Growth of Several Tree spp. in Containers in Response to N Loading, Fertilizer Type and Substrate[1]

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Abstract

Two studies were conducted to determine if Comtil, a composted municipal sewage sludge, could be used as a substrate component and a slow release N source in a containerized whip production system and to determine the growth potential of nine tree species not widely grown in the industry. Also, in the second study the effects of fertilizer type on five oak species were studied. In the first study, total N from Comtil was estimated to be 64 gm per No. 3 nursery container, representing between 48 and 100% of the N loading. Despite the potential high N loading from Comtil, tree height was unaffected. No simple fertilizer treatment consistently produced the tallest plants for the four species studied. Fertilizer type affect growth of only two species (*Q. macrocarpa* and *Q. muehlenbergii*) and then only in the first year of the two year study. There were significant differences in height growth among the six *Q. alba* sources. The nine tree species in this study could be grown in 3:1 (by vol) pine bark:coir and pine bark:Comtil substrates.

Index words: substrate, composted municipal sewage sludge, coir, container production, woody ornamentals.

Species used in this study: yellowwood (*Cladrastus kentukea* K. Koch); persimmon (*Diospyros virginiana* L.); white oak (*Quercus alba* L.); sawtooth oak (*Q. acutissima* Carruth.); bur oak (*Q. macrocarpa* Michx.); chinkapin oak (*Q. muehlenbergii* Engelm.); chestnut oak (*Q. prinus* L.); English oak (*Q. robur* L.); northern red oak (*Q. rubra* L.).

Significance to the Nursery Industry

Difficult-to-transplant tree species with coarse root systems can be successfully produced in copper-treated containers using either 3:1 (by vol) pine bark:Comtil or pine bark:coir substrates under a range of fertility programs. Comtil is a composted municipal sewage sludge; coir is a coconut fruit by-product. When producing plants from seed it is important to remember that seed source often affects growth rate. In this study one *Q. alba* source grew twice as fast as four other seed sources. Coir and Comtil are renewable resources that can be used as substrate components. A grower wanting to add these species to their product mix should be able to produce 1 to 1.5 m (3 to 5 ft) tall two-year-old whips.

Introduction

Many studies conclude that coir, a renewable resource, is a viable substitute for sphagnum peat moss (3, 9, 10, 11, 12, 15, 20, 22, 24, 26, 27). However, the reports of woody plant growth in coir-amended substrates are limited (11, 12). Coir pith or dust is composed of short fibers and mesocarp tissue from coconut fruit. It is primarily lignin and cellulose with a high C:N ratio (22). Coir substrates immobilize N when used

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as a substrate component; recommendations suggest increasing N fertility by 10 mg/liter (15). Coir quality is dependent on source; it can have high electrical conductivity, K^+, Na^+ and Cl^- ion concentrations (20), which can be corrected by leaching. Coir has similar bulk density and cation exchange capacity to sphagnum peat moss. When mixed with perlite it produced substrates with similar percent total pore space, lower air-filled pore space and higher water-filled pore space than perlite:sphagnum peat substrates of similar proportions (10).

Nitrogen form can affect plant growth through changes in substrate pH; nitrate-N fertilizers tend to raise pH, while ammonium-N fertilizers tend to lower pH (1, 2, 7). Also, plants fertilized with ammonium-N have higher foliar N concentrations than plants fertilized with nitrate-N (1). The effects of fertilizer N-source on woody plant growth are mixed. High ammonium-N fertilizers caused reduced growth, leaf necrosis and plant death in Doublefile Viburnum (*Viburnum plicatum* var. *tomentosum* (7)). A study with mountain laurel (*Kalmia latifolia*) showed that best growth occurred with a combination of ammonium and nitrate sources (19); while Chong (6) found that linden (*Tilia cordata* 'Glenleven') and honeylocust (*Gledistia triaconthos* var. *inermis* 'Skyline') growth was unaffected by N source.

