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Evaluation of Sawdust Derived from Three Different Softwood Tree Species as Substrate Amendments

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Summary

Peat moss alternatives are needed as the use of soilless substrates has increased. Wood as a peat moss amendment has been used for decades. In this study, three different softwood tree species: Douglas Fir (*Pseudotsuga*), Hemlock (*Tsuga*), and Southern Yellow Pine (*Pinus*) were blended with peat and perlite at 20- and 40% (by vol.) to create six unique soilless substrate blends. Plugs of Marigold (*Tagetes patula*) 'Janie Yellow', *Zinnia* 'Preciosa Yellow', and *Helianthus* 'Busy Bee' were grown in the sawdust substrates. Static physical properties, chemical properties, and plant health were evaluated. Overall, findings were similar to other studies that show sawdust having low bulk density, high air space and container capacity, and can grow crops comparable to a standard greenhouse growing media.

INTRODUCTION

Sphagnum peat moss is the primary component of most greenhouse production growing media. However, as the horticultural industry continues to grow, peat moss alternatives are needed to keep up with demand and lower costs for growers. Wood fibers are currently some of the leading peat alternatives that have promise (Bilderback et al., 2013; Durand et al., 2021; Jackson, 2016).

Wood as a component in soilless media has been used since the 1980's (Laiche and Nash, 1986). Its use in greenhouse production has increased due to its world-wide availability and because it can be processed into different particle sizes and textures to achieve desirable physical properties (Jackson et al., 2009; Jackson, 2018). There are many methods for processing wood components including disc-refining, hammermilling, and screw extruding (Poleatewich et al., 2022). These are all actively processed materials. Currently, the most popular wood fiber amendment for horticultural use in the U.S. is a thermally refined (i.e. heat is applied as the wood chips are spun into a fiber to reduce any chemical or biological activity that could potentially be harmful to crops) product (Hydrafiber, Profile Products, Buffalo Grove, IL). However, sawdusts are another wood product that is ubiquitous across the country and are considered waste products.

Sawdust has been utilized for plant cultivation due to its low cost, high availability, moisture retention, and adequate root-aeration for decades (Bowen, 1983; Jung et al., 2017; Yasin et al., 2023). Sawdust is easily available and widely used in places that have wood processing industries (Jung et al., 2017). Utilizing an amendment that is readily available can be more cost-effective than having components such as peat or coconut coir shipped (Yasin et al., 2023).

The primary challenge with sawdust, and other wood amendments, is nitrogen immobilization. This is when plant available nitrogen, such as nitrate ($NO3^-$) and ammonium ($NH4^+$), is converted to unavailable nitrogen by microorganisms. For this reason, soilless substrates amended with wood are often composted or supplemented with additional nitrogen through fertilization to prevent nutrient deficiencies to the crop (Jackson et al., 2009). If not treated or composted, sawdust can contain phenols and toxins which can harm plants. Additionally, the differences between properties among different species of wood makes the use of sawdust in soilless substrates variable (Jung et al., 2023). While various sources of sawdust such as Douglas Fir (*Pseudotsuga*), Red Cotton Tree (*Bombax ceiba*), and White Spruce (*Picea glauca*) have proven to yield adequate plant growth with proper irrigation and supplemental fertilizer (Depardieu et al., 2016; Yasin et al., 2022), there have not been many studies comparing sawdust from different tree species. Therefore, the objective of this study was to compare sawdust from three tree species, each harvested from a different geographic region, as a component in soilless growing media, and to evaluate the sawdust species effects on crop productivity and health. The three tree species used in this study include Douglas Fir (DF; *Pseudotsuga*), Hemlock (H; *Tsuga*), and Southern Yellow Pine (SYP; *Pinus*).

