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Original Article

Silviculture

Water Management for *Schinus terebinthifolius* Raddi Seedlings in Degradable Containers

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ABSTRACT

The research consisted of two experiments (64 and 85-day production cycles), applying three irrigation depths (8, 11 and 14 mm) to determine the most appropriate depth, using *Ellepot*™ degradable containers for the production of *Schinus terebinthifolius* seedlings; the possibility of shortening the production cycle; and the influence of water management in nursery on the early development of plants in pots. Results indicated that the most appropriate irrigation depth is 14 mm for both the 64 and 85-day production cycles; that it is possible to produce *Schinus terebinthifolius* seedlings with a shortened cycle, given that quality indicators were adequate; and that there was an influence of water management used in the nursery on the development of plants in pots for 64-day seedlings.

Keywords: forest nursery, *Ellepot*™, brazilian pepper tree, irrigation depth, container development.

1. INTRODUCTION

The production of tree seedlings using tubes began in the 1970's, representing an evolution in nurseries worldwide (José et al., 2005). Given that they are petroleum-based products however, which take around 400 years to break down (Flores et al., 2011), they pose an environmental problem (Norashikin & Ibrahim, 2009). One alternative for these tubes is degradable containers (Briassoulis, 2006; Shey et al., 2006).

Given that degradable containers are planted with the seedlings (Narayan, 2001), they present advantageous characteristics such as better and faster development of the seedlings in the field with less stress during planting. One reason for this is that the integrity of the roots, that can perforate the porous walls, is maintained. Another is the reduced time that seedlings remain in the nursery, making earlier planting possible and increasing productive capacity (Iatauro, 2004).

It is necessary to adapt water management to guarantee seedling quality when irrigating seedlings in degradable containers. Water management studies of native Brazilian forest species are scarce (Silva & Silva, 2015) and in conjunction with degradable containers, practically nonexistent. Knowledge of appropriate irrigation parameters for better nutrient use for seedlings, inhibition of disease proliferation, water efficiency and decreased production costs is necessary (Montague & Kjelgren, 2006).

Among the Brazilian native species, *Schinus terebinthifolius* Raddi (Brazilian pepper tree) is recommended for the recuperation of low fertility, shallow, rocky, hydromorphic or saline soils, due to its rusticity, pioneering and aggressiveness. It belongs to the Anacardiaceae family and to the successional group of pioneers (Durigan et al., 1997), and this species can be planted in full sun (Carvalho, 2003) as well as in areas with short or moderate periodic flooding (Rogge et al., 1998).

Thus, the objectives of this study were to identify the most appropriate gross irrigation depth for the development and quality of Brazilian pepper tree seedlings in degradable containers; verify the possibility of shortening the production cycle; and verify if the treatments applied in the nursery phase influence the initial development of the potted plants.

2. MATERIAL AND METHODS

The study was conducted from February to August 2014, in a nursery located at 22° 51' 03" South Latitude and 48° 25' 37" West Longitude; 840 m Altitude; and Cwa type climate, according to Köppen classification.

The research included two experiments, both comparing three gross irrigation depths in the production of Brazilian pepper tree seedlings in degradable containers. The first one with a shorter production cycle, was indicated for the degradable container, because the root system does not need to be fully developed, given that the container is planted with the seedling, thereby providing protection. The second, with a longer production cycle, with a more developed root system, was recommended when working with polyethylene containers.

The experiments were conducted in a completely randomized design with three treatments with gross irrigation depths of 8, 11 and 14 mm, divided twice daily. Each treatment was composed of four plots (trays) consisting of 27 plants, adopting 10 central plants of each plot for evaluation. For development in the pot, 12 seedlings per treatment were considered.

The degradable container used was Ellepot™, 9.5 cm high and 4.5 cm in diameter (151 cm^3). As a holder, flat polyethylene trays were used. The occupation in the tray generated a density of 236 seedlings per m^2.

The substrate used was a commercial product consisting of *Sphagnum* peat, vermiculite and charcoal rice husk at a ratio of 2:1:1 (volume base). The physical characteristics of the substrate were determined according to Guerrini & Trigueiro (2004) and the chemical characteristics according to Brasil (2008) (Table 1).

