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Morphology, development, and transplant potential of *Prunus avium* and *Cornus sanguinea* seedlings growing under different LED lights

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Abstract: The objective of the present study was to investigate the impact of light-emitting diodes (LEDs) on the morphological and developmental characteristics of wild cherry (*Prunus avium*) and common dogwood (*Cornus sanguinea*). The LEDs used were L20AP67 (moderate blue, red and far-red, high green), AP673L (moderate blue, high red), G2 (low blue, high red and far-red), AP67 (moderate blue, red and far-red), and NS1 (high blue and green, low red, high red:far-red, 1% ultraviolet). Fluorescent light [FL (high blue and green, low red)] tubes served as the control treatment. The growth rate and subsequently the shoot height of *Cornus sanguinea* were greater under FL. Root length of *Prunus avium* was longer under NS1. *Prunus avium* produced more biomass under NS1 and AP67, while *Cornus sanguinea* was favored under G2 and AP67. Greater root:shoot ratio was found under NS1 for *Prunus avium* and under NS1, AP67, G2, and AP673L for *Cornus sanguinea*. Root growth capacity (RGC) was also assessed in order to evaluate the transplanting response. RGC of *Prunus avium* and *Cornus sanguinea* was favored after precultivation under G2 and AP67, and under NS1 and AP67, respectively. Our study demonstrated that LEDs were more efficient in promoting a number of morphological characteristics than conventional FL in *Prunus avium* and *Cornus sanguinea*.

Key words: Nursery, LED, photomorphogenesis, wild cherry, common dogwood, transplanting

1. Introduction

Restoration and reforestation attempts in the Mediterranean area include the use of seedlings to increase genetic diversity within species. That, along with the increased number of regenerated species, sufficiently favors the sustainability of ecosystems with high biodiversity levels (Ciccarese et al., 2012). Planting many woody species for aesthetical and ornamental purposes in urban areas requires high amounts and high quality of planting stock material. Consequently, it is highly important to improve nurseries' seedling cultivation practices in order to produce high-quality stock seedlings with high survival and growth rates after outplanting (Grossnickle, 2005; Navarro et al., 2006; Wilson and Jacobs, 2006). Wild cherry (*Prunus avium* L.) is a deciduous tree used extensively in Europe for the afforestation of agricultural land (Petrokas, 2010). It is important as an ornamental plant and its fruit has medicinal uses. The species is highly valued for its timber, as it is cultivated for wood production in natural forests and in plantations (Zimmermann, 1988; Schalk, 1990). The common dogwood (*Cornus sanguinea* L.) is a deciduous shrub, native to most of Europe and western Asia. Its fruits and leaves contain medicinally active substances (Stanković and Topuzović, 2012), and its straight woody shoots have many uses. Both *Prunus avium* and *Cornus sanguinea* contribute to wildlife nutrition.

The use of artificial lighting in plant production is constantly growing, since it enables increased photoperiods, triggering of desirable plant traits, intensification of production, and cultivation in places where natural light is depleted. The most common lamp types used in plant cultivation are fluorescent light (FL), high-pressure sodium, incandescent, and metal halide. Light-emitting diode (LED) technology is constantly growing and employed in greenhouses, nurseries, and growth chambers. Compared to the rest of the lamp types, LEDs have longer lives, minimal heat emission (allowing the plants to be placed close to the lamp fixtures), and the option of spectral setting. In addition, their high energy conversion efficiency leads to lower utilization cost

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(Schuerger et al., 1997; Massa et al., 2008; Morrow, 2008). However, their capital cost is still higher than most other lamp types.

Certain wavebands are received differently by each plant species, leading to variations in physiological responses and morphological and developmental processes. The red:far-red ratio affects stem and petiole length, leaf thickness and chlorophyll content, and apical dominance in many species (Franklin and Whitelam, 2005). The combination of red and blue light has been shown to have a crucial effect on seedling morphology (Mohr, 1986). Numerous studies have shown that blue light is essential for phototropism, photomorphogenesis, chlorophyll formation, and stomatal opening (Dougher and Bugbee, 1998). However, the effects of blue light on every species are diverse.

