Compost and Rubber Tire Chips as Peat Substitutes in Nursery Container Media: Effects on Chemical and Physical Media Properties[1]

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Abstract

Physocarpus opulifolius 'Dart's Gold', *Forsythia* x 'Meadowlark', *Spiraea* x *billiardii*, *Juniperus chinensis* 'Seagreen', *J. sabina* 'Mini Arcade', *J. horizontalis* 'Hughes', and *Lamiastrum galeobdolon* were grown in container media amended with three yard waste (YW) composts, one municipal solid waste (MSW) compost and shredded rubber tire chips. Each of the five amendments was used to replace 50% or 100% of the sphagnum peat in a standard container medium resulting in eleven media treatments. Effects of peat replacement with compost or tire chips were compared relative to chemical and physical media characteristics. Amendments evaluated had limited long term nutritional value. Initial pH was increased when peat was replaced with compost or rubber tire chips; the increase in pH was proportional to the amount of peat replaced (50 or 100%). Over time, pH of all media equilibrated with irrigation water pH. Soluble salts were reduced for media amended with rubber tire chips while peat replacement with compost had variable effects on soluble salt levels based on compost source. Media amended with compost exhibited increased bulk density and decreased porosity, water infiltration capacity and water holding capacity compared to the standard, peat-based control medium. Peat replacement with rubber tire chips increased bulk density and porosity and decreased water holding capacity compared to the standard control medium. Water infiltration capacity was greatly increased and water holding capacity decreased when peat was replaced 100% with rubber tire chips.

Index words: yard waste, rubber tire chips, municipal solid waste, garbage, peat replacement, fertility, porosity, pH, bulk density, infiltration, water holding capacity, soluble salts.

Species used in this study: 'Seagreen' Juniper (*Juniperus chinensis* L. 'Seagreen'); 'Mini Arcade' Juniper (*Juniperus sabina* L. 'Mini Arcade'); 'Hughes' Juniper (*Juniperus horizontalis* Moench. 'Hughes'); 'Dart's Gold' Ninebark (*Physocarpus opulifolius* (L.) Maxim. 'Dart's Gold'); 'Meadowlark' Forsythia (*Forsythia* Vahl. x 'Meadowlark'); Billiard Spirea (*Spiraea* x *billiardii* Herincq.); Yellow Archangel (*Lamiastrum galeobdolon* (L.) Ehrend. & Polatsch.).

Significance to the Nursery Industry

Sphagnum moss peat has long been a primary component in horticultural media. Peat is potentially the most expensive media component because of its high cost and the large quantities used. Current sphagnum peat harvesting practices raise ecological concerns that may limit peat availability in the future. Peat availability can also be limited by weather conditions. Recycled organic wastes, such as municipal solid waste compost, might be used as a peat substitute in container media. Reliable supplies of consistent, high quality, low cost compost would, however, be necessary for compost to become a viable peat substitute. Prior to use in container media, waste derived composts must be evaluated to determine their effects on media characteristics and plant growth. This research investigated peat replacement (50 and 100%) with four municipal composts and rubber tire chips. Effects on chemical and physical media characteristics that influence production practices and plant growth were quantified.

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Introduction

In 1988, 1.65 × 10^8 metric tons (1.82 × 10^8 tons) of municipal solid waste (MSW) were produced in the United States (31). It is estimated that 1.97 × 10^8 metric tons (2.17 × 10^8 tons) of MSW will be produced in the United States by the year 2000 and 2.28 × 10^8 metric tons (2.51 × 10^8 tons) by the year 2010 (31). Yard waste (YW) comprises approximately 20% of the MSW produced (31): 3.94 × 10^7 metric tons (4.34 × 10^7 tons) in the year 2000. Many municipalities have implemented composting programs to transform yard and other municipal solid wastes into usable products and reduce reliance on landfills. For such recycling programs to be self-sustaining and cost effective, markets will be needed for such compost products.

Compost has been explored for potential use in horticultural production systems (15). Specifically, integration of various composts (composted sewage sludge, street sweepings, food processing waste, yard waste, and municipal solid waste) into greenhouse and nursery growing media has been studied (6, 7, 19, 24, 25, 26, 30).

Through sales of trees, shrubs and lawn care products, the nursery and landscape industry contributes to proliferation of yard waste. By using compost generated by landscaping activities, the nursery industry can close the loop by integrating recycled organic wastes into nursery production systems.

To be widely accepted by growers, compost must be comparable to peat in cost, reliably available, of consistent quality, free of off odors, free of human or plant pathogens, and free of hazardous materials. Compost amended media must also support plant growth similar to or better than growth in conventional, peat-based growing media.