The base fertilization performed on the substrate was composed of soluble fertilizers Yoorin™ Master 1S and Fosmag™ 500B, and Osmocote™ controlled release with 19:6:10 N-P-K formulation. All these fertilizers provided the macronutrients N, P, K, S, Ca and Mg at dosages of 42.3, 69, 31.3, 25.2, 48.2 and 18 mg/tube, respectively; and the micronutrients B, Cu, Mn, Si and Zn at the dosages of 0.3, 0.1, 0.6, 18.4 and 1 mg/tube, respectively.

When the seedlings presented a mean of 6.0 cm in height, they were transplanted into the degradable container, remaining in the greenhouse for two weeks, and then placed in suspended mini-tunnels, covered with light-diffusing plastic film to control precipitation. An automatically activated micro-sprinkler irrigation system with a nozzle flow rate of 200 L h^{-1} was used.

During this period, growth fertilization was performed twice a week, with a 4 mm gross depth of nutrient solution applied through fertigation in all treatments. The growth solution was composed of purified monoammonium phosphate, magnesium sulfate, potassium nitrate, calcium nitrate and urea at concentrations of 488, 155.4, 328.1, 312, 72.2 and 98.8 mg L^{-1} of N, P, K, Ca, Mg and S, respectively; and the solution of micronutrients, by boric acid, sodium molybdate and manganese, zinc, copper and iron sulfates at concentrations of 3, 3.9, 1.2, 0.6, 0.3 and 48 mg L^{-1} of B, Mn, Zn, Cu, Mo and Fe, respectively.

Hardening solution, composed of potassium chloride at concentration of 750 mg L^{-1} and boric acid, sodium molybdate and manganese, zinc, copper and iron sulfates at concentrations of 4.2, 5.5, 1.7, 0.8, 0.4 and 67 mg L^{-1} of K, B, Mn, Zn, Cu, Mo and Fe, respectively was applied twice a week during the final 15 days of each cycle.

At the end of each experiment, 12 seedlings were randomly selected from each treatment and planted in pots with a volume of 14 L of soil, obtained from the 0-20 cm deep layer from Fazenda Experimental Lageado (Lageado Experimental Farm), classified as a medium texture dystrophic Red Latosol (Carvalho et al., 1983). The seedlings were randomly assigned to the greenhouse to monitor initial development until 90 days after planting. The soil was chemically analyzed (Table 2) to determine the base fertilization recommended by Gonçalves et al. (2008) for native forest species.

The evaluation of seedling development and quality at the end of the experiments was constituted by shoot height (H), stem diameter (D), shoot dry masses (SDM) and root dry mass (RDM). Total dry mass (TDM), height/diameter ratio (H/D) and Dickson Quality Index (DQI) were calculated.

For the evaluation of the potted seedlings, H, D, SDM, RDM and TDM were obtained.

The data was submitted for normality testing, then to analysis of variance and, in cases where there were significant differences, the Tukey test was performed at 5% probability for comparison of the means.

3. RESULTS AND DISCUSSION

3.1. Experiment with shorter production cycle

At 64 days after transplanting, the seedlings of all treatments had a height and diameter suitable for field planting.

The highest daily gross irrigation depth provided higher average development in height, diameter, height/diameter ratio, shoot dry mass and total dry mass. Root dry mass and Dickson Quality Index (DQI) were not influenced by the irrigation depth. The depths of 8 and 11mm were statistically similar (Table 3).

The seedling H/D ratios showed the influence of the treatments, but all were within the range recommended by Birchler et al. (1998), i.e., less than 10.

On the importance of maintaining the natural architecture of the seedling root, as occurred in this experiment through the use of degradable containers planted with the seedling, which maintains the architecture of the root system, Laclau et al. (2001) reports that a

Table 1. Physical and chemical characteristics of the substrate used.

Physical characteristics	Porosity (%)			Water retention (mL/tube)
	Macro	Micro	Total	
	24.2	59.3	83.4	54.6
Chemical characteristics	Electrical conductivity (dS m^{-1})			pH
	0.5			6.5

Table 2. Chemical analysis of soil used in the development of seedlings in pots.

pH	M.O.	P_{resin}	Al^{3+}	H+Al	K	Ca	Mg	SB	CTC	V%	S
$CaCl_2$	g dm^{-3}	mg dm^{-3}		mmol$_c$ dm^{-3}							mg dm^{-3}
4.0	17	3	11	78	0.4	3	2	6	84	7	13

high density of fine roots increases the contact of water with the litter fall, increasing the ability of plants to absorb water and nutrients on the surface, during short rains of the dry seasons. This preoccupation is not new. Grossnickle (2012) cites a work by Toumey (1916), in which seedlings with more and better quality roots present better post-planting survival potential, a result similar to the one found by Davis & Jacobs (2005).