Composts and animal manures are organic sources of nitrogen, where the ammonium-N form predominates (5). Animal composts and manures tend to have high initial N release when incorporated into soil or soilless substrates (4, 14, 23). Composted yard wastes and municipal sludge have slow N mineralization rates (3, 8, 17, 18, 25, 29), suggesting they could be safely used as slow release N sources. However, with vegetable plants, composted municipal sludge supplied adequate N nutrition for only six weeks (13). Hartz et al. (16) concluded that composted green wastes did not significantly contribute to tomato and marigold nutrition, even at a 50% incorporation.

Our experiments were designed to determine if Comtil, a composted municipal sewage sludge, could serve as a slow-release N fertilizer source, and the effect of N source on height growth of five oak species. Upon completion of our studies we anticipate being able to provide cultural information for crops not commonly grown in the nursery industry.

Materials and Methods

Experiment 1. In late September 1997, seeds of *Quercus acutissima*, (sawthooth oak) *Q. robur*, (English Oak) *Diospyros virginiana* (persimmon), and *Cladrastus kentukea* (yellowwood) were collected from trees at Dawes Arboretum, Newark, OH. Acorns were placed in plastic bags, and cold stratified at 7C (45F) until February. *Diospyros virginiana* seeds were removed from the fruits in September and given a similar cold stratification treatment. *Cladrastus kentukea* seeds were removed from the fruits in September and stored in plastic bags at 7C (45F). In early February, seeds were sown in flats in 100% pine bark and placed in a greenhouse with day/night temperatures set at 75/65F (23/18C) under natural photoperiod. Prior to sowing, *Cladrastus kentukea* seeds were scarified by bringing water to a boil, removing it from the heat and placing seeds in the water to soak overnight. When seedlings emerged, they were transplanted to copper-treated (Spinout, Griffin Corp., Valdosta, GA) 250 XL containers [13.3 cm square by 16.5 cm (5.25 in × 6.5 in)] Nursery Supplies, Inc., Fairless Hill, PA] using Metro Mix 510 (O. M. Scotts, Marysville, OH). Seedlings were fertilized once weekly with 100 mg N/liter from 20N–8.8P–16.6K (20–20–20 Peters, O. M. Scotts, Marysville, OH) water soluble fertilizer.

In late May, the seedlings were moved outdoors under 70% shade for one week before potting into No. 3 round copper-treated plastic containers [Spinout, Classic 1200, 28 cm (11 in) diameter × 24 cm (9.5 in) high, Nursery Supplies, Fairless Hill, PA]. Each container was filled with approximately 10 liters (903 cu in) of substrate. Half the plants of each species were potted into 3:1 (by vol) pine bark:Comtil (composted municipal sewage sludge, City of Columbus) substrate and half were potted into a 3:1 (by vol) pine bark:peatmoss substrate. Comtil has a 2N–1.3P–0K (2–3–0) nutrient analysis and is a source of micro nutrients. The pine bark:peatmoss substrate was supplemented with 2.1 kg/cu m dolomite (6 lb/cu yd) and 520 g/cu m Micromax (1.5 lb/cu yd) trace element mix (O. M. Scotts, Marysville, OH). The plants were placed on a gravel container pad at 0.45 m (1.5 ft) within row and 1 m (3 ft) between row spacing.

All plants were irrigated with 13.7 liters/hr (3.6 gal/hr) Spot-Spitter emitters (030–001005, mini flow 90° spray pattern, Roberts Irrigation, San Marcos, CA) for 15 minutes, twice daily. Each plant received 6.9 liters (1.8 gal) daily irrigation. The substrate had 47% total pore space, or approximately 4.7 liters total pore space per container. Thus the containers received an estimated 0.7 leaching fraction at each irrigation.