Peat is frequently the most expensive component in container media (6). In addition, environmental concerns associated with current peat harvesting practices, essentially strip mining, may limit sphagnum peat availability in the future. Conceivably, compost could serve as a peat substitute in nursery container media. This research was designed to evaluate compost and rubber tire chips as potential replacements for peat in container growing media relative to effects on chemical and physical media characteristics. Rubber tire chips have not been evaluated for use in container media, but have recently been investigated as a potential soil amendment to reduce soil compaction in high-traffic turf (22).

Materials and Methods

This research was carried out at the University of Minnesota, St. Paul Campus, nursery facility. Three coniferous, three deciduous, and one herbaceous perennial species were included in the research: *Juniperus chinensis* 'Seagreen' ('Seagreen' Juniper), *Juniperus sabina* 'Mini Arcade' ('Mini Arcade' Juniper), *Juniperus horizontalis* 'Hughes' ('Hughes' Juniper), *Physocarpus opulifolius* 'Dart's Gold' ('Dart's Gold' Ninebark), Forsythia x 'Meadowlark' ('Meadowlark' Forsythia), *Spiraea* x *billiardii* (Billiard Spirea), and *Lamiastrum galeobdolon* (Yellow Archangel).

Ten media treatments were formulated wherein the peat component of a standard nursery container medium was replaced (50 or 100%) with one of five amendments (Table 1). Compost amendments were not leached prior to incorporation. A standard nursery growing medium [composted hardwood woodchips:peat (pH 4.3):coarse sand (3:2:1 by vol)] was used as a control. Slow release fertilizer, 2.38 kg/m^3 (4.0 lb/yd^3) each of Osmocote 13N–5.6P–10.8K (13–13–13) [7–8 month release] and Osmocote 14N–6.1P–11.6K (14–14–14) [3–4 month release] (O.M. Scott & Sons Company, Marysville, OH) and 1.78 kg/m^3 (3.0 lb/yd^3) of Woodace PERK micronutrients (Vigoro Industries, Inc. Fairview, IL) was incorporated into all media. No additional fertilizer was supplied during the study. Deciduous plants (rooted cuttings) were containerized in 6.5 liter containers (#2 Polytainer, Nursery Suppliers, Inc., Chambersburg, PA). Evergreens (plugs) and *Lamiastrum* (divisions) were planted in 2.8 liter containers (#1 Polytainer). Containerized plants were maintained for two years under overhead irrigation in a standard nursery production environment. Each species/medium combination was replicated eight times using a randomized block experimental design.

Parameters measured. Amendments (compost, tire chips) and standard media components (peat, woodchips, sand) were individually tested for pH, soluble salts and fertility levels (University of Minnesota Soil Testing Lab; Nursery and Florist Test (Spurway); 0.017 N acetic acid extraction). Periodic media fertility, soluble salt, and pH levels were determined for the formulated media using pour through leachate analysis whereby one liter of water was poured through each 6.5 liter container and the leachate collected. Leachates were filtered and analyzed for P, K, Ca, Mg, Na, Fe, Mn, Zn, and B using inductively coupled plasma atomic emission spectrometry and NO_3-N and NH_4-N were determined using copperized cadmium reduction and indophenol blue spectrometric methods, respectively (University of Minnesota Soil Testing Lab). Initial tests were performed 48 hr after the first irrigation. Media leachate analysis was repeated at the end of the first growing season and again after two growing seasons. Irrigation water was analyzed at the same times.

Water infiltration rate, porosity, relative water holding capacity, and bulk density were measured *in situ* for three replicates (6.5 liter containers) of each medium at the end of the first growing season. To determine infiltration rate, each medium was saturated and drained to container capacity. A liter of water was then added to each container and the time required until no visible water remained on the surface (percolation time) was measured. Average infiltration rate (ml/sec) for each medium was calculated.

To measure total porosity, aeration porosity, water retention porosity, relative water holding capacity and bulk density for each medium, container contents were removed intact, containers were lined with a plastic bag and the con-

Table 1. Media amendment/peat replacement treatments and descriptions.

