Pine Bark Physical Characteristics Influence Pour-through Nitrogen Concentrations

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Abstract. Pine bark (PB), either unamended or amended with sand (S) at 9 PB: 1 S or 5 PB: 1 S (v/v), was fertilized with solutions of 100,200, or 300 mg N/liter solution and tested for N concentration using the pour-through method (PT). PB, 9 PB: 1 S, and 5 PB: 1 S had porosities of 84%, 75%, and 66%, respectively. PT NO₃-N concentrations, obtained via PT, of the 5 PB: 1 S substrate were 43%, 28%, and 15% higher than PB NO₃-N values for the 100,200, and 300 mg-liter⁻¹ treatments, respectively. Differences in N concentration obtained with PT can be attributed to substrate physical characteristics. Based on the results, data for PT should be interpreted with regard to substrate porosity.

The pour-through method (PT), essentially a displacement method to sample the substrate solution of soilless media, has been shown to be a relatively quick and reliable technique of substrate analysis for container-grown plants (Yeager et al., 1983). Furthermore, N, P, and K concentrations and pH levels for PT used with a pine bark substrate have been shown to be highly correlated with levels of the saturated media extract method (Yeager et al., 1983). For nurseries in the eastern United States, pine bark is the most commonly used substrate for container-grown plants and is used unamended or amended with sand. Growers report that sand is incorporated to increase water-holding capacity and to add weight to the substrate to keep containers from falling over during windy conditions. Brown and Porkorny (1975) found that amending pine bark with sand decreased percolation rate and increased bulk density. However, there are no reports on how the altered substrate physical properties influence N concentrations for PT, which is an important aspect because the bark : sand ratio varies considerably between growers. The objective of this experiment was to determine how amending pine bark with sand influences the N concentration for PT.

Materials and Methods

Dolomitic limestone (3 kg·m⁻³)-amended pine bark (PB) was amended with sand (S) at ratios of 9 PB : 1 S or 5 PB : 1 S (v/v); unamended bark served as a control. Substrates were analyzed for particle size, drainage volume, solids percentage, total porosity (TP), air space (AS), container capacity (CC), available (AW) and unavailable water (UW) at 1.5 MPa tension, and bulk density (BD) at the Horticultural Substrates Laboratory, Dept. of Horticultural Science, North Carolina State Univ., Raleigh. Substrate analysis was conducted using five aluminum cylinders (volume = 347.5 cm³, diameter = 7.6 cm, height = 7.6 cm) per substrate, using packing procedures described by Bilderback et al. (1982). Separate substrate samples were used to determine water retention using procedures of Milks et al. (1989).

To determine TP, AW, UW, and AS for each substrate, a base plate was attached to each aluminum cylinder. This base plate consisted of an inner and outer plate with eight holes in each plate. Plates were fitted together as one unit to rotate so that holes could be aligned in the open position to allow drainage through plates or rotated in the opposite direction to a closed position to prevent any seepage of water through plates. Each unit (cylinder with attached base plate) was placed in a Buchner funnel that had been modified to accept the unit into a fixed position where the outside plate would not move. Rubber stoppers were inserted into the bottom of funnels. Units were rotated into the open position, and distilled water was added between cylinder and funnel walls to move through the base

plate. Water was added slowly in a step-wise fashion to prevent air entrapment, as outlined in Karlovich and Fonteno (1986). Water level was eventually brought to the top of the substrate and allowed to equilibrate for 15 min. The base plate was then closed by carefully rotating the unit with no disturbance to cylinder contents. Rubber stoppers were removed, and water from around the units was allowed to drain. A graduated cylinder was placed under each funnel, and the base plate was opened and the sample allowed to drain for 60 min. After drainage, the units were removed from the funnels, and the base plates were detached from cylinders. Wet weights of the samples were recorded. Samples were placed in a forced-air drying oven at 110°C for 24 h, and dry weight was recorded. Container capacity (percent volume) was defined as (wet weight – oven dry weight)/volume. Air space was the volume of water drained from the sample/volume of sample. Total porosity was CC + AS. An estimate of UW water was defined as the amount of water held at 1.5 MPa. Using pressure plate extraction and procedures of Milks et al. (1989), available water was determined for each sample as CC – UW. Substrate physical characteristics data were subjected to analysis of variance (ANOVA) (SAS) and mean separation at $P \leq 0.5$ using the Wailer–Duncan k ratio *t* test (k ratio = 100).