Fertilizer treatments were begun on June 1, 1998. Plants under the water soluble fertilizer treatment were fertigated twice daily; they received two, 3.4 liter (0.9 gal) irrigation events per day of 200 mg/liter N from 20–8.8–16.6 (Peters 20–20–20, O. M. Scotts, Marysville, OH) for four weeks. For the next 12 weeks, the plants were fertilized one day/week using two, 3.4 liter (0.9 gal) irrigation events of 200 mg N/liter from 20–8.8–16.6. There were two controlled release fertilizer (CRF) treatments. Plants received either one top dress application of 45 g (three tablespoons) 17N–2.6P–10.0K (17–6–12 Osmocote + Minors, nine month release formulation, O. M. Scotts, Marysville, OH) on June 1 (CRF 1) or two 22.5 g applications, one on June 1, a second on July 24 (CRF 2). The last two fertilizer treatments were the water soluble fertilizer treatment combined with CRF 1 or CRF 2. Control plants in the pine bark:Comtil and pine bark:peatmoss substrates received no additional fertilizer. Control plants and plants under the CRF only treatments were irrigated with two, 3.4 liter (0.9 gal) irrigations daily.

Nitrogen loading was calculated by summing all of the N inputs from the different fertilizer treatment combinations applied to individual containers within a treatment. The g N added to each container from Comtil was estimated by taking 25% of the filled container volume, 10 liters [or 10,000 cu cm (353 cu in)], multiplying by the bulk density of Comtil, 0.32 g/cu cm, and then multiplying by the N concentration of Comtil, 2% (28). There were 800 g (5.5 lbs) of Comtil per container, which added 16 g N. For the water soluble fertilizer treatments, there were 40 days of fertigation; each day added 1.38 g N/container; for the season, 55.2 g N/container was added.

There were two replications of eight plants of *Q acutissima* and *Q. robur* per treatment for a total of 96 plants of each species in the study. There were two replications of 14 and 20 plants for *D. virginiana* and *C. kentulea*, respectively, a

Table 1. Estimated grams of N applied per container during one growing season from various sources.

Fertilizer treatment	Substrate[y]	Comtil[w]	Water soluble	Controlled release	Total
Control[z]	Pine bark:Comtil	16.0	0.0	0.0	16.0
	Pine bark:peat	0.0	0.0	0.0	0.0
WS	Pine bark:Comtil	16.0	55.2	0.0	71.2
	Pine bark:peat	0.0	55.2	0.0	55.2
CRF 1	Pine bark:Comtil	16.0	0.0	15.3	31.3
	Pine bark:peat	0.0	0.0	15.3	15.3
CRF 2	Pine bark:Comtil	16.0	0.0	15.3	31.3
	Pine bark:peat	0.0	0.0	15.3	15.3
WS + CRF 1	Pine bark:Comtil	16.0	55.2	15.3	86.5
	Pine bark:peat	0.0	55.2	15.3	70.5
WS + CRF 2	Pine bark:Comtil	16.0	55.2	15.3	86.5
	Pine bark:peat	0.0	55.2	15.3	70.5

[z]Plants received no fertilizer after upcanning; WS plants received 3.4 liters (0.9 gal)/day of 200 mg/liter N from from 20N–8.8P–16.6K for four weeks, then 3.4 liters (0.9 gal) application once per week of 200 mg/liter N for 12 weeks; CRF 1 plants received one application of 45 grams of 17N–2.6P–10.0K controlled release fertilizer (CRF) on June 1, CRF 2 plants received two applications of 22.5 grams of 17N–2.6P–10.0K CRF, one June 1, and a second application on July 24, WS + CRF 1 application plants received a combination of WS and CRF 1 treatments, WS + CRF 2 applications plants received a combination of WS and CRF 2 treatments.

[y]The pine bark:Comtil and pine bark:peatmoss substrates were 3:1 (by vol).

[w]Comtil is a composted municipal sewage sludge product from the City of Columbus, OH; it has a 2N–1.3P–0K ratio.

total of 168 *D. virginiana* and 240 *Cladrastis kentukea* plants. The experimental design was a randomized complete block design. Plant height was measured in October.

