Combined Proceedings IPPS 74:341-350. 2024.

Wood Fiber Type and Substrate Temperature Affect Growth of Knockout Rose

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[a]First Place – Charles Student Research Paper Competition

Keywords: soilless media, wood fiber, peat moss, alternative potting media, nursery production

Summary

Peat moss and pine bark are important resources in the horticulture industry but have sustainability concerns. Research efforts have been made to find suitable amendments to reduce reliance on these resources, with the most promising amendment being wood fibers. This study evaluated the effects of two substrates amended with differently engineered wood fibers made from *P. taeda* on rose growth in white and black containers with two fertilizer rates. Results showed that differently engineered wood fibers and container color can influence the performance of crops grown, as well as the physical properties of substrates.

INTRODUCTION

In 2021, the ornamental horticulture industry reported a 10.1% increase in the cost of production (McClellan, 2022), and there continues to be concern around rises in the cost and sustainability of materials essential for container production, such as peat moss and pine bark (Bilderback et al., 2013; Dunn and Freeman, 2011; Fields et al., 2023). Numerous alternatives have been studied to relieve the reliance upon any particular substrate material for soilless production, with the most promising being wood fiber (Bobo and Jackson, 2024; Boyer, 2008; Gruda and Schnitzler, 1999). However, nitrogen immobilization remains a major concern when utilizing wood fibers in production.

Wood is composed of easily available carbon which is consumed by bacteria and fungi within the substrate by utilizing nitrogen, which can cause a decrease in plant health due to nutrient deficiencies (Jackson and Wright, 2008). Many commercial wood fibers are processed using heat and pressure (e.g. disc-refining) to alleviate concerns of microbial activity and neutralize chemical toxins found in wood materials (Bunt, 1988; Dickson and Helms et al., 2022). Low-input processing methods (e.g., hammermilling), do not generate heat and pressure during processing, and therefore must be aged prior to use to avoid nitrogen immobilization (Poleatewich et al., 2022). Another proven method to alleviate the concern of nitrogen immobilization is additional fertilizer applications (Jackson, 2009), yet some studies have shown comparable crop growth in wood-produced plants without additional fertilizer treatments (Fain et al., 2008).

Overall substrate physical properties are influenced by the type of wood fiber (e.g., wood processing method), as more fibrous wood fibers tend to hold more water compared to a coarse wood material. This is important to consider to be able to provide optimal conditions for the specific crop being cultivated and to suit the region in which the crop is being produced. In regions such as the southeastern U.S., temperatures during summer months can reach upwards of 40°C. Therefore, pot color is another consideration for optimal crop health. The standard black plastic nursery container will absorb heat and can cause extensive root damage and impact overall plant health (Ingram et al., 1989).

Considering these factors, this study was developed to compare crop production with two common wood fiber amendments and adjusted container color to evaluate substrate temperature variations, and subsequent effects on nursery crop growth and fertility.

MATERIALS AND METHODS

Substrate preparation. Two unique substrates were developed consisting of 10:30:60 (v/v/v) peat moss (Lambert Peat Moss Inc., Quebec, CA)/wood fiber/aged pine bark (Phillips Bark Processing Co.; Brookhaven, MS). The wood fibers used to amend the substrates were both derived from loblolly pine (*P. taeda*) but were processed utilizing two different methods. One wood fiber was a commercially available disc-refined wood fiber material (HF; HydraFiber Ultra; Profile Products, Buffalo Grove, IL), the second wood fiber was processed via hammermilling (HW) at North Carolina State University using a hammer mill fitted with 6.35 mm screen (Meadows

Mills, Inc., North Wilkesboro, NC, U.S.). Both substrates were separately blended on a clean concrete surface using a shovel. Substrates were limed using pelletized dolomitic lime (6 $lb \cdot yd^{-3}$, Lime-Rite, Roswell, GA) and received granular nutrients (3 $lb \cdot yd^{-3}$, Micromax Micronutrients, ICL, Tel Aviv, Israel) and mixed again.

A total of 32 nursery containers (C600, Nursery Supplies, Inc., Kissimmee, FL, USA) were separated into two groups of 16. One group of the pots were spray painted white (Rust-Oleum, Hawthorn Parkway, Vernon Hills, IL) and the other 16 were left black. Thus 8 replicates of HF in black pots, 8 replicates of HF in white pots, 8 replicates of HM in black pots, and 8 replicates of HM in white pots.

