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INFLUENCE OF THE LIGHT COLOUR ON THE SEEDLING QUALITY OF FRENCH MARIGOLD AND SCARLET SAGE

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Abstract

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The purpose of the conducted experiment was to assess the influence of the light colour on the seedling quality of French marigold (*Tagetes patula* L.) and Scarlet sage (*Salvia splendens* Buc'hoz ex Etl.) cultivated with no access to natural light. Germination and seedling quality of French marigold and Scarlet sage were significantly dependent on the light colour. The red light stimulated seedling elongation. The plants cultivated under the red light were taller, characterised by longer hypocotyl and epicotyl, and had smaller fresh and dry weights in comparison to other light colours. The blue light had a favourable effect on the plants. The seedlings were rigid and of medium size, and had large leaves. The best quality French marigold and Scarlet sage seedlings were obtained when cultivated under the blue and white light. Promising results were also obtained under the joint treatments of blue and red, and blue and white light.

Key words: germinated, LEDs, light colour, seeds

Introduction

French marigold and Scarlet sage are highly rated as flower bed plants. In a number of species of ornamental plants propagated by seeds the problem while producing seedlings is their etiolation, especially under insufficient illumination. Application of growth retardants is common in order to receive good quality seedlings (Pasian and Bennett, 2001). With current ecological restrictions alternative methods of growth retardation and improving the quality of seedlings are being currently sought. This effect can be obtained by means of treating plants with suitable temperature, mechanical stimuli and by using spectral filters or photoselective films, which make it possible to change the spectral composition of light reaching the plants. An innovative method is cultivating plants in growth chambers with no access to natural light under lamps emitting light of different colour. Dynamic development of growth facilities used to cultivate fruit, vegetables and ornamental plants is observed worldwide, especially in Asian countries (Kozai et al., 2004, 2006; Goto, 2011, 2012). These facilities deprived of natural light access, equipped with shelves and lamps for illuminating plants, with the possibility of adjusting the temperature, day length, light intensity, CO_2 feeding are referred to as "closed system". Closed systems for plant production with artificial light have several potential benefits, such a s higher quality of transplants, shorter production period and smaller use of resources as compared with conventional production. Plant factory is the top pattern of modern protected horticulture. Owing to the fact that plants are placed on shelves, higher space efficiency is achieved and costs of heating are reduced as compared to greenhouse cultivation. Introduction of multilayer cultivation shelves has contributed greatly to increasing productivity. Four to 10-layer shelf system are currently used in commercial plant factories.

There are many environmental factors affecting the growth and development of plants and amongst which light condition is one of the most important variables. Most aspects of plant life are influenced by the quality and quantity of light received. Light is not only an energy source for photosynthesis but also a stimulus that regulates numerous developmental process from seed germination to the flowering (Christie,

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2007). According to Watanabe (2011) LEDs were introduced to plant factories in the 2000s as a more efficient light source LEDs are expected to reduce the electricity costs of lighting and cooling because they have a higher they have a higher efficiency of converting electric power to light power and exert lower cooling loads then conventional light sources. The high capital cost is still an important aspect delaying the uptake of LED technology in horticultural.

The influence of light on plant growth and development has been the subject of numerous scientific studies. In recent years more and more attempts of using several combinations of light colour for plant illumination have been conducted. These attempts involve a simultaneous use of several light sources emitting different light colour. Such attempts have been conducted in *Kalanchoë blossfeldiana* with the use of various combinations of blue, red and white light (Perez et al., 2006). Similar experiments were carried out by Woźny (2011) who combined day light with blue light and Michalczuk and Goszczyńska (2002) who obtained best quality primulas due to the simultaneous use of red and white light.

The purpose of the following study was to determine the influence of light colour on the quality of French marigold and Scarlet sage seedlings cultivated in a growth chamber with no access to natural light.