Experiment 2. In September 1998, acorns from six *Q. alba* (white oak) sources, two *Q. prinus* (chestnut oak) sources, two *Q. muehlenbergii* (chinkapin oak) sources, and one source each for *Q. macrocarpa* (bur oak) and *Q rubra* (northern red oak) were collected from central Ohio, with the exception of one commercial *Q. alba* source (Sheffield Seeds, Inc., Locke, NY). The central Ohio sources were collected from individual trees. The acorns were stratified, germinated, transplanted to 250XL containers in Metro Mix 360 substrate and grown in the greenhouse similarly to those in experiment 1.

Seedlings were moved outdoors in mid-June, placed under shade for a week and potted into No. 3 copper-treated containers similar to those described in experiment 1. Two substrates were used; half the plants within a species and/or source were potted into 3:1 (by vol) pine bark:Comtil; the other half were potted into 3:1 (by vol) pine bark:coir. The pine bark:coir substrate was supplemented with 2.1 kg/cu m (6 lb dolomite/cu yd) and 520 g/cu m Micromax (1.5 lb/cu yd) trace elements. The plants were placed on a container pad at similar spacing and irrigated similar to those in experiment 1. On July 15, 1999, two fertigation treatments were begun. Plants were fertilized with either 100 mg/liter N from 20N–4.4P–16.6K (20–10–20) General Purpose or 21N–3.0P–5.8K (21–7–7) Acid Special water soluble fertilizer (Peters, O. M. Scotts, Marysville, OH). Fertigation treatments were stopped on September 1, but plants were irrigated on the same schedule (twice per day for 15 minutes) until late October when the plants were moved to an unheated polyhouse for overwintering. In May 2000, the plants were returned to the irrigation lines. Plants were fertigated from June 1 to September 1 with the same treatments as they were in 1999. The 20–10–20 General Purpose fertilizer had 60% of its N in the nitrate form and 40% N in ammoniacal form. The 21–7–7 Acid Special fertilizer had 44% N in ammoniacal and 56% in urea form.

Plants were placed on the container pad in a randomized complete block design at similar spacings as in experiment 1. There were two replications, with equal numbers of plants per treatment within a species. Plant heights were measured in October of each year. Height data were subjected to ANOVA by species using SPSS for the personal computer. Means were separated by the Student-Neuman-Kuels test at ? = 0.05 level of significance.

Results and Discussion

Experiment 1. Estimated N applications rates ranged from 0 to 86.5 g/container over the 16 week experiment (Table 1). However, based on total pore space of the substrate-container system, estimated maximum N retained per container ranged from 0 to 69.0 g, assuming a 1.4% daily leaching fraction for the water soluble fertilizer. There was a highly significant fertilizer effect for all species ($P < 0.0001$). Seedlings in the control treatments were always significantly smaller than the other fertilizer treatments (Table 2). No one fertilizer treatment consistently produce the largest seedlings. For instance, the largest *Q. acutissima* and *C kentukea* plants were produced under a range of fertilizer treatments: either one 45 g application of CFR, or with a combination of water soluble and one 45 g or two 22.5 g applications of CRF. For *Q. robur*, all fertilizer treatments (except for the control) produced similar sized plants whereas the largest *D. virginiana* plants were produced with one 45 g application of CRF combined with fertigation.

Within each species, the correlations between N loading and plant height were low. The highest correlation was for *Q. robur* ($r^2 = 0.46$), the lowest was for *D. virginiana* ($r^2 = 0.01$).

There were no significant fertilizer × substrate interactions (data not presented). There was only one significant substrate effect; *Q. acutissima* seedlings were taller when grown in the pine bark:Comtil than in the pine bark:peatmoss substrate, 93.7 vs 72.4 cm (37 and 29 in), respectively. Despite the N loading from Comtil, (an estimated 16 g per container) it did not consistently increase growth, except as noted for *Q. acutissima* seedlings. Kraus, et al. (21) estimated N mineralization of composted municipal sewage sludge at two temperatures [45/25C (112/

Table 2. Height of four species grown in six fertilizer treatments.

