Physical Properties and Microbial Activity in Forest Residual Substrates

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Significance to Industry: Many growers have expressed concern that switching from growing in a pine bark-based substrate to one with a significant wood content will increase microbial activity, resulting in nitrogen (N) immobilization. This study evaluated four growth substrates (pine bark, peat moss and two hammer mill screen sizes of clean chip residual or CCR) in a simulated 60-day production cycle. Physical properties of each substrate were different, though pine bark and CCR had more air space and less container capacity than peat moss, in general. Results of the incubation study indicate that CCR has only slightly more microbial activity than pine bark. Peat moss had the least microbial activity. This data shows that while there is a slight but significant difference between pine bark and CCR the disparity is minimal and will likely have nominal effects for fertilizer requirements as growers switch to crop production in CCR.

Nature of Work: Clean chip residual is a by-product of the pulp industry. Forest operators harvest small caliper pine trees during thinning operations and sell the 'clean chips' (99.9% wood) to pulp mills for the production of paper products. The material remaining after trees have been harvested for clean chips is either sold for boiler fuel at the pulp mill or spread back across the plantation due to lack of a market. This residual material (CCR) is composed of approximately 50% wood, 40% pine bark and 10% needles, etc. Clean chip residual has been evaluated in several studies (3, 4, 5, 6) as a replacement for pine bark since the latter is becoming increasingly difficult to obtain in production horticulture. A study by Boyer et al. (2) indicated that perennial plants (*Buddleia davidii* 'Pink Delight' Franch., *Gaura lindheimeri* 'Siskiyou Pink' Engelm. & A. Gray and *Coreopsis rosea* 'Sweet Dreams' Nutt.) exhibited similar growth whether grown in pine bark or CCR and did not require supplemental N during production. Nevertheless, tie up of nutrients in a wood-based substrate is a significant concern for many nursery crop producers. Jackson and Wright (7) reported less plant growth in a pine tree-based substrate (approximately 95% wood) due to severe N-immobilization. Therefore, the objective of this study was to measure microbial activity in pine bark, peat moss and two screen sizes of CCR (3/8-inch and 3/16-inch) over the course of 60 days in a soil incubation experiment. Substrate air space, container capacity, and total porosity were determined following procedures described by Bilderback et al. (1). Substrate bulk density (measured in g·cm3) was determined from 347 cm^3 (21 in^3) samples dried in a 105°C (221°F) forced air oven for 48 hours. Four rates of supplemental N (0, 1, 2, and 3 mg N) were added to each of the four substrates in the

study. The incubation procedure consisted of weighing 20 g (dry weight basis) of substrate into plastic containers. Samples were adjusted to similar moisture contents, treated with fertilizer (0, 0.5, 1.0 or 1.5 ml of 2000 ppm stock solution of NH_4NO_3) and placed in a sealed glass jar containing 10 ml water to maintain humidity and a vial containing 10 ml of 1 M NaOH as a CO_2 trap. Jars were placed in a dark incubation chamber at 25°C (77°F) for 60 days. Four samples of each treatment were removed at 7, 15, 30 and 60 days after treatment (total data, from 0 to 60 days, is presented) and evaluated for microbial activity. Carbon mineralization, which is a direct measurement of microbial respiration, was measured in this study. Carbon dioxide in the NaOH traps was determined by titrating the excess base with 1 M HCl in the presence of $BaCl_2$. All traps were measured at each sampling date. Data were analyzed using Waller-Duncan k ratio t tests ($P \leq 0.05$) using a statistical software package (SAS® Institute, Cary, NC).

Results & Discussion: Physical properties of the four substrates tested varied (Table 1). Percent air space among substrates was significantly different: 3/16-inch CCR having the greatest (48%) and peat moss having the least (11%). Container capacity was also different for each substrate, with peat moss having the greatest container capacity (87%) and 3/16-inch CCR having the least container capacity (42%). Both CCR treatments were similar in total porosity and were between the high of 98% for peat moss and 79% for pine bark. Bulk density was greatest for 3/8-inch CCR (0.22 $g \cdot cm^3$) and least for peat moss (0.11 $g \cdot cm^3$).

Initial substrate pH was 4.1 for pine bark, 5.0 for 3/8-inch CCR, 5.5 for 3/16-inch CCR and 4.8 for peat moss (data not shown). Initial substrate electrical conductivity ($mS \cdot cm^{-1}$) was 0.23 for pine bark, 0.21 for 3/8-inch CCR, 0.15 for 3/16-inch CCR and 0.29 for peat moss.

Microbial respiration (as measured by carbon mineralization) was evaluated at each rating date (Table 2). Peat moss consistently had the least microbial respiration regardless of rating date or supplemental N rate. The greatest microbial respiration occurred with the CCR treatments. As N rate increased, microbial respiration increased in CCR and pine bark.

