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Improving Air-Filled Porosity in Woody Propagation at the Hammond Research Station

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Summary

Extreme heat during summer propagation of woody species often necessitates frequent mist applications to maintain proper leaf turgor. This frequent mist can result in excess moisture in propagation substrates, which tend to have low air space due to small container sizes and fine substrate particles. This study evaluated the use of substrate stratification, Growcoons, and wood fiber inclusion to increase air-filled porosity in propagation substrates and improve success and quality of rooted cuttings. Several woody species were selected to test each method and were rooted over the summer of 2023. Substrate stratification with 100% perlite did not yield significant benefit to rooting success or plug quality in most species, while Growcoons and wood fiber inclusion increased rooting success with little to no effect on root and plug quality.

INTRODUCTION

Achieving proper moisture content and aeration of rooting substrate is important for successful propagation of woody plants. The substrate must be lightweight with a sufficient water holding capacity, while also providing appropriate aeration to reduce fungal growth and gnats, and improve oxygen supply to the developing roots. The small container volumes and generally finer particles used for propagation, however, result in increased water holding capacity at the expense of air-filled porosity (Yafuso et al., 2019 and Milks et al., 1989). Common propagation substrates include varying proportions of peat, sand, perlite, vermiculite, and pine bark, typically targeting 25-40% air space (Dirr and Heuser, 2006).

Many woody species can be propagated in 100% perlite or pine bark, provided moisture levels are adequately maintained in the rooting substrate as well as on the leaf surface. When propagating woody species through the summer, maintaining proper moisture tends to be difficult in warm climates such as the U.S. Gulf South. In these climates, misting schedules that maintain sufficient leaf moisture can often result in excess substrate moisture, reducing propagation success. Increasing the air-filled porosity in the rooting substrate maintains adequate gas exchange under high mist schedules needed to prevent leaf drop.

There are various options available for propagators to increase air-filled porosity or airspace (AS). Commercial products exist, which can be lined in a propagation tray to maintain a boundary layer of air between the substrate and plastic cell, improving air flow. One such product, Growcoons, are a netted, cup-like seed and plug holder made of biodegradable material and designed to be transplanted with the plug (https://growcoon.com/en). These hold the plug roots together during transport and transplanting.

Substrate stratification is an emerging practice that involves the layering of substrate components of differing textures and physical properties on top of one another to achieve desired water and air holding properties. The practice is gaining momentum in container production where finer-textured, higher water-holding capacity substrates are layered on top of coarse, higher AS substrates. This improves aeration and oxygenation of the lower portion of the container (Criscione, et al., 2021; Fields and Criscione, 2023) providing plants access to the full container volume without saturated conditions. A similar phenomenon of substrate saturation in lower portions of the rooting cell trays often occurs, indicating potential benefit of stratification.

Wood fiber has also been gaining momentum as a substrate component. Previous research has shown that wood components and commercially available wood-fiber substrate products can significantly increase the AS of the substrate when blended (Jackson, 2018; Dickson et al., 2022; and Harris et al., 2020). Nitrogen immobilization concerns are less significant in propagation as nutrient demand of rooting plants is lower than those in larger containers, and the production time is often much shorter. Therefore, wood fibers lend themselves particularly useful to propagation systems.

Thus, the objective of this experiment was to evaluate the use of stratifying substrates, Growcoons, and wood fiber inclusion to alleviate excessive moisture in peat-based rooting substrate on rooting success and plug quality of several propagated woody shrub species.

MATERIALS AND METHODS

This experiment took place at the Louisiana State University Agricultural Center Hammond Research Station in Hammond, Louisiana. All four substrate treatments (**Table 1**) utilized 72-cell, star-shaped, deep propagation trays ((PL-72-STAR-DP-VH, T.O. Plastics, Clearwater, MN).

Table 1. Substrate treatments used in propagation study.