The effect of LEDs on a great deal of horticultural [lettuce (Shen et al., 2014), cucumber (Hernández and Kubota, 2016), basil (Bantis et al., 2016)] and ornamental [*Phalaenopsis* (Ouzounis et al., 2014)] plants has already been studied. However, only a few studies have been conducted using forest tree species as test material (Astolfi et al., 2012; Riikonen, 2016; Smirnakou et al., 2016).

The research hypothesis of the present study was that LEDs enhance the growth and development of *Prunus avium* and *Cornus sanguinea* seedlings compared to conventional FL tubes. It was also hypothesized that the transplant success of the tested species would be better after precultivation under some LEDs. Therefore, the objectives of the present study were: 1) the examination of the effects of LED and FL (control) lights on the morphological and developmental characteristics of *Prunus avium* and *Cornus sanguinea* during precultivation in a controlled environment, 2) the determination of the best light quality treatment for nursery cultivation of the two tested species, 3) the evaluation of the seedlings' transplant capacity, and 4) the investigation of possible species-dependent responses.

2. Materials and methods

2.1. Plant material, growth conditions, and light treatments

Prunus avium L. fruits were collected from Vermio Mountain (32°58′80″N, 45°06′042″E), Edessa provenance, Greece, in August 2011. The fruits were depulped and the seeds were stored at 3–5 °C until pretreatment for dormancy break. In order to break dormancy, seeds were hydrated for 24 h and placed in a growth chamber with controlled conditions for warm stratification (20 °C, 8/16 h day/night, 70% RH) for 4 weeks. This was followed by 8 weeks of cold stratification at 3–5 °C (Iakovoglou and Radoglou, 2015). Fruits of *Cornus sanguinea* were collected from Kydonies (43°04′56″N, 45°29′236″E) in the province of Thessaloniki, Greece, in July 2012. Similarly to *Prunus avium*, the fruits were depulped and the seeds were stored at 3–5 °C until dormancy break pretreatment. For breaking dormancy, the seeds were hydrated for 24 h and cold stratified for a period of 9 months at 3–5 °C. In order to achieve maximum uniformity, only pregerminated seeds were used for the experiments. Immediately after germination, the pregerminated seeds were placed in plastic miniplug container trays (QP D 104 VW QuickPot, Herkuplast-Kubern, Germany) with identical dimensions (310 × 530 mm, density: 630 seedlings/m^2; 27 mL). For pine species, the miniplug trays have been proven to perform as well as the conventional containers (280 mm × 360 mm) used for the production of planting stock in Greek nurseries, leading to the production of high-quality seedlings (Radoglou et al., 2011). The miniplug trays were filled with a stabilizing peat (Preforma PP01, Jiffy Products, Norway) containing a binding agent that facilitates the transplanting process.

The experiments were conducted from February to April 2014. In total, 60 seedlings per species and treatment were used. The miniplug trays with pregerminated seeds of *Prunus avium* and *Cornus sanguinea* were placed in growth chambers for 42 days (6 weeks) and 28 days (4 weeks), respectively, under six different light treatments (Table 1). *Prunus avium* was supposed to stay for 28 days in the growth chambers, but after that time the seedlings did not exhibit sufficient growth in order to be transplanted. The LED lights used in the experiment [provided by Valoya (Valoya Oy, Helsinki, Finland)] generate a wide continuous spectrum comprising ultraviolet (UV, <400 nm), blue (B, 400–500 nm), green (G, 500–600 nm), red (R, 600–700 nm), and far-red (FR, 700–800 nm) wavelengths. The LED lights used were L20AP67 (moderate B, R, and FR; high G), AP673L (moderate B, high R), G2 (low B, high R and FR), AP67 (moderate B, R, and FR), and NS1 (high B and G, low R, high R:FR, 1% UV). White fluorescent lamps (FL, Osram, Fluora, Munich, Germany) were used as the control treatment. Inside the growth chambers, environmental conditions were maintained at 14 h photoperiod, day/night temperature of 20 °C/15 °C, and air relative humidity of 80 ± 10%. Photosynthetic photon flux density (PPFD) was constant (about 200 ± 20 µmol m^{-2} s^{-1} for all treatments at plant height). The seedlings were irrigated daily with automated water sprinklers and the miniplug trays were rotated regularly in order to ensure uniform growth conditions.

