This Journal of Environmental Horticulture article is reproduced with the consent of the Horticultural Research Institute (HRI – www.hriresearch.org), which was established in 1962 as the research and development affiliate of the American Nursery & Landscape Association (ANLA – http://www.anla.org).

HRI's Mission:

To direct, fund, promote and communicate horticultural research, which increases the quality and value of ornamental plants, improves the productivity and profitability of the nursery and landscape industry, and protects and enhances the environment.

The use of any trade name in this article does not imply an endorsement of the equipment, product or process named, nor any criticism of any similar products that are not mentioned.

Compost and Rubber Tire Chips as Peat Substitutes in Nursery Container Media: Growth Effects[1]

James B. Calkins, Beth R. Jarvis, and Bert T. Swanson[2]
Department of Horticultural Science
University of Minnesota, St. Paul, MN 55108

Abstract

This research investigated the feasibility of using composted yard wastes, composted municipal solid waste and shredded rubber tire chips in nursery container media. Containerized *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 media amended with five recycled waste materials used as peat substitutes in a standard container medium of composted woodchips, peat, and sand (3:2:1 by vol). Waste materials used included three yard waste composts, one municipal solid waste compost and shredded rubber tire chips. Fifty or 100% of the peat in the standard growing medium was replaced with each amendment. Ten treatments (five amendments, each at 50% and 100% peat replacement) and a control (standard medium) were used for all seven plant species. Visual ratings, height and width measurements (crown volume), number of growing points and plant dry weights indicated that media in which 50% of the peat was replaced by an amendment produced larger plants of superior quality compared to the control. Rubber tire chips were acceptable as a 50% peat substitute for plants that prefer well-drained conditions, while 100% peat substitution with tire chips was detrimental to plant growth and performance. Use of immature compost in container media negatively influenced plant growth.

Index words: yard waste, compost, rubber tire chips, municipal solid waste, garbage, peat replacement.

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

The nursery industry uses media composed of composted woodchips, sand, peat, and occasionally soil, vermiculite or perlite in the production of container grown nursery stock. Peat is potentially the most costly media component because of the large quantities used. Environmental concerns associated with current peat harvesting practices may limit peat availability in the future. Municipal composting programs not only divert yard wastes from landfills, but have increased the supply of compost. Increased compost availability, combined with growing interest in recycling, could make compost a potentially low cost, environmentally sound peat replacement option for container media.

This research investigated peat replacement (50 and 100%) with four municipal composts and rubber tire chips. Amendment suitability was species and rate specific. In general, 50% peat replacement with mature compost in conventional container media enhanced plant growth and performance. Rubber tire chips were unacceptable as a peat substitute when used at high rates. Compost quality and consistency remain concerns and additional research will be required to further quantify compost suitability before recommendations can be standardized.

Introduction

Peat is potentially the most expensive component in standard container media (1). Environmental concerns associated with current peat harvesting practices may limit peat availability in the future. At the same time, many municipalities are implementing composting programs in an attempt to recycle yard and municipal solid wastes and reduce reliance on landfills. In order for such recycling programs to be cost effective, markets must be found for these compost products. Through sales of trees, shrubs and lawn care products, the nursery and landscape industry contributes to the proliferation of such wastes. Composts generated from yard and municipal wastes could function as peat substitutes in container growing media as well as meet other production and landscape needs including soil amendments and landscape mulches.

To be widely accepted by growers and landscapers, compost must be dependably available, of consistent quality, odorless, free of human or plant pathogens, and free of hazardous materials. When used as a peat substitute, compost must also be comparable to peat in cost. Compost amended media must also support plant growth that is similar to or better than growth in conventional, peat based growing media.