About 3.5 liters of each substrate type was added to a 3.8-liter plastic container, set on a metal mesh bench in a glasshouse, and irrigated with a breaker-equipped hose to initially settle bark. Container height and diameter were 17 and 15 cm, respectively. For 4 weeks, ≈ 850 ml of either 100,200, and 300 mg N/liter was applied to each container (all substrate treatments) on Monday, Wednesday, and Friday with a water breaker-equipped hose in concert with a fertilizer proportioner (venturi principle). This relatively large application volume (applied to all substrates) resulted in considerable leaching, which minimized salt accumulation in the substrate. Nitrogen source was a soluble dry fertilizer (Peters Potash Special, 20N–2.1P–24.9K, Grace-Sierra, Fogelsville, Pa.) with N in the form of NO₃-N (8.8%), NH₄-N (1.0%), and urea (10.2%). After the third and fourth weeks of fertilization, substrate solutions were obtained 1 h following irrigation using PT in which each container was placed into a shallow collection tray and 100 ml tap water, containing 5 mg Fe/liter as FeEDTA, was applied to the bark's surface. Iron chelate is relatively stable and noninteractive with other cations (Norvell, 1972) in the pH of this substrate (5.2); chelate was used as a tracer to determine the degree of channeling of the applied solution from the substrate. Polyvinyl chloride rings were placed between container bottom and tray to prevent substrate from interacting with the collected solution. PT solution (leachate) volume was measured and analyzed for NH₄-N and NO₃-N using ion-selective electrodes. The Fe concentration was analyzed using an atomic absorption spectrophotometer. The experiment was conducted twice in a factorial arrangement (three substrates × three N concentrations); because re-

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suits of both experiments were very similar, only data from the second experiment are shown. Containers were arranged in a randomized complete-block design-with one container per treatment in each of six blocks. Nutrient concentrations and volumes of solution collected with PT were subjected to ANOVA (SAS).

Results and Discussion

Relative to 100% pine bark, amending pine bark with sand resulted in decreased TP, drainage, AS, and UW; increased solids, AW, BD, and the proportion (by weight) of the smaller particle sizes; and container capacity was unaffected (Tables 1 and 2). Brown and Porkorny (1975) also showed similar findings regarding BD, and proportion of smaller particle sizes. Of interest and previously unreported was the finding that CC values were the same for PB and sand-amended PB; however, PB had 9% less AW (absolute basis) than 5 PB : 1 S. Apparently, the addition of sand created micropores that held water less strongly than the surface and intraparticle water adsorption sites of PB.

Data for PT for the third and fourth week of fertilization were similar, and therefore only data for week 3 will be presented and dis-

cussed. Nitrate concentrations increased as N application rate increased (Tables 3 and 4). Although the PT solution was not measured for urea-N (a constituent of the fertilizer), the urea concentration in it likely was similar to that of $\text{NO}_3\text{-N}$ due to the lack of a positive charge on the urea molecule. In addition, the transitory nature of urea in pine bark was demonstrated by Wright (1987), who showed that 71% of urea-N was hydrolyzed in 24 h. Nitrate concentrations also increased when sand was added to the pine bark (Tables 3 and 4) and can be explained on the basis of substrate physical characteristics. In determining drainage values, bark is saturated and allowed to drain. After saturation, PB (84% porosity) drained nearly six times more volume than 5 PB : 1 S (66% porosity) (Table 2). This result implies a much greater macropore fraction in PB than 5 PB : 1 S and hence more voids for applied PT solution to channel through the substrate with less opportunity for this solution to displace (or intermix with) that held in micropores. Brown and Porkorny (1975) also showed a decrease in percolation when sand was added to pine bark. The lower amount of AS (percentage of pore volume that drains) of the 5 PB : 1 S compared to PB (Table 2) is directly related to particle size distribution (weight basis) in which 64.7% of the 5 PB : 1

S particles were ≤ 0.5 mm, whereas only 25.1% of the PB substrate particles were ≤ 0.5 mm (Table 1). Because hydraulic conductivity is directly related to pore size and geometry (Brady, 1974), the greater proportion of small pores of 5 PB : 1 S allowed for less percolation and more dispersion of the PT solution than PB (Ross, 1989). Evidence for this explanation was demonstrated when Fe chelate was added to 100 ml PT solution. Iron concentration of PB was about four times higher than that of 5 PB : 1 S, substantiating the greater degree of solution channeling through the more porous PB and a greater displacement effect in the sand-amended substrates (Tables 3 and 4). The substrate $\times$ N treatment interaction for Fe (Table 3) was due to the relatively high Fe concentration found with the 300 mg N/liter treatment for PB. We believe that this interaction is not of practical importance and maybe related to the occasional variable nature of micronutrient detection in a pine bark substrate (Leda, 1986). About 25% more solution was displaced in 5 PB : 1 S than in PB PT volume (Tables 3 and 4), again indicating the greater displacement capacity of applying a liquid to a substrate with a greater bulk density.