	Height (cm)			
Fertilizer treatment	***Quercus acutissima***	***Quercus robur***	***Diospyros virginiana***	***Cladrastis kentukea***
Control[z]	40.1c[y][w]	29.3b	13.2d	24.7d
WS	77.8b	108.7a	29.8bc	60.8d
CRF 1 application	103.7a	77.5a	34.4b	83.9cd
CRF 2 applications	71.3b	82.7a	22.5cd	69.3cd
WS + CRF 1 application	116.6a	94.2a	48.5cd	79.3bcd
WS + CRF 2 applications	118.0a	105.9a	40.9c	93.8a

[z]Plants received no fertilizer after upcanning; WS plants received 3.4 liters (0.9 gal)/day of 200 mg/liter N from 20N–8.8P–16.6K for four weeks, then 3.4 liters (0.9 gal) application once per week of 200 mg/liter N for 12 weeks; CRF 1 application plants received one application of 45 grams of 17N–2.6P–10.0K controlled release fertilizer (CRF) in June, CRF 2 plants received one application of 22.5 g of 17N–2.6P–10.0K CRF on June 1 and a second on July 24, WS + CRF 1 application plants received a combination of the WS and the CRF 1 treatments, WS + CRF 2 applications plants received a combination of the WS and CRF 2 treatments.

[y]Each value is the mean of two replications of 16, 16, 14 and 10 plants for *Q. acutissima, Q. robur, D. virginiana* and *C. kentukea*, respectively.

[w]Means within a column followed by different letters are significantly different from each other using the Student-Neuman-Kuels test at ? = 0.05 level.

76F) and constant 25C (76F)] to be 7.0 and 5.5%, respectively, of total N over the 16-week study period. In this study, similar N mineralization rates from Comtil would have released between 1.1 and 0.9 g N. Highest N loading, excluding Comtil, was from the water soluble plus CRF 2 treatment, 70.5 g N. Thus, at most 1.1 g N, approximately 1.5% [(1.1/71.6) × 100] of the total N loading, was contributed by the mineralization of Comtil.

Experiment 2. There was only one significant two-way interaction (seed source × substrate for *Q. muehlenbergii*); *Q. muehlenbergii* height growth was taller in 2000 for the Greenlawn source when seedlings were grown in pine bark:Comtil substrate than in pine bark:coir (Table 3). There was no difference in height attributed to substrate for Clintonville source seedlings. There was no N-source effect (data not presented).

For *Q. alba*, there was not a significant N-fertilizer effect (data not presented). There was a significant substrate effect in 2000 ($P < 0.036$) and a seed source effect in 1999 and 2000 ($P < 0.0001$ and 0.0001, respectively). Seedlings grown in pine bark:Comtil substrate were larger than those grown in pine bark:coir, 71.3 and 64.7 cm (28 and 25 in), respectively (Table 4). In both years, seedlings produced from the 9618 source were the tallest, those from the Olsen source were the second tallest. There were no significant differences in height among the other sources.

For *Q. prinus* and *Q. rubra*, there were significant substrate effects in 2000, but not in 1999. *Q. prinus* and *Q. rubra* grown in pine bark:coir were significantly taller than those grown in pine bark:Comtil after two growing seasons (Table 5). There were no significant height differences in 1999. There was not a significant N-source effect (data not presented).

In 1999, but not in 2000, there were significant differences in height growth due to N fertilizer for *Q. macrocarpa* and *Q. rubra* ($P < 0.002$ and 0.029, respectively). For both species, seedlings fertilized with 21–7–7 were taller than those fertilized with 20–10–20 (Table 6).

Under the conditions of this study, the different oak species grew equally well (except for the first growing season with *Q. muehlenbergii* and *Q. macrocarpa*) regardless of fertilizer type. Pine bark substrate amended with coir did increase growth of *Q. prinus* and *Q. rubra* seedlings after two years and Comtil increased growth of one *Q muehlenbergii* source. The largest difference, 29 cm (11 in) for *Q. rubra* seedlings, is commercially important, but the other statistically significant differences in height growth attributed to substrate or fertilizer type are probably not commercially significant. Of significance was the difference in growth among the *Q. alba* sources. The 9618 source grew at twice the rate of four other sources. If the proper seed sources can be identified and whips produced under conditions similar to this study, then *Q. alba* production maybe economically feasible. For the other species, even under high fertility levels, growth

Table 3. Height for two *Q. muehlenbergii* sources grown in two pine bark substrates amended with Comtil or coir.