Various composts have been evaluated for potential use in horticultural and agronomic production systems. Integration of composted leaves, sewage sludge, sawdust, food processing wastes, and other industrial and municipal solid wastes into greenhouse and nursery growing media has been investigated on a limited basis (1, 2, 6, 8, 9, 10, 11, 12). This research was designed to evaluate yard and municipal solid waste composts and shredded rubber tires as potential replacements for peat in container growing media. Rubber tire chips have not been previously evaluated for use in container

[1]Received for publication on September 18, 1995; in revised form December 23, 1996. Paper No. 22,021 of the Scientific Journal Series, Minnesota Agricultural Experiment Station. Research supported in part by the Minnesota Agricultural Experiment Station, Minnesota Nursery and Landscape Industry, Minnesota Composting Industry, University of Minnesota Computer Center, and the Minnesota Extension Service.

[2]Post-Doctoral Research Associate, Graduate Student, and Professor, respectively.

media, but have recently been investigated as a potential soil amendment to reduce compaction in high traffic turf (7).

Materials and Methods

The research was conducted at the University of Minnesota, St. Paul campus, Teaching Research, and Extension 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 container medium was replaced (50 or 100%) with one of five amendments (Table 1). A standard nursery container growing medium composed of composted hardwood woodchips, peat (pH 4.3), and coarse sand (3:2:1 by vol) served as the control. 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] (Grace-Sierra, Milpitas, CA) were each incorporated at 2.38 kg/m^3 (4.0 lb/yd^3) into all media combinations. Woodace PERK micronutrients (Vigoro Industries, Inc., Fairview, IL) were also incorporated at a rate of 1.78 kg/m^3 (3.0 lb/yd^3). No additional fertilizer was supplied during the study. Deciduous plants (rooted cuttings) were planted in 6.5 liter containers (#2 Polytainer; Nursery Supplies, Inc., Chambersburg, PA). Evergreens (plugs) and *Lamiastrum* (divisions) were planted in 3.8 liter containers (#1 Polytainer). 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.

Plant parameters measured. To determine plant response to the various amended media, plant quality, mortality, and growth were measured each fall. Plant quality (visual quality ratings: 0 = dead, 5 = excellent) was determined by three nursery professionals. Plants rated 3 or above were considered saleable. Branch terminals (growing points) were counted for *Forsythia*, *Spiraea*, *Physocarpus*, and *Lamiastrum* as a measure of plant density (branching). *Forsythia*, *Physocarpus*, and *Lamiastrum* plants were then topped at 10 cm (4 in) above the medium surface for dry weight determination. Second year growth data for these species was, thus, based on regrowth. At the end of the second growing season, dry weight was also determined for *Spiraea*. Height and width measurements were made at the end of each growing season for all species except *Lamiastrum* and were used to calculate plant crown volume (height x width x width). In lieu of plant height, total runner length was measured for *Lamiastrum*.

Results and Discussion

Plant mortality. Poor initial survival for *Physocarpus* was attributed to inferior cuttings, however, *Physocarpus* mortality may have also been aggravated by peat substitution with municipal solid waste compost (R50, R100) and the higher levels of yard waste compost and rubber tire chips. High sodium levels differentiated compost derived from municipal solid waste (Recomp) from the other composts (data not shown). Composts were not leached prior to use. When combined with the poor quality of liner roots, high salt levels may have reduced survival of *Physocarpus*.

Lamiastrum mortality was significantly increased by the 100% peat substitution with tire chips (T100) treatment. *Lamiastrum* prefers shade and moist growing conditions, however the 100% tire chip amended medium was very well drained which could have resulted in drought stress. Of the amendments studied, tire chips as a 100% peat replacement reduced plant performance for woody deciduous species, especially in the first growing season. This reduction in plant performance may similarly have been related to drought stress. Water holding capacity was significantly reduced for the tire chip amended media (data not shown). The negative effect of diminished moisture holding capacity of tire chip amended media was species dependent and was less apparent for the more drought tolerant species (e.g., *Juniperus* spp.).

