# Pine Tree Substrate: Fertility Requirements for Nursery and Greenhouse Crops©

**Brian E. Jackson and Robert D. Wright**

Virginia Tech University, Dept. of Horticulture, Blacksburg, Virginia 24061

Email: wrightr@vt.edu

**As the cost and supply of container substrates continue to be an issue for nursery and greenhouse growers, recent research has focused on the use of wood as a possible material to replace the traditional peat moss (P) and pine bark (PB) substrates currently in use. A pine tree substrate (PTS) has recently been developed from whole processed delimbed loblolly pine trees (*Pinus taeda* L.) for use as a container substrate in horticulture crop production. The objective of this work was to determine the extent of nitrogen (N) immobilization (a possible reason for higher fertilizer requirements for PTS) in PTS compared to P and PB. Pine tree substrate, P, and PB were filled into containers (fallow) and fertilized with 200 ppm N prior to incubation for N-immobilization determination. Substrate $CO_2$ efflux was measured to asses the microbial activity occurring in each substrate as an indicator for the potential of microbial immobilization of N. Marigold (*Tagetes erecta* Big. 'Inca Gold') seedlings were potted in each substrate and fertilized similarly for plant growth determinations. Over the 4-week experiment P had approximately 13% of the available substrate N immobilized followed by PB with 29% and PTS had the highest at 68%. Substrate $CO_2$ efflux rates were twice as high in PTS than in PB and nearly five times as high as in P indicating higher microbial activity. Plant growth was highest in P and lowest in PTS. Results indicate that the high microbial activity, and thereby higher N-immobilization that occurs in PTS, is a likely reason for the reduced**

**plant growth compared to P and PB. With increased N applications to PTS during crop production plant growth is similar to that of P and PB.**

## INTRODUCTION

For the past 30 years P and PB have been the main constituents of container substrates in the horticulture industry. Peat moss is especially important in the industry because it is a stable material, light weight, and readily available. However, P is a non-renewable resource, and it is mined from wetlands which raises environmental concerns. Since most P utilized in the U.S. is mined and shipped from Canada, increasing energy and transportation costs are increasing its cost as well. Pine bark of consistent quality and quantity is getting more difficult to obtain and will be even less available in the future based on current trends (Lu et al., 2006). The decreased availability of PB substrate is due to several factors including a decrease in timber production, use as a potting soil ingredient for the retail consumer market, and its use as a landscape mulch (Griffith, 2007). Alternative substrates for container production of horticultural crops are therefore important. Much work has been published on the use of alternative substrates produced from wood and wood based products as suitable substrates, or substrate components, in horticulture crop production (Jackson et al., 2006; Boyer et al., 2007;).

Work in Europe has been conducted for over two decades on the development of alternative and renewable substrates composed of wood. Researchers have had success using wood substrates, and have developed several commercialized products currently available to growers (Penningsfeld, 1992; Gruda and Schnitzler, 1999). More recently at Virginia Tech, PTS has been developed from chipped delimbed loblolly pine logs to successfully produce numerous annual, herbaceous, and woody crops (Wright and Browder, 2005; Wright et al., 2006). However, the problem with wood substrates is their requirement for higher fertilizer applications to achieve optimal plant growth. Jackson et al., (2006) reported that Japanese holly (*Ilex crenata* Thunb.'Compacta') required an additional 2.3 kg·$m^{-3}$ (4 lb·$yd^3$) of controlled release fertilizer when grown in PTS to achieve comparable growth to plants grown in PB. The amount of additional fertilizer required for optimal growth of woody crops in PTS will likely vary depending on plant species, irrigation regime, etc. Greenhouse crops have also shown the need for additional fertilizer based on work by Wright et al., (2007) and Still et al., (1972) who reported that chrysanthemums grown in a wood substrate require an additional 100 ppm N to perform as well as plants grown in a commercial P substrate. It has been hypothesized that N-immobilization is the primary reason for the lower nutrient levels that are reported in growth trials when using PTS, but it has not been proven (Wright et al., 2006). Numerous authors have reported that N-immobilization occurs in wood substrates during the production of horticulture crops (Handreck, 1993a; Handreck 1993b; and Bragg and Whiteley,1995); however no studies have been conducted on PTS to understand its N-immobilization rate during crop production. The higher fertilizer requirement for PTS compared to P and PB is of concern and must be addressed before PTS can become a viable container substrate for the nursery and greenhouse industries.