MATERIALS AND METHODS

Preparation of Substrate Blends. Sawdust was collected from an industrial lumber mill and allowed to age for one year. Substrate blends consisted of peat:perlite:sawdust at rates of 80:20:0 (control), 60:20:20, or 40:20:40 (v/v/v) for a total of seven substrate blends. Substrate treatments will be referred to as CTL, SYP20, SYP40, DF20, DF40, H20 and H40 for the remainder of this paper. Components were hydrated and slowly incorporated using an electric concrete mixer (Yardmax, Roselle, IL).

Greenhouse experiment. Plugs of Marigold (*Tagetes patula*)'Janie Yellow', Zinnia 'Preciosa Yellow', and *Helianthus* 'Busy Bee' (**Fig. 1**) were each planted in a 2.5 L container containing one of the seven substrate blends with five replicates each for a total of 105 units (7 substrate treatments x 3 plant species x 5 replicates). Crops were grown on a greenhouse bench for 63 days and hand-fertigated weekly with 200 mL of 20-10-20 water-soluble fertilizer solution adjusted to 200 ppm N (Peters Professional, Dublin, OH). Measurements including growth index, leaf chlorophyll content, flower count, substrate shrinkage, and pH and electrical conductivity (via pour-through analysis; LeBude and Bilderback, 2009) were collected bi-weekly. Crops were destructively harvested at the conclusion of the study by cutting the shoot at the substrate line and removing the substrate from the roots. Shoots and roots were dried in an oven at 70°C for five days and weighed for accumulated biomass.

