UV-B, UV-A and blue light during the night on growth and coloring in red-leaf lettuce. J. SHITA 20:158-164. (In Japanese with English summary)

Ichimura, M., Tomitaka, Y. and Kimura, M.1987. Effects of light intensity on the growth and essential oil contents in sweet basil. Abstr. Japan. Soc. Hort. Sci. Autumn Meet. p.410-411. (In Japanese)

Ichimura, M., Kimura, M. and Tomitaka, Y. 1991. Effects of temperatures and photoperiods on the growth and essential oil contents in sweet basil. J. Japan. Soc. Hort. Sci. 60 (Suppl. 1):338-339. (In Japanese)

Ichimura, M., Noguchi, A. and Kimura, M.2008. Changes in flavor and essential oil components by location of leaf in sweet basil (*Ocimum basilicum* L.). J. Agric. Sci., Tokyo Univ. Agric., 53: 91-95. (In Japanese with English summary)

Ioannidis, D., Bonner, L. and Johnson, C.B. 2002. UV-B is required for normal development of oil glands in *Ocimum basilicum* L. (Sweet Basil). Annals of Botany 90:45-460.

Johnson, C.B., Kirby, J., Naxakis, G. and Pearson, S.1999. Substantial UV-B-mediated induction of essential oils in sweet basil (*Ocimum basilicum* L.). Phytochemistry 51:507-510.

Nishimura, T., Zobayed, S.M.A., Kozai, T. and Goto, E. 2007. Medicinally important secondary metabolites and growth of *Hypericum perforatum* L. plants as affected by light quality and intensity. Environ. Control Biol., 45:113-120.

Table 1. Effects of light quality on the growth in sweet basil for 70 days w respective lights at 50 μmol m^{-2} s^{-1} PPFD.

Light condit	Total fresh weight ($g\ plant^{-1}$) (		Leaf fresh weight ($g\ plant^{-1}$) (		Stem diam
	Top	Roots	Main stem	Lateral shoots	(cm)
White (combined)	10.6b*	1.8b	8.1b	0.4ab	3.5ab
Blue (470 nm)	11.0b	2.6ab	7.9b	0.7a	3.6ab
Blue-green (500 nm)	9.6b	1.6b	8.2b	0.2b	3.6ab
Green (525 nm)	14.9a	3.1a	11.0a	0.5ab	3.8a
Red (660 nm)	10.5b	2.0ab	8.4b	0.3b	3.3b

*:Different lettering for each column of mean values indicates significan

Table 2. Effects of light quality on the contents of essential oils in leaves of sweet basil. Plants were cultivated at 24±2 ºC for 70 days under respective lights at 50 μmol m^{-2} s^{-1} PPFD. Essential oils were extracted by head space method.

Light condition	Leaf position	Content (mg kg^{-1} leaf fresh weight)							
		α-pinene	β-pinene	myrcene	limonene	1,8-cineol	γ-terpinene	linalool	Total
White (combined)	First	18.81	20.27	28.99	3.71	28.62	4.94	13.81	119.2
	Third	6.56	7.21	6.40	1.10	38.97	2.35	14.18	76.8
	Fifth	8.37	8.57	1.31	0.76	11.86	0.65	0.67	32.2
	(Mean)	*11.25*	*12.02*	*12.23b**	*1.86*	*26.48b*	*2.65b*	*9.55b*	*76.0b*
Blue (470 nm)	First	21.92	24.73	52.81	5.18	132.24	15.64	69.63	322.2
	Third	10.51	7.72	16.63	1.68	40.80	5.93	9.51	92.8
	Fifth	16.79	15.25	24.41	3.35	67.35	7.63	6.97	141.8
	(Mean)	*16.41*	*15.90*	*31.28a*	*3.40*	*80.13a*	*9.33a*	*28.70a*	*185.6a*
Blue-green (500 nm)	First	8.70	10.15	17.15	2.41	50.15	3.45	13.75	105.8
	Third	2.68	2.56	3.08	0.55	4.50	0.89	0.95	15.2
	Fifth	5.24	5.13	3.09	1.09	13.56	1.63	0.48	30.2
	(Mean)	*5.54*	*5.95*	*7.77b*	*1.35*	*22.74b*	*1.99b*	*5.06b*	*50.4c*
Green (525 nm)	First	11.57	11.17	1.74	0.75	23.57	1.05	0.58	50.4
	Third	6.58	6.72	3.53	1.23	12.84	1.38	0.97	33.3
	Fifth	1.94	1.55	nd	nd	0.50	nd	nd	4.0
	(Mean)	*6.70*	*6.48*	*1.76c*	*0.66*	*12.30b*	*0.81b*	*0.52c*	*29.2c*
Red (660 nm)	First	5.97	5.40	nd	0.72	2.59	0.46	nd	15.1
	Third	11.05	12.50	5.40	1.23	23.62	2.54	2.77	59.1
	Fifth	1.68	1.32	0.31	0.18	2.31	0.30	0.13	6.2
	(Mean)	*6.23*	*6.41*	*1.90c*	*0.71*	*9.51b*	*1.10b*	*0.97c*	*26.3c*

*:Different lettering for each column of mean values indicates significant difference at 5 % level.