		Height (cm)	
Seed source	**Pine bark substrate**	**1999**	**2000**
Clintonville	Comtil[z]	55.0a[y]	142.8a
	Coir	45.6a	149.7a
Greenlawn	Comtil	50.0a	150.9a
	Coir	30.9a	127.2b

[z]Comtil is a composted municipal sewage sludge product; coir is coconut fibers. Pine bark was mixed with Comtil or coir in a 3:1 ratio (by vol) to form the substrates.

[y]Each value is the mean of two 16-plant replications. Means within a column followed by different letters are significantly different from each other using the Student-Neuman-Kuels test at ? = 0.05 level.

Table 4. Number of *Quercus alba* seedlings per central Ohio seed source (n) and seedling heights.

		Height (cm)	
Seed source	**n**	**1999**	**2000**
9618[z]	32	44.7a[y]	119.4a
Olsen	31	25.2a	76.9b
Pickerington	63	19.0a	59.5c
Sleigh	64	18.9a	59.7c
Sydnor	62	14.6a	45.3c
Commercial	32	11.3a	47.5c

[z]Sources 9618 and Olsen were collected from individual trees, other sources were open pollinated seeds collected from three or more trees.

[y]Means within a column and species followed by different letters are significantly different from each other using the Student-Neuman-Kuels test at ? = 0.05 level.

Table 5. Height of *Quercus rubra* and *Q. prinus* seedlings when grown in two pine bark based substrates.

Species	Substrate	Height (cm) 1999	2000
Q. rubra	Comtil[z]	55.6a[y]	144.8b
	Coir	59.7a	173.7a
Q. prinus	Comtil	28.2a	76.6b
	Coir	32.0a	90.4a

[z]Comtil is a composted municipal sewage sludge product from the City of Columbus, OH. Coir is a coconut fiber product. Seedlings received 6.9 liters (1.8 gal) of 100 mg/liter N from water soluble fertilizer per day from July 15 to September 1 in 1999 and from June 1 to September 1 in 2000.

[y]Each value is the mean of two replications of 39 and 21 seedlings for *Q. rubra* and *Q. prinus*, respectively. Means within a column and species followed by different letters are significantly different from each other using the Student-Neuman-Kuels test at ? = 0.05 level.

Table 6. *Quercus macrocarpa* and *Q. muehlenbergii* one- and two-year heights after treating with 21N–3.0P–5.8K (21–7–7) or 20N–4.4P–16.6K (20–10–20) water soluble fertilizer.

Species	Fertilizer	Height (cm) 1999	2000
Q. macrocarpa	21–3.0–5.8[z]	53.8b[y]	138.5a
	20–4.4–16.6	41.3a	132.5a
Q. muehlenbergii	21–3.0–5.8	52.5b	146.9a
	20–4.4–16.6	38.3a	138.4a

[z]Seedlings received 6.9 liters (1.8 gal) of 100 mg/liter N from each fertilizer type per day from July 15 to September 1 in 1999 and from June 1 to September 1 in 2000.

[y]Each value is the mean of two replications of 44 seedlings. Means within a column and species followed by different letters are significantly different from each other using the Student-Neuman-Kuels test at ? = 0.05 level.

was less than that of more commonly grown taxa. For instance, under commercial production *Acer rubrum* cultivars exceed 2 m (6 ft) in height during a two-year production schedule. In this study, only *Q. robur* approached that growth rate. If slower growing taxa are to be widely grown, then producers must be compensated for innately slower growth rates. Comtil, and possibly other compost products, may be added to container substrates for their peat moss-like physical properties (28) but not as slow release N sources.

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