IMPROVING NUTRIENT AND MOISTURE RETENTION IN PINE BARK SUBSTRATES WITH ROCKWOOL AND COMPOST COMBINATIONS

T. E. Bilderback and W.C. Fonteno
Department of Horticultural Science,
North Carolina State University,
Raleigh, NC 27695-7609 USA

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Abstract

Cotoneaster dammeri Schneid.'Skogholm' were potted into combinations of pine bark (PB), horticultural rockwool (RW), composted municipal yardwaste (CYW), composted turkey broiler litter (TBL) and washed builders sand (S). The objective of the study was to characterize the physical and chemical properties and subsequent plant growth and foliar tissue levels of the resultant substrates. Of the physical parameters tested the three component substrates PB:RW:CYW and PB:RW:TBL (70:20:10 by v) appeared to have the most consistent favorable physical properties with higher total porosities and available water content, equivalent air space and container capacity and lower unavailable water content than the pine bark control substrate. Electrical conductivity (EC) was extremely high the first day after initiation (DAI) in the substrates containing TBL but was not different for other sampling dates. Leachate pH initially ranged from 4.9 to 6.1 but through most of the study ranged from 5.2 to 5.8. As with EC all nutrient levels were very high one day after initiation. Leachate phosphate levels were maintained at recommended levels in the substrates containing TBL throughout most of the study while other substrates were generally deficient. The same was true for foliar tissue phosphate levels. The greatest top dry weight was yielded in the PB:RW:TBL (70:20:10, by v) substrate and least in the PB:S (80:20) substrate.

1. Introduction

Container nurseries in the Southeastern United States, have evolved to use of frequent irrigation ,porous substrates and slow release fertilizers which provide rapid plant growth with few disease problems. However, organic pine bark substrates have low anion and cation exchange capacities therefore these practices can lead to excessive leaching of nutrients and have potential water quality environmental impacts. Solid waste management of urban yardwastes and agricultural animal wastes have also become environmental concerns in the U.S. and composted wastes are being targeted for use in the nursery industry.

Preliminary studies have indicated that addition of composts to porous substrates have limitations by volume due to loss of air space and animal waste composts have high nutrient capacity factors. Granulated horticultural rockwool appears to have properties which can increase air space when added to coarse pine bark substrates amended with composts (Bilderback and Fonteno, 1990). In 1990, turkey broiler litter compost was added at 15, 25 and 33 percent (by volume) to pine bark or pine bark and horticultural rockwool substrates. The results of the study indicated that turkey broiler litter compost when blended with pine bark maintained higher phosphate and other nutrient levels during the growing season in substrates and plant tissue than pine bark alone, while rockwool increased air space when compost was used. Use of both components with pine bark produced growth equal to the pine bark control substrate for *Cotoneaster dammeri* 'Skogholm' and suggested that these materials could be beneficial in commercial nursery potting substrates. However further studies appeared to be necessary to establish more optimal component ratios to reduce the negative effects of the turkey broiler litter compost which were loss of air space, available water content and excessive initial soluble salt levels. The objective of this study conducted in 1991 was to evaluate physical and chemical parameters and plant response to the addition of yardwaste and turkey broiler litter composts as components for potting substrates when added at 10 percent (by volume) in combination with pine bark and horticultural rockwool.

2. Materials and Methods

2.1 Experimental Procedures

The experiment, a randomized complete block design with six replications, was conducted at North Carolina State University, Raleigh. The main factors were: twelve substrate combinations of pine bark , granulated horticultural rockwool, yardwaste compost, turkey broiler litter compost and coarse builders sand and two irrigation frequencies (1 or 2 days). The effects of daily irrigation and six substrate combinations will be reported in this manuscript. Uniform rooted cuttings of `Skogholm' cotoneaster were potted into 2.7 l containers on 23 May 1991. Pine bark screened to pass 12.3 mm was amended on a m^3 basis with 3.0 kg dolomitic limestone. No dolomitic limestone was added to substrates containing composts as previous work had indicated that the calcium levels in compost were approximately equivalent to 3.0 kg of dolomitic limestone. All substrates were amended with 0.59 kg Step micronutrient fertilizer and 6.0 kg of Scotts 20N-1.3P-8.3K (O.M. Scotts, Marysville, Ohio) per m^3 on 23 May 1990 (Day 0). All plants received 800 ml of water daily via Netafim 7.6 l/hr pressure compensated emitters (Netafim Irrigation Products, Inc.).