Substrate Physical Properties. Static physical properties including container capacity (CC), air space (AS), bulk density (D_b), and total porosity (TP) were determined on both substrate blends via NCSU porometer analysis as described by Fonteno and Bilderback (1993) on three replicates from each treatment. Particle size distribution was determined on both substrate blends by shaking 100 g of oven dried substrate through sieves consisting of 6.3, 2.0, 0.7, 0.5, 0.3, and 0.1 mm with a catch pan at the bottom using a Ro-Tap shaker (Rx-29; W.S. Tyler, Mentor, OH, U.S.A.) for five minutes. The contents of each tray were weighed and classified into four size classifications: extra-large (> 6.3 mm), large (2.0 – 6.3 mm), medium (2.0 – 0.7 mm), and fine (< 0.7 mm).

Growth Trial. All pots were filled to the top with one of the two substrates, tamped down three times, and leveled to ensure uniform compaction. A temperature sensor (HOBO data loggers, MX2201, Bourne, MA) was buried half-way down the pot's height into the substrate, and half-way between the wall of the pot and where the plug would be placed. Double Red Knockout Rose plugs (*Rosa* x 'Radtko') were planted in all 32 experimental units and fertilized by top-dressing with a 3 month 16-6-12 (16% N, 6% P_2O_5, 12% K_2O) controlled-release fertilizer (Harrell's, Lakeland, FL). Half the replicates receiving a low rate (L; 19 $g \cdot 2\ gal^{-1}$) and the other half receiving a high (H; 39 $g \cdot 2\ gal^{-1}$) rate. Thus, a multifactorial completely randomized design was used for this experiment, where the treatments consisted of black (B) or white (W) containers, L or H fertilizer rate, and disc-refined or hammermilled wood fiber (example of treatment label: B:L:HW representing black pot: low fertilizer rate: hammermilled wood).

Irrigation. Container units were hand-watered to CC using a water hose on the day of transplanting, and then set to irrigate for 12 min (~157 $mL \cdot min^{-1}$) at 0800 every day targeting a leaching fraction of 10%. On d 25, slight heat stress was observed in the crops (**Fig. 1**) and irrigation was set to run for 10 min (~130 $mL \cdot min^{-1}$) at 0800 and 5 min (~65 $mL \cdot min^{-1}$) at 1500 for the remainder of the study.

Data Collection. Growth index (GI; average of the height of the plant from substrate surface, width of the widest part of the plant, and width perpendicular to widest part of the plant), chlorophyll content estimated via SPAD meter (SPAD 502 Plus, Spectrum Technologies, Aurora, IL, USA), and substrate pH and electrical conductivity (EC) using a non-destructive pour-through method described by Wright (1986) utilizing a hand-held pH meter (GroLine HI9814, Hanna Instruments, Smithfield, RI, USA) were collected bi-weekly for a total of 3 measurement events throughout the study. At culmination of the study (45 d), all units were destructively harvested by cutting the shoots at the base of the substrate, collecting the substrate from the roots, and drying the shoots and roots in an oven set at 68°C for 7 d to be weighed for accumulated plant biomass.

Data Analysis. All data presented in tables and figures with corresponding statistical analysis was analyzed in JMP Pro (17.0; SAS Institute, Inc.; Cary, NC, U.S.) utilizing Analysis of variance (ANOVA) and Tukey's Honestly Significant Difference at the α = 0.05 significance level.