Clean chip residual consistently had the greatest amount of microbial respiration among the substrates over the course of the incubation (0-60 days) (Table 2). At 0 mg N rate, 3/8-inch CCR had greater microbial respiration than 3/16-inch, but at 1 and 2 mg N they were statistically similar. At 3 mg N 3/16-inch CCR had more microbial respiration than 3/8-inch CCR. Across the N rates for 3/8-inch CCR, microbial respiration increased with increasing N rate. For 3/16-inch CCR, microbial respiration increased with increasing N rate, though 2 and 3 mg N were similar. Pine bark and peat moss were different from each other and less than CCR treatments for microbial respiration. Pine bark was statistically similar at 1, 2 and 3 mg N rates, only 0 mg N had less microbial respiration. There was no difference in microbial respiration across N rates for peat moss.

These data support the results of plant growth studies (2, 3, 4, 5, 6) which demonstrated that under similar production systems a variety of annuals, herbaceous perennials, and woody nursery crops, in general, can have similar plant growth when grown in either CCR or pine bark. Since microbial respiration in CCR and pine bark is

relatively similar during a 60-day production cycle, it can be inferred that plant production in the high wood-fiber content substrate CCR will not result in N-immobilization.

Literature Cited:

1. Bilderback, T.E., W.C. Fonteno, and D.R. Johnson. 1982. Physical properties of media composed of peanut hulls, pine bark and peat moss and their effects on azalea growth. J. Amer. Soc. Hort. Sci. 107:522-525.
2. Boyer, C.R., G.B. Fain, C.H. Gilliam, T.V. Gallagher, H.A. Torbert, and J.L. Sibley. 2007. Clean chip residual (CCR) substrate for container-grown perennials: Effect of supplemental nitrogen rates. HortScience 42:439. Abstr.
3. Boyer, C.R., G.B. Fain, C.H. Gilliam, J.L. Sibley, T.V. Gallagher, and H.A. Torbert. 2007. Performance of container-grown *Loropetalum* grown in clean chip residual substrate. Proc. Intl. Plant Prop. Soc. (In Press).
4. Boyer, C.R., G.B. Fain, C.H. Gilliam, T.V. Gallagher, H.A. Torbert, and J.L. Sibley. 2008. Clean chip residual as a substrate for perennial nursery crop production. J. Environ. Hort. (In Press)
5. Boyer, C.R., G.B. Fain, C.H. Gilliam, T.V. Gallagher, H.A. Torbert, and J.L. Sibley. 2008. Clean chip residual: A substrate component for growing annuals. HortTechnology 18:423-432.
6. Ingram, D.M., G.B. Fain, C.H. Gilliam, C.R. Boyer, P.M. Hudson, and K.K. Crouse. 2007. Comparison of organic and inorganic substrates in greenhouse tomato production. HortScience 42: 989. Abstr.
7. Jackson, B.E. and R.D. Wright. 2007. Pine tree substrate: Fertility requirements. Proc. Southern Nurs. Assoc. Res. Conf. 52:523-526.

Table 1. Physical properties of clean chip residual, pine bark and peat moss substrates.[z]

Substrates[y]	Air space[x]	Container capacity[w]	Total porosity[v]	Bulk density ($g \cdot cm^{-3}$)[u]
	(% Vol)			
3/8-inch CCR	28 b[t]	57 b	85 b	0.22 a
3/16-inch CCR	48 a	42 d	90 b	0.19 b
Pine bark	31 b	48 c	79 c	0.18 b
Peat moss	11 c	87 a	98 a	0.11 c

[z]Analysis performed using the North Carolina State University porometer.

[y]CCR = clean chip residual.

[x]Air space is volume of water drained from the sample ¸ volume of the sample.

[w]Container capacity is (wet weight - oven dry weight) ¸ volume of the sample.

[v]Total porosity is container capacity + air space.

[u]Bulk density after forced-air drying at 105°C (221.0 °F) for 48 h; 1 $g \cdot cm^{-3}$ = 62.4274 lb/ft^3.

[t]Means within column follwed by the same letter are not significantly different based on Waller-Duncan k ratio *t* tests at $\alpha = 0.05$ (n = 3).

Table 2. Accumulated microbial respiration (0-60 days) in clean chip residual, pine bark and peat moss substrates incubated with different nigrogen (N) rates (as estimated by Carbon mineralization).

	Carbon mineralization (mg/kg)				
	0 mg N[y]	**1 mg N**	**2 mg N**	**3 mg N**	*MSD N-rate*[x]
Substrate[z]		**Total: 0-60 days**			
3/8-inch CCR	12,360	13,414	13,778	14,108	*609*
3/16-inch CCR	11,016	13,110	14,377	14,624	*799*
Pine bark	8,954	10,097	10,313	10,484	*422*
Peat moss	2,989	2,922	2,762	2,781	*440*
MSD Substrate	*668*	*405*	*662*	*409*	

[z]CCR = clean chip residual.

[y]2000 ppm stock solution of NH_4NO_3 (0, 0.5, 1.0, 1.5 ml).

[x]MSD (minimum significant difference) based on Waller-Duncan k ratio t tests ($\alpha = 0.05$).