Root systems occupied a smaller portion of the container volume during the establishment year; less extensive root systems may have increased susceptibility to drought stress

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

Media treatment		Composition by volume	% Peat replacement
CTRL	Control—woodchips:peat:sand	3:2:1	0
M50	Minneapolis compost[z]—woodchips:peat:compost:sand	3:1:1:1	50
M100	Minneapolis compost—woodchips:compost:sand	3:2:1	100
R50	Recomp compost[y]—woodchips:peat:compost:sand	3:1:1:1	50
R100	Recomp compost—woodchips:compost:sand	3:2:1	100
P50	Pecar compost[x]—woodchips:peat:compost:sand	3:1:1:1	50
P100	Pecar compost—woodchips:compost:sand	3:2:1	100
C50	Composting Concepts compost[w]—woodchips:peat:compost:sand	3:1:1:1	50
C100	Composting Concepts compost—woodchips:compost:sand	3:2:1	100
T50	Rubber tire chips[v]—woodchips:peat:tire chips:sand	3:1:1:1	50
T100	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.

Table 2. **Effect of peat replacement with compost and rubber tire chips on visual quality ratings of three evergreen and three deciduous species and one herbaceous perennial.**

Media treatment[z]	*Juniperus* 'Seagreen'		*Juniperus* 'Hughes'		*Juniperus* 'Mini-Arcade'		*Physocarpus* 'Dart's Gold'		*Forsythia* x 'Meadowlark'		*Spiraea* x *billiardii*		*Lamiastrum galeobdolon*	
	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992
CTRL	4.2ab[y]	3.5b	3.5cd	3.2b	4.1a	3.9abc	3.6abc	2.7bcd	3.7c	3.1c	3.7ab	3.4d	3.2b	3.0c
M50	4.4ab	4.5a	4.1ab	4.5a	3.9abc	4.6a	3.3bcd	2.3cd	4.0bc	4.1ab	2.7c	3.7c	3.9a	4.1a
M100	4.0b	4.5a	3.7bc	4.3a	3.4abc	3.9abc	2.0d	1.5d	3.5cd	3.2c	1.7d	2.6e	3.9a	3.6abc
R50	4.6a	4.8a	4.2a	4.6a	3.8abc	4.0abc	4.9ab	4.0abc	3.8c	4.5ab	4.0ab	4.4abc	4.2a	4.2a
R100	4.2ab	4.7a	4.3a	4.7a	3.7abc	4.4ab	5.0a	4.7a	3.4cd	4.2ab	3.7ab	4.3abc	4.3a	3.9ab
P50	4.1ab	4.6a	4.2a	4.5a	3.4bc	3.8bc	4.8ab	5.0a	3.7c	4.3ab	4.2ab	4.5ab	4.1a	3.9ab
P100	4.5ab	4.6a	4.1ab	4.7a	4.0ab	4.6a	4.0abc	3.7abc	3.8c	4.4ab	4.1ab	4.8a	4.3a	4.0ab
C50	4.6a	4.8a	4.3a	4.8a	4.1a	4.3ab	4.9ab	4.3ab	4.7a	4.8a	3.8ab	4.1abc	4.1a	3.3bc
C100	4.7a	4.8a	4.1ab	4.5a	3.9abc	4.7a	4.5ab	4.2ab	4.0bc	4.7ab	3.5b	4.0bcd	4.1a	3.9ab
T50	4.2ab	4.4a	4.3a	4.5a	3.4bc	3.4c	3.3bcd	3.7abc	4.5ab	3.9b	3.9ab	4.5ab	4.3a	3.6abc
T100	3.4c	3.0c	3.2c	3.0b	3.2c	2.5d	2.8cd	1.0d	2.9d	3.2c	4.3a	4.3abc	3.3b	3.0c

[z]CTRL = 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. Means followed by the same letter are not significantly different.

especially in the well drained medium amended with tire chips. This effect became less apparent during the second growing season after plants had become established. In the final analysis, plants requiring a well drained growing medium (e.g., *Juniperus*, *Spiraea*) appeared to grow better in the media containing 50% tire chips. Peat replacement with 100% tire chips, however, proved detrimental even to such drought tolerant species.