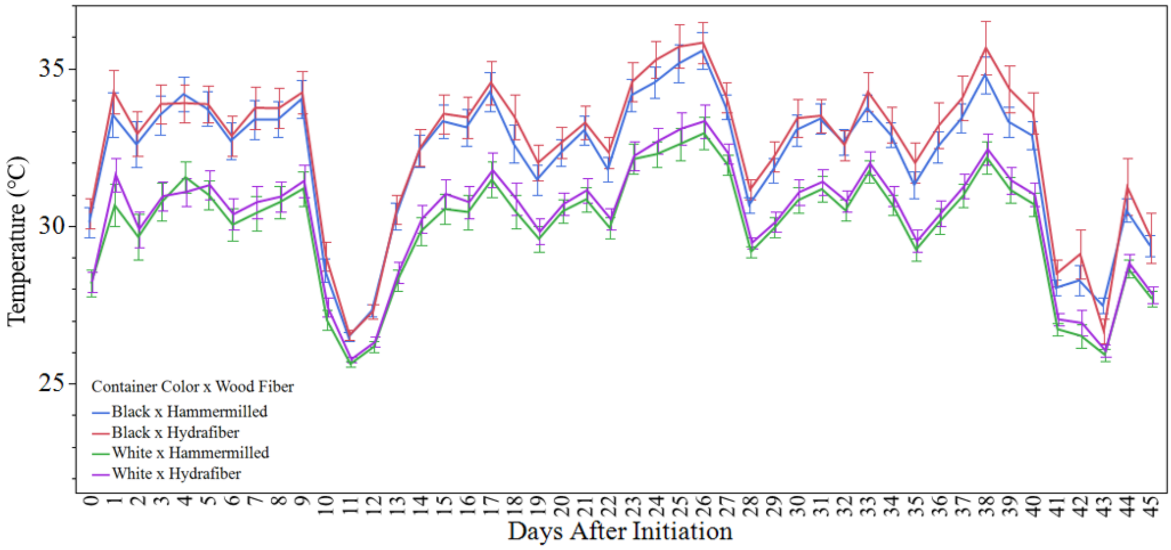

Figure 1. Temperature fluctuations of substrates amended with hammermilled wood (HW) or hydrafiber (HF) in white (W) or black (B) containers.

RESULTS AND DISCUSSION

Substrate Static Physical Properties. There were significant differences across all physical properties between the substrates amended with HW and HF (**Table 1**). This was hypothesized to be the case, as the physical properties of differently processed wood fibers have been shown to be variable (Poleatewich et al., 2022). The HF blend had a higher AS ($p = 0.0014$) and TP ($p = 0.0016$) compared to the HW blend, which had a higher CC ($p = 0.0255$) and D_b ($p = <.0001$). The HF fibers are fibrous and airy compared to the coarse HW; therefore, it was hypothesized that the HF substrate would have a higher AS and lower D_b. However, this substrate was not in the recommended range of 10-30% AS or 0.19-0.70 $g \cdot cm^{-3}$ D_b set by Yeager et al. (2007). The HW substrate had overall more suitable physical properties compared to the HF substrate. The treatments had different proportions of large, medium, and fine particles (**Table 1**). The substrate with HF amendments had a higher proportion of large particles ($p = <.0001$), while the HW-amended substrate had higher proportions of medium ($p = <.0001$) and fine particles ($p = 0.0093$). These results may be misleading, as usually substrates with smaller particles hold more water (Bilderback et al., 2005). Shown in the TP from the static physical properties, the HF blend held more water as opposed to the HW blend, which had more medium and fine particles than the HF blend. The HF particles are long and thin fibers that tend to clump together regardless of how well blended they are into a substrate. Whereas the HW fibers are shorter and wider particles and do not clump. Therefore, during the particle size measurement process, the HF fibers may have stayed on a larger size sieve due to the length of the fibers and clumps holding them there, even though they technically have a smaller particle size than the hammermilled wood.

Table 1. Static physical properties and particle size distribution of substrates consisting of bark, peat, and hammermilled wood fibers or hydrafiber.[z]

Static Physical Properties				
Treatment	Air Space[y] ($cm^3.cm^{-3}$)	Container Capacity[v] ($cm^3.cm^{-3}$)	Total Porosity[w] ($cm^3.cm^{-3}$)	Bulk Density[x] ($cm^3.cm^{-3}$)
Bark:Peat:HW[s] (60:10:30)	0.17 b[u]	0.53 a	0.70 b	0.18 a
Bark:Peat:HF[r] (60:10:30)	0.33 a	0.45 b	0.78 a	0.13 b
P-value[t]	0.0014	0.0255	0.0016	<.0001
Particle Size Distribution				
Treatment	Extra-large (>6.3 mm) ($g.g^{-1}$)	Extra-large (>6.3 mm) ($g.g^{-1}$)	Extra-large (>6.3 mm) ($g.g^{-1}$)	Extra-large (>6.3 mm) ($g.g^{-1}$)
Bark:Peat:HW[s] (60:10:30)	21.30 a	21.30 a	21.30 a	21.30 a
Bark:Peat:HF[r] (60:10:30)	24.27 a	24.27 a	24.27 a	24.27 a
P-value[t]	0.0655	0.0655	0.0655	0.0655