Treatment	Description
Standard Mix	2:1:1 bark fines: peat: perlite (non-stratified, loose-fill)
Stratified	Top layer – standard mix; bottom layer – 100% perlite
Growcoon	Filled with standard mix
Wood fiber blend	1:1 bark fines: southern yellow pine wood fiber

The standard (loose-fill, non-stratified) propagation substrate consisted of a 2:1:1 mix of pine bark fines (Phillips Bark Processing Co., Brookhaven, MS): peat (XL Commercial Peat Moss, Lambert Peat Moss, QC, Canada): perlite (Horticultural Grade, PVP Industries, Bloomfield, OH). Growcoons (Klasmann-Deilmann GmbH, Geeste, Germany) were placed in the propagation tray and filled with the standard propagation substrate. The stratified treatment consisted of filling the lower half of the cells of the propagation tray with 100% moistened perlite and the upper half of the cells with the standard propagation substrate (**Fig. 1**).

Figure 1. Stratified propagation trays contained 100% perlite in the bottom half and the standard mix in the top half.

The wood fiber treatment consisted of blending pine bark fines and an extruded southern yellow pine wood fiber at a 1:1 ratio. After filling, all individual cells were thoroughly moistened to drainage before sticking cuttings. Additionally, each substrate was evaluated for AS, container capacity (CC), and solid portion using a modified NCSU Porometer method (**Fig. 2**; Fonteno, Hardin, and Brewster, 1995).

Figure 2. Modified NCSU porometer method using individual 1-inch cells for determining air space, container capacity, and bulk density.

Propagation trays were filled with the substrate treatments and thoroughly moistened. Seven cells of each substrate treatment were individually cut from the trays and manually submerged in water to the level of substrate fill until the surface of the substrate glistened. A finger was placed over the drainage hole in the bottom of the cell and the cell was transferred to a funnel installed over a graduated cylinder and allowed to drain completely.

Precautions were used to ensure the cell remained vertical and was not squeezed. The volume of drainage was divided by the cell volume to calculate the AS of the substrate in the propagation cell. Cells were then weighed and the substrate dried in an oven at 105°C for 24 h for calculation of CC and solid portions. Container capacity, the total water holding capacity of a substrate in a given container, was calculated as the difference between the substrate's oven-dry weight and drained weight divided by the volume of the cell; solid portion was calculated as the volume remaining after AS and CC were subtracted from 100%.

Semi-hardwood stem cuttings of several woody shrub species were collected between May and July 2023 in the morning and stuck before noon the same day in four different rooting substrates, (**Tables 2, 3, and 4**).

Table 2. Species tested with substrate stratification

Species, cultivar	Date Stuck	Hormone used	Total Weeks
Callicarpa americana	6/8/2023	None	10.7
Callistemon 'Woodlander's Hardy'	6/20/2023	Hormodin 2, 3000ppm	9
Camellia 'Reverend Ida'	6/8/2023	Hormodin 2, 3000ppm	17.7
Ilex crenata	7/25/2023	Hormodin 2, 3000ppm	10.8
Ilex glabra	7/25/2023	Hormodin 3, 8000ppm	10.8
Ilex cornuta	7/26/2023	Hormodin 2, 3000ppm	10.8
Itea virginica 'Henry's Garnet'	7/24/2023	Hormodin 2, 3000ppm	11

Table 3. Species tested with Growcoons and Standard mix (2:1:1 Bark Fines: peat: perlite)

Species, cultivar	Date Stuck	Hormone used	Total Weeks
Callistemon 'Woodlander's Hardy'	6/20/2023	Hormodin 2, 3000ppm	9
Camellia 'Reverend Ida'	6/8/2023	Hormodin 2, 3000ppm	17.7
Itea virginica 'Henry's Garnet'	5/4/2023	Hormodin 2, 3000ppm	15.6
Rhododendron indicum 'Brilliant'	6/8/2023	Hormodin 2, 3000ppm	15.6

Table 4. Species tested with wood fiber blended 1:1 with bark fines.

Species, cultivar	Date Stuck	Hormone used	Total Weeks
Callistemon 'Woodlander's Hardy'	6/20/2023	Hormodin 2, 3000ppm	9
Rhododendron indicum 'Fisher Pink'	6/20/2023	Hormodin 2, 3000ppm	12

Cutting material was taken from the new flush of growth as it began losing flexibility. Stem cuttings were approximately six cm long (**Fig. 3**). The lower half of the stems were stripped of their leaves, wounded, and dipped in a talc-based rooting hormone (Hormodin 2 & 3, OHP, Mainland, PA). Cuttings were then placed in an enclosed plastic-lined tent (**Fig. 4**) under intermittent mist at 4 s every 10 min. At four weeks, mist was adjusted to 6 s every 15 min; at 7 weeks, one side of the plastic sheeting was opened to allow air flow and the mist schedule was adjusted to 6 s every 20 min.