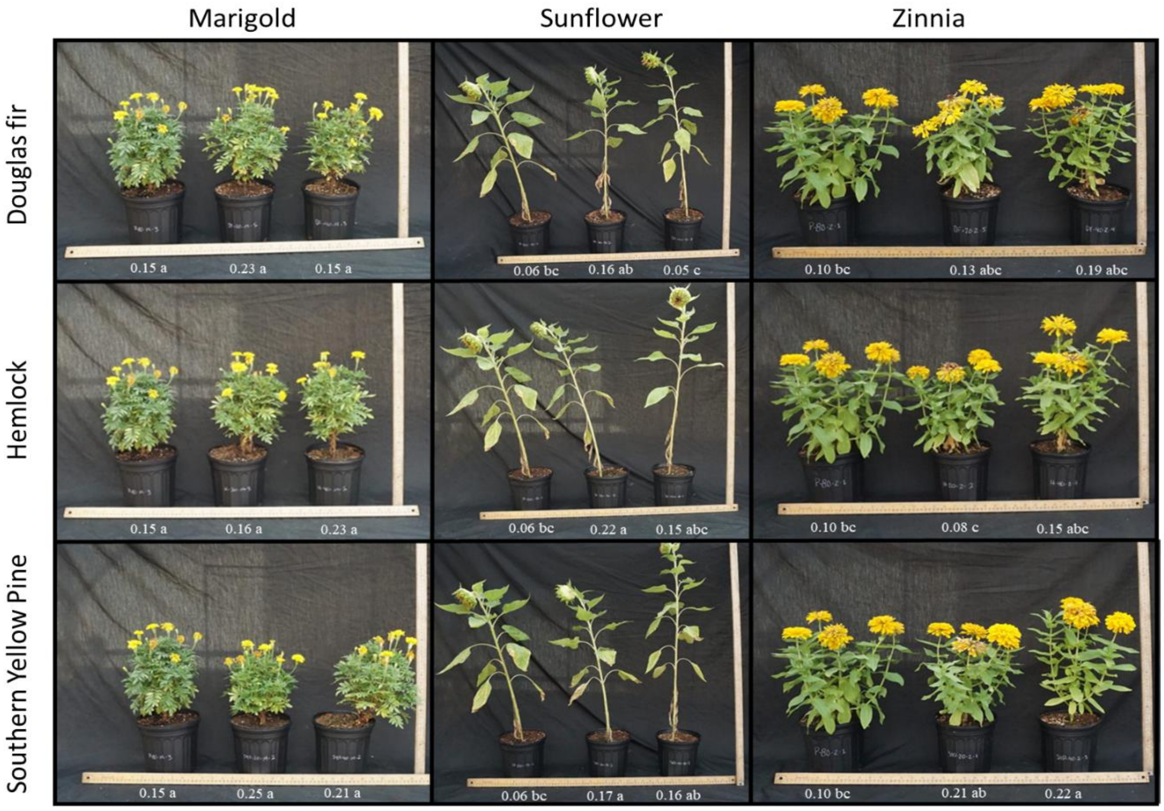

Figure 1. Representative plants of each treatment with corresponding R:S ratios. In each photograph the plant on the left is the control (CTL), the center plant has 20% sawdust (by vol.), and the right plant has 40% (by vol.) sawdust.

Static Physical Properties. Physical properties including container capacity (CC), air space (AS), bulk density (D_b), and total porosity (TP) were determined on all substrate blends via NCSU porometer analysis of three replicates as described by Fonteno and Bilderback (1993). Particle size distribution was determined on all 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.) for five minutes. The contents of each tray were weighed and classified into four size classifications: extra-large (>6.30 mm), large (2.00–6.30 mm), medium (2.00–0.71 mm), and fine (<0.71 mm).

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 $\alpha = 0.05$ significance level.

RESULTS AND DISCUSSION

Static Physical Properties. There were significant differences in CC across substrate blends

($P < .0001$). The SYP20 blend had the highest CC (0.66 $g \cdot g^{-1}$) and the CTL had the lowest (0.56 $g \cdot g^{-1}$). Research has shown that sawdust substrates contain relatively high water storage capacity (Marinou, 2013). The SYP20 blend also had the lowest AS (0.10 $g \cdot g^{-1}$); however, the SYP40 blend had the highest AS (0.19 $g \cdot g^{-1}$; **Table 1**). The AS and TP across all substrate blends were significant and were all in the recommended range of 10%-30% AS and 50%-85% TP (Yeager et al., 2007; $P < .0001$). The SYP40 blend had the highest TP (0.76 $g \cdot g^{-1}$) and the CTL had the lowest (0.68 $g \cdot g^{-1}$; Table 1). The SYP blends seem to have the most suitable physical properties compared to the other species. The differences in bulk density were not as significant ($P = 0.0273$), considering sawdust is well-known for having low bulk density (Haidar and Rishmany, 2021).

Particle size distribution was significantly different across all substrate blends (**Table 1**). The H40 blend had the greatest amount of extra-large particles (2.26 $g \cdot g^{-1}$) and the lowest amount of fine particles (38.8 $g \cdot g^{-1}$; $P < .0001$; **Table 1**). In contrast, CTL had the greatest proportion of fine particles (45.1 $g \cdot g^{-1}$) and the lowest amount of extra-large particles (0.26 $g \cdot g^{-1}$; **Table 1**). All substrate blends exhibited greater quantities of fine particle proportions (**Table 1**). There was significant substrate shrinkage across all substrate blends (**Fig. 2).** The greater amount of substrate shrinkage may be due to the inherent fine particle percentages of sawdust substrates. Research has shown that smaller particle size wood substrates tend to have more shrinkage than substrates that contain larger particle sizes (Jackson, 2008; Wang, 1994)

Growth Trial. There were no significant differences in growth index across both marigolds or zinnias ($P = 0.7039$ and $P = 0.5515$, respectively); however, the sunflowers grown in 40% sawdust incorporation across all wood species exhibited significantly greater growth than the other treatments ($P = 0.0007$; **Fig. 2**). Overall, all plants were considered salable at the end of this study (**Fig. 1**). When using sawdust as a substrate amendment, it usually does not make up more than 50% of the substrate to avoid nutrient loss (Marinou, 2013). Therefore, using a smaller amount of sawdust, like in this study, with added nitrogen can lead to comparable growth to that of a traditional greenhouse media of peat and perlite. The greater growth could also be due to the adequate air space that sawdust can provide to roots after drainage (Jackson, 2008). The plants grown in CTL had the greatest chlorophyll content across all species and were significantly highest in marigolds and sunflowers (P = 0.0394 and P = 0.0001, respectively; **Fig. 2**).