[z]Analysis performed using North Carolina State University porometer method (Fonteno et al., 1995).
[y]Air space = volume of water drained from sample ÷ volume of sample.
[x]Bulk density = oven dry weight of sample ÷ volume of sample
wTotal porosity = container capacity + air space
[v]Container capacity = (wet weight of sample – oven dry weight of sample) ÷ volume of sample.
[u]Means within columns separated using Tukey's HSD test (P = 0.05; n=3). Values followed by the same letter are not significant.
[t]Measures of substrate treatment effects using analysis of variance (P = 0.05).
[s]Bark:Peat:Hammermilled wood (v/v/v) substrate treatment.
[r]Bark:Peat:Hydrafiber (v/v/v) substrate treatment.

Rose Growth and Development. There were significant differences in crop GI across treatments (p = 0.0005; **Fig. 2**). Fertilizer treatment did not have a significant effect on crop growth (p = 0.6765). However, pot color had the most significant effect on growth (p = <.0001) followed by substrate blend (p = 0.0013). Plants had significantly higher growth when grown in white containers with the hammermilled wood substrate blend in high fertilizer (20.3 cm) and low fertilizer (20.2 cm) treatments. Crops grown in black containers with the HF substrate had the lowest growth in low fertilizer (12.8 cm) and high fertilizer (12.5 cm) treatments. All other treatments had no significant differences in growth.