Plant quality. All control plants were marketable after one growing season having received an average visual quality rating of at least 3.0 (Table 2; 0 = dead, 5 = excellent). After one year, 'Seagreen' juniper plant quality was not significantly different from the control for all treatments except for T100, which reduced quality. Quality of 'Hughes' juniper was at least equal to the control for all treatments after one growing season; M100 and T100 produced significantly higher quality plants than the control. First year 'Mini Arcade' plant quality was similar to the control for all treatments except for P50, T50, and T100, which significantly reduced plant quality. After two years, 'Seagreen' and 'Hughes' juniper quality was significantly increased for all treatments except T100, which reduced plant quality compared to plants grown in the control medium. After two years, 'Mini Arcade' juniper quality for all treatments was not significantly different from that of the control except for T100, which reduced plant quality.

All treatments produced *Physocarpus* plants with quality equal to the control after one year except for M100 and T100. After two years, P50 and R100 significantly increased *Physocarpus* plant quality while all other treatments were comparable to the control. After one growing season, treatment C50 produced *Forsythia* plants of significantly higher quality than controls while T100 resulted in plants of significantly reduced quality; *Forsythia* quality for the remaining treatments was not significantly different from the control. After two growing seasons, *Forsythia* plants were of significantly higher quality than the control for all treatments except for M100 and T100. For *Spiraea*, first year plant quality was reduced for treatments M50 and M100 while all other treatments produced plants comparable to the controls; M100 was, however, significantly worse than M50. At the end of the study, all treatments produced *Spiraea* plants of equal (C100, R50, M50) or better (P100, P50, T50, T100, R100, C100) quality than the control except for M100. After the first year, quality of *Lamiastrum* plants was significantly higher for all treatments, except T100, compared to the control. After two years, all treatments produced *Lamiastrum* plants of equal (M100, C50, T50, T100) or better (M50, R50, R100, C100, P50, P100) quality than the control.

Regardless of species, the quality of plants grown in the control medium tended to be reduced by the end of the second growing season compared to first year quality ratings. With a few exceptions, plant quality generally remained the same or was increased over time for plants grown in compost amended media.

Plant height. Significant differences in plant height were observed among treatments after one and two growing seasons (Table 3); treatment differences were species dependent. After one growing season, 'Seagreen' juniper growth was similar for treatments C50, C100, and T50 all of which were significantly taller than control plants. After two growing seasons, 'Seagreen' juniper plants remained significantly

Table 3. **Effects of peat replacement with compost and rubber tire chips on height (cm) of three evergreen and three deciduous species and one herbaceous perennial.**