2.2. Measurements

During the experimental period in the growth chambers, height growth rate measurements were applied. For this purpose, the shoot height of *Prunus avium* was measured on a weekly basis, with the first measurement taking place 7 days after germination, while *Cornus sanguinea*

Table 1. Spectral distribution and red:far-red (R:FR) ratio for six light treatments (FL serves as the control treatment).

Light treatments	UV <400 nm	Blue 400–500 nm	Green 500–600 nm	Red 600–700 nm	Far-red 700–800 nm	R:FR
FL	0%	35%	24%	37%	4%	5.74
L20AP67	0%	10.5%	26.2%	48.9%	14.4%	2.91
AP673L	0%	12%	19%	61%	8%	5.56
G2	0%	8%	2%	65%	25%	2.51
AP67	0%	14%	16%	53%	17%	2.77
NS1	1%	20%	39%	35%	5%	8.16

shoot height was measured every 2 weeks, with the first measurement taking place 14 days after germination. At the end of the experimental period in the growth chambers, 10 randomly selected seedlings per species and light treatment were sampled. The morphological characteristics measured were leaf number, shoot height, root length, leaf area, and leaf, shoot, and root dry weights (DWL, DWS, and DWR). In addition, root:shoot dry weight ratio (R/S) was determined. Leaf area meter LI-3000C (LI-COR Biosciences, Lincoln, NE, USA) was used on fresh leaves for the estimation of leaf area (cm^2) on every sample.

After the growth chamber cultivation, eight randomly selected seedlings per species and light treatment were transferred to another growth room. The seedlings were moved into stainless steel containers with a 1:1 mixture of peat and sand and then placed on the surface of a water tank in order to evaluate root growth capacity (RGC) (Mattsson, 1986). The water tank is essential for the maintenance of a constant temperature (20 ± 1 °C) for the root system. Inside the growth room, environmental conditions were maintained at a 14 h photoperiod, temperature of 20 °C, and air relative humidity of 60 ± 10%. PPFD was constant (about 300 ± 20 μmol m^{-2} s^{-1} for all treatments at plant height), while irrigation was applied every 2 days. After 31 days of cultivation, seedlings were harvested and new root length and new root dry weight were measured. The dry weights of every sample were estimated after holding them in a drying oven for 3 days at 80 °C. The shoot height, root length, and length of new roots were measured with a Powerfix digital caliper (Milomex, Pulloxhill, UK).

2.3. Statistical analysis

SPSS 15.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Repeated measures were used for the analysis of growth rate data. At the end of the growth chamber cultivation of both species, data were analyzed by analysis of variance (ANOVA), while mean comparisons were conducted using a Bonferroni test at $P < 0.05$.

3. Results

3.1. Growth rate

Prunus avium seedlings did not exhibit significant growth rate differences on days 14 and 42 after germination. However, on day 28, AP67 promoted greater height increase than FL (Table 2). Regarding the growth rate of *Cornus sanguinea* seedlings, day 7 revealed no significant differences. On day 14, height increase in G2 was greater than in L20AP67. On day 21, FL, L20AP67, and G2 exhibited higher values than AP673L and NS1. After 28 days of cultivation, L20AP67 showed significantly higher growth rates compared to AP673L, G2, and NS1 (Table 2).