Media treatment	Ratio (by vol)	% Peat replacement
Control—composted woodchips:peat:sand	3:2:1	0
Minneapolis compost[z]—woodchips:peat:compost:sand	3:1:1:1	50
Minneapolis compost—woodchips:compost:sand	3:2:1	100
Recomp compost[y]—woodchips:peat:compost:sand	3:1:1:1	50
Recomp compost—woodchips:compost:sand	3:2:1	100
Pecar compost[x]—woodchips:peat:compost:sand	3:1:1:1	50
Pecar compost—woodchips:compost:sand	3:2:1	100
Composting Concepts compost[w]—woodchips:peat:compost:sand	3:1:1:1	50
Composting Concepts compost—woodchips:compost:sand	3:2:1	100
Rubber tire chips[v]—woodchips:peat:tire chips:sand	3:1:1:1	50
Rubber tire chips—woodchips:tire chips:sand	3:2:1	100

[z]Yard waste compost; City of Minneapolis, Minneapolis, MN.
[y]Municipal solid waste compost; Recomp, Inc., St. Cloud, MN.
[x]Yard waste compost; Richard Pecar Co., Lakeville, MN.
[w]Yard waste compost; Composting Concepts Inc., Afton, MN.
[v]Kanntech, Inc., Minneapolis, MN.

tents replaced. Water was added to saturate each medium (total porosity). The plastic liner was then perforated; free water that drained from the medium was measured to determine aeration pore volume. Porosity values were determined on a percent volume basis (29). At container capacity, the medium from each container was weighed to determine wet weight, then oven dried for two weeks to determine dry weight. Bulk density and relative water holding capacity were determined on a dry weight basis.

Results and Discussion

Container media characteristics including fertility, pH, soluble salts, bulk density, water holding capacity, and porosity may impact plant growth more significantly than field soil attributes because of the restricted root zone and associated limiting effect of containers. These factors are to a large extent determined by the individual components used to formulate container media. Irrigation water can also influence fertility, soluble salt, and pH levels.

Chemical media characteristics. A container medium pH of 6.0–7.0 is optimal for nutrient availability to plants (3). The pH of the amendments used to replace peat are presented in Table 2. Except for the control medium, which had an initial pH of 7.0, initial pH levels of amended media were high and variable ranging from 7.8 to 8.4 (Table 3). Therefore, all amendments significantly increased initial media pH compared to the standard control medium. Increase in pH was relative to amendment pH and peat replacement percentage. By early September of the first growing season, media pH ranged from 7.5 to 7.9 and by September of the second growing season, the pH of all media was less variable and had equilibrated with irrigation water pH (pH = 7.9–8.3). Over the long term, irrigation water pH was the principal determinant of media pH. Initially, the acidifying effect of peat (pH = 4.3) was evident for 50% peat replacement treatments since pH levels were consistently lower than for 100% peat replacement media (Table 3). This effect was reduced over time through irrigation with high pH water. Ticknor et al. (30) have also reported increased alkalinity (mediated by calcium and magnesium carbonate and bicarbonate levels) associated with high Ca and Mg levels in irrigation water. As with media pH, levels of Ca and Mg in all media equilibrated with levels of these elements in irrigation water. In response to high media pH, the acid loving billiard spirea quickly developed marked chlorosis consistent with high pH induced iron deficiency. This effect of irrigation water on media pH and plant performance highlights the importance of acidification of high pH irrigation water for crops that are sensitive to a high pH medium.

Chemical analyses of the standard media components and amendments are presented in Table 2. Initial levels of extractable NO_3-N, NH_4-N, phosphorus, and potassium for each treatment medium are presented in Table 3. Yard waste compost from Pecar was by far highest in N (618 mg/kg NO_3-N) and K (502 mg/kg), followed by Composting Concepts (198 and 275 mg/kg, respectively). Pecar (20 mg/kg) and Composting Concepts (22 mg/kg) YW composts were also highest in phosphorus followed by Minneapolis YW compost (7 mg/kg) and Recomp MSW compost (1 mg/kg). As expected, the nutrient content of the rubber tire chips was very low. Initial nutrient levels for the media components were generally reflected in amended media, especially regarding potassium content (Tables 2 and 3). When used as peat substitutes, all amendments tended to reduce initial nitrate levels in leachates compared to the standard, peat-based control medium. This was especially true for media amended with City of Minneapolis compost which was incompletely composted (immature). Even though fertilizer had been added to the media, these results may have been in response to differences in compost maturity and nitrogen demand associated with continued compost degradation. By the end of the first growing season, nitrate levels in the control medium were virtually depleted while nitrate levels remained considerably more stable for amended media (Table 3). Compost was a longer term, but limited source of nitrate than the slow release fertilizer used.

Phosphorus, and more significantly potassium, followed the same trends. Extractable phosphorus was initially highest for the control medium compared to media amended with compost or rubber tire chips (Table 3). The more acidic pH of the control medium may have resulted in reduced binding of phosphorus. Even though fertilizer containing phosphorus was added to all media, available phosphorus levels were consistently low. This may contrast with results reported by Ticknor et al. (30) where foliar levels of phosphorus were adequate for plants grown in compost based media. Potassium levels of compost based media were initially relatively high (Table 2). This result deviates from reports by Ticknor et al. (30) that potassium levels in compost and compost based media and foliar potassium levels for plants grown in compost amended media were low enough to warrant addition of supplemental potassium.