Media treatment[z]	*Juniperus* 'Seagreen'		*Juniperus* 'Hughes'		*Juniperus* 'Mini-Arcade'		*Physocarpus* 'Dart's Gold'		*Forsythia* x 'Meadowlark'		*Spiraea* x *billiardii*		*Lamiastrum galeobdolon*	
	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992
CTRL	23.3cd[y]	29.3bc	21.2ab	19.9ab	14.1ab	14.4abc	30.9abcd	22.3b	40.6a	44.9a	46.6abc	63.9abc	129.5f	397.8d
M50	25.9abc	33.4ab	21.9a	18.8ab	14.6ab	14.8abc	27.8bcd	17.7b	40.6a	48.6a	41.5c	64.7abc	496.1bcd	1207.6ab
M100	24.4bcd	32.0abc	20.9ab	18.1b	12.3b	13.9bc	20.8d	18.3b	36.3a	44.9a	29.8d	56.9c	369.6de	823.5abcd
R50	26.7abc	31.3abc	22.2a	21.7ab	14.0ab	15.4abc	33.7abc	32.0ab	44.4a	51.0a	52.8ab	62.4abc	881.1a	1297.5a
R100	25.4abcd	31.8abc	22.8a	22.4a	13.2ab	15.6abc	39.5a	45.0a	43.0a	46.6a	52.2ab	67.3a	621.0bc	800.8bcd
P50	22.9cd	31.6abc	21.5ab	20.8ab	12.1b	15.9ab	36.0ab	31.8ab	37.8a	50.7a	53.4ab	66.4ab	549.7bcd	1189.9ab
P100	26.0abc	31.8abc	20.8ab	18.7ab	15.6a	17.7a	32.0abc	29.3ab	43.9a	47.9a	51.3ab	62.4abc	447.1cde	716.3bcd
C50	28.3ab	32.1abc	22.8a	19.5ab	14.1ab	14.2bc	36.4ab	31.1ab	42.2a	47.2a	48.1abc	58.4bc	387.4de	502.7cd
C100	28.8a	34.6a	19.6ab	20.7ab	14.2ab	15.9ab	38.5ab	30.0ab	40.8a	48.0a	48.3abc	61.8abc	654.3b	953.8abc
T50	28.0ab	32.7abc	23.5a	21.6ab	13.1ab	13.1bc	28.9abcd	32.0ab	45.1a	44.2a	55.5a	63.1abc	473.5bcde	580.4cd
T100	21.6d	28.3c	18.1b	19.9ab	12.8ab	12.2c	23.0cd	23.0b	33.5a	41.2a	45.7bc	58.0bc	277.0ef	528.8cd

[z]CTRL = 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, $p = 0.05$. Means followed by the same letter are not significantly different.

Table 4. **Effect of peat replacement with compost and rubber tire chips on crown volume (cm^3) of three evergreen and three deciduous species and one herbaceous perennial.**

Media treatment[z]	*Juniperus* 'Seagreen'		*Juniperus* 'Hughes'		*Juniperus* 'Mini-Arcade'		*Physocarpus* 'Dart's Gold'		*Forsythia* x 'Meadowlark'		*Spiraea* x *billiardii*	
	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992
CRTL	15932cd[y]	35162bc	12573bc	21469c	4004abc	13041bc	39125abc	15652b	57926c	76482ab	82623bc	150798ab
M50	23026abc	53642a	14291ab	35993ab	4682ab	20795ab	35569bc	14667b	69163bc	107905a	62694c	152465ab
M100	13593de	48069ab	12976b	38655a	2404bc	14176abc	11816c	5883b	48013c	75677ab	18775d	93473c
R50	25211ab	56700a	15751ab	46445a	4193abc	22413a	59885ab	63329ab	75013bc	96383a	109138ab	176947ab
R100	18348bcd	61832a	16686ab	47696a	3650abc	18263abc	62676ab	90734a	57245c	86925ab	97392abc	196517a
P50	19284bcd	50146ab	15162ab	41349a	2806abc	17034abc	66682ab	71989ab	92543bc	103347a	124084a	174122ab
P100	19076bcd	54535a	16236ab	38288a	5349a	22690a	44750abc	40773ab	115954ab	108607a	111949ab	176469ab
C50	27759a	57396a	17341ab	47113a	3777abc	17362abc	67610ab	68319ab	159445a	98306a	95089abc	151035ab
C100	22019abc	64209a	14114ab	38165a	4743ab	22407a	72523a	53060ab	78016bc	110861a	79970bc	155481ab
T50	16326cd	48342ab	19790a	44317a	2448bc	11036cd	36855bc	45774ab	120995ab	93323a	109586ab	173724ab
T100	7642e	29578c	7433c	24995bc	2002c	3528d	15614c	10350b	47054c	54328b	74178bc	145942b

[z]CTRL = 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, $p = 0.05$. Means followed by the same letter are not significantly different.

taller than control plants for treatment C100 while all other treatments were essentially equal. There were no significant differences in height among treatments for 'Mini Arcade' juniper, 'Hughes' juniper, *Forsythia* and *Physocarpus* throughout the study. In the first year, *Lamiastrum* growth was significantly increased compared to the control for all treatments except T100. By the end of the second growing season, *Lamiastrum* growth was greater than the control only for treatments M50, R50, P50 and C100.