3.2. Leaf color, leaf number, shoot height, root length, root:shoot ratio, and leaf area

Visual examination revealed that seedlings of both species exhibited differences regarding leaf color. *Prunus avium* seedlings grown under FL and L20AP67 formed dark green leaves, while the rest of the LEDs induced the formation of light green leaves. Quite similarly for *Cornus sanguinea*, FL and L20AP67 led to the formation of dark green seedlings, while the seedlings cultivated under all the other LEDs appeared reddish. *Prunus avium* seedlings formed between 5 and 7 leaves, and *Cornus sanguinea* seedlings formed 5–6 leaves, showing no significant differences among the light treatments (data not shown). Shoot height of *Prunus avium* was not affected by the different spectra (Table 3). *Cornus sanguinea* seedlings grown under FL demonstrated significantly taller shoots than G2, AP67, and NS1 (Table 3). On the contrary, *Prunus avium* had the longest roots under NS1 (Table 3), while *Cornus sanguinea* seedlings did not show any significant differences among the light treatments (Table 3). R/S ratios in *Prunus avium* seedlings were significantly higher under NS1 than under L20AP67 (Table 3). *Cornus sanguinea* seedlings grown under FL and L20AP67 had significantly lower values than the rest of the LEDs (Table 3). Leaf area was not significantly affected by any light treatment for either species (Table 3).

Table 2. Height growth rate of *Prunus avium* and *Cornus sanguinea* seedlings grown for 6 weeks and 4 weeks, respectively, under six different light treatments (FL serves as the control treatment) with the same abbreviations as in Table 1. Average values (n = 10, ±SE) followed by different letters within a row differ significantly (=0.05).

Species	Time (days)	Light treatments					
		FL	L20AP67	AP673L	G2	AP67	NS1
Prunus avium height growth rate (cm)	14	3.29 ± 0.51a	3.42 ± 0.47a	2.94 ± 0.32a	3.62 ± 0.33a	3.46 ± 0.43a	3.39 ± 0.24a
	28	4.16 ± 0.63b	4.65 ± 0.60ab	4.29 ± 0.35ab	5.37 ± 0.53ab	5.42 ± 0.48a	4.99 ± 0.30ab
	42	4.53 ± 0.61a	5.27 ± 0.64a	4.65 ± 0.27a	5.67 ± 0.54a	5.67 ± 0.43a	5.34 ± 0.29a
Cornus sanguinea height growth rate (cm)	7	2.33 ± 0.55a	2.30 ± 0.39a	1.96 ± 0.38a	2.01 ± 0.24a	1.87 ± 0.20a	1.89 ± 0.30a
	14	3.00 ± 0.60ab	2.71 ± 0.58b	2.74 ± 0.61ab	2.90 ± 0.40a	2.55 ± 0.38ab	2.48 ± 0.57ab
	21	3.82 ± 0.61a	3.64 ± 0.69a	3.21 ± 0.80b	3.73 ± 0.47a	3.26 ± 0.36ab	2.95 ± 0.62b
	28	4.51 ± 0.65ab	4.37 ± 0.68a	3.51 ± 0.97c	4.15 ± 0.58bc	3.77 ± 0.43abc	3.38 ± 0.56bc

Table 3. Morphological and developmental parameters of *Prunus avium* and *Cornus sanguinea* seedlings grown under six different light treatments (FL serves as the control treatment) with the same abbreviations as in Table 1. Average values (n = 10, ±SE) followed by different letters within a row differ significantly (=0.05).