Figure 3. *Callistemon* 'Woodlander's Hardy' cuttings with lower leaves stripped.

Figure 4. Enclosed mist tent.

Cuttings were evaluated on one of two dates (21 August 2023 or 9 October 2023) depending on root establishment. A cutting was determined "rooted" when it could be gently pulled from its cell with 75% of the rooting substrate remaining intact.

The total number of rooted cuttings were counted for each species and treatment combination. Five random cuttings were taken from rooted cuttings, washed of all rooting substrate and/or Growcoons, and rated 1-5 on root quality (**Table 5**) and plug quality (**Table 6**).

Table 5. Root quality rating principles.

Rating Number: Root Quality	**Description**
1	Brown to black in color, or dried or slimy
2	Brown to tan in color, break easily
3	Tan to beige in color, healthy turgor
4	Beige to white in color, healthy turgor
5	White in color, healthy turgor and easily withstands washing

Plug quality was based on the visual appearance of the stems and foliage. For the standard, stratified, and wood blend treatments, roots were then individually teased apart and the average of the two longest roots measured. Root tissue was collected from stratified cuttings and placed in an oven at 70° C for 48 h and weighed.

All data were analyzed in JMP Pro 17 (SAS Institute, Cary, NC). Analysis of Variance (ANOVA) and means separation using Tukey's honestly significant difference (α=0.05) were used to evaluate substrate blend effect on air space. Within each substrate treatment and each species, root quality, plug quality, average root length, and root dry weight (N=5) were compared between the treatment substrate and the standard mix using a 1:1 t-test at α=0.05.

Table 6. Plug quality rating principles for the stems and foliage.

Rating Number: Plug Quality	Description
1	Dead and dried out
2	Stems alive and green, no visible foliage, roots low quality
3	Has some foliage, but foliage has signs of drying or disease; roots not filled out
4	Healthy foliage and root system
5	Significant and healthy foliage and root system

RESULTS AND DISCUSSION

Substrate Physical Properties. The mean AS (N = 7) for each experimental substrate was significantly different. The standard propagation mix had an AS of 18%, which corresponds to the lower end of the recommended range (18-40%; Dirr and Heuser, 2006). Stratification and wood fiber incorporation raised AS to 25% and 29%, respectively. The Growcoons increased AS the most, reaching 42%, just exceeding the recommended aforementioned range (**Fig. 5a**).

