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USE OF LIGHT TO CONTROL THE GROWTH OF *Salvia splendens* Sellow ex Roem. et Schult. SEEDLINGS

Anita Woźny

University of Technology and Life Sciences in Bydgoszcz

Abstract. In many ornamental plant species the light spectrum can, to a varied extent, modify growth and flowering. The literature offers information on the inhibition of growth of seedlings and cuttings of ornamental plants exposed to blue light. In this paper was investigated the effect of light of a varied spectral composition on the growth of scarlet sage (*Salvia splendens*) seedling. The plants were cultivated in the growth chamber at the 16-hour and 20-hour day. The following kinds of light were used: daylight – similar in its spectral composition to natural light, blue and mixed light – with the same share of daylight and blue light as well as with 75% share of blue light. The intensity of the quantum irradiance in the range PAR was the same for all the experiment combinations and it was 110 μmol · m^{-2} · s^{-1}. The scarlet sage grown in mixed light with the advantage of blue light was lower than the plants produced in daylight both at the 16-hour and 20-hour day.

Key words: spectral composition of light, plant height, fresh and dry weight of steam and leaves

INTRODUCTION

Even though chemical growth retardants are still commonly applied in horticultural production, the increasing environmental pollution and high retardant costs call for a search for new organic methods to produce the desired plant habit. In practice growth modification by providing an adequate temperature or the application of mechanical stimuli triggering stress leading to the growth inhibition, without a negative effect on the plant quality have been already applied.

Many reports demonstrate that light of a specific colour can affect growth and morphogenesis of many plant species [Rajapakse and Kelly 1994, McMahon and Kelly 1999, Kim et al. 2002, Runkle and Heins 2002, Ilias and Rajapakse 2005]. In horticultural production photoselective films are used, however due to a relatively short durability and a lower sunlight transmission, in practice, the sources of light of a specific spec-

Corresponding author – Adres do korespondencji: Anita Woźny, Department of Ornamental Plants and Vegetables, University of Technology and Life Sciences in Bydgoszcz, Bernardyńska 6/8, 85-029 Bydgoszcz, Poland, e-mail: wozny@utp.edu.pl

tral composition can be more applicable. It refers to both lamp fluorescent tube and diodes, becoming more and more popular. The present experiment aimed at determining the effect of blue light and daylight as well as mixed light, emitted by fluorescent tubes on the growth of scarlet sage seedlings exposed to different photoperiods.

MATERIAL AND METHODS

The experiment was performed in the growth chamber, at artificial light and under controlled climate conditions. The experiment involved four types of artificial light emitted by Philips fluorescent tubes: daylight, similar in its spectral composition to natural light, in the wavelength 307–770 nm (fig. 1), blue light, in the wavelength 393–580 nm (fig. 2) and two types of mixed light; the first one, type A, obtained thanks to four lamps emitting daylight and four lamps – blue light, installed on the racks, the second type, type B, thanks to the application of two lamps emitting daylight and six lamps emitting blue light. The intensity of the quantum irradiation in the PAR range was the same for all the experimental treatments and it was 110 μmol · m^{-2} · s^{-1}.