Species	Parameters	Light treatments					
		FL	L20AP67	AP673L	G2	AP67	NS1
Prunus avium	Shoot height (cm)	5.23 ± 0.57a	6.17 ± 0.59a	5.71 ± 0.35a	6.39 ± 0.52a	6.47 ± 0.39a	6.13 ± 0.24a
	Root length (cm)	4.84 ± 0.66b	6.07 ± 0.51b	7.20 ± 0.43b	6.25 ± 0.71b	6.72 ± 0.67b	12.57 ± 1.50a
	Leaf area (cm^2)	40.31 ± 9.79a	69.62 ± 6.07a	51.47 ± 5.02a	55.89 ± 5.05a	57.93 ± 5.86a	49.38 ± 7.07a
	Root:shoot ratio	0.26 ± 0.03ab	0.22 ± 0.03b	0.33 ± 0.04ab	0.30 ± 0.03ab	0.35 ± 0.05ab	0.42 ± 0.04a
Cornus sanguinea	Shoot height (cm)	6.60 ± 0.27a	6.05 ± 0.25ab	5.32 ± 0.44abc	5.22 ± 0.27bc	4.57 ± 0.16c	4.53 ± 0.18c
	Root length (cm)	5.13 ± 0.39a	5.00 ± 0.39a	5.17 ± 0.37a	5.20 ± 0.20a	6.48 ± 0.62a	6.09 ± 0.48a
	Leaf area (cm^2)	8.84 ± 0.50a	8.06 ± 0.49a	7.00 ± 0.76a	7.63 ± 0.59a	9.21 ± 0.53a	6.77 ± 0.60a
	Root:shoot ratio	0.24 ± 0.02b	0.38 ± 0.03b	0.55 ± 0.04a	0.56 ± 0.02a	0.55 ± 0.05a	0.66 ± 0.03a

3.3. Dry weights

Total dry weight of *Prunus avium* was significantly greater under the influence of AP673L, G2, AP67, and NS1 than under FL and L20AP67. Particularly, DWL followed the same pattern as total dry weight. The shoot and root dry weights were significantly lower under FL compared to AP673L, G2, AP67, and NS1 (Figure 1a).

Total biomass production of *Cornus sanguinea* seedlings was significantly greater under AP673L, G2, AP67, and NS1 than under FL. Specifically, FL induced the formation of significantly less leaf biomass than G2, AP67, and AP673L. Regarding the DWS, FL exhibited significantly lower values than G2, AP67, and AP673L. Finally, G2, AP67, AP673L, and NS1 favored the production of DWR compared with FL and L20AP67 (Figure 1b).

3.4. Root growth capacity

After 31 days of cultivation in the growth chamber where RGC was assessed, *Prunus avium* seedlings formed significantly longer new roots under precultivation with G2 and AP67 than with L20AP67. G2 also induced significantly greater new root dry weight production than L20AP67 and AP673L (Figure 2a).

In the case of *Cornus sanguinea*, the length of new roots was greater after precultivation under NS1 than under FL, L20AP67, AP673L, and G2. Finally, NS1 and AP67 promoted significantly greater new root biomass production than L20AP67 and AP673L (Figure 2b).