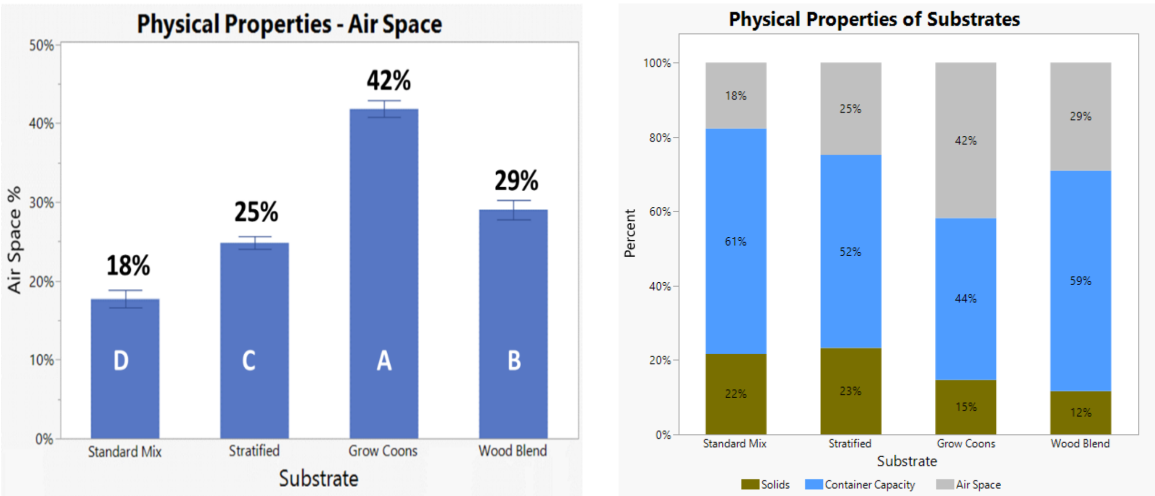

Figure 5a. Air-filled porosity in each substrate measured in 72-cell (1-inch) containers using a modified NCSU Porometer technique. **5b.** Air-filled porosity, container capacity, and solid portion in each substrate measured in 72-cell (1-inch) containers using a modified NCSU Porometer technique.

While each of these treatments increased the AS of the propagation substrate, it should be noted that the location of this added AS differs for each treatment – in the lower half of the cell for the stratified treatment, around the outer circumference of the cell for the Growcoon, and throughout the cell for the wood fiber blend. Container capacity followed a similar trend as AS; the standard propagation mix had the highest CC (61%). Stratification and addition of wood fiber reduced CC to 52% and 59% respectively, and the Growcoons had the lowest CC at 44%. The standard mix and stratified substrates had the highest proportion of solids, and Growcoons and wood blend had the lowest (**Fig. 5b**).

It should be noted that climactic extremes occurred at the Hammond Research Station during the summer of 2023 due to the heat dome that affected much of the U.S. midwestern and Gulf South states, resulting in higher temperatures and lower humidity than normal for our region.

Stratification Experiment. Rooting success in stratified substrate was 5-61% lower than in standard non-stratified substrate (**Table 7**), with the exception of *Ilex crenata*. Stratified substrate was associated with decreases in root quality, average root length, and root dry mass as well (**Table 7**) in the majority of species propagated. Roots in stratified substrates were less dense and showed more brown discoloration than the non-stratified counterparts (**Fig. 6**). Plug quality rarely differed between substrate treatments. It was also noticed that in *Camellia* and *Ilex cornuta*, little root exploration occurred in the bottom perlite layer (**Figs. 6C and 6D**). Regardless of root exploration, the lower portions of the plugs often disintegrated during the data collection process, an undesirable quality during transplanting. It is possible that excessive air space and insufficient water holding capacity were present in the lower half of the cells to provide a buffer against the especially hot and dry climate conditions experienced in 2023. Testing this method in subsequent years or stratification with a material having less drastic differences in water holding capacity and AS is needed.

Growcoon Experiment. Rooting success was similar in *Callistemon* and higher by 6% in all other species tested with Growcoons compared to loose-fill standard mix (Table 8). Root quality was reduced in all species with the Growcoons, but only statistically significant in *Rhododendron* and *Itea virginica*. Plug quality was statistically and visually similar between the Growcoon and loose fill standard mix in all species except *I. virginica*, where plugs had defoliated (**Fig. 7**). It was noted that the Growcoon treatments rooted faster and more densely than their standard mix counterparts, and it is believed that this higher root mass and further root development caused the plugs to have higher irrigation requirements, especially during the 2023 heat wave. Both treatments were irrigated similarly, and the Growcoon treatments were likely more susceptible to the effects of the 2023 heat wave, leading to increased root browning due to possible drying. Use of Growcoons should take this faster and denser root development into account in irrigation practices and production time.

Table 7. Rooting success, root quality, plug quality, average root length, and root dry mass of several woody species in standard (non-stratified) and stratified substrate.