Table 2. Chemical analysis[z] of media components.

	pH	SS[y]	NO_3-N	NH_4-N	P	K	Ca	Mg	Na	Fe	Mn	Zn	B
Media component		mhos × 10^{-5}	mg/kg										
Composted woodchips	8.6	32	3	<1	13	146	133	23	12	0.28	0.28	0.05	0.16
Sphagnum peat	4.3	13	9	9	<1	9	15	5	12	0.46	0.53	0.07	<0.03
Sand	8.9	5	5	<1	<1	2	25	3	5	0.12	0.09	0.02	0.04
Rubber tire chips	8.4	49	5	<1	<1	4	65	27	11	0.02	0.08	0.53	<0.03
Composting concepts compost	7.7	103	198	<1	22	275	167	46	16	0.28	0.38	0.06	0.57
Minneapolis compost	8.8	76	3	<1	7	136	141	48	15	0.20	0.98	0.11	0.59
Pecar compost	6.8	258	618	<1	20	502	194	76	19	0.60	0.57	0.04	0.48
Recomp compost	7.8	210	31	<1	1	167	206	23	202	0.27	0.57	0.67	0.77

[z]University of Minnesota Soil Testing Lab; Nursery and Florist Test (Spurway); 0.01 N acetic acid extraction.

[y]Electroconductivity based on a 5:1 water to substrate suspension.

Table 3. Chemical analysis[z] of irrigation water and leachates collected from a standard peat-based container medium and media amended with yard waste compost, municipal solid waste compost and rubber tire chips over two growing seasons.

	pH	SS[y]	NO_3-N	NH_4-N	P	K	Ca	Mg	Na	Fe	Mn	Zn	B
Media treatment		mhos × 10^{-5}	mg/kg										
June 1991													
CTRL	7.0	150	323	1	28	300	106	37	19	1.10	0.24	0.45	0.49
M50	8.2	105	22	2	3	186	80	32	18	0.25	0.11	0.20	0.38
M100	8.4	122	17	2	2	239	90	38	17	0.09	0.12	0.15	0.46
R50	8.1	138	77	4	4	226	79	23	90	1.28	0.10	0.32	0.66
R100	8.2	178	54	3	2	267	94	27	151	1.38	0.15	0.31	1.04
C50	7.9	155	210	2	9	332	96	35	18	1.48	0.31	0.34	0.68
C100	8.1	155	182	3	6	338	95	36	22	1.01	0.15	0.25	0.62
P50	7.8	175	296	7	7	362	101	40	25	2.04	0.33	0.38	0.47
P100	8.1	155	281	2	4	341	86	38	18	1.14	0.14	0.18	0.40
T50	7.9	102	50	7	6	198	69	26	16	0.84	0.33	0.56	0.41
T100	8.3	88	23	5	3	146	70	28	17	0.28	0.13	0.24	0.17
Irrigation water	8.3	48	6	<1	<1	2	63	26	11	0.02	0.02	0.06	<0.03
September 1991													
CTRL	7.9	54	6	<1	3	14	72	27	13	0.04	<0.01	0.04	0.05
M50	7.5	82	147	5	9	45	111	30	12	0.04	0.01	0.02	0.17
M100	7.9	70	86	<1	5	26	110	26	12	0.02	<0.01	0.03	0.16
R50	7.8	71	68	<1	4	36	94	27	12	0.05	0.01	0.07	0.10
R100	7.8	71	73	<1	2	36	96	27	13	0.05	<0.01	0.09	0.13
C50	7.9	60	52	<1	5	32	77	27	12	0.05	0.01	0.05	0.09
C100	7.9	62	66	<1	5	28	80	27	11	0.07	0.01	0.04	0.11
P50	7.7	60	33	1	4	25	73	28	11	0.06	0.01	0.04	0.08
P100	7.9	67	79	3	6	44	74	29	12	0.08	<0.01	0.05	0.11
T50	7.9	62	67	<1	6	27	79	26	12	0.02	0.01	0.08	0.06
T100	7.9	61	44	3	5	33	76	26	11	0.02	0.02	0.11	0.08
Irrigation water	7.9	49	4	<1	<1	2	64	26	10	0.02	0.03	0.09	0.03
September 1992													
CTRL	8.2	43	4	<1	1	4	60	26	13	0.03	<0.01	0.12	0.04
M50	8.2	51	4	<1	2	9	69	24	13	0.02	<0.01	0.10	0.06
M100	8.2	44	4	<1	<1	5	68	25	10	<0.02	0.01	0.20	0.05
R50	8.3	53	3	<1	2	16	68	24	13	0.03	<0.01	0.10	0.05
R100	8.3	46	3	<1	2	13	70	22	12	0.03	<0.01	0.14	0.06
P50	8.3	47	4	<1	<1	23	64	27	12	<0.02	0.01	0.12	0.05
P100	8.3	50	3	<1	3	24	62	25	12	0.03	<0.01	0.27	0.06
C50	8.3	50	4	<1	2	18	65	26	13	<0.02	<0.01	0.19	0.04
C100	8.3	48	2	<1	2	14	65	24	11	<0.02	<0.01	0.17	0.05
T50	8.3	47	2	<1	2	12	62	24	13	<0.02	<0.01	0.16	0.05
T100	8.3	46	3	<1	1	7	64	24	12	<0.02	<0.01	0.25	0.05
Irrigation Water	8.2	48	3	<1	<1	2	62	26	9	<0.02	0.01	0.21	0.05