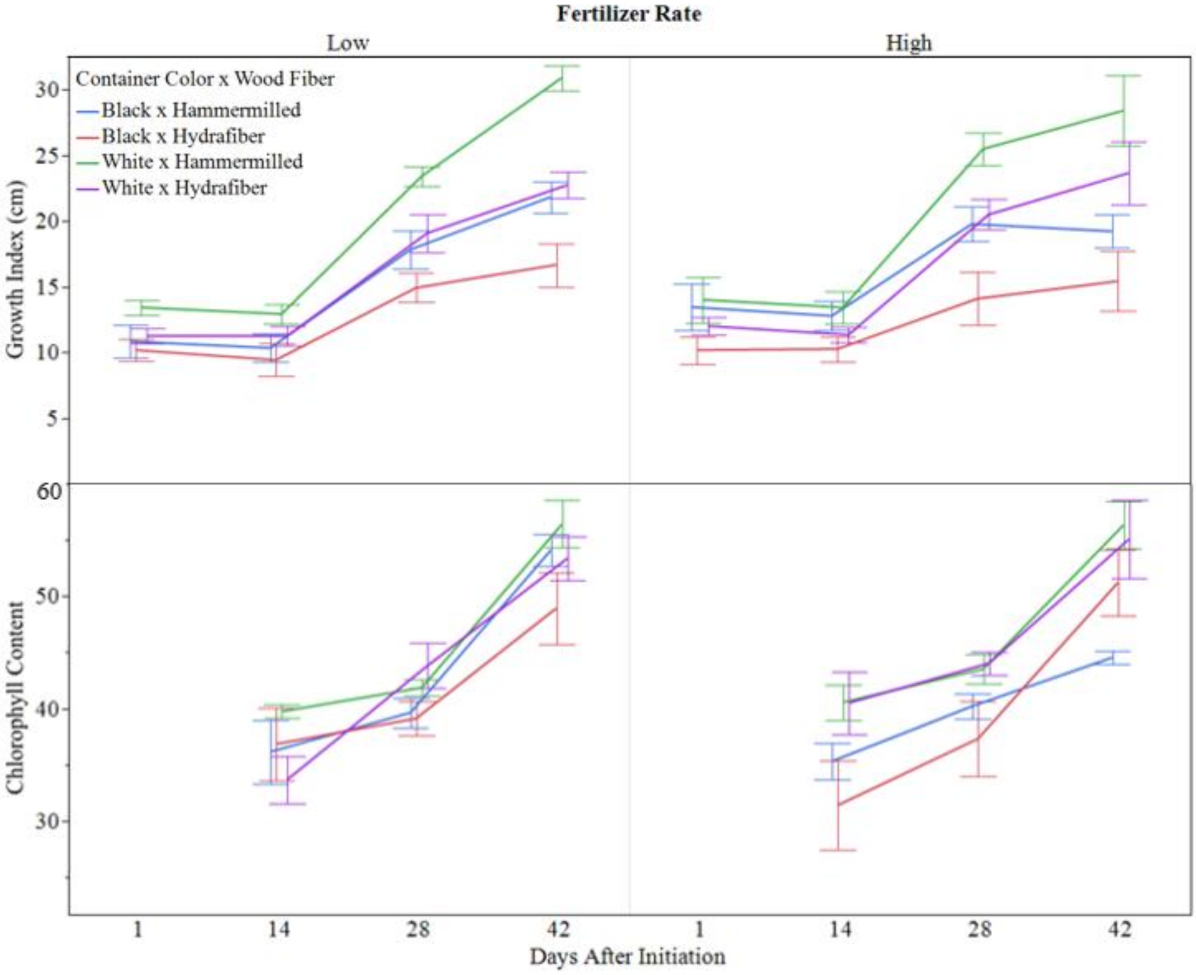

Figure 2. Growth index (GI) and chlorophyll content of roses grown in white (W) or black (B) containers, substrates amended with hammermilled wood (HW) or hydrafiber (HF), and at high (H; 39 g·2 gal^{-1}) and low (L; 19 g·2 gal^{-1}) fertilizer rates over time.

An important takeaway from these results is that the black pots remained at significantly higher temperatures than the white pots (p = <.0001), which could have caused extensive root damage. The temperatures in the black pots were, on average, around 32° C, with maximum temperatures reaching the upper 40°C, which has been shown to stop root growth completely (Mathers, 2003). Additionally, with the heavy rain events that occurred throughout the study, the HF substrate treatments held onto water much longer than the HW substrate blends, as would be assumed to be the case when considering the physical properties of the two substrates. The HF blend holding onto more water could have led to root rot in the roses, which tend to prefer a drier environment.

Furthermore, there were significant differences in the R:S ratios of accumulated biomass of the crops (**Table 2**, p = 0.0071), where the B:H:HF treatment had the highest R:S ratio and the W:L:HW treatment had the lowest. All other treatments had statistically similar R:S ratios.

Table 2. Ratios of Dried Root and Shoot Biomass of Crops grown in white (W) or black (B) containers, substrates amended with hammermilled wood (HW) or hydrafiber (HF), and at high (H; 39 g·2 gal^{-1}) and low (L; 19 g·2 gal^{-1}) fertilizer rates.

Root:Shoot Ratio of Biomass			
Container color	Fertilizer rate	Fiber type	Root:Shoot ratio
Black	Low	Hydrafiber	0.53 ab[z]
Black	High	Hydrafiber	0.57 a
Black	Low	Hammermilled wood	0.37 ab
Black	High	Hammermilled wood	0.44 ab
White	Low	Hydrafiber	0.25 ab
White	High	Hydrafiber	0.23 ab
White	Low	Hammermilled wood	0.17 b
White	High	Hammermilled wood	0.23 ab
P-value[y]			0.0071

[z]Means within columns separated using Tukey's HSD test (P = 0.05; n=4). Values followed by same letter are not significant.
[y]Measures of treatment effects using analysis of variance (P = 0.05).

Plants grown in W containers had overall higher chlorophyll content (45.7) compared to plants grown in B containers (41.0, p = 0.0071). It has been shown that high root zone temperatures can lead to chlorosis of plants and interfere with nutrient uptake (Ingram et al., 1989), which could have caused these results. There were no statistical differences in chlorophyll content of crops between substrate treatments (p = 0.4375) or fertilizer rates (p = 0.7478).

Substrate Fertility. There were no significant differences in substrate pH between the individual treatments (p = 0.3450). Fertility rate did effect substrate EC (p = 0.0066), with H fertilizer yielding increased EC (1.93 mS/cm) compared to low fertilizer treatments (1.58 mS/cm, p = 0.0001; **Fig. 3**).