Ammonium concentrations, as those for $\text{NO}_3\text{-N}$, were higher with increasing N concentration applied. In contrast to $\text{NO}_3\text{-N}$ concentration, a substrate $\times$ N treatment interaction (Table 3) showed that $\text{NH}_4\text{-N}$ concentrations were higher for PB than for sand-amended PB at the high N treatment, in which $\text{NH}_4\text{-N}$ concentrations in PB increased (with increasing N application) at a greater rate (PB linear regression line slope = 0.28) than in sand-amended substrates (9 PB : 1 S and 5 PB : 1 S linear regression line slopes = 0.21) (Table 4). The reason for this interaction is not understood.

Because each substrate held the same volume of water after saturation and drainage (CC) (Table 2), the $\text{NO}_3\text{-N}$ concentration can also be interpreted on the basis of mechanisms that may affect $\text{NO}_3\text{-N}$ retention in each substrate. Pine bark held more UW and less AW than sand-containing substrates (Table 2). The high unavailable water content would be assumed to be tightly bound around bark particles and in vesicles inside bark particles even at low tensions, such as after drainage (0 kPa), despite the fact that percent volume of unavailable water was measured at a much higher tension (1.5 MPa). This bound water likely contained applied $\text{NO}_3\text{-N}$. A case for this can be inferred where $\text{NO}_3\text{-N}$ concentrations were higher for 5 PB : 1 S than 9 PB : 1 S as well as for PB.

These results can be interpreted to demonstrate that PT testing of a porous substrate will yield lower N concentrations than for a substrate amended with sand even when both substrate types receive the same fertilization. Thus, data obtained for PT must be interpreted in view of substrate porosity. The difference in $\text{NO}_3\text{-N}$ concentrations obtained with PT between substrates, regardless of N application concentration, are marginally significant in terms of the current interpretation of N suffi-

Table 1. Particle-size distribution of screened aged pine bark (PB), 9 PB : 1 coarse sand (S) (v/v), and 5 PB : 1 S (v/v) substrates.^a

NBS sieve #	Sieve opening (mm)	Particle distribution in substrates (% wt of sample collected on each screen)		
		PB	9 PB : 1 S	5 PB : 1 S
0.25	6.40	10.7	5.1	2.5
5	4.00	14.0	5.9	3.1
7	2.80	11.7	7.1	4.8
10	2.00	11.1	7.7	6.1
14	1.40	9.5	7.7	5.3
18	1.00	8.7	7.5	5.4
25	0.71	9.4	10.0	8.3
35	0.50	8.7	12.2	12.2
45	0.36	5.5	11.8	14.2
60	0.25	4.4	11.2	15.7
80	0.18	2.4	6.0	9.9
140	0.11	2.1	4.4	7.1
pan	0.00	2.0	3.4	5.6

^aEach value represents the mean of five air-dried samples.

Table 2. Physical properties of substrates.^a

Substrates	Drainage ^b (ml)	Solids ^c	Total porosity ^d (%)	Air space ^e (%)	Container capacity ^f (% vol)	Unavailable water ^g	Available water ^h	Bulk density ⁱ (glee)
PB (ml)	70.4 a	16	84 a	20 a	64 a (221)	39 a (137)	24 c (83)	0.19 c
9 PB : 1 S (ml)	39.2 b	25	75 b	11 b	64 a (222)	37 b (127)	27 b (95)	0.38 b
5 PB : 1 S (ml)	12.2 c	34	66 c	3 c	63 a (218)	29 c (102)	33 a (116)	0.69 a

^aAnalysis performed using standard aluminum soil sampling cylinders (7.6 cm id., 7.6 cm high). Mean separation in columns by Waller-Duncan k ratio t test (k ratio = 100), $P = 0.05$. Each value represents the mean of five cylinders.

^bDrainage = amount (in milliliters) of water drained from each cylinder after saturation before container capacity was reached.

^cSolids = total porosity - 100. Represents the total volume (in percentage) of solids in each substrate.