3.2. Experiment with longer production cycle

For the 85-day production cycle, the higher the daily gross irrigation depth, the greater the height, diameter, shoot dry mass and total dry mass of the seedlings (Table 4). There was no influence of the irrigation depth on the root dry mass and Dickson Quality Index.

Morais et al. (2012), producing seedlings of the same species on different irrigation depths, observed that the effective 10 mm depth provided greater gains in height (20.1 cm) and diameter (3.40 mm). Additionally, the shallower depth (8 mm) produced lowest results. Other studies, with other species, but maintaining the same ecological characteristics, indicated that the use of 11 mm daily gross depth provided greater development in height and diameter of *Piptadenia gonoacantha* seedlings (Silva & Silva, 2015). But for *Inga vera*, the best depth was 10 mm (Delgado, 2012).

The H/D ratio obtained in this experiment, from 6.19 to 8.40 indicates seedling quality, whenever considering the criterion of José et al. (2005) and Morais et al. (2012); although this ratio presents averages that vary greatly according to the species studied.

The highest root dry mass values were found at depths lower then 10 mm in the studies of Morais et al. (2012) and Delgado (2012), and an 11 mm depth for Silva & Silva (2015), producing seedlings of *Schinus terebinthifolius*, *Inga vera* and *Piptadenia gonoacantha*, respectively.

As DQI defines the quality of the seedlings through the morphological variables representing their survival and development capacities in the field (Fonseca et al., 2002), those variables should be as high as possible to attest to the quality. However, there is no specific value for each species or group of species. Moreover, it is inferred that this index may vary depending on the species, on management the seedlings in the nursery, on the type and proportion of the substrate, on the volume of the container and also on the age at which the seedlings were evaluated (Trazzi et al., 2012); although in this study, the different DQI do not disqualify the species.

Variations in water volume applied for each species may seem small, but imply high consumption when considering the entire cycle and scale of production. According to Wendling & Dutra (2010), it is essential to define the frequency and volume of water to be applied, regarding the type of substrate, the container and the species, as well as the stages of seedling formation.

Table 3. Effect of daily gross depths on morphological variables of 64-day seedlings after transplantation.

Irrigation Depth (mm)	H (cm)	D (mm)	H/D	SDM (g)	RDM (g)	TDM (g)	DQI
8	26.3 b	4.01 b	6.55 b	2.73 b	1.45 a	4.18 b	0.53 a
11	25.5 b	4.03 b	6.35 b	2.78 b	1.39 a	4.17 b	0.51 a
14	33.4 a	4.46 a	7.53 a	3.57 a	1.54 a	5.10 a	0.53 a

Table 4. Effect of daily gross depths on morphological variables of 85-day seedling after transplantation.

Irrigation Depth (mm)	H (cm)	D (mm)	H/D	SDM (g)	RDM (g)	TDM (g)	DQI
8	29.4 c	4.45 c	6.63 b	2.75 c	1.69 a	4.43 c	0.66 a
11	34.1 b	4.94 b	6.89 b	3.97 b	1.83 a	5.81 b	0.67 a
14	45.0 a	5.39 a	8.40 a	5.14 a	2.08 a	7.22 a	0.67 a

Mean values followed by equal lowercase letters within the same variable do not differ statistically by Tukey test ($p < 0.05$). H - height; D - stem diameter; SDM - shoot dry mass; RDM - root dry mass; TDM - total dry mass; DQI - Dickson quality index.

3.3. Development of the seedlings in pots for the shorter production cycle

The height of the seedlings 30-days after planting was greater in those where a daily irrigation depth of 14 mm was applied. This finding was similar to that for seedlings at the end of the cycle in the nursery. However, at 90 days, this effect was no longer present, because the seedlings produced in the greater depth did not differ statistically from the shallower depth (Table 5).

For the diameter, the same phenomenon was observed in the seedlings 30 days post-planting in the nursery, that is, seedlings irrigated at a depth of 14 mm showed greater development. At 90 days, the 11 mm depth seedlings were equal to those of the 14 mm depth.

The dry masses (shoot, root and total) of the seedlings, similar at 30 days, differed between the irrigation depths applied at 90 days post-planting, being greater in the seedlings produced with an irrigation depth of 14 mm, repeating the statistical results for the seedlings at the end of the cycle in the nursery.