2.2 Foliar tissue and leachate water analysis

On 1 October 1991, the shoots (aerial tissue) of both species were removed and dried at 60°C for 96 hours. Leaves were removed and ground in a Wiley mill to pass a 40 mesh (0.525 mm) screen. Each tissue sample (1.25 g) was combusted at 490°C for 6 hr. The resulting ash was dissolved in 10 ml of 6 N HCl and diluted to 50 ml with distilled deionized water. Phosphorus, K, Ca and Mg concentrations were determined by inductively coupled plasma emission spectroscopy (Perkin Elmer Plasma II emission spectrometer). Nitrogen was determined using 10 mg samples in a Perkin Elmer 2400 CHN elemental analyzer. All analyses were conducted at the Analytical Service Laboratory, Dept. of Soil Science, North Carolina State Univ., Raleigh. The medium solution was extracted from containers via VTEM pour-through nutrient extraction method (Wright, 1986) and were collected one day after initiation (DAI) and on days 22, 42, 63 and 84 for a total of 5 collection dates. The pour-through samples were obtained by pouring 150 ml of distilled water on the medium surface 2 hr after irrigation and collecting the leachate. The samples were filtered through Whatman #1 paper and immediately frozen until analysis. Solution samples were analyzed for Nitrate-N (Calaldo et al. 1975), NH_4-N (Chaney and Marback 1962) and P (Chapman and Pratt 1961) by colormetric procedures using a spectrophotometer (Spectronic 1001 Plus, Milton Roy Co., Rochester, NY.). Leachate solution pH and electrical conductivity were measured with a pH and conductivity meter, respectively in the Horticultural Substrates Laboratories. Potassium , Ca, Mg and other elements were determined by inductively coupled plasma emission spectroscopy (Perkin Elmer Plasma II emission spectrometer) at the Analytical Service Laboratory , Department of Soil Science.

Irrigation water, which was sampled at each collection time, averaged: NO_3-N, 0.05 mg/l; NH_4-N, 0.34 mg/l; P, 0.2 mg/l; K, 0.0 mg/l; Ca, 16.3 mg/l; Mg, 2.5 mg/l; pH, 7.8; and electrical conductivity, 0.16 $dS{\cdot}m^{-1}$.

2.3 Physical properties analysis

All physical properties were conducted in the Horticultural Substrates Laboratory, Department of Horticultural Science, North Carolina State University, Raleigh, N.C. Eight containers of each of the pine bark, yardwaste compost, turkey broiler litter compost and rockwool combinations were filled at initiation of the study. Aluminum cylinders (347.5 cc, 7.6 cm dia. X 7.6 cm h) subsamples were placed in each of the 8 containers as they were filled with substrate following the procedures of Warren and Bilderback (1992). These containers were irrigated daily for 16 weeks before the cylinders with intact, naturally compacted medium were extracted. The subsamples were used to determine total porosity, container capacity and air space,. Additional substrate in each of the sampled containers was used to determine water retention at 1.5 MPa, using procedures of Milks et al. (1989).

In order to determine total porosity, water holding capacity and air space for each substrate/treatment combination, a base plate was attached to each aluminum cylinder. This aluminum base plate consisted of an inner and outer plate with 8 holes in each plate. The plates were fitted together as one unit to rotate so that the holes could be aligned in the open position to allow drainage through the plates or rotated in the opposite direction to a closed position to prevent any seepage of water through the 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 the funnels.

The units were rotated into the open position and distilled water was added in between the aluminum cylinder and the Buchner funnel walls to allow water to be absorbed 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 where it was allowed to equilibrate for an additional 15 minutes.