In general, height of plants grown in all amended media was at least equal to that for control plants at the end of each growing season, regardless of species.

Plant volume. After one growing season there were no significant differences based on plant volume for *Physocarpus* (Table 4). A year later, *Physocarpus* volume had increased only for R100 compared to the control. After two growing seasons, there were significant treatment differences in plant volume compared to the control for all species except *Forsythia*. Volume of *Forsythia* was increased compared to the control for treatments P100, C50 and T50 after two years. By the end of the first growing season, 'Seagreen' juniper crown volume was increased compared to the control for treatments R50 and C50 (Table 4); plant volume was reduced for T100. After two years, 'Seagreen' juniper volume was greater than the control for treatments C100, R100, R50, C50 and M50. First year volume of 'Hughes' juniper was unaffected by treatment except for treatment T50, which increased crown volume compared to the control. All treatments except T100 increased volume of 'Hughes' juniper after two years compared to the control. There were no significant treatment differences in plant volume compared to the control for *Juniperus* 'Mini Arcade' after one growing season. After two years, 'Mini Arcade' juniper volume was significantly increased for treatments P100, R50 and C100 while T100 reduced volume compared to the control. *Spiraea* x *billiardii* volume, after one growing season, was increased for treatment P50 and decreased for M100 compared to the control; M50 was significantly better than M100. *Spiraea* volume was significantly reduced the second year for the M100 treatment; there were no significant differences between any other treatments.

Overall, crown volume was equal to or greater than the control for all plants except for 'Seagreen' juniper grown for one year and 'Mini Arcade' juniper grown for two years in the T100 medium and billiard spirea grown in the M100 medium.

Plant density. Plant density or branching (quantified by the number of growing points) was only measured for deciduous species (Table 5). Based on first year data, treatments R50, C50, and C100 increased *Physocarpus* plant density compared to the control while M100 and T100 reduced density. In the second year, *Physocarpus* density was comparable for all treatments except for C100 which significantly increased plant density compared to the control. After one growing season, *Forsythia* plant density was equal to the control for all treatments except for T100. *Forsythia* density, after the second year, was significantly greater for the C50 medium while all others did not differ from the control plants. After one growing season, *Spiraea* plant density was increased by treatment C50 while all other treatments were

Table 5. Effect of peat replacement with compost and rubber tire chips on branching (number of growing points) 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	*Spiraea* x *billiardii* 1991	*Spiraea* x *billiardii* 1992	*Lamiastrum galeobdolon* 1991	*Lamiastrum galeobdolon* 1992
CTRL	6.3cd[y]	13.7bcd	4.0abc	9.6bcd	9.6bc	32.3ab	6.4d	12.0d
M50	7.2bcd	12.7bcd	4.5abc	13.0abc	9.9bc	25.9b	20.9bc	31.6ab
M100	4.3d	7.0d	3.1cd	7.9cd	6.3c	13.2c	18.4c	21.1c
R50	14.0a	19.5abcd	3.4bcd	11.7abc	13.4ab	37.8a	31.6a	32.5a
R100	11.5abc	22.0abc	3.1cd	7.6cd	12.1ab	34.6ab	25.1abc	22.2c
P50	12.0abc	25.0ab	4.0abc	12.5abc	11.4ab	32.8ab	24.6bc	24.4abc
P100	9.0abcd	13.0bcd	3.4bcd	11.1abc	11.9ab	35.9ab	25.7ab	23.5bc
C50	13.8a	25.5ab	5.1a	15.9a	14.3a	34.8ab	19.4bc	18.4cd
C100	12.5ab	27.3a	4.1abc	13.4ab	9.5bc	26.9ab	25.6ab	26.3abc
T50	7.7bcd	23.5abc	4.8ab	12.6abc	12.3ab	31.4ab	20.9bc	18.7cd
T100	5.3d	11.0cd	2.4d	5.7d	11.7ab	30.4ab	10.6d	20.0cd

[z]CTRL = 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. Means followed by the same letter are not significantly different.