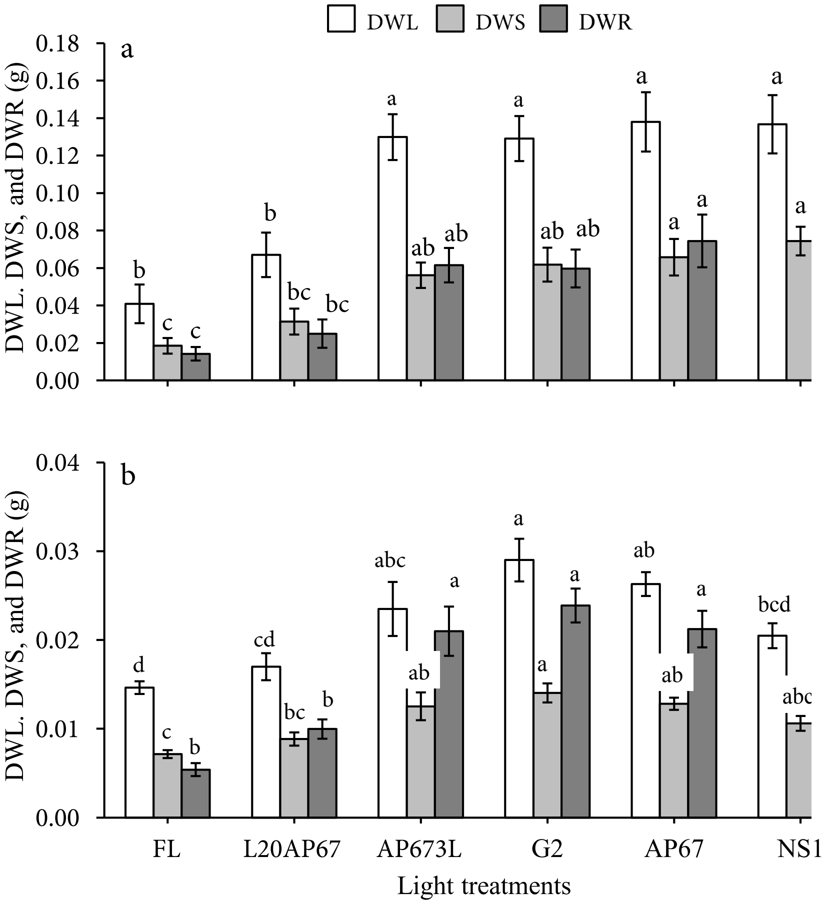

Figure 1. Dry weight of leaves (DWL), shoots (DWS), and roots (DWR) of *Prunus avium* (a) and *Cornus sanguinea* (b) seedlings grown under six different light treatments (FL serves as the control treatment) with the same abbreviations as in Table 1. Data are mean values (n = 10, ±SE). Error bars represent the SE. Bars followed by a different letter within a parameter differ significantly (=0.05).

4. Discussion

Plant morphology can be controlled with changes in the light spectra, especially in the red and blue part of the PAR (Hoenecke et al., 1992). During the experiment, the growth conditions practiced were appropriate for both species, which was confirmed by the ordinary morphology and development of the plants. In our study, the different light conditions variably affected the growth and morphogenesis of the two tested species, *Prunus avium* and *Cornus sanguinea*. In general, the height of *Prunus avium* seedlings was not affected by the different light treatments. However, the *Cornus sanguinea* height was greater under the FL treatment than under NS1 and AP67 (the highest B portion among the LEDs), as shown by the growth rate and shoot height measurements. Blue radiation has been reported to cause inhibition of internode growth in several species (Folta et al., 2003; Dougher and Bugbee, 2004). This is in contrast to previous studies with *Prunus avium*, beech, and holm oak, where taller plants were grown under AP67 light compared with FL (Astolfi et al., 2012).

The root length of *Prunus avium* was not affected by the different radiation spectra, but the roots of *Cornus sanguinea* were longer under the most B-containing LED treatment, NS1 (high B and G, low R, high R:FR, 1% UV). In a study with basil, seedlings of the cultivar Lettuce Leaf formed longer roots under AP673L treatment (Bantis et al., 2016).

The observed color difference is probably the result of varying pigment concentration as a result of exposure to different light spectra. In *Phalaenopsis*, it has been reported that reddish leaves formed under increasing B light (Ouzounis et al., 2014). Leaf coloration is affected by many factors with varying effects (Sims and Gamon, 2002).

For both species, no differences were observed regarding the number of leaves and leaf area under the different radiation spectra. Beech seedlings developed larger leaves under AP67, while holm oak formed greater