The base plate was then closed by carefully rotating the unit with no disturbance to the contents in the cylinder. Rubber stoppers were removed and water from around the units was allowed to drain away. A graduated cylinder was placed under each funnel, the base plate opened and the sample allowed to drain for 60 minutes. After drainage the units were removed from the funnels and the base plates were detached from the cylinders. Wet weights of the samples were recorded. Samples were placed in a forced-air drying oven at 110° C for 24 hours and dry weight recorded. Container capacity (CC) (% volume) was defined as (wet weight-dry weight)/volume. Air space (AS) was the volume of water drained from the sample/ volume of sample. Total porosity (TP) was CC + AS. The effects of incorporation rate within substrate on TP, CC and AS were examined using regression. An estimate of unavailable water (UW) was defined as the amount of water held at 1.5 MPa. Available water capacity (AWC) was determined for each sample as CC - UW using pressure plate extraction and procedures of Milks et al. (1989).

Data was subjected to analysis of variance and regression analysis (SAS Institute, Cary, NC). Mean separation within columns of tables followed by the same letter or letters were not significantly different at the 5% level using Waller-Duncan k-ratio t-test (k-ratio =100).

3. Results and Discussion

3.1 Particle Size Distribution

The addition of composted municipal yard waste (CYW) to pine bark slightly increased the percent weight of particles collected on sieves with openings of 2.0 and 1.4 mm and had slightly fewer particles on the 0.5 sieve as compared to unamended pine bark (Table 1). The Turkey broiler litter compost (TBL) in pine bark increased particles on the 2.8, 2.0 and 1.4 mm sieves compared to pine bark and decreased particles on the 0.71 and 0.5 sieves. Rockwool and compost additions to pine bark reduced particle weight collected on the 4.0, 2.8, 1.0, 0.71 and 0.50 mm sieves and increased particle weight on sieves < 0.36. The composts did not increase the fine particles (< 0.5 mm) however addition of rockwool did. Addition of sand to pine bark in substrate reduced the percent weight of particles collected on larger sieves (6.4 to 1.4 mm) and increased the percent weight of particles collected on sieves with openings < 1.0 mm.

3.2 Physical Properties

Total porosity of all substrates ranged from 81 to 86 % volume with the exception of the pine bark: sand (80:20) substrate (Table 2.). The three component PB:RW:TBL had the highest total porosity but was not higher than the PB:TBL. Air space was decreased with the addition of sand to pine bark well below air space values for all other substrates. Container capacity was least among the substrates in the PB: CYW treatment.

The largest volume of unavailable water was held in the PB:TBL (90:10) substrate. Addition of RW to substrates decreased unavailable water content in three component substrates. The PB:S had the lowest unavailable water content. The greatest volume of available water capacity was held by the PB:S and PB:RW:CYW. The least amount of available water capacity was held by the pine bark : compost two component substrates and pine bark. Of the physical parameters tested three component substrates PB:RW:CYW and PB:RW:TBL (70:20:10) appeared to have the most consistent favorable physical properties of higher total porosity, and available water capacity; equivalent air space and container capacity and lower unavailable water content than the pine bark control substrate.

3.3 Container Solution Capacity Factors (Data not Shown, except for Phosphorus)

Electrical conductivity (soluble salts) was extremely high on day 1 after potting in substrates containing TBL. The PB:RW:TBL had an EC value of 4.5 $dS \cdot m^{-1}$ which was higher than all other treatments. The PB:TBL and 90:10) had an EC value of 3.1 $dS \cdot m^{-1}$, and was higher than all other treatments. The PB, PB:CYW and PB:S treatments ranged from 1.7 to 2.0 and were not different among treatments with the exception to the TBL substrates. High EC levels were apparently due to high leachate concentrations of NH_4-N, P, and K. Electrical conductivity was not significantly different on any other sampling dates.

Leachate pH initially ranged from 4.9 to 6.1. During the study pH increased and all substrates ranged from 5.2 to 5.8 and were not significantly different among treatments on day 42. The pH then decreased by day 84 when PB and PB:CYW treatments were 5.0 to 5.1 and the 3 component substrates ranged 5.6 to 5.8.

Leachate NH_4-N levels from VTEM extraction of 30-50 mg/l are suggested as adequate in container solution (Wright, 1986). Leachate NH_4-N were greater than 60 mg/l in all treatments on day 1 but drastically decreased and were not different among treatments on other sampling dates. NH_4-N levels ranged between 16 to 30 mg/l on day 22, 4.5 to 14.5 mg/l by day 42, and 0.1 to 4.4 mg/l by day 84. On day one, 100 to 182 mg/l NH_4-N were found in the PB:TBL and PB:RW:TBL substrates compared to the initial PB leachate level of 85 mg/l which was similar to all the CYW substrates and PB:S.