Table 1. Physical properties of substrate substrates comprised of blends of peat, perlite and sawdust from three tree species.

	Static physical properties				Particle size distribution ($g \cdot g^{-1}$)			
Substrate	Container capacity ($cm^3 \cdot cm^{-3}$)	Air space ($cm^3 \cdot cm^{-3}$)	Total porosity ($cm^3 \cdot cm^{-3}$)	Bulk density ($g \cdot cm^{-3}$)	Extra-large (>6.3mm) ($g \cdot g^{-1}$)	Large (6.3mm-2.00mm)	Medium (2.00mm-0.71mm)	Fines (<0.71 mm)
80:20 peat:perlite[a]	0.56 d[b]	0.12 bcd	0.68 c	0.12 ab	0.26 d	24.9 c	29.9 ab	45.1 a
40:20:40 peat:perlite :DF[c]	0.61 bc	0.12 cd	0.73 b	0.11 ab	2.13 ab	28.1 ab	30.6 ab	40.3 cd
60:20:20 peat:perlite: DF	0.60 bcd	0.16 ab	0.76 ab	0.12 a	0.76 cd	26.6 bc	31.5 a	42.4 b
40:20:40 peat:perlite: H[d]	0.63 ab	0.12 cd	0.76 ab	0.11 b	2.26 a	28.2 ab	30.6 ab	38.8 d
60:20:20 peat:perlite: H	0.61 bc	0.15 bc	0.76 ab	0.12 ab	1.5 abc	30.1 a	29.0 b	40.0 cd
40:20:40 peat:perlite: SYP[e]	0.58 cd	0.19 a	0.78 a	0.11 ab	1.16 bcd	28.9 a	29.2 b	41.8 bc
60:20:20 peat:perlite: SYP	0.66 a	0.10 d	0.76 ab	0.12 a	1.26 bc	27.9 ab	29.2 b	43.0 b
P Value	<.0001	<.0001	<.0001	0.0273	<.0001	<.0001	0.0047	<.0001

[a]Standard 80:20 peat:perlite substrate used as a control. [b]Letters down columns represent similarities and differences according to Tukey's Honest Significant Different α = 0.05. [c]Douglas fir (*Pseudotsuga*). [d]Hemlock (T*suga*). [e]Southern Yellow Pine (*Pinus*)

Considering the nitrogen drawdown effect that sawdust tends to have on crops, the low chlorophyll content of the sawdust blends was hypothesized (Jackson, 2009). Large amounts of fertilizer are typically needed to compensate for the nutrient loss associated with using sawdust as a substrate amendment, especially if the sawdust is not treated or composted (Jackson, 2008).

Substrate Chemical Properties. The pH across all substrate blends were significantly different. However, there were no significant differences in electrical conductivity (EC; **Fig. 2**). Initial pH was lower in all substrates and increased over time. Sawdust has been shown to increase in pH over time (Davis, 2022), like what was observed in this study. The opposite was true regarding EC, which decreased over time.