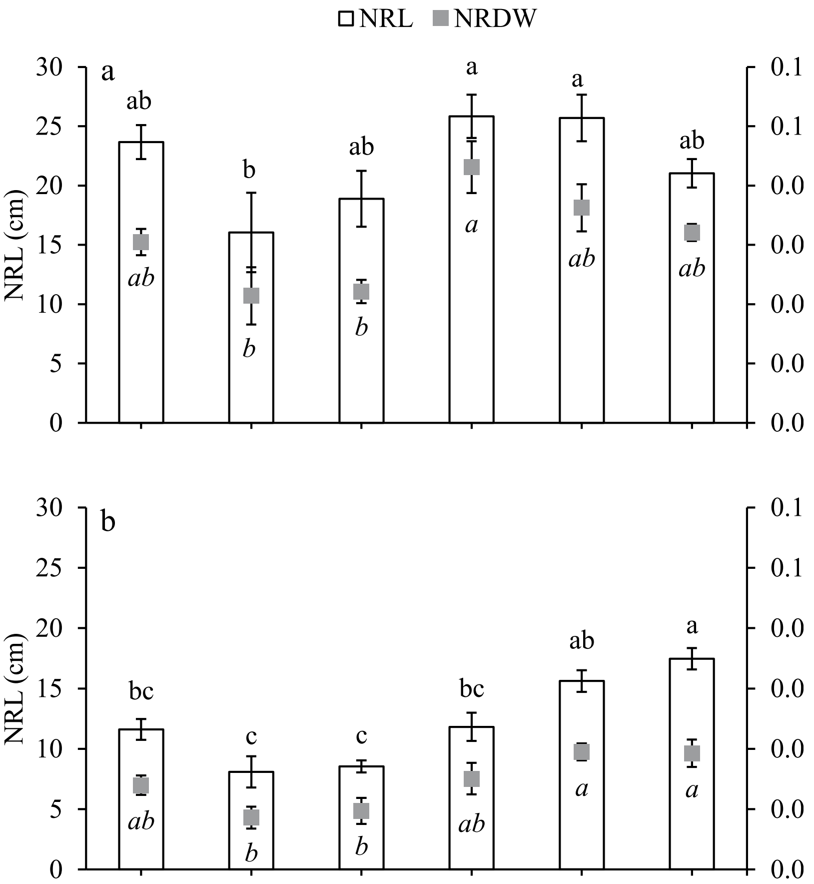

Figure 2. New root length (NRL) and new root dry weight (NRDW) of *Prunus avium* (a) and *Cornus sanguinea* (b) seedlings after 31 days in the RGC water bath after growth under six different light treatments (FL serves as the control treatment) with the same abbreviations as in Table 1. Data are mean values (n = 10, ±SE). Error bars represent the SE. Bars followed by a different letter differ significantly (=0.05).

leaves under the FL treatment (Astolfi et al., 2012). Leaf area of cucumber seedlings was greater under 10% B supplemented to R light (Hernández and Kubota, 2016).

Both species produced more total biomass under the influence of AP673L, G2, AP67, and NS1 (relatively high R portion). Similar results were obtained from two basil cultivars with the same LED treatments having greater total biomass compared to FL light (Bantis et al., 2016). In *Pinus sylvestris*, greater dry weight was also found under similar LED lights compared to FL (Smirnakou et al., 2016). In the case of *Prunus avium*, even though there were no differences in shoot height, leaf area, and leaf number among the treatments, the overground part of the seedlings was heavier under AP67 and NS1 (the highest B portion among the LEDs). Red light acting via the phytochrome photoreceptor is the main light source that affects biomass formation and stem elongation (Sager and McFarlane, 1997), while B light acting via cryptochromes and phototropins also affects photomorphogenic responses. The aforementioned photoreceptors operate both independently and synergistically (de Carbonnel et al., 2010; Kozuka et al., 2013). In addition, only NS1 induced the longest roots, but root dry weight was greater under both NS1 and AP67. This finding might be the result of greater secondary root development under the aforementioned LEDs. In the case of *Cornus sanguinea*, FL favored the shoot height of the seedlings, but at the same time they exhibited the lowest overground dry mass. As mentioned above, R and B lights affect photomorphogenesis via the phytochrome, cryptochrome, and phototropin photoreceptors. Similar to *Prunus avium* results, although no differences in leaf area, leaf number, and root length were observed among the light treatments, greater biomass was obtained mainly under G2 (the highest R portion) and secondarily under AP67. Regarding the root system of *Cornus sanguinea*, G2, AP67, NS1, and AP673L promoted the formation of more secondary roots, leading to greater root biomass. Quite similarly, a study with beech seedlings revealed a higher DWS under AP67 than FL, whereas cherry and holm oak did not exhibit any significant differences (Astolfi et al., 2012). In a study with lettuce, no differences were observed between the FL and RB LED in the overground biomass, but FL light induced greater root biomass compared to the RB LED (Shen et al., 2014). Finally, two basil cultivars produced more leaf and shoot biomass under G2 and AP67, and more root biomass under NS1, compared to the rest of the lights (Bantis et al., 2016).

