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Effect of Red or Blue Supplementary Light on Rooting of Cuttings and Growth of Young Plants of *Juniperus Scopulorum* 'Skyrocket' and *Thuja Occidentalis* 'Smaragd'

Einfluss von rotem oder blauem Zusatzlicht auf die Bewurzelung von Stecklingen und das Wachstum von Jungpflanzen von Juniperus scopulorum 'Skyrocket' und Thuja occidentalis 'Smaragd'

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Summary

Supplementary monochromatic red or blue light (20 µmol $m^{-2}s^{-1}$) did not effect rooting of cuttings taken from *Juniperus scopulorum* 'Skyrocket' and *Thuja occidentalis* 'Smaragd' neither after irradiation of stock plants prior to cutting collection nor after application of monochromatic light to cuttings during rooting. In contrast, red or blue light increased the root to shoot fresh weight ratio of *Juniperus* and *Thuja* and decreased the height and height to width ratio of *Thuja*. The total fresh weight was influenced in neither species.

Zusammenfassung

In dem Versuch wurde gezeigt, dass die Zusatzbelichtung der Mutterpflanzen von *Juniperus scopulorum* 'Skyrocket' und *Thuja occidentalis* 'Smaragd' mit monochromatischem roten oder blauen Licht (20 µmol $m^{-2}s^{-1}$) während der letzten 4 Wochen vor der Abnahme der Stecklinge keinen Einfluss auf die Bewurzelung gehabt hat.

Die Belichtung der Stecklinge während der Bewurzelungsperiode hat auch die Bewurzelung nicht verbessert.

Dagegen hat die Zusatzbelichtung der jungen Pflanzen einen deutlichen Einfluss auf das Wachstum und den Habitus dieser Gattungen gehabt. Die Pflanzen, die mit rotem oder blauem Licht belichtet waren, hatten ein größeres Verhältnis des Frischgewichts der Wurzeln zu den Sprossen bei *Juniperus* und *Thuja* und eine verminderte Höhe und ein vermindertes Verhältnis von Höhe zu Breite bei *Thuja.* Die Belichtung hatte keinen Einfluss auf die Zunahme des Frischgewichtes bei den geprüften Gattungen.

Introduction

Traditionally, the production of conifers both for ornamental and forestry use involves a propagation period followed by a couple of years of cultivation in the nursery. The long time spans required to obtain saleable plants result in considerable high production costs. Therefore methods that can speed up either the rooting of cuttings or the further growth of plants are necessary.

It is well known that the status of the stock plant as well as environmental conditions during rooting i.e. temperature, light, humidity, rooting media etc. are crucial for the successful rooting of cuttings (MOE and ANDERSEN 1988). However, little research has been carried out on the effect of light quality on root formation (BIDDLE 1993). Red light was shown to induce root formation in cultures of *Ficus benjamina* (GABRYSZEWSKA and RUDNICKI 1997) and *Prunus* rootstocks (ROSSI et al. 1993) when applied in combination with exogenous auxin. On the other hand there are data suggesting that a treatment of the mother plants with blue light produces cuttings which root easier (BIDDLE 1993).

A greenhouse cultivation with the opportunity to control climate conditions can shorten the time needed to produce saleable plants. Unfortunately, although it was proven that the growth of conifers in a greenhouse is hastened, an apparent decrease in plant quality was often observed (MARGOLIS et al. 1991). This may include excessive shoot elongation, poor branching or reduced root growth. It is well documented that the light spectrum (especially red/far red ratio and blue light) influences the morphology of plants (MOE 1997). High red/far red ratio resulted in lower, more compact plants of *Campanula isophylla* and *Campanula carpatica* compared to plants grown under light with low red/far red ratio (KRISTIANSEN 1988; MOE et al. 1991). The same effect was observed with *Dendranthema* × *grandiflorum* (McMahon et al. 1991) and *Lycopersicon esculentum* (MORTENSEN and STRØMME 1987). Far red light can also inhibit branching as shown by MOE et al. (1991) with *Campanula isophylla* which corresponds to the results obtained by TUCKER (1975) with tomato. Blue light reduced height and dry matter content but stimulated branching in *Chrysanthemum* × *morifolium* and *Lycopersicon esculentum* (MORTENSEN and STRØMME 1987). In contrast, length of both main and secondary shoots of *Rosa* 'Mercedes' was increased by reducing the amount of blue light (MAAS and BAKX 1997). Data on effects of light quality on growth of conifers are scarce but they suggest similar reactions. DOWS and PIRINGER (1958) found that *Pinus taeda* and *Pinus ponderosa* irradiated with supplementary fluorescent light (high red/far red ratio) produced shorter stems and needles than plants receiving incandescent light (low red/far red ratio).