[z]University of Minnesota Soil Testing Lab.

[y]Electroconductivity of leachate collected from each medium.

[x]CTRL = Standard nursery container medium: 3 parts composted woodchips, 2 parts sphagnum peat, 1 part sand.

M50 = Peat replaced 50% with yard waste compost, City of Minneapolis.

M100 = Peat replaced 100% with yard waste compost, City of Minneapolis.

R50 = Peat replaced 50% with composted garbage, Recomp, Inc.

R100 = Peat replaced 100% with composted garbage, Recomp, Inc.

P50 = Peat replaced 50% with yard waste compost, Pecar, Inc.

P100 = Peat replaced 100% with yard waste compost, Pecar, Inc.

C50 = Peat replaced 50% with yard waste compost, Composting Concepts.

C100 = Peat replaced 100% with yard waste compost, Composting Concepts.

T50 = Peat replaced 50% with shredded rubber tire chips, Kanntech, Inc.

T100 = Peat replaced 100% with shredded rubber tire chips, Kanntech, Inc.

Calcium and magnesium levels were relatively consistent throughout the research, having equilibrated with irrigation water levels, and were sufficient for plant growth (Table 3). Ticknor et al. (30) also reported that irrigation water can provide adequate calcium and magnesium for plant growth. In addition, Ticknor et al. (30) found that supplemental trace nutrients were not required in compost based media except where boron was deficient. In our research, micronutrient levels were in some instances increased compared to the control medium when compost was included as a media component, however, the results were mixed.

Incorporation of tire chips into container media supplemented with fertilizer resulted in initially reduced nitrate levels compared to the control medium (Table 3). This effect was similar to that observed for the immature Minneapolis compost. Relative nitrate levels for tire chip amended media increased, however, by the end of the first growing season. Biodegradation of rubber tire chips may have accounted for these trends in nitrate levels. That vulcanized rubber is susceptible to microbial degradation (within a few months) and has the potential to release nitrogen has been documented in the literature (9, 13, 17, 18, 20). In research where growth of corn (*Zea mays* L.) plants was increased when vulcanized rubber was added to the growing medium, rubber from worn out automobile tires has also been identified as a potential source of zinc (2). Analysis of the rubber tire chips used in this research seems to support this finding as Zn levels were high compared to all other media components except for the Recomp MSW compost which exhibited even higher levels of Zn (Table 2).

In this research, nutrient levels appeared to be below optimum by the end of the first growing season, yet plants were judged as fair to excellent in quality. Quality of control plants was generally reduced compared to plants grown in compost amended media (data not shown). The low, but relatively constant, long term nutrient release provided by compost in compost amended media may explain the maintenance of plant quality compared to the control medium.

Recomp (MSW) compost was very high in sodium (Table 2) and this was reflected in initial sodium levels for media amended with this compost (Table 3). Compost amendments should always be analyzed for sodium levels and composts or media high in salts should be leached, especially when low input irrigation systems are used.

Compost maturity can affect plant growth; soil amendment with immature compost has been shown to have an inhibitory effect on growth (14). Media amended with fully decomposed YW compost (Pecar and Composting Concepts) and MSW compost (Recomp) generally supported increased plant growth compared to the control medium, media containing immature YW compost (Minneapolis), and media amended with tire chips (Table 4). Based on appearance, texture, effluvium and compost history, the Minneapolis compost used in this research was deemed immature. Media amended with incompletely decomposed compost (M50 and M100) had lower nitrogen levels in initial media analyses compared to other media and later tests (Table 3). Initial low levels of nitrate in Minneapolis compost amended media to which fertilizer had been added might be attributed to high carbon:nitrogen ratios and nitrogen utilization in the breakdown of immature compost. That immobilization of N can be a serious problem in compost amended media has previously been reported (23, 27). Competition for available iron may have also occurred since iron levels were also considerably lower for media amended with the immature Minneapolis compost.