Rooting Success	Non-Stratified	Stratified
Callicarpa americana	83%	67%
Callistemon 'Woodlander's Hardy'	61%	56%
Camellia 'Reverend Ida'	83%	22%
Ilex cornuta	83%	22%
Ilex crenata	50%	56%
Ilex glabra	50%	28%
Itea virginica 'Henry's Garnet'	44%	17%
Root Quality	Non-Stratified	Stratified
Callicarpa americana	4.2	3.0
Callistemon 'Woodlander's Hardy'	4.6	3.0*
Camellia 'Reverend Ida'	5.0	2.8*
Ilex cornuta	5.0	3.3*
Ilex crenata	4.4	5.0
Ilex glabra	3.2	2.8
Itea virginica 'Henry's Garnet'	3.0	3.0
Plug Quality	Non-Stratified	Stratified
Callicarpa americana	2.6	3.2
Callistemon 'Woodlander's Hardy'	4.8	4.8
Camellia 'Reverend Ida'	5.0	4.8
Ilex cornuta	5.0	5.0
Ilex crenata	5.0	4.6
Ilex glabra	5.0	5.0
Itea virginica 'Henry's Garnet'	3.6	2.0*
Average Root Length (cm)	Non-Stratified	Stratified
Callicarpa americana	7.45	8.45
Callistemon 'Woodlander's Hardy'	5.10	4.55
Camellia 'Reverend Ida'	5.20	3.31*
Ilex cornuta	5.00	1.88*
Ilex crenata	4.75	4.05
Ilex glabra	6.35	6.00
Itea virginica 'Henry's Garnet'	3.55	2.42
Root Dry Mass (g)	Non-Stratified	Stratified
Callicarpa americana	0.062	0.070
Callistemon 'Woodlander's Hardy'	0.036	0.010*
Camellia 'Reverend Ida'	0.070	0.043
Ilex cornuta	0.070	0.020*
Ilex crenata	0.032	0.026
Ilex glabra	0.034	0.028
Itea virginica 'Henry's Garnet'	0.014	0.013

Quality, root length, and mass data represent least-square means of five replicates. Means were compared using a 1:1 t-test at $\alpha = 0.05$, with significantly different means denoted with an asterisk (*).