Since the photosynthesis depends mainly on total photon flux density in the range of 400–700 nm, the light spectrum affects mostly plant morphogenesis (MORTENSEN and STRØMME 1987). As photomorphogenetic reactions are mediated through relatively low light intensity, modifications of light quality seem to be a promising way of controlling plant growth. Development of new, more efficient sources of monochromatic light like LED diods or fluorescent tubes as well as new filters make the alteration of the light spectrum more practical for commercial use.

The aim of the project was to examine the effects of supplementary lighting with red or blue monochromatic light on rooting of cuttings and growth of young *Juniperus scopulorum* 'Skyrocket' and *Thuja occidentalis* 'Smaragd' plants.

Material and methods

The project consisted of 3 experiments. Two commercially important ornamental conifers: *Juniperus scopulorum* 'Skyrocket' (which is quite difficult to root) and *Thuja occidentalis* 'Smaragd' (a relatively easy to root cultivar) were used for all experiments. Each experiment was repeated during two consecutive years.

Experiment 1. Irradiation of stock plants

Four-year-old plants grown in 3-litre containers were placed in a greenhouse compartment on Nov. 10th and given supplementary lighting with red, blue or white fluorescent tubes (TLD 36W/15, TLD 36W/95 and TLD 36W/18, respectively, Philips, Holland). The supplementary lights were adjusted to give 20 µmol $m^{-2}s^{-1}$ PPFD at plant level. The lamps were automatically switched on in the morning and turned off 30 min. after sunset. The plants were irradiated for 28 days prior to the collection of cuttings. 96 cuttings in four replicates were taken for each treatment, treated with 0,3 % IBA in talk and inserted under polytunnels with bottom heat (20 °C) and mist (2s mist every 1 hour) in coarse perlite. After 10 weeks rooting was assessed by checking the percentage of rooted cuttings, the average number of roots per rooted cutting and the average quality of the root system. The quality of roots was evaluated according to the following scale: 0 – no roots, 1 – first root tips visible, 2 – poor roots, 3 – many short roots or few longer ones, 4 – strong root system.

Experiment 2. Irradiation of cuttings

In this experiment cuttings taken from stock plants grown outdoors were given supplementary lighting during the entire rooting period. The cuttings were collected in mid-February, treated with 0.3 % IBA powder and inserted in rooting medium consisting of 50 % sphagnum peat and 50 % coarse perlite (v/v). Soil temperature was kept at 20 °C and high air humidity was ensured by low polytunnels. The same light treatments were applied as in the first experiment i.e. red, blue, or white supplementary lighting at 20 µmol $m^{-2}s^{-1}$. Each treatment consisted of 4 replicates with 24 cuttings in each replicate. Rooting was assessed after 10 weeks and the same parameters were evaluated as in experiment I.

Tab.1 Rooting of cuttings taken from mother plants irradiated with red, blue or white supplementary light (mean values of 2 years).
Stecklingsbewurzelung nach Zusatzbeleuchtung der Mutterpflanzen mit rotem, blauem oder weißem Licht (Mittelwerte von 2 Jahren).