^dTotal porosity is equal to container capacity + air space.

^eAir space was the volume of water drained from the sample $\div$ volume of the sample.

^fContainer capacity was (wet weight - oven dry weight) $\div$ volume.

^gPercent volume at 1.5 MPa.

^hCalculated as the difference between container capacity and unavailable water.

ⁱGrams per cubic centimeter after drying samples in a forced-air drying oven at 110C for 24 h.

Table 3. Standard error of means and sums of squares from analysis of variance for NO₃-N, NH₄-N, Fe (mg-liter⁻¹), and volume (in milliliters) obtained from PT after 3 weeks of N applications.

Source	df	Sums of squares			
		NO ₃ -N	NH ₄ -N	Fe	Volume
Block	5	293.5 ^{ns}	64.7 ^{ns}	0 ^{ns}	302.3 ^{ns}
Substrate	2	5261.8***	544.8***	4.6***	3075.1***
N rate	2	131266.6***	19738.0***	0.2*	459.4*
Substrate × N rate	4	370.1 ^{ns}	369.1**	0.3*	481.7 ^{ns}
SE ±		7.05	2.74	0.04	1.55

^{ns}, *, **, *** Nonsignificant or significant at *P* = 0.05, 0.01, or 0.001, respectively.

ciency or inadequacy. However, as research further defines substrate solution N adequacy concentrations and government regulations mandate reduced runoff, understanding how amending substrates affects physical characteristics and subsequent interpretation of PT analysis will become increasingly important.

Literature Cited

- Bilderback, T.E., W.C. Fonteno, and D.R. Johnson. 1982. Physical properties of media composed of peanut hulls, pine bark and peatmoss and their effects on azalea growth. *J. Amer. Soc. Hort. Sci.* 107:522-525.
- Brady, N.C. 1974. The nature and property of soils. 8th ed. Macmillan, New York.
- Brown, E.F. and F.A. Porkorny. 1975. Physical and chemical properties of media composed of milled pine bark and sand. *J. Amer. Soc. Hort. Sci.* 100:119-121.
- Karlovich, P.T. and W.C. Fonteno. 1986. Effect of soil moisture tension on the growth of chrysanthemum in three container media. *J. Amer. Soc. Hort. Sci.* 111:191-195.
- Leda, C.E. 1986. Iron and manganese requirements of containerized plants grown in pine bark. MS Thesis, Virginia Polytechnic Inst. and State Univ., Blacksburg.
- Milks, R.R., W.C. Fonteno, and R.A. Larson. 1989. Hydrology of horticultural substrates: II. Predicting physical properties of media in containers. *J. Amer. Soc. Hort. Sci.* 114:53-56.
- Norvell, W.A. 1972. Equilibria of metal chelates in soil solution, p. 115-138. In: J.J. Mortvedt, P.M. Giordano, and W.L. Lindsay (eds.). *Micronutrients in agriculture*. Soil Sci. Soc. Amer., Madison, Wis.
- Ross, S. 1989. *Soil processes: A systematic approach*. Routledge, New York.
- Wright, R.D. 1987. Nitrogen availability from urea in a pine bark medium. *HortScience* 22:70-72.
- Yeager, T.H., R.D. Wright, and S.J. Donohue. 1983. Comparison of pour-through and saturated pine bark extract N, P, K, and pH levels. *J. Amer. Soc. Hort. Sci.* 108:112-114.

Table 4. Concentrations of NO₃-N, NH₄-N, and Fe in solution and volume of solution collected at the end of the third week of N application of a PT test in which 100 ml of tap water containing 5 mg Fe/liter had been applied to each substrate.

Substrate ¹	N applied (mg-liter ⁻¹)		
	100	200	300
<i>NO₃-N recovered (mg-liter⁻¹)</i>			
PB	46 ²	104	164
9 PB : 1 S	53	125	175
5 PB : 1 S	66	132	188
<i>NH₄-N recovered (mg-liter⁻¹)</i>			
PB	10	32	65
9 PB : 1 S	8	27	50
5 PB : 1 S	9	27	52
<i>Fe recovered (mg-liter⁻¹)</i>			
PB	0.87	0.66	0.1
9 PB : 1 S	0.47	0.26	0.1
5 PB : 1 S	0.17	0.14	0.
<i>Volume of solution recovered (ml)</i>			
PB	61	69	56
9 PB : 1 S	72	69	68
5 PB : 1 S	75	86	80

¹PB = pine bark, S = sand.