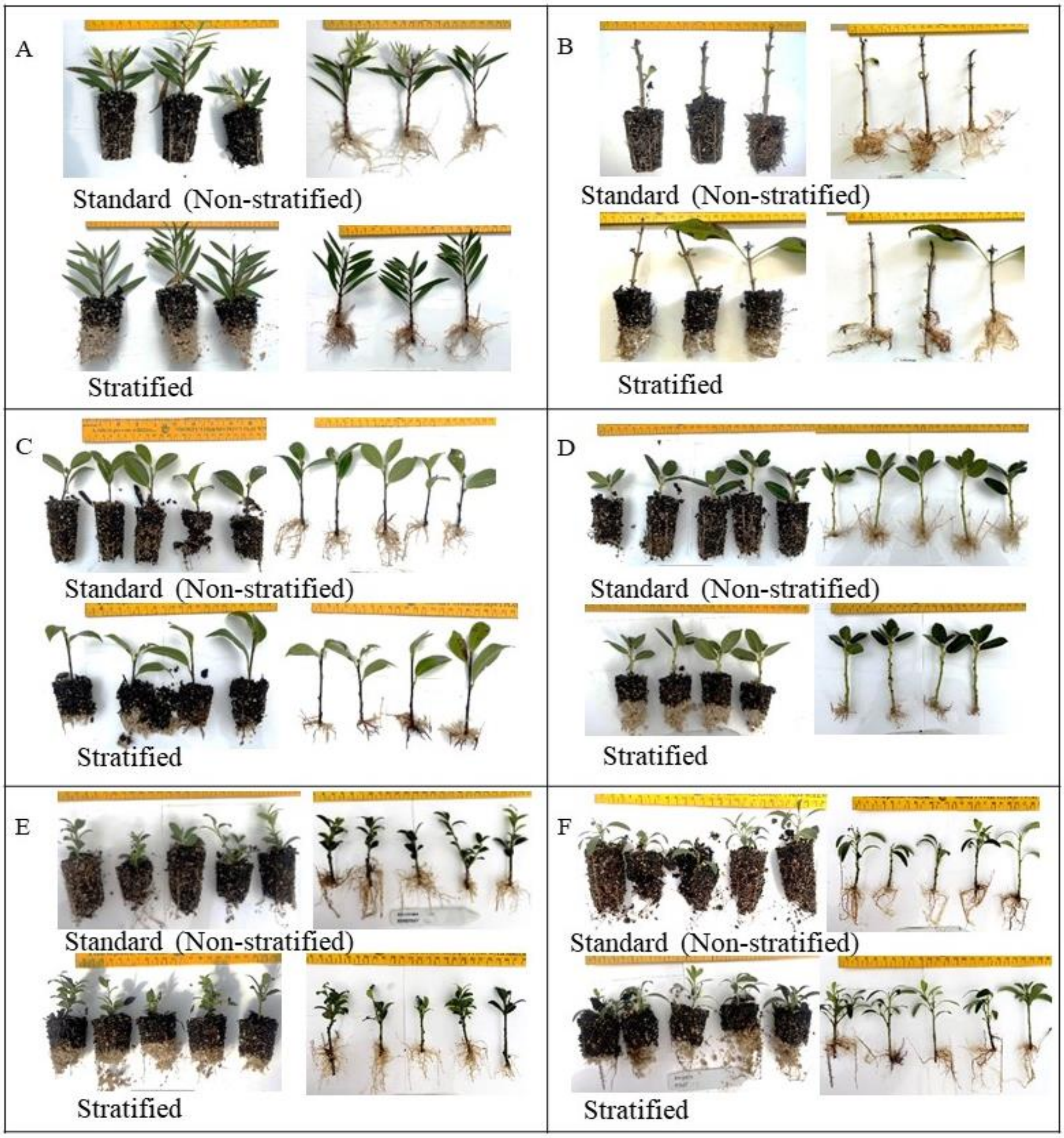

Figure 6. Plugs (left) and rooted cuttings washed of substrate (right) grown in standard (non-stratified) (top) and stratified (bottom) substrate in A) *Callicarpa americana*, B) *Callistemon* 'Woodlander's Hardy,' C) *Camellia* 'Reverend Ida,' D) *Ilex cornuta*, E) *Ilex crenata*, and F) *Ilex glabra*.

Wood Fiber Experiment. *Rhododendron indicum* cuttings died during the 2023 heat wave and this data was not included in this study. In *Callistemon*, rooting success was higher using the wood fiber blend substrate than the standard substrate by 11% (**Table 9**). Root quality and average root length were slightly lower and plug quality was slightly higher with wood fiber incorporation (**Fig. 8**); however, these figures were not statistically significant. The similar quality and rooting success in *Callistemon* propagated in wood fiber shows promise in using this material as an alternative to peat moss in propagation substrates.