Parameter	*Juniperus s.* 'Skyrocket'			*Thuja o.* 'Smaragd'		
	Red	Blue	White	Red	Blue	White
Percentage of rooted cuttings	47.3 a	41.1 a	46.0 a	99.0 a	100 a	100 a
Number of roots per rooted cutting	2.6 a	2.6 a	3.2 a	7.4 a	9.1 a	8.2 a
Quality of the root system	2.8 a	2.9 a	3.2 a	3.6 a	3.7 a	3.7 a

Data marked with the same letter, within the species, do not differ significantly according to Duncan test at P = 0.05.

Experiment 3 Growth of young plants

Rooted cuttings planted into standard 9 × 9 × 10 cm square pots were placed in the greenhouse under natural light conditions on May 5th. Plant height and fresh weight were noted before potting. The potting mixture consisted of 50 % sphagnum peat and 50 % composted pine bark (v/v). Each plant was fertilized with Osmocote Plus 3–4 M (Scotts b.v., Holland) at 3.0 g/dm^3. The required water was applied manually. After 14 days of acclimation to greenhouse conditions supplementary lighting with monochromatic lights was started. Again there were three treatments with red, blue or cool white fluorescent light at an intensity of 20 µmol $m^{-2}s^{-1}$ given in addition to natural light and switched off 30 min. after sunset. After 27 weeks the plants were measured, weighed and dry matter contents of shoots and roots were determined after drying in 75 °C to the constant weight. There were 4 replicates with 20 plants each.

All data were statistically analysed using analysis of variance and Duncan's Multiple Range test at p = 0.05.

Results

Experiment 1.

Irradiation of mother plants prior to the taking of cuttings had no effect on the subsequent root formation on cuttings of *Juniperus* and *Thuja*. Neither the percentage of rooted cuttings nor the number of roots per rooted cutting or the quality of the root system were influenced (Tab.1). The results were consistent in both years.

Experiment 2.

Cuttings of *Juniperus* and *Thuja* kept under supplementary red or blue monochromatic light rooted similarly to those given only white light. Again all rooting characteristics i.e. the rooting percentage, the number of roots per rooted cutting, and the quality of the root system were the same under all three light treatments (Tab. 2) in both years.

Tab. 2 Rooting of cuttings receiving supplementary red, blue or white light during the rooting period (mean values of 2 years).
Stecklingsbewurzelung nach Zusatzbeleuchtung mit rotem, blauem oder weißem Licht während der Bewurzelungsphase (Mittelwerte von 2 Jahren).

Parameter	*Juniperus s.* 'Skyrocket'			*Thuja o.* 'Smaragd'		
	Red	Blue	White	Red	Blue	White
Percentage of rooted cuttings	41.4 a	39.3 a	36.8 a	93.4 a	92.4 a	93.0 a
Number of roots per rooted cutting	2.9 a	2.8 a	2.2 a	7.9 a	8.0 a	8.3 a
Quality of the root system	2.5 a	2.7 a	2.7 a	3.2 a	3.1 a	3.0 a

Data marked with the same letter, within the species, do not differ significantly according to Duncan test at P = 0.05.

Experiment 3.

In contrast to the lack of effect on rooting, supplementary lighting with monochromatic light, both red and blue, influenced significantly the growth of *Juniperus* and *Thuja*.

Juniperus scopulorum 'Skyrocket': Monochromatic lights had no effect on the height and fresh weight of plants of *Juniperus scopulorum* 'Skyrocket'. Neither was the height to width ratio of plants changed (Tab.3), nor the ratio of fresh weight of shoots to plant height. However, the ratio of fresh weight of roots to fresh weight of shoots was altered significantly. Red or blue light stimulated the root growth compared to white light resulting in a higher root/shoot ratio. Additionally, monochromatic light lowered the dry matter content in roots but not in shoots.

Thuja occidentalis 'Smaragd': The application of red or blue light suppressed the height growth of *Thuja* (Tab. 3). However, the growth of side shoots was not altered and as a result height to width ratio was reduced. Furthermore, the ratio of fresh weight to height of the shoots was higher in these treatments. The ratio of fresh weight of roots to fresh weight of shoots was increased under red light. Similarly to *Juniperus*, the total fresh weight of plants was not influenced by the light spectrum. Also dry matter contents of shoots and roots were the same in all light treatments.