CONCLUSION

The results from this study emphasize the importance of choosing materials that best suit the specific crop being grown and the region in which the crop is growing in, as substrate and container color can greatly influence crop growth and productivity. In terms of this experiment, which was conducted in southeastern Louisiana during the summer months where temperature spikes and heavy rain events are prominent, roses grown in a better-draining substrate in combination with a white pot out-performed crops grown in a substrate that holds more water and in a black pot. In a region where temperatures are cooler and rain events are less of an issue, this temperature difference may not be as influential. Another takeaway from this study was that crops did not perform any better with a higher fertilizer treatment compared to a low treatment. This study was relatively short, and likely did not allow enough time for the variation of fertilizer rate to make a difference. However, this may potentially allude to the little N-drawdown occurrence in ornamental crops grown with wood fibers which have been properly processed. This research indicates that perhaps nursery crops may not need a higher rate of fertilizer when being produced in a wood fiber-amended substrate. This, in combination with the cost reduction that comes with using wood fiber amendments, can substantially help growers save on production costs.

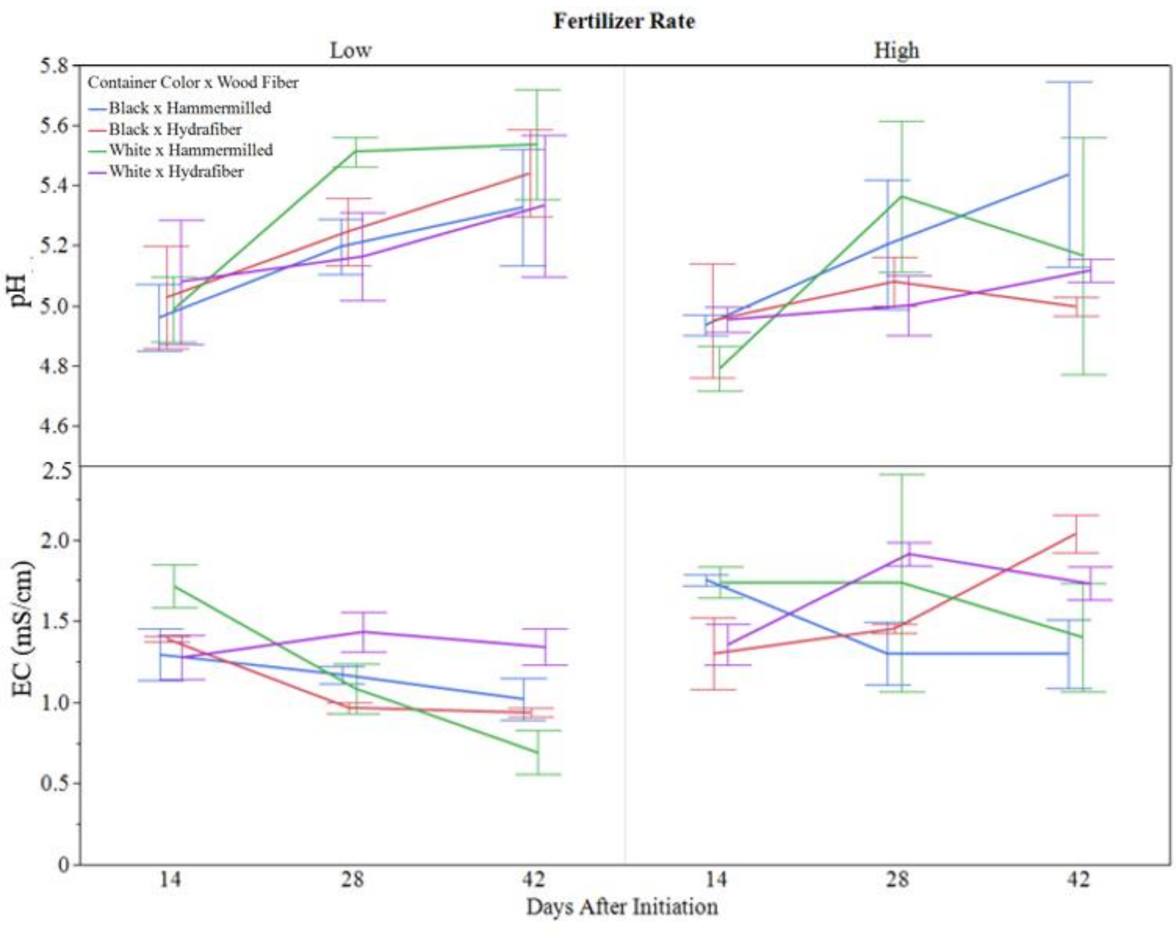

Figure 3. Electrical conductivity (EC) and pH of substrates consisting of (60:10:30; by vol.) bark, peat, and hammermilled wood fibers or hydrafiber over time

LITERATURE CITED

Bilderback, T.E., Warren, S.L., Owen, .S., and Albano, J.P. (2005). Healthy substrates need physicals too. HortTech. *15*: 747-751.