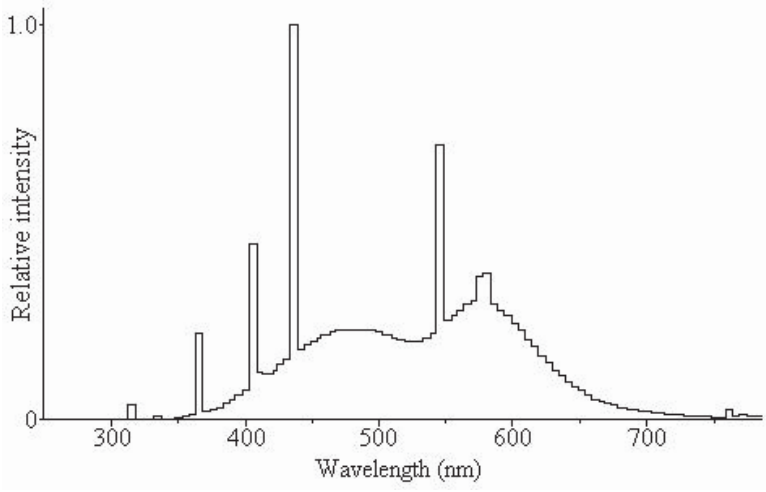

Fig. 1. Spectral characteristics of lamps emitting daylight by Philips (TLD 36W/54)
Ryc. 1. Charakterystyka spektralna lamp emitujących światło dzienne wg firmy Philips (TLD 36W/54)

The seeds of scarlet sage (*Salvia splendens* Sellow ex Roem. et Schult.) were sown into the substratum based on peat and pearlite in the volumetric ratio 2:1. After about two weeks 60 healthy seedlings of similar height were selected and pricked out into pots 6 cm in diameter, filled with substratum for annual plants growing. In the first part of research seedlings were transferred to the growth chamber where the photoperiod was fixed as 16 hours, while in the other one – a longer day, namely 20-hour day, was applied. The plants were cultivated during 28 days in each part of research.

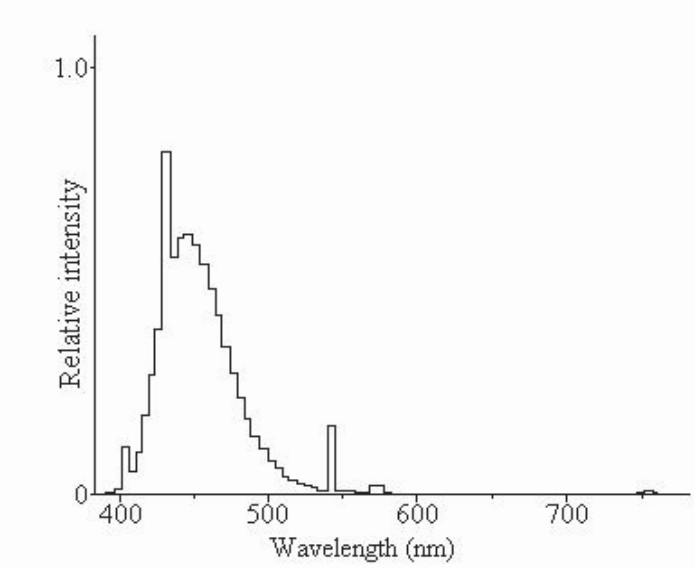

Fig. 2. Spectral characteristics of lamps emitting blue light by Philips (TLD 36W/18)
Ryc. 2. Charakterystyka spektralna lamp emitujących światło niebieskie wg firmy Philips (TLD 36W/18)

The air temperature throughout the experiment was maintained at 22°C when the lamps were switched on and 19°C when the lamps were switched off. The relative humidity in the growth chamber was 65%. After two weeks of growing, when the plants had developed 4–6 leaves, the multicomponent fertilizer, Florovit, at the concentration of 0.2 and 0.3% as well as Mikrovit 2, at the concentration of 0.2%, were applied. When the cultivation was completed, upon the appearance of the first flower buds, the seedling height was measured. The thickness of the main stem was measured over the first pair of leaves and the number of lateral shoots – recorded. The fresh weight was defined and when the plant material was dried at 105°C – also the dry weight of stems and leaves was weighed. To determine the content of chlorophyll in each experimental treatment five plant samples were selected. One sample was made up of the 4^{th} and the 5^{th} leaf from the bottom of the plant. Chlorophyll was extracted in 80% water solution of acetone [Kłyszejko-Stefanowicz 1999, Wettstein 1957]. The measurement of the absorption was made with the spectrophotometer UV-Vis 1601 SHIMADZU. The readings were made at the wavelength of 645 nm and 663 nm.