Tab. 3 Growth of young plants grown under red, blue or white supplementary light (mean values of 2 years).
Wachstum der Jungpflanzen mit zusätzlichem roten, blauen oder weißen Licht (Mittelwert von 2 Jahren).

Parameter	*Juniperus s.* 'Skyrocket'			*Thuja o.* 'Smaragd'		
	Red	Blue	White	Red	Blue	White
Increase in height (mm)	83a	87a	89a	69a	68a	74b
Height/width ratio	5.67a	5.40a	5.53a	1.91a	1.91a	2.11b
Increase in total fresh weight (%)	92.1a	80.9a	75.5a	164.3a	148.1a	156.8a
Ratio of fresh weight/height of shoots (mg/mm)	36.2a	28.8a	30.2a	117.2b	111.8b	98.0a
Ratio of fresh weight of roots/ fresh weight of shoots	0.236b	0.214b	0.177a	0.366b	0.323a	0.304a
Dry matter content of shoots (%)	45.2a	45.8 a	44.0 a	39.6a	39.5a	40.5a
Dry matter content of roots (%)	29.4a	31.0a	35.9b	20.7a	20.9a	20.8a

Data marked with the same letter, within the species, do not differ significantly according to Duncan test at P = 0.05.

Discussion

Little literature exists on the effects of monochromatic light on rooting of cuttings but the research carried out on in vitro plants showed a stimulation of the rooting process through red light at least in some plants (GABARKIEWICZ et al. 1997, GABRYSZEWSKA and RUDNICKI 1997). The presented results are therefore in contrast with these data which might be for three reasons. First of all, in most experiments the basal parts of the cuttings were exposed to monochromatic light during the rooting period. This was not the case in this experiment, as it seems impractical for commercial use. Instead, the bases of the cuttings were exposed to red or blue light by irradiation of stock plants prior to collection of cuttings. As this treatment also proved to be unsuccessful it is suggested that the light spectrum may possibly change only processes directly involved in root formation which in *Juniperus* and *Thuja* take place after cutting preparation. Second, although the intensity of monochromatic light was similar in the cited experiments, due to high natural light intensity in this research, modifications of the spectrum were quite limited. Again it would be difficult to obtain more apparent changes in light quality in commercial propagation facilities. Finally, the reactions to monochromatic light may be also species dependent. In conclusion it can be supposed that even if some influence of the light quality on rooting might be observed after modification of the experimental conditions the technical and economical limitation will prevent growers from taking advantage of this technique in near future.

The influence of the light spectrum on the growth of plants was quite profound in the presented experiment and this agrees generally with the results obtained previously with other plants (MOE 1997). However, the reactions of the plants tested differed considerably between the two species. While for *Juniperus* only the balance between root and shoot growth was changed, for *Thuja* an evident dwarfing (or anti-elongational) effect of blue or red light was noticed. The latter agrees with numerous findings on herbaceous plants (MOE et al. 1991; MCMAHON et al. 1991) and may be attributed to the high R/FR ratio or high B/R ratio. In contrast with results in *Dendranthema* and *Lycopersicon* (OYAERT et al. 1998; MORTENSEN and STRØMME 1987) no reduction in dry matter content of shoots was observed in

our experiment. While DOWS and PIRINGER (1958) reported reduced growth of shoots of Pinus they did not notice any changes in root growth. In the presented experiment increased root to shoot weight ratios were found under red (*Thuja* and *Juniperus*) or blue (*Juniperus*) light treatments which suggests that changes in mass partitioning took place within the plants. The findings show that altering the light spectrum can help to obtain high quality plants in the greenhouse. In addition, the relatively better development of roots should enable these plants to better survive the transfer shock from the greenhouse to outdoor conditions.

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