Materials and Methods

The experiment was performed in the growth chamber at artificial light and under controlled climate conditions. The seeds of French marigold (*Tagetes patula* L.)'Laura' and Scarlet sage (*Salvia splendens* Buc'hoz ex Etl.) 'Czardasz' were sown into multi-pot trays with 54 cells filled with peat substrate. The trays with seeding were placed in the growth room (Three-layer shelf system) on 120 x 50 cm shelves previously inlaid with needle felt. The shelves were equipped with LEDs (Light Emitted Diode) lamps emitting the light of different colour, ranging from white, blue, and green light to combinations of two colours: white and blue (50:50), red and blue (75:25). Spectral characteristics of the used lamps was made by means of spectroradiometer (USB 4000), which is presented in figure 1.

During the whole period of cultivation the temperature in the growth chamber was ± 21°C, and the day length was 12 -h photoperiod. The quantum irradiance was 35 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and was measured by means of Optel phytophotometer FR- 10 (Sonopan, Poland).

The number of emerging seedlings was recorded every two days. At the end of the experiment shoot thickness was measured together with their stiffness rated on a four-point scale, where 1 pertained to shoots which were extremely flabby, 2 to flabby shoots, 3 to stiff ones and 4 to very stiff ones. Other morphological features such as the plant height, the length of the hypocotyl and epicotyl, the length and the width of the leaf blade and the number of leaves were also determined. The index of leaves greenness (SPAD) was determined by means of Yara N-Tester apparatus. This measurement is used to determine the intensity of green colour in leaves and consists in the determination of light absorption coefficient connected with the presence of chlorophyll at a wave length of 650 nm and absorption by the leaf tissue at a wave length of 940 nm (Samborski and Rozbicki, 2004). After taking biometrical measurements terrestrial part of the plant was weighed and then dried in a drier at the temperature of 60°C, and finally weighed again.

The experiment was established in two culture cycles. Results of measurement given as mean from two years of research. A single experimental combination covered 5 replications with 5 plant each. Obtained results were analyzed with the statistical software STATISTICA 9.1. Means of the analysis of variance were grouped with the use of Duncan's test at level of $P < 0.05$.

Results and Discussion

For some species light is an essential factor for proper seed germination, for others, on the other hand it is not necessary, or even has a negative effect on the process. In the conducted experiment the light colour determines significantly the process of sprouting. In both species the highest percentage of seeds germinated under the lamps emitting blue light. The smallest number of seeds germinated under the white light (Tables 1 and 3). As reported by Linding-Cisneros and Zedler (2001) in the case of *Phalaris arundinacea* 80% of seeds germinate under the white and red light, whereas 40% germinate under the light with a high share of red light range when compared to the far red region of the visible spectrum.

The study demonstrated that the light colour is essential in photomorphogenetic processes influencing growth, development and differentiation of plants. The highest but simultaneously of the poorest quality seedlings of French marigold were obtained under the influence of the red light. Similar results were obtained in the case of Scarlet sage (Table 1). According to the available literature red light stimulates stem elongation in petunia 'Ursynia' and also in geranium (Witomska and Ładyżyńska, 2001). Chrysanthemums cultivated for a long period of time under the red light are spindle-shaped, curl and have small leaves. The far red light causes stem excessive elongation due to the increase in the gibberellins content (King, 2006). Also Pérez et al. (2006) obtained highest *Kalanchoë blossfeldiana* plants while cultivating them under the red light.

Table 1
Percentage of seed germination and morphological traits of Scarlet sage as affected by the light colour

Light colour	Percentage of seed germination, %	Plant height, cm	Lenght of epicotyl, mm	Lenght of hypocotyl, mm	Diameter of shoots, mm	Stiffnes of shoot (scale 1-4)	Fresh weight, g	Dry weight, g
White	39	2.9 b*	6.0 ab	13.7 b	2.0 b	3	0.64 b	0.39 b
Green	44	2.3 a	4.5 a	14.7 b	1.0 a	2	0.36 a	0.21 a
Blue	54	3.1 b	5.5 ab	11.5 a	2.0 b	4	1.02 c	0.82 c
Red	46	3.9 c	7.8 b	22.9 c	1.0 a	1	0.31 a	0.16 a
Red+blue	50	3.3 b	6.3 ab	10.2 a	2.0 b	4	0.73 b	0.44 b
White+blue	52	3.1 b	4.9 a	9.8 a	1.0 a	4	0.95 c	0.76 c

*Means followed by the same letter are not significantly different $P < 0.05$.