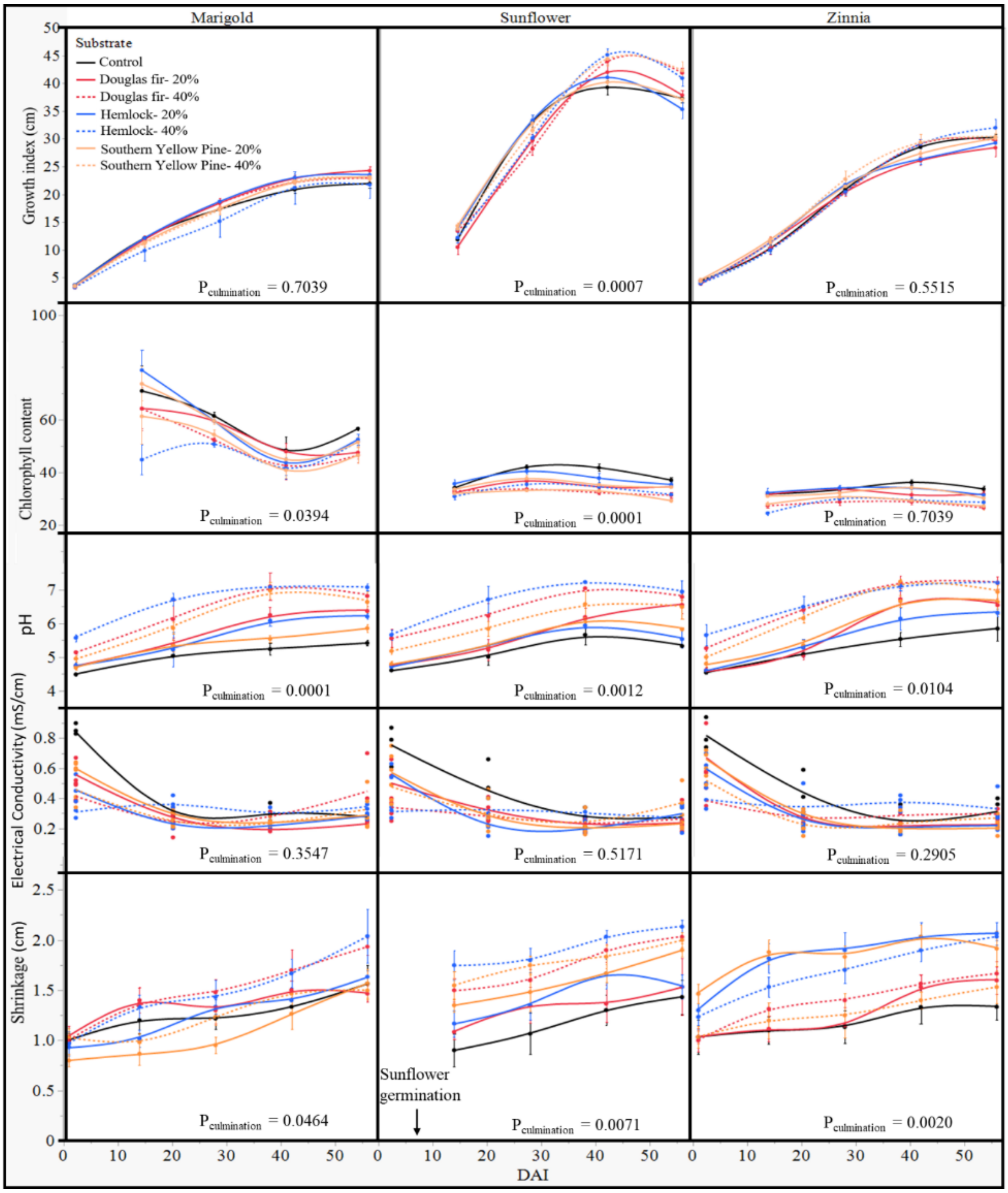

Figure 2. Growth index (cm), chlorophyll content, pH, electrical conductivity (mS/cm), and substrate shrinkage (cm) of marigold, sunflower, and zinnia crops grown in substrates developed made from peat:perlite:sawdust blends.

CONCLUSIONS

In conclusion, there seems to be very little measured differences in these short-term crops grown with and without the presence of 20- and 40% sawdust (by vol.), nor did the sawdust tree species influence crop growth. There is still more research that needs to be done to understand the stability of sawdust as a substrate amendment to better manage its fertility and irrigation requirements in a greenhouse setting. However, considering the low bulk density of sawdust and its ubiquity, it makes an excellent alternative to many peat moss alternatives that may not be as easily available or as inexpensive. This study, in combination with others that exhibit the successful use of sawdust in soilless substrates, further supports the use of sawdust across the country as the industry continues to grow and seek alternative substrate components to extend peat supplies.

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