Bilderback, T.E., Riley, E.D., Jackson, B.E., Owen, J.S., Kraus, H.T.J., Fonteno, W.C., Altland, J., Fain, G.B. (2013). Strategies for developing sustainable substrates in nursery crop production. Acta Hortic. *1013*: 43–56.

Bobo, J.G. and Jackson, B.E. (2024). North American and European conifer species evaluated for use as wood components in growing media: a mini review. Acta Hortic. *1389*.
DOI: 10.17660/ActaHortic.2024.1389.16

Boyer, C.R. (2008). Evaluation of clean chip residual as an alternative substrate for container-grown plants. (Doctoral Dissertation). Auburn University.

Bunt, A.C. (1988). Media and mixes for container grown plants. 2nd Ed Unwin Hyman, London, UK.

Dickson, R.W., Helms, K.M., Jackson, B.E., Machesney, and Lee J.A. (2022). Comparison of fertilizer nitrogen availability, nitrogen immobilization, substrate carbon dioxide efflux, and nutrient leaching in peat-lite, pine bark, and pine tree substrates. HortScience 57(2):304–311.
https://doi.org/10.21273/HORTSCI16177-21

Dunn, C. and Freeman, C. (2011). Peatlands: our greatest source of carbon credits? Carbon Manag. *2*: 289-301.
https://doi.org/10.4155/cmt.11.23

Fain G.B., Gilliam, C.H., Sibley, J.L. and Boyer, C.R. (2008). Whole tree substrates derived from three species of pine in production of annual vinca. HortTech. *18*:13-17.

Fields, J., Owen, J., Lamm, A., Altland, J., Jackson, B., Oki, L., Samtani, J., Zheng, Y., and. Criscione, K. (2023). Surveying North American specialty crop growers' current use of soilless substrates and future research and education needs. Agricul. *13*: 1727. https://doi.org/10.3390/agriculture13091727.

Fonteno, W.C., Hardin, C.T., and Brewster, J.P. (1995). Procedures for determining physical properties of horticultural substrates using the NCSU Porometer. Horticultural Substrates Laboratory, North Carolina State University.

Gruda, N. and Schnitzler, W.H. (1999). Influence of wood fiber substrates and N application rates on the growth of tomato transplants. Advan. Hort. Sci. *13*: 20-24. https://www.jstor.org/stable/42881976

Ingram, D.L., Martin, C., and Ruter, J. (1989). Effect of heat stress on container-grown plants. Comb. Proc. Int. Plant Propagators Soc. *39*:348–353.

Jackson, B.E., Wright, R.D., and Barnes, M. (2008). Pine tree substrate, nitrogen rate, particle size, and peat amendment affect poinsettia growth and substrate physical properties. HortScience. *43*:2155–2161.

Jackson, B.E., Wright, R., and Alley, M. (2009). Comparison of fertilizer nitrogen availability, nitrogen immobilization, substrate carbon dioxide efflux, and nutrient leaching in peat-lite, pine bark, and pine tree substrates. HortScience *44*:781–790.

Mathers, H. (2003). Summary of temperature stress issues in nursery containers and current methods of protection. HortTech. *13*:617–624.

McClellan, M. (2022). Looking ahead. https://www.nurserymag.com/article/state-of-the-industry-2023-economic-outlook/

Poleatewich, A., Michaud, I., Jackson, B., Krause, M., and DeGenring, L. (2022). The Effect of peat moss amended with three engineered wood substrate components on suppression of damping-off caused by *Rhizoctonia solani*. Agricul. *12*: 2092. https://doi.org/10.3390/agriculture12122092.

Wright, R.D. (1986). The pour through nutrient extraction procedure. HortScience *21*:227–229.

Yeager, T.H., Gilliam, C.H., Bilderback, T.E., Fare, D.C., Niemiera, A.X., and Tilt, K.M. (1997). Best management practices guide for producing container grown plants. Southern Nursery Assn., Marietta, GA.