Table 2
Morphological traits of Scarlet sage leaves as affected by the light colour

Light colour	Number of leaves	Width of leaf blade, cm	Length of leaf blade, cm	Index of leaf greenness, SPAD
White	7.7 b*	3.2 bc	2.1 b	31.0 cd
Green	6.7 a	2.3 a	1.5 a	28.5 b
Blue	8.8 c	3.9 d	2.5 c	30.7 cd
Red	6.5 a	1.9 a	1.4 a	32.5 e
Red+blue	8.4 bc	2.9 b	2.3 bc	32.8 e
White+blue	8.0 bc	3.5 cd	2.4 bc	30.8 cd

*Means followed by the same letter are not significantly different at $P < 0.05$

Table 3
Percentage of seed germination and morphological traits of French marigold as affected by the light colour

Light colour	Percentage of seed germination, %	Plant height, cm	Lenght of epicotyl, mm	Lenght of hypocotyl, mm	Diameter of shoots, mm	Stiffnes of shoot (scale 1-4)	Fresh weight, g	Dry weight, g
White	74	4.3 c*	6.3 ab	27.9 b	2.0 b	4	0.8 e	0.5 e
Green	76	3.5 a	5.9 ab	29.9 d	1.0 a	2	0.4 b	0.2 b
Blue	89	4.5 c	8.4 d	29.6 d	2.0 b	3	0.7 d	0.5 e
Red	83	4.9 d	7.6 d	32.9 e	1.0 a	1	0.3 a	0.1 a
Red+blue	85	4.1 bc	6.1 ab	25.8 a	2.0 b	4	0.8 e	0.5 e
White+blue	87	3,6 a	5.2 a	24.0 a	2.0 b	4	0.7 d	0.4 d

*Means followed by the same letter are not significantly different at $P < 0.05$

In both species the shortest seedlings were obtained under the green light, and in sage also under the joint influence of blue and white colour light (Tables 1 and 3, Figure 1). This means that the results obtained by Shimizu et al. (2006) on blue light having retarding effect on elongation of geranium and chrysanthemum were not confirmed. Results obtained by Woźny (2010, 2011) prove the possibility of regulating flower bed plants growth by means of applying different light colour. In the case of the blue light the author's results were inconclusive. In the production process of African marigold and petunia the blue light had no influence on the plant height. However, in Scarlet sage this light colour retarded significantly plant growth. According to Heo et al. (2002, 2011) providing supplementary lighting of the blue colour stimulates the stem growth of flos flower, Scarlet sage and African marigold. Higher *Hibiscus Sabdariffa* plants were obtained by Yerima et al. (2012) under the blue and red light. This suggests that Hirai et al. (2006) might be right in concluding that the light colour influences the plant growth in different ways depending on the species.

Light plays an important role in the morphogenesis process. Light deficiency may result in etiolation and abnormal leaf development (Kopcewicz and Lewak, 1998). Illuminating plants with the red or far red light results in the settling of the photostationary state of the phytochrome φ ($\varphi=P_{FR}/P_{TOTAL}$). In etiolated seedlings hypocotyl elongation is dependent on the phytochrome φ content. Its low content results in intensive plant growth (Casal and Sanchez, 1992).