Physocarpus opulifolius and *Spiraea* x *billiardii* were the only plants to show nutrient deficiency symptoms as evidenced by chlorotic foliage. Chlorosis most likely resulted from iron deficiencies caused by alkaline media (Table 3). The authors have observed that *Spiraea* x *billiardii* tends to be sensitive to high pH. The low nitrate levels observed after the first growing season may have also exacerbated plant chlorosis. A number of factors have been cited as possible causes of chlorosis in container grown plants. Sanderson (25) reported chlorosis for woody plants within six months of containerization and suggested rapid decomposition of MSW compost, high media pH, high soluble salts and the slow release rate of the urea formaldehyde fertilizer used. Chlorosis has also been reported within three weeks after containerizing *Forsythia* and *Thuja* in compost based media (19); chlorosis was attributed to boron toxicity. High calcium levels, resulting from irrigation with alkaline water, can cause chlorosis related to magnesium deficiency. Magnesium levels should be 1/3 that of calcium for proper plant growth (11).

Physical media characteristics. Compared to the control medium, all amendments used as peat substitutes, except tire chips, increased bulk density, but decreased pore space, media aeration, water infiltration capacity, and relative media water content at container capacity (Table 5). These important media characteristics are often overlooked by growers during formulation or modification of container media. Physical characteristics of any container medium should be considered together with an understanding of growing requirements of specific plants being produced to promote optimum plant performance.

Bulk density is a measure of soil, or in this case, container growing medium, mass per unit volume. Bulk densities between 1.25 and 1.65 g/cm^3 have been shown to restrict plant growth (1, 12). All peat replacement treatments significantly increased media bulk density compared to the peat-based control medium (Table 5); however, bulk densities were well below the range where plant growth would be negatively influenced. Bulk density was higher for 100% compared to 50% peat substituted media. Amendment of container media with mature composts (Pecar, Composting Concepts, and Recomp) resulted in higher bulk densities compared to media amended with immature compost (Minneapolis). Fully decomposed composts, and to a lesser degree immature composts, often have smaller particle sizes than peat and when used as media components promote media packing and reduce aeration pore volume, thereby increasing media bulk density.

Total media porosity (pore space occupied by air and water at media saturation) was highest for the standard control medium and lowest for the 100% tire chip amended medium (Table 5). Media aeration porosity (pore space occupied by air at container capacity) is considered by some to be the most important physical characteristic of a container medium (4). Although species dependent, media aeration porosities ranging from 10–20% are sufficient for most plants (4, 5, 8, 10, 21). Aeration porosity for media compared in this research was highest for media amended with 100 (22.2%) and 50% (15.3%) rubber tire chips followed by the

Table 4. Effect of peat replacement with compost and rubber tire chips on top dry weight (g) for three deciduous species and one herbaceous perennial.

Media treatment[z]	*Physocarpus* 'Dart's Gold' 1991	*Physocarpus* 'Dart's Gold' 1992	*Forsythia* x 'Meadowlark' 1991	*Forsythia* x 'Meadowlark' 1992	*Lamiastrum galeobdolon* 1991	*Lamiastrum galeobdolon* 1992	*Spiraea* x *billiardii* 1991	*Spiraea* x *billiardii* 1992
CTRL	10.2cde[y]	20.6bc	10.4d	33.7cd	3.2e	8.1f	—[x]	43.0cde
M50	9.5de	17.6bc	19.3ab	46.5ab	10.5cd	26.7ab	—	46.1bcde
M100	7.2e	15.12c	11.2cd	30.9cd	9.6cd	18.0bcde	—	35.8e
R50	23.4ab	35.6ab	19.9ab	57.9a	17.9a	29.9a	—	58.9a
R100	25.4a	35.8ab	13.8bcd	47.7ab	12.9bc	21.6abcd	—	54.7abc
P50	20.5abc	39.9a	17.4abc	40.6bc	11.9bc	23.83abc	—	52.8abcd
P100	14.7cde	22.3abc	16.8abcd	52.3ab	11.0bc	15.3cdef	—	55.8ab
C50	23.7ab	26.0abc	23.3a	46.9ab	9.5cd	13.4def	—	50.8abcd
C100	19.8abcd	30.7abc	19.8ab	48.4ab	14.4b	21.3abcd	—	46.1bcde
T50	11.4cde	15.4c	21.0a	46.8ab	11.0bc	12.1ef	—	53.8abc
T100	5.2e	—[w]	10.8cd	24.8d	7.0d	10.9ef	—	41.2de