The results were statistically verified with the analysis of variance of the two-factor experiment in completely randomized design and the differences between the means were estimated using the Tukey test at the level of significance of $\alpha = 0.05$. A single experimental combination covered 5 reps., 3 plants each.

RESULTS

The experiment demonstrated that the spectral composition of light applied for the production of the scarlet sage seedlings affected the plant height (tab. 1). Irrespective of the photoperiod the plants grown in daylight were higher from the seedlings obtained in blue light and both types of mixed light. The analysis of the interaction showed that during the cultivation at 16-hour day, the seedling under mixed light type B, namely with a greater share of blue light, was lower than the one obtained in daylight and blue light. At the 20-hour day, on the other hand, in blue light and mixed light type B a poorer plant growth was noted, as compared with the daylight.

Table 1. Effect of light quality and day length on the height of *Salvia splendens* Sellow ex Roem. et Schult. seedlings (cm)
Tabela 1. Wpływ jakości światła i długości dnia na wysokość rozsady szałwii lśniącej (cm)

Day length Długość dnia (B)	Type of light – Rodzaj światła (A)				
	daylight dzienne	blue niebieskie	mixed light światło mieszane		mean for (B) średnia dla (B)
			type A typ A	type B typ B	
16 h	4.08	4.05	3.86	3.77	3.94
20 h	4.37	3.98	4.14	4.04	4.13
Średnia dla (A) Mean for (A)	4.22	4.01	4.00	3.90	
$LSD_{0.05} – NIR_{0,05}$	A = 0.17 B = 0.09 A/B = 0.24				

It was shown that, irrespective of the type of light applied, thicker stems were recorded in the seedlings grown at shorter day (tab. 2). During the cultivation at 16-hour day the plants exposed to daylight formed thicker stems than in both types of mixed light. When the day was extended to 20 hours, however, the stems of the seedlings grown in mixed light, with blue light prevailing, were thicker than in the blue light.
The number of lateral shoots depended only on the day length (tab. 2). Irrespective of the type of light, the seedlings grown at 20-hour day were branched-out better.

Irrespective of the light type applied, the seedlings produced in longer day demonstrated a greater fresh weight of the stem (tab. 3). The analysis of the interaction showed a varied reaction of plants to the light applied depending on the day length. At 16-hour day the fresh weight of stems in seedlings under mixed light B type was lower than in daylight, while at the 20-hour long day – the fresh weight of stems in seedlings in blue light – lower than in the day light.

No effect of the light type and the photoperiod on the content of dry weight in scarlet sage seedlings stems was noted (tab. 3).

Table 2. Effect of light quality and day length on the thickness of stem and number of lateral shoots in *Salvia splendens* Sellow ex Roem. et Schult. seedlings

Tabela 2. Wpływ jakości światła i długości dnia na grubość łodygi rozsady szałwii lśniącej oraz liczbę pędów bocznych

	Day length Długość dnia (B)	Type of light – Rodzaj światła (A)				
		daylight dzienne	blue niebieskie	mixed light światło mieszane type A typ A	mixed light światło mieszane type B typ B	mean for (B) średnia dla (B)
Thickness of stem Grubość łodygi cm	16 h	0.35	0.32	0.31	0.30	0.32
	20 h	0.30	0.29	0.29	0.32	0.30
	średnia dla (A) mean for (A)	0.32	0.30	0.30	0.31	
	$LSD_{0.05} - NIR_{0,05}$	A = n.s n.i B = 0.01 A/B = 0.03				
Number of lateral shoots Liczba pędów bocznych	16 h	5.6	5.9	5.4	5.6	5.6
	20 h	5.6	6.1	6.5	5.7	6.0
	średnia dla (A) mean for (A)	5.6	6.0	6.0	5.6	
	$LSD_{0.05} - NIR_{0,05}$	A = n.s n.i B = 0.4 A/B = n.s n.i				

Table 3. Effect of light quality and day length on the fresh and dry weight of stem in *Salvia splendens* Sellow ex Roem. et Schult. seedlings