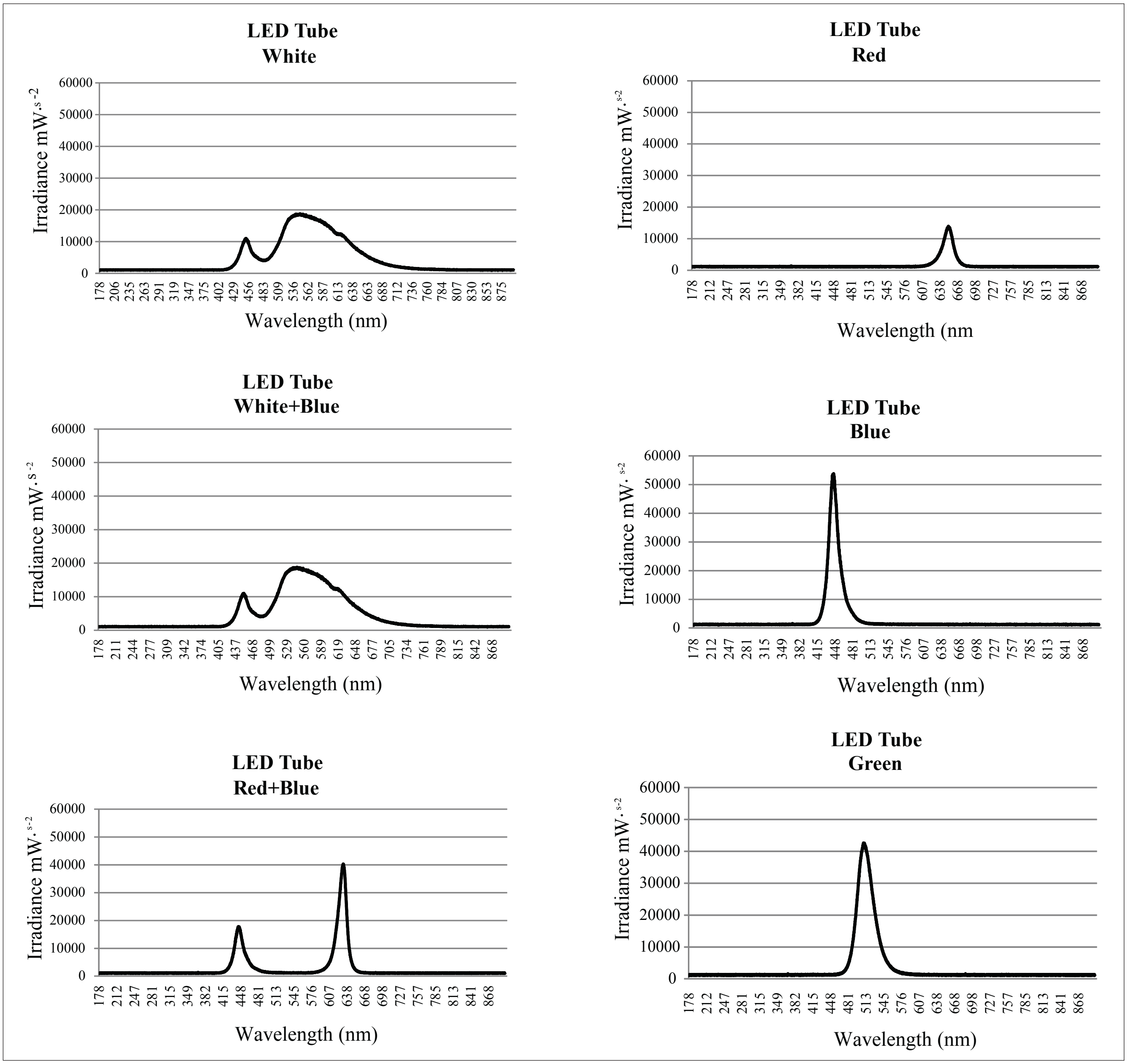

Fig. 1. Spectral characteristic of the LEDs lamps

A good quality seedling should have a short hypocotyl. Proper stem circumference and its rigidity are also important. Marigold seedlings characterized by stiff stems and greater circumference were obtained under the combination of two light colours: red and blue, and also white and blue. The white light brought similar results. In sage short and thick hypocotyl was obtained under the blue, blue and red, white and blue light Table 2, 4). According to Tsegay et al. (2005) both red and far red light result in hypocotyl growth retardation of birch seedlings, however, a joint use of both colours has a stronger effect.