[z]Standard nursery container medium: 3 parts composted woodchips, 2 parts peat, 1 part sand.
M50 = Peat replaced 50% with yard waste compost, City of Minneapolis.
M100 = Peat replaced 100% with yard waste compost, City of Minneapolis.
R50 = Peat replaced 50% with composted garbage, Recomp, Inc.
R100 = Peat replaced 100% with composted garbage, Recomp, Inc.
P50 = Peat replaced 50% with yard waste compost, Pecar, Inc.
P100 = Peat replaced 100% with yard waste compost, Pecar, Inc.
C50 = Peat replaced 50% with yard waste compost, Composting Concepts.
C100 = Peat replaced 100% with yard waste compost, Composting Concepts.
T50 = Peat replaced 50% with shredded rubber tire chips, Kanntech, Inc.
T100 = Peat replaced 50% with shredded rubber tire chips, Kanntech, Inc.
[y]Treatment means within columns separated by Duncan's Multiple Range test, P = 0.05.
[x]No dry weight data collected for *Spiraea* in 1991.
[w]All *Physocarpus* plants grown in the 100% peat substitution with tire chips medium were dead by the end of the 1992 growing season.

Table 5. Effect of peat substitution with compost and rubber tire chips on media physical characteristics compared to a standard peat-based medium.

Media treatment[z]	Bulk density (g/cm^3)	Total media porosity (%)	Aeration porosity (%)	Water retention porosity (%)	Percolation time (sec)[y]	Water infiltration rate (ml/sec)	Relative water content[x]
CTRL	0.463e[w]	73.5a	11.8bcd	61.7a	57.7ef	17.2b	1.33a
M50	0.610d	66.0b	8.3c	57.7b	81.3def	12.3c	0.95b
M100	0.637d	64.5bc	8.7c	55.8bcd	68.3ef	14.7bc	0.88cd
R50	0.653cd	63.9c	7.3c	56.6bc	142.0cde	7.0d	0.86cd
R100	0.720a	63.5c	7.6c	55.9bcd	239.0ab	4.2de	0.78e
P50	0.627d	63.0cd	9.9c	53.1cd	99.0def	10.1cd	0.84d
P100	0.760a	61.3e	7.7c	53.6cd	306.0a	3.3e	0.70f
C50	0.627d	65.4bc	9.1c	56.3bc	161.0bcd	6.2de	0.90c
C100	0.717ab	63.7c	8.3c	55.4bcd	193.3bc	5.2de	0.77e
T50	0.613d	61.5de	15.3b	46.2d	57.7ef	17.2b	0.75e
T100	0.690bc	57.8f	22.2a	35.6e	28.3f	35.7a	0.52g

[z]CTRL = Standard nursery container medium: 3 parts composted woodchips, 2 parts sphagnum peat, 1 part sand.
M50 = Peat replaced 50% with yard waste compost, City of Minneapolis.
M100 = Peat replaced 100% with yard waste compost, City of Minneapolis.
R50 = Peat replaced 50% with composted garbage, Recomp, Inc.
R100 = Peat replaced 100% with composted garbage, Recomp, Inc.
P50 = Peat replaced 50% with yard waste compost, Pecar, Inc.
P100 = Peat replaced 100% with yard waste compost, Pecar, Inc.
C50 = Peat replaced 50% with yard waste compost, Composting Concepts.
C100 = Peat replaced 100% with yard waste compost, Composting Concepts.
T50 = Peat replaced 50% with shredded rubber tire chips, Kanntech, Inc.
T100 = Peat replaced 100% with shredded rubber tire chips, Kanntech, Inc.
[y]Time (sec) required for absorption of 1 liter of water relative to medium surface area (= 1256 cm^2).
[x](Wet weight of medium at container capacity/dry weight of medium) – 1.
[w]Treatment means within columns separated by Duncan's multiple range test, p = 0.05.

standard peat-based control medium (11.8%) (Table 5). Conversely, water retention porosity (pore space occupied by water at container capacity) was highest for the peat-based control medium and lowest for media amended with tire chips (Table 5). Aeration porosity was reduced to levels considered less than optimum (<10%) for all media amended with compost. Siminis and Manios (26) and Wilson (32) have also reported reductions in porosity for greenhouse media amended with compost, however, Bugbee et al. (7) observed increased media aeration when compost was used. Peat substitution with 100% tire chips increased aeration porosity to levels considered detrimental for most plant species. Plant growth (top dry weight) was not significantly reduced for compost amended media or media where peat was replaced 50% with tire chips (Table 4). Plant growth was, however, reduced when peat was substituted 100% with rubber tire chips which resulted in a medium with low water holding capacity that was susceptible to drought. This effect was similar to that reported by Bugbee and Frink (5) where growth was reduced when media aeration porosity was greater than 20–25%. Growers should be aware that regardless of the porosity chacteristics of a medium, container depth will affect media drainage and aeration (16, 28).