In general, the development of potted seedlings still reflects the quality of seedlings in the nursery. According to Takoutsing et al. (2014), the search for improvements and good practices used in forest nurseries will determine the quality of the seedlings produced, and thus, the success or failure of the plantations.

According to Davis & Jacobs (2005), the development of seedlings in the field depends directly on the morphophysiological qualities of the seedlings dispatched, thus associated with favorable growth and survival under adverse environmental conditions.

3.4. Development of the seedlings in pots for the longer production cycle

In the case of long-cycle seedlings, no influence from the water management system applied in the nursery was observed at 30 days post-planting, except on the height, which presented greater development with the 14-mm depth (Table 6).

The seedlings produced over 85 days showed a greater increase in height and diameter on the 90th day after planting, when compared to 64 days, with the average increase in height being 140% and 49%, respectively for seedlings in the longer and shorter cycles. Regarding the stem diameter, the average increase was 116% (85-day seedlings) and 55% (64-day seedlings). Considering that potting occurred under the same climatic conditions, and that water was not limited for the seedlings of the different cycles, the better performance by 85-day seedlings may be related to a greater photosynthetic area, and consequently, a greater root weight.

The quality of the seedlings guides their establishment by improving the physiological and morphological performance as soon as they are planted in the field (Grossnickle & El-Kassaby, 2016), adapting to the planting site conditions. According to Grossnickle (2005), one of the main successes of establishing seedlings in field is the ability of seedlings to rapidly develop new roots, which will absorb nutrients, especially water, from the soil.

The use of a degradable container did not affect the development of Brazilian pepper tree seedlings, and the same situation was reported by Khan et al. (2000) and Kuehny et al. (2011), who found no impediment of the wall during the root growth in different degradable containers and species, mainly because of the porous materials.

Table 5. Development of *Schinus terebinthifolius* seedlings in pot, produced in 64-day cycle.

Irrigation Depth (mm)	Initial	30 days	90 days	Initial	30 days	90 days	Initial	30 days	90 days
	Height (cm)			Diameter (mm)			Shoot dry mass (g)		
8	27.8 b	31.5 b	42.1 ab	3.77 ab	4.68 b	5.20 b	1.78 a	2.31 a	3.65 b
11	24.5 b	31.0 b	35.1 b	3.72 b	4.88 b	6.00 ab	4.28 a	6.27 a	6.97 b
14	33.2 a	38.4 a	50.8 a	4.31 a	5.56 a	7.17 a	3.84 a	4.90 a	18.67 a
Irrigation Depth (mm)	Root dry mass (g)			Total dry mass (g)					
8	0.95 a	1.07 a	1.52 b	0.95 a	3.39 a	7.17 b			
11	1.46 a	2.21 a	2.52 b	5.75 a	8.48 a	9.49 b			
14	1.68 a	2.13 a	8.12 a	5.52 a	7.03 a	26.78 a			

Mean values followed by lower case letters on the same line within the same variable do not differ statistically by Tukey test (p <0.05).

Table 6. Development of *Schinus terebinthifolius* seedlings in pot, produced in an 85-day cycle.

Irrigation Depth (mm)	Initial	30 days	90 days	Initial	30 days	90 days	Initial	30 days	90 days
	Height (cm)			Diameter (mm)			Shoot dry mass (g)		
8	31.5 b	37.9 b	88.1 a	4.42 b	5.85 a	10.19 a	3.57 a	4.46 a	54.60 a
11	34.0 b	40.8 b	80.3 a	4.78 ab	6.26 a	10.21 a	4.47 a	6.28 a	60.66 a
14	44.5 a	48.2 a	90.6 a	5.17 a	6.42 a	10.54 a	5.88 a	7.51 a	51.95 a
Irrigation Depth (mm)	Root dry mass (g)			Total dry mass (g)					
8	2.22 a	4.47 a	13.00 a	5.79 a	8.93 a	67.61 a			
11	2.18 a	7.14 a	12.78 a	6.56 a	13.42 a	73.44 a			
14	2.09 a	5.64 a	16.76 a	8.06 a	13.15 a	68.71 a			

4. CONCLUSIONS

The most suitable irrigation depth for the degradable container was 14 mm daily in both the 64 and 85-day cycle seedlings.

It is possible to produce Brazilian pepper tree seedlings with a shorter cycle, since the quality indicators were adequate.

Water management influenced the shorter cycle seedlings, applied during the nursery phase in the development of the potted plants. However, in longer cycle seedlings, the height was the only variable that was influenced.

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