Table 6. 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'		*Forsythia* x 'Meadowlark'		*Lamiastrum galeobdolon*		*Spiraea* x *billiardii*	
	1991	1992	1991	1992	1991	1992	1991	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]CTRL = 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. Means followed by the same letter are not significantly different.

[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.

comparable to the controls. At study's end, *Spiraea* plants were of comparable density for all treatments except for M100 which significantly reduced plant density. Plant density was increased for *Lamiastrum* in all treatments except T100 when compared to the control after one year. After two years, the control, C50, T50 and T100 produced *Lamiastrum* plants of equal density while all other treatments increased plant density compared to the control.

Deciduous plants in 50% peat replacement media generally produced a greater number of growing points during the first year compared to plants grown in 100% replacement media or the control (Table 5). This effect was reduced after two years.

Plant dry weight. Dry weights were taken for *Physocarpus*, *Forsythia* and *Lamiastrum* at the end of each growing season (Table 6). Dry weight was also determined for *Spiraea* at the end of the second growing season (Table 6). First year dry weights for *Physocarpus* were not different from the control for all treatments except for R100, R50, and C50, which significantly increased plant dry weight. After two years, *Physocarpus* dry weight was increased by the P50 treatment and reduced for the T100 treatment. *Forsythia* dry weight was increased for all 50% peat replacement treatments and the C100 treatment after one growing season; none of the treatments significantly reduced plant dry weight compared to the control. *Forsythia* dry weight was comparable to, or better than, the control for all treatments after two years, however, R50, P100, C100, R100, C50, T50 and M100 significantly increased plant dry weight over the control. Second year *Spiraea* dry weight was increased for treatments R50 and P100 while all other treatments were not significantly different from the control. *Lamiastrum* dry weight was significantly increased by all treatments compared to the control after one year. Second year dry weights of *Lamiastrum* were equal to or increased compared to the control for all treatments.

Top dry weight for plants grown in all amended media was consistently equal to or greater than that of control plants.

Growth responses to the various media evaluated were mixed and species specific. In general, compost amended media enhanced plant performance compared to the control. Growth responses of *Juniperus* cultivars were typically less pronounced than for deciduous species. Where compost amendments were assumed to be similar in composition (e.g., yard wastes), differences in plant performance might be explained by variations in compost maturity, percentage of peat replacement, composting method, and raw materials source. Media incorporating Minneapolis compost (M50 and M100) contained the most immature compost of those evaluated and complete (100%) peat replacement with Minneapolis compost generally had a negative impact on plant performance compared to 50% peat substitution. Nitrogen levels were reduced for media amended with Minneapolis compost (data not shown) and competition for nitrogen attributed to microorganism activity in immature composts may have caused this negative effect (3). Other factors, such as phytotoxic byproducts of fermentation (1, 3, 4) or allelopathic substances

(5) may have played a role. Screening for these substances was beyond the scope of this research. The adverse effects of the immature compost became less significant after two years.

Results of this research suggest yard waste or municipal solid waste compost can successfully replace peat in container growing media. Negative effects of an incompletely decomposed compost on plant growth can, however, be significant as evidenced by the Minneapolis compost used in this study. In general, and depending on compost source, 50% peat replacement initially enhanced plant growth compared to a standard peat based growing medium, although, after two years, positive effects on plant growth related to the amount of compost used were negligible for most of the media evaluated. These results support findings by Tichnor et al. (12) that plant growth in media containing 50% compost can equal or surpass growth in a standard container medium. Waste products such as tire chips might also be used in situations where a well drained medium is critical, however 100% replacement of peat with rubber tire chips is not recommended. Taking into account