The objective of this work was to determine the extent of N-immobilization in PTS compared to P and PB substrates.

**MATERIALS AND METHODS**

Pine tree substrate was produced by taking wood chips from chipped delimbed pine logs (freshly harvested) and further grinding them in a hammer mill (Meadows Mills, Inc., North Wilkesboro, NC) to pass through a 4.76 mm (3/16 inch) screen. The PTS was used fresh (uncomposted) and incorporated with 0.6 kg·$m^{-3}$ (1 lb·$yd^{-3}$) $CaSO_4$. Peat and PB were incorporated with 3.5 kg·$m^3$ (6 lb·yd$^3$) dolomitic lime and 0.6 kg·m$^{-3}$ (1 lb·yd$^{-3}$) $CaSO_4$. Containers were filled with each respective substrate and stored fallow on greenhouse benches. Twelve day old marigold seedlings were planted in separate 2 liter (2 quart) containers filled with each of the substrates. All containers (fallow and with plants) were equally fertilized three times per week with a 200 ppm $NO_3$-N fertilizer derived from $Ca(NO_3)_2$ and $KNO_3$ sources as outlined by Handreck (1992) and placed on greenhouse benches for the duration of the experiment in Blacksburg, VA.

Every 7 days three single container replications of each substrate were taken from the greenhouse and prepared for nitrogen drawdown index (NDI) testing to determine N-immobilization (Handreck, 1992). N-immobilization was determined weekly and was estimated by measuring the difference in $NO_3$-N available in the substrate solution after different lengths of incubation. The NDI value is represented as a range between 0-1 with a value of 1 representing no N-immobilization and a value of 0 representing complete (severe) N-immobilization. After 4 weeks shoot dry weights of marigold plants were determined on six container replications of each substrate. Substrate $CO_2$ efflux (respiration) rates (µmol $CO_2 \cdot m^{-2} \cdot s^{-1}$) were also determined for each substrate using a LI-6200 (LI-COR, Lincoln, NE) and a $CO_2$ flux soil chamber designed to take nondestructive respiration measurements from the substrate filled containers. Substrate $CO_2$ efflux is considered an assessment of microbial metabolic activity and therefore is an indicator of the potential for N-immobilization to occur (Wang, 2003). The experiment was a completely randomized design and data were analyzed using GLM procedures and means separation using Least Significant Differences ($P$ = 0.05).

**RESULTS AND DISCUSSION**

Results from the NDI show that PB and PTS have significantly higher rates of N-immobilization occurring over 4 weeks than does P (Figure 1). Pine bark had 29% of the plant available N lost to microbial immobilization over 4 weeks while PTS lost 68% respectively. N-immobilization did occur in P during the first two weeks (Figure 1), but the total N loss was only 13%. The initial drawdown may explain why commercial P substrates are often pre-charged with a quick release N source to compensate for this initial loss. The severity of N-immobilization decreases during the four weeks for all substrates suggesting that less fertilizer is required after the first 2-3 weeks of plant production to satisfy the needs of the plants and microbial immobilization of N. The authors have made personal observations that the initial fertilizations during the first week of herbaceous plants (after being transplanted into PTS) are the most critical for plants in PTS to perform as well as plants in P or PB. Data from the NDI analysis showing significantly higher rates of N-immobilization in PTS compared to P and PB during the first 3 weeks helps to explain the possible reason for those observations.