Leachate NO_3-N levels of 30-50 mg/l are suggested as adequate in container solution (Wright, 1986). Leachate NO_3-N ranged from 2.0 to 7.7 mg/l on day one and was not different among substrate treatments. Nitrate nitrogen levels increased by sampling date 22 DAI. On Day 22 the PB:RW:CYW substrate had 55.7 mg/l NO_3-N and was significantly greater than the PB:TBL substrate 23.7 mg/l. By day 84, NO_3-N levels ranged from 9.4 to 32.3 mg/l and were not different among substrates.

Leachate P levels in substrates containing TBL were very high initially, generally 3 to 4 fold greater than other substrates, however the TBL substrates also maintained leachate P within suggested solution levels through day 42 (Table 3). Substrates without TBL were well below suggested levels by day 42.

TBL substrates had higher K levels initially than other substrates with the PB:RW:TBL having 834 mg/l K while PB:TBL was 543 mg/l. However all the substrates had relatively high K leachate concentrations with 201 mg/l K in the PB leachate which was statistically the same as all other substrates with the exception of the TBL substrates. TBL substrates generally remained higher in K leachate concentrations than other substrates throughout the sampling period but fell within the 30 to 50 mg/l suggested VTEM guidelines on the third sampling date, 42 DAI. By 84 DAI, there were no differences among treatments for K leachate values which ranged from 23.7 to 31.2 mg/l.

Leachate Ca levels are suggested to be adequate if they remain between 10-30 mg/l in VTEM leachate solution. All data were above 10 mg/l Ca throughout the growing season. As with other leachates, initial concentrations were high and the TBL substrates tended to have the highest Ca VTEM leachate levels.

Mg is suggested to be adequate if VTEM leachate values remain between 10-30 mg/l in VTEM leachate solution. After the first sampling date the PB:CYW substrates tended to be low in Mg and by 22 DAI the PB:CYW 90:10 treatment had dropped to 5.9 mg/l. These substrates remained low throughout the remainder of the study. The PB and PB:S substrates amended with dolomitic limestone were 11.1 and 17.3 mg/l at 84 DAI. All RW containing substrates maintained adequate Mg levels, indicating that the RW may have contributed to Mg nutrition in this study. The irrigation water contained 2.5 mg/l. This data indicates that some Mg supplementation may be required to maintain Mg levels in substrates containing composts.

Leachate Fe was similar for all treatments. A zinc: iron interaction due to high Zn levels is sometimes a concern when composts are used in potting substrates. No problems were apparent in leachate or foliar data. Cadmium, lead and nickel leachate levels were undetectable in all treatments of either species.

3.4 Plant Growth Response

The greatest top dry weight of was yielded in the PB:RW:TBL (70:20:10) substrate but this treatment was not different from the PB:TBL (90:10) substrate (Table 4). The least growth growth occurred in the PB:S substrate. Root dry weights were not significant among substrate treatments.

3.5 Foliar Nutrition:

'Skogholm' cotoneaster tissue levels were from samples collected at the end the growing season. Most guidelines for foliar tissue nutrient levels are express as mid-season optimal levels as given in the table (Jones, 1991). Substrates containing TBL had foliar P levels twice as high as PB and generally higher than substrates without TBL although all the P levels would have been considered deficient by the guidelines given . Nitrogen levels were low compared to the guidelines and tended to be lowest in substrates containing TBL and corresponds with leachate data which indicated greater solubility earlier in the year. Potassium and Ca foliar levels were generally within ranges suggested while Mg foliar levels for all treatments were some what higher than suggested and indicate that even in the PB:CYW and PB:TBL treatments where Mg solution levels were low through much of the study, adequate Mg absorption occurred . The foliar Ca data indicated the addition of the CYW and TBL yielded approximately equivalent foliar values as the dolomitic lime addition in non-compost treatments. However, as noted previously, the irrigation water contained 20 mg/l Ca and 2 mg/l Mg and may have played a roll in maintaining adequate Mg and Ca levels. Foliar tissue levels for Zn and Mn were not excessive and were not antagonistic with Fe in any treatments. Cadmium, lead and nickel levels were below detectable limits for all treatments.