Tabela 3. Wpływ jakości światła oraz długości dnia na świeżą i suchą masę łodygi rozsady szałwii lśniącej

	Day length Długość dnia (B)	Type of light – Rodzaj światła (A)				
		daylight dzienne	blue niebieskie	mixed light światło mieszane type A typ A	mixed light światło mieszane type B typ B	mean for (B) średnia dla (B)
Fresh weight of stem Świeża masa łodygi mg	16 h	374	344	330	261	327
	20 h	413	270	380	340	351
	średnia dla (A) mean for (A)	393	307	355	301	
	$LSD_{0.05} - NIR_{0,05}$	A = 74 B = n.s n.i A/B = 105				
Dry weight of stem Sucha masa łodygi mg	16 h	32	29	25	21	27
	20 h	33	23	25	28	27
	średnia dla (A) mean for (A)	32	26	25	28	
	$LSD_{0.05} - NIR_{0,05}$	A = n.s n.i B = n.s n.i A/B = n.s n.i				

Irrespective of the spectral composition of the light applied, the seedlings produced under the longer day demonstrated a higher fresh and dry matter of leaves than on the shorter day (tab. 4). The effect of the light spectrum was noted only for the cultivation on 16-hour day; the plants produced in daylight showed a greater content of dry matter than the seedlings exposed to mixed light type B, namely with blue light prevailing.

Table 4. Effect of light quality and day length on fresh and the dry weight of leaves in *Salvia splendens* Sellow ex Roem. et Schult. seedlings

Tabela 4. Wpływ jakości światła oraz długości dnia na świeżą i suchą masę liści rozsady szałwii lśniącej

	Day length Długość dnia (B)	Type of light – Rodzaj światła (A)				
		daylight dzienne	blue niebieskie	mixed light światło mieszane type A typ A	mixed light światło mieszane type B typ B	mean for (B) średnia dla (B)
Fresh weight of leaves Świeża masa liści g	16 h	2.561	2.583	2.308	1.987	2.360
	20 h	3.550	3.053	3.585	3.450	3.409
	średnia dla (A) mean for (A)	3.055	2.818	2.946	2.718	
	$LSD_{0.05} - NIR_{0,05}$	A = n.s n.i B = 0.232 A/B = n.s n.i				
Dry weight of leaves Sucha masa liści g	16 h	0.245	0.242	0.206	0.182	0.219
	20 h	0.375	0.315	0.365	0.340	0.349
	średnia dla (A) mean for (A)	0.310	0.279	0.285	0.261	
	$LSD_{0.05} - NIR_{0,05}$	A = 0.045 B = 0.024 A/B = 0.063				

Table 5. Effect of the light used during the cultivation and day length on the total chlorophyll (a+b) content in *Salvia splendens* Sellow ex Roem. et Schult. seedlings leaves ($mg \cdot g^{-1}$ fresh weight)

Tabela 5. Wpływ światła użytego w trakcie uprawy oraz długości dnia na zawartość chlorofilu całkowitego (a+b) w liściach rozsady szałwii lśniącej ($mg \cdot g^{-1}$ świeżej masy)

Day length Długość dnia (B)	Type of light – Rodzaj światła (A)				
	daylight dzienne	blue niebieskie	mixed light światło mieszane type A typ A	mixed light światło mieszane type B typ B	mean for (B) średnia dla (B)
16 h	0.926	0.654	0.754	0.921	0.814
20 h	1.922	1.499	1.550	1.474	1.611
Średnia dla (A) Mean for (A)	1.424	1.076	1.152	1.197	
$LSD_{0.05} - NIR_{0,05}$	A = n.s n.i B = 0.188 A/B = n.s n.i				

No effect of the light quality on the colour intensity of the seedlings leaves was observed, except for the effect of the photoperiod on that character (tab. 5). The leaves in scarlet sage grown at the 20-hour long day contained more total chlorophyll a+b than the plants produced in 16-hour day.