Seedlings with vigorous root systems have better chances of survival and active growth after transplanting. The NS1 LED (high B and G, low R, high R:FR, 1% UV) benefited the R/S ratio of *Prunus avium* seedlings, indicating that they partitioned more of their dry weight into the roots under the aforementioned spectrum. Similarly, greater R/S ratio under B-containing LEDs was found in Scots pine and Norway spruce (Riikonen, 2016) and in basil (Bantis et al., 2016). The *Cornus sanguinea* seedlings cultivated under FL and L20AP67 led to decreased R/S values compared to the rest of the LEDs. Previous results from lettuce revealed a lower S/R (greater R/S) ratio in FL cultivation compared to the RB LED (Shen et al., 2014). The R/S ratio results of *Prunus avium* and *Cornus sanguinea*, along with the stem height values, suggest that FL and L20AP67 induce the formation of a compact root system that reduces the plant's ability to absorb sufficient water and nutrients, and thus it might not be able to satisfactorily supply the seedling's overground part.

The production of seedlings with quick root system expansion is crucial for the achievement of high transplantation survival, especially in regions with a tendency for drought stress incidents like the Mediterranean (Radoglou et al., 2003). The seedlings' performance and establishment success after transplantation can be assessed using the RGC index, which displays a seedling's ability to develop its root system by elongating already existing roots and/or forming new roots (Mattsson, 1986, 1996). It has been reported that the parameters that determine the RGC index and the morphological characteristics are species-dependent (Kostopoulou et al., 2010). RGC has also been reported to be a more efficient parameter than root electrolyte leakage for the assessment of seedling vigor and survival in pine (Chiatante et al., 2002). Thirty-one days after transplanting, *Prunus avium* seedlings had formed longer roots after precultivation under G2, AP67, and NS1, but their root biomass was high only after G2 treatment (low B, high R and FR). In a similar study with *Abies borisii-regis*, G2 also induced greater root biomass production (Smirnakou et al., 2016). For *Cornus sanguinea* plants, the case was different. Specifically, seedlings precultivated under NS1 formed the longest roots, but the greatest root biomass was achieved under NS1 and AP67 (the highest B portion among the LEDs). This is in contrast with a previous study with Red Rubin hybrid basil, which had the shortest roots under the NS1 light regime, while new root biomass generally followed the same pattern (Bantis et al., 2016). New root biomass production mainly determines RGC, since it refers to the mass of both primary and secondary roots. The secondary roots are essential for the successful exploitation of the surrounding soil by the seedling. The results show that *Prunus avium* seedlings cultivated under G2, and *Cornus sanguinea* seedlings grown mainly under NS1 and AP67, performed better regarding RGC. The aforementioned light treatments for the respective species may provide the transplanted seedlings with an enhanced ability to rapidly exploit the surrounding soil after transplanting. It should be mentioned, though, that the G2 LED fixture mainly radiates in the R and FR part of the light spectrum, creating unfavorable light conditions for personnel, and thus it can be unsuitable for use in growth chambers.

Overall, some LED lights proved better than conventional FL for several morphological and developmental characteristics of the two tested species. In particular, the G2 (low B, high R and FR) LED promoted better transplanting capacity of *Prunus avium* seedlings, but NS1 (high B and G, low R, high R:FR, 1% UV) favored the developmental parameters before transplanting. In the case of *Cornus sanguinea*, NS1 and AP67 (the highest B portion among the LEDs) performed better regarding RGC, with AP67 (moderate B, R, and FR) also showing high values for the rest of the studied parameters. The observed species' dependency under different light spectra proves that further investigations should be conducted for other ecologically and economically important woody species.

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