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Table 1. Particle size distribution of substrates.[z]

NBS SIEVE #	SIEVE OPENING (mm)	Substrate (by volume) (% weight of sample collected on each screen)					
		PB (100%)	PB:CYW (90:10)	PB:TBL (90:10)	PB:RW: CYW (70:20:10)	PB:RW: TBL (70:20:10)	PB:S (80:20)
.25	6.40	8.39	8.14	7.27	8.03	6.18	3.77
5	4.00	12.02	12.16	11.26	10.75	9.85	5.01
7	2.80	11.63	11.08	12.14	9.94	10.21	5.54
10	2.00	11.83	12.36	13.97	11.09	12.19	7.39
14	1.40	11.16	12.05	13.29	10.87	11.13	9.63
18	1.00	11.00	11.42	11.57	9.99	9.68	12.21
25	0.71	10.58	10.26	9.64	8.94	8.32	15.30
35	0.50	8.21	7.56	6.93	7.51	7.50	14.76
45	0.36	4.71	4.34	4.02	5.25	5.61	11.20
60	0.25	3.63	3.44	3.43	5.01	5.77	8.28
80	0.18	2.05	2.09	2.27	3.27	4.08	3.16
140	0.11	2.00	2.15	2.19	3.64	4.18	2.00
pan	0.00	2.79	2.96	2.03	5.72	5.29	1.74

[z]Each value represents the mean of five oven-dried samples.

Table 2. Physical properties of substrates.[z]

Media[y]	TP	AS	CC (% Volume)	UAW	AWC	BD (g/cc)
PB	83.70c	18.48a	65.22ab	31.92b	33.30c	0.19c
PB + CYW (90:10)	81.42c	20.60a	60.82c	30.18c	30.64c	0.23bc
PB + TBL (90:10)	85.28ab	18.24a	67.04a	33.97a	33.07c	0.20bc
PB+RW+ CYW (70:20:10)	84.78bc	16.98a	67.80a	27.35d	40.45a	0.24b
PB + RW + TBL (70:20:10)	86.08a	18.07a	68.00a	28.42d	39.58b	0.22bc
PB + S (80:20)	76.62d	10.94b	65.68b	24.58e	41.10a	0.45a

[z]Each value represents the mean of 8 test samples.

Table 3 . Container leachate phosphate levels from 6 substrates on 5 sampling dates.[z]

Substrate	Sampling Dates (Days after potting) 1	22	42	63	84
Suggested leachate levels= 10-15mg/l	Phosphate Leachate Concentration (mg/l)				
PB	86.0b	11.8c	2.3c	0.7c	1.2c
PB + CYW (90:10)	66.3b	7.5c	1.9c	0.97c	1.5c
PB + TBL (90:10)	330.3a	78.5a	16.8a	8.9a	8.9a
PB+RW+ CYW (70:20:10)	41.8b	7.1c	2.2c	0.8c	1.2c
PB+RW+ TBL (70:20:10)	376.5a	43.1b	9.3b	2.2bc	2.6bc
PB + S (80:20)	84.8b	4.6c	1.6c	0.7c	1.1c

[z]Each value represents the mean of 3 containers.

Table 4. Effect of substrates on *Cotoneaster dammeri* 'Shogholm' foliar nutrient levels and top dry weight.[z]

Container Sustrate	N	Percent Foliar Tissue Dry Weight P	K	Ca	Mg	Top Dry Weight
Acceptable Levels (Mid-Season)	2.8	0.34	1.1	1.1	0.27	(g)
PB	2.1a	0.06c	1.03a	1.04c	0.45ab	65.7cd
PB + CYW (90:10)	2.1a	0.08bc	1.06a	1.23c	0.30c	64.4cd
PB + TBL (90:10)	1.5b	0.15a	0.99a	1.70a	0.34c	90.5ab
PB+RW+CYW (70:20:10)	1.6b	0.10b	0.87b	1.55ab	0.48a	84.4bc
PB+RW+TBL (70:20:10)	1.5b	0.13a	0.79b	1.46b	0.43b	103.8a
PB + S (80:20)	2.3a	0.06c	0.98a	1.08c	0.48a	50.6d

[z]Each value represents the mean of 6 plants.