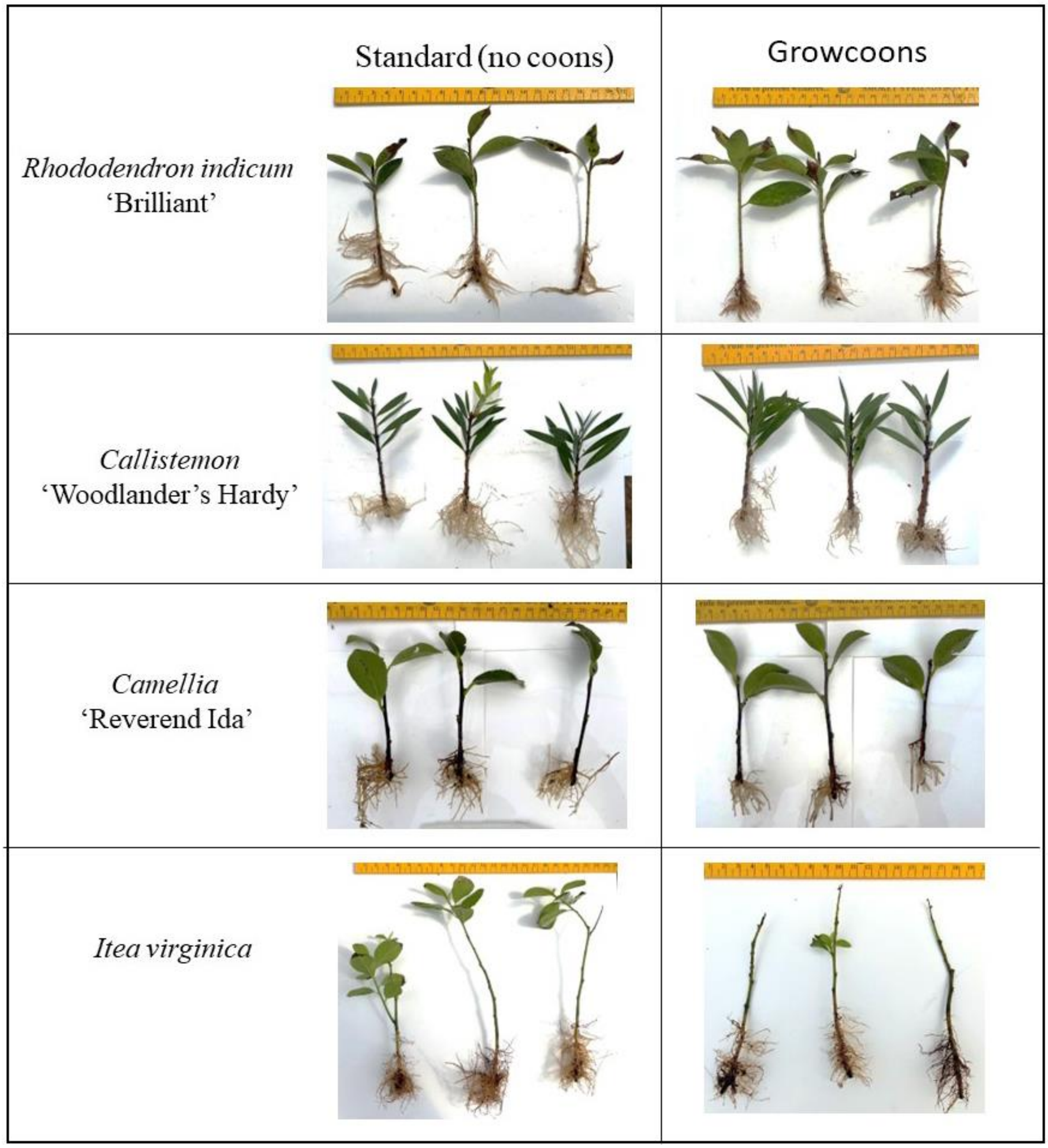

Figure 7. Rooted cuttings grown in loose-fill standard substrate (left) and in Growcoons filled with the standard substrate (right) with substrate and Growcoons removed.

Table 8. Rooting success, root quality, and plug quality of several woody species in standard (loose-fill) propagation mix and Growcoons.

Rooting Success	Standard	Growcoon
Camellia 'Reverend Ida'	44%	50%
Callistemon 'Woodlander's Hardy'	61%	61%
Itea virginica 'Henry's Garnet'	94%	100%
Rhododendron indicum 'Briliant'	44%	50%
Root Quality	**Standard**	**Growcoon**
Camellia 'Reverend Ida'	4.8	4.4
Callistemon 'Woodlander's Hardy'	4.8	4.4
Itea virginica 'Henry's Garnet'	3.2	2.6
Rhododendron indicum 'Briliant'	4.4	3.2*
Plug Quality	**Standard**	**Growcoon**
Camellia 'Reverend Ida'	5	5
Callistemon 'Woodlander's Hardy'	5	5
Itea virginica 'Henry's Garnet'	3.8	2.2*
Rhododendron indicum 'Briliant'	3.8	4.2

Quality data represent least-square means of five replicates. Means were compared using a 1:1 t-test at $\alpha = 0.05$, with significantly different means denoted with an asterisk (*).

Table 9. Rooting success, root quality, plug quality, and average root length in *Callistemon* 'Woodlander's Hardy' in standard propagation mix and 1:1 wood fiber and bark fines.

Callistemon 'Woodlander's Hardy'	Standard	Wood Blend
Rooting Success	61%	72%
Root Quality	4.7	4.4
Plug Quality	4.9	5.0
Average Root Length	5.4 cm	4.3 cm

Quality data and average root length represent least-square means of five replicates. Means were compared using a 1:1 t-test at $\alpha = 0.05$, with significantly different means denoted with an asterisk (*) (no significant differences found in this treatment).