Substrate respiration rates were highest in PTS followed by PB (Figure 2), indicating increased microbial activity in these substrates. Microbial activity (as measured by the $CO_2$ efflux) in PTS was twice as high as PB and nearly five times higher than P, likely due to the higher C:N ratio of both PTS and PB compared to P. Plant growth decreases as $CO_2$ efflux increases in PB and PTS, with PTS plants being less than half the size of plants in P and PB (Figure 2). Longer N-immobilization evaluations are needed to monitor N losses in PTS over several months so that long term fertility management strategies can be determined. Also, future work needs to be conducted on nutrient leaching from PTS, which is a second potential reason for the higher fertilizer requirement; in addition to the N-immobilization that we now know is occurring.

The work reported in this paper is part of an in-depth multifaceted evaluation of the fertility requirements and management recommendations for growing crops in PTS. Despite the higher fertilizer requirement, the potential for PTS to be successfully used in greenhouse and nursery crop production is evident in the promising results that have been reported in recent years. Although there is an added production cost associated with extra fertilizer, there are cost advantages with PTS compared to P and PB substrates. For example PTS can be ground to a particle size that will provide acceptable water and aeration levels in the substrate (comparable to P) (Saunders et al., 2006), without the added expense of incorporating perlite or vermiculite which are normally added to P. Unlike PB, composting/aging of PTS is not needed, making it readily available to growers to meet immediate substrate demand. Also, PTS can be produced locally where loblolly pine trees are grown, reducing transportation costs associated with P and PB.

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**Figure 1.** Nitrogen Drawdown Index (NDI) on peat (P), pine bark (PB), and pine tree substrate (PTS) when fertilized at 200 ppm N. NDI values range from 0-1, with 1 representing no N-immobilization, and 0 representing total (severe) N-immobilization.

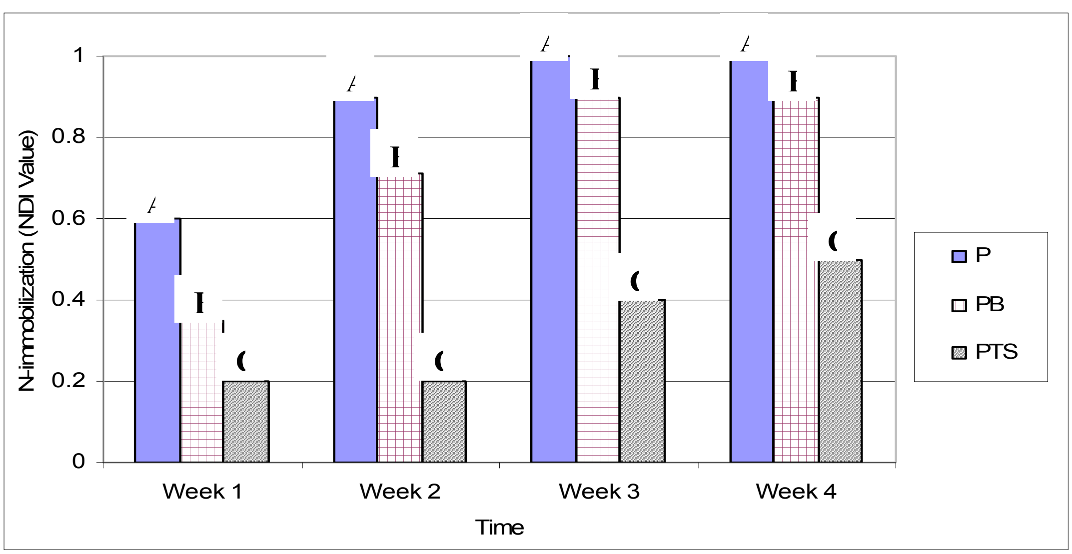

**Figure 2.** Substrate $CO_2$ efflux (µmols $CO_2 \cdot m^{-2} \cdot s^{-1}$) of peat (P), pine bark (PB) and pine tree substrate (PTS) after 28 days when fertilized at 200 ppm N, and shoot dry weight of marigolds after 28 days grown in each substrate.