In the conducted study the largest numbers of leaves were produced by marigold seedlings cultivated under the white light. The green and red colour light had a retarding effect on the process. Similar tendency one could observe in sage, in which the smallest numbers of leaves were produced under the illumination with the green and red light (Tables 2 and 4). This is confirmed by the studies conducted by Miler and Zalewska (2006). They obtained a smaller number of leaves in chrysanthemum propagated *in vitro* under the red light colour.

The size of leaves in French marigold and Scarlet sage differed due to the light colour used. Marigold seedlings cultivated under the white light and sage seedlings cultivated under the blue light produced the largest leaf blades. The red light in both species had a negative effect (Tables 2 and 4). According to Miler and Zalewska (2006) red, yellow and blue light leads to production of shorter leaves in chrysanthemum propagated *in vitro*.

In the conducted experiment both fresh and dry matter of the terrestrial part of the plant differed depending on the light colour used. In French marigold the biggest weight was obtained with the use of the white, blue or the joint use of the blue and red light, whereas in Scarlet sage with the use of the blue light or a combination of the blue and white light. The least favourable effect was obtained under the red light (Tables 1 and 3). Favourable effect of the blue light onto this feature in English lavender was reported by Bielenin and Joustra (2000). In the experiment conducted by Heo et al. (2002) on the other hand, Scarlet sage cultivated under fluorescent lamps with addition of the blue light emitted by diodes (LED), under fluorescent lamps with addition of the red light (LED), and under fluorescent lamps with addition of the far red light (LED) was characterized by higher dry weight. As reported by Heo et al. (2011) African marigold and Scarlet sage seedlings had larger dry matter due to the supplementary lighting with the blue and red colour light in comparison to seedlings growing under natural light.

The quality of plants is determined not only by plant habit but also by leaf greenness. The values of the index of leaves greenness (SPAD) were significantly dependent on the light colour used and on the species as well. In the case of French marigold darker leaves with a higher value of the index of leaves greenness were obtained in plants cultivated under the blue and red light, the lightest, on the other hand, were obtained under the red light. In the case of Scarlet sage, however, the positive effect on leaf greenness was obtained by means of the red light and the joint use of the blue and red light. In both species the green light had an unfavourable effect on the leaf greenness (Tables 2 and 4).

Conclusion

Seed germination and seedling quality of French marigold and Scarlet sage was dependent on the light colour. Red light colour stimulated seedling elongation. The plants under the treatment were higher, had a longer hypocotyl and epicotyl and smaller fresh and dry matter in comparison to other light colours. Blue light had a favourable effect on plant quality. Seedlings under the blue light treatment were rigid, of medium size and had large leaves. French marigold and Scarlet sage seedlings cultivated under the blue and white light were

Table 4
Morphological traits of French marigold leaves as affected by the light colour

Light colour	Number of leaves	Width of leaf blade, cm	Length of leaf blade, cm	Index of leaf greenness, SPAD
White	7.8 e*	3,7 d	2.8 de	34.8 c
Green	6.1 a	2.1 a	2.6 d	29.8 a
Blue	7.7 de	3.4 d	2.6 d	32.3 b
Red	6.6 a	2.3 ab	1.4 a	28.7 a
Red+blue	7.5 cde	3.6 d	2.5 cd	39.4 d
White+blue	6.9 bc	3.3 d	3.0e	36.4 c

*Means followed by the same letter are not significantly different at $P < 0.05$

characterised by the best quality. Promising results were also obtained with the joint use of the blue and red light, and the blue and white light.

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