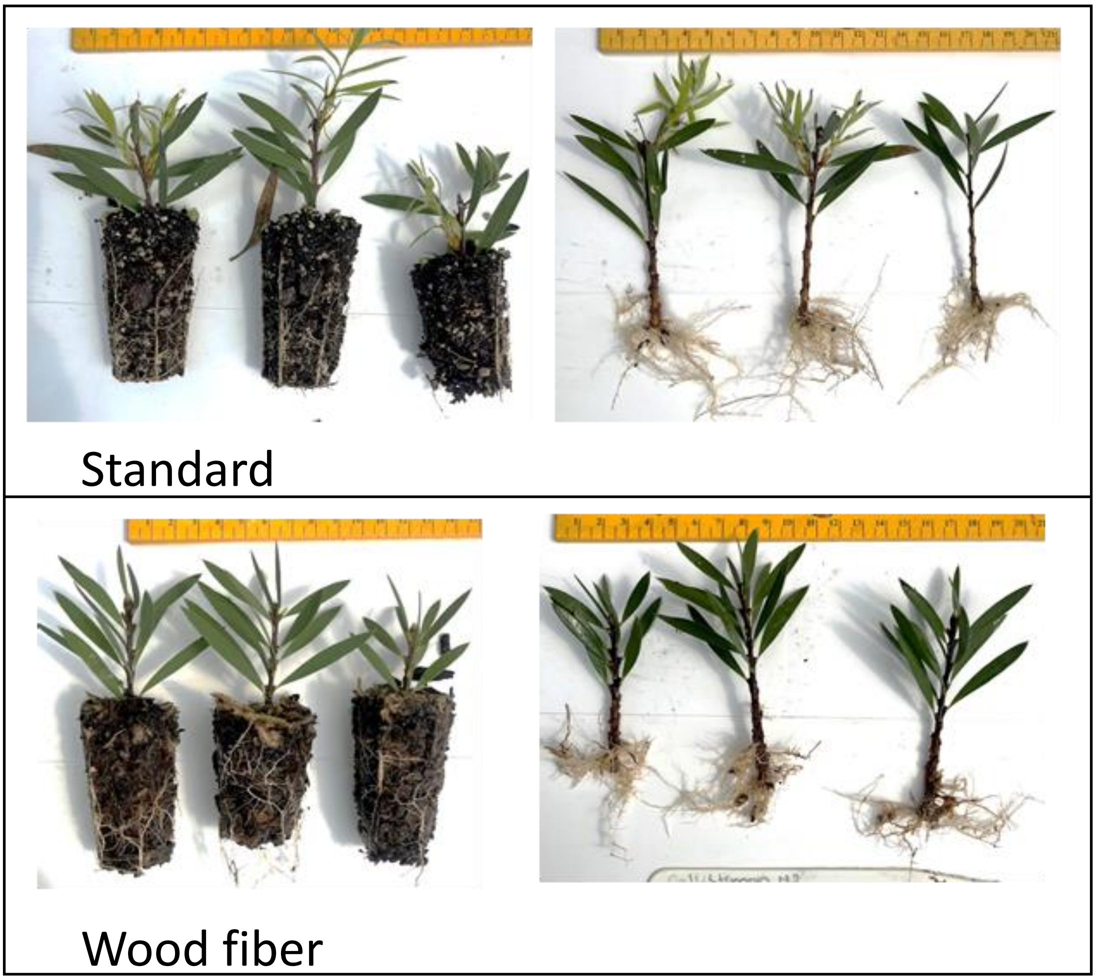

Figure 8. Rooted *Callistemon* cuttings grown in loose-fill standard substrate (top) and in wood fiber blend (bottom) with the substrate intact (left) and removed (right).

CONCLUSION

The study's objective was to ameliorate the effects of excessive substrate moisture content often resulting from frequent misting associated with extreme heat in propagation environments. Substrate stratification, Growcoons, and incorporation of wood fiber all increased the substrate air space compared to a 2:1:1 bark fines: peat: perlite standard propagation mix. Stratification with 100% perlite did not offer any rooting benefits and should be further investigated with different materials. Growcoons improved rooting success and shortened rooting time in most species trialed, but quality results need further trials to hone management techniques for improved quality. A promising result is the improved rooting success and similar root and plug quality of *Callistemon* when rooted in a wood fiber and bark blend. These results indicate the suitability of wood fiber in reducing peat and perlite usage in propagation with no adverse effects on rooting percentage or resulting liner quality. Further trials with wood fiber in propagation of other woody species is therefore another favorable next step, as well as repeated trials assessing all these methods under more normal weather conditions.

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