Water infiltration rate (ml/sec) was decreased for all compost amended media compared to the standard control medium (Table 5). Infiltration rate was essentially the same for the 50% tire chip amended medium and the control medium. Water infiltration rate for the 100% tire chip amended medium (T100) was two to ten times that of other media and twice that of the standard peat-based medium (Table 5). The effect of peat substitution with compost and rubber tire chips on percolation time (time required for 1 liter of water to enter media surface) was negatively correlated with infiltration rate (Table 5).

Peat replacement with compost significantly reduced water holding capacity (Table 5). Water holding capacity was lower for media wherein peat was substituted 100% with compost and rubber tire chips compared to 50% peat replacement with these amendments. The standard peat-based medium had the highest water holding capacity.

No one amendment demonstrated overall superiority in all respects. Mature composts can, however, be a valuable addition to container media. Based on the physical and chemical media characteristics and plant growth and performance documented by this research, peat use can be reduced by substituting MSW and YW composts for peat as organic media components. Replacement of 50% (v:v) of the peat in a standard container medium with mature compost appears to provide a medium that supports production of quality plants and reduces reliance on sphagnum peat. When compared to standard peat-based container media, plant growth was generally enhanced through partial peat substitution with YW and MSW compost. This was true even though compost effects on media characteristics were often negative regarding theoretical impacts on plant growth. One hundred percent peat substitution with compost would not be recommended based on results of this research. Although total fertility inputs may be slightly reduced when compost is used, composts are generally a low analysis source of nutrients, so supplemental fertilizer will typically be required to avert nutrient deficiencies. Rubber tire chips were a suitable peat substitute when used to replace up to 50% of the peat in a standard container medium. One hundred percent peat replacement with tire chips is not recommended because of negative effects on media moisture holding capacity.

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Trade Flows and Marketing Practices within the California Nursery Industry—Survey Results from 1988 and 1993[1]

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Abstract

Nurseries were surveyed nationwide in 1989 and 1994 to collect information on products, customers, and business practices during the previous year. California's nursery industry is the largest in the nation and provided the majority of seedlings, liners, whips, and grafted material from within the state. Landscape firms were the most important customers for wholesale nurseries in 1993 (35% of sales), followed by garden centers and re-wholesalers (26% and 25% of sales), and mass merchandisers (12% of sales). Over 90% of California nursery wholesale products were sold within the state, and the rest were shipped to the north, west, midwest, and parts of the east coast. Production cost was used as the most important criteria for price determination of nursery stock. Sales methods such as in-person and telephone, negotiated and non-negotiated sales varied in popularity between the two years surveyed. Nurseries spent about 3.5% of their revenue on advertising, primarily in catalogs and the Yellow Pages. Twenty-six percent and 70% of medium and large nurseries, respectively, were represented at trade shows versus only 11% of small nurseries. Capital and land were the major factors limiting expansion of nurseries in 1988 and 1993, with market demand becoming a more prevalent factor in 1993.

Index words: product inventory and sales, nursery customers, business practices, advertising.

Significance to the Nursery Industry

The greenhouse and nursery industry is the second most important sector of agriculture in the United States, and generated more than $10 billion value in cash receipts in 1994. Although an important economic force, nursery statistics on trade and business practices of the industry are scarce. Compared to other agricultural commodities, nursery production is extremely diversified, including a wide range of products such as bulbs, bedding plants, perennials, roses, Christmas trees, and deciduous or evergreen shrubs or trees. Within each of these plant categories, anywhere between a few to several hundred species are grown commercially, making the collection of detailed statistics a daunting task. In 1989 and 1994, national surveys of the nursery industry collected information on destinations of nursery products, origins of propagation materials, sales methods used, price determination practices, and resources allocated to advertising. We have summarized the survey results for the California nursery industry, the leader in nursery and greenhouse production in the United States. We have further categorized responses by small, medium, and large nurseries, based on their annual sales volume. The results show characteristic differences and similarities in business practices for nurseries of different size and how the industry adapted to the recent recession.

Introduction

The United States greenhouse and nursery industry is the second most important sector in U.S. agriculture in terms of economic output (3). Over the last ten years the value of cash receipts for greenhouse and nursery products has increased from $5.4 billion to $10 billion nationwide (7). California leads the nation's greenhouse and nursery production with cash receipts valued at $1.98 billion in 1994. From 1980 to 1990 the value of cash receipts doubled, but stagnated for the following four years.

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