DISCUSSION

The possibility of controlling ornamental plants growth without chemical retardants has been attracting interest for many years both among researchers and producers. Many reports points to a potential of ornamental plants stem elongation inhibition by changing the spectral composition of light. Eliminating the far-red wavelength range, and thus increasing the form of the phytochrome P_{FR} to P_R leads to the growth inhibition and plant internodes shortening [Rajapakse et al. 1999, Kim et al. 2002, Cerny et al. 2003], which makes it possible to produce short compact plants, applicable both at the stage of glasshouse production and at the stage of transport. It was observed that the reaction of plants to the growth modification method depends on the type of the light source applied, however, it is mostly species-specific.

The present experiment demonstrated a desirable, from the practical point of view, growth inhibition of scarlet sage seedlings, while maintaining good quality when growing the plants in mixed light: daylight and blue light. Similar results were reported by Wlison and Rajapakse [2001] as well as Krumfolz et al. [2001] growing three species of sage under photoselective film, absorbing light in the range of far red. Depending on the species, the height reduction ranged from 17 to 36%. The disadvantage of this kind of film is a decrease in the transmission of photosynthesis-active light even by 25% [Runkle and Heins 2002, Bachman and McMahon 2006]. Such films can only be used in summer months when the sunlight intensity is very high.

The opposite reaction than the one recorded in the present experiment was reported by Heo et al. [2002a, 2002b]. The sage seedlings grown as exposed to monochromatic blue light, emitted by diodes as well as mixed light: fluorescent and blue light, was higher than in daylight, which constituted the control, which must have been due to the fact that using diodes is connected with the heat emission which, in turn, stimulates the plant growth.

In the experiment a positive reaction of sage to the extension of the day length from 16 to 20 hours was noted, irrespective of the light type. It refers to an increase in the number of lateral shoots, fresh and dry weight of leaves, which coincides with earlier literature reports stating that the species represents a group of plants of high light requirements.

CONCLUSIONS

1. The blue light prevailing during the production of scarlet sage seedlings, at 16h and 20h day leads to the inhibition of plant growth as compared with the daylight.

2. The expected, from the practical point of view, growth inhibition does not deteriorate the quality of the seedlings.

3. The plants grown at 20-hour day, irrespective on the type of the light applied, are branched-out better and contain more chlorophyll A+B, as compared with the seedling produced at 16-hour day.

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WPŁYW ŚWIATŁA NA KONTROLĘ WZROSTU ROZSADY *Salvia splendens* Sellow ex Roem. et Schult.

Streszczenie. U wielu gatunków roślin ozdobnych barwa światła może w różnym stopniu modyfikować wzrost i kwitnienie. W literaturze można znaleźć informacje dotyczące zahamowania wzrostu siewek, rozsady oraz sadzonek roślin ozdobnych poddanych działaniu światła niebieskiego. W doświadczeniu badano wpływ światła o różnym składzie spektralnym na wzrost rozsady szałwii lśniącej. Uprawę prowadzono w pokoju wzrostowym, przy 16-godzinnym i 20-godzinnym dniu. Zastosowano następujące rodzaje światła: dzienne – zbliżone składem spektralnym do światła naturalnego, niebieskie i mieszane – z jednakowym udziałem światła dziennego i niebieskiego oraz z 75% udziałem światła niebieskiego. Natężenie napromieniowania kwantowego w zakresie PAR było jednakowe dla wszystkich kombinacji doświadczenia i wynosiło 110 $\mu mol \cdot m^{-2} \cdot s^{-1}$. Rozsada szałwii lśniącej uprawiana w świetle mieszanym z przewagą niebieskiego była niższa od roślin uzyskanych w świetle dziennym zarówno przy krótkim (16 h), jak i długim (20 h) dniu.

Słowa kluczowe: skład spektralny światła, wysokość roślin, świeża i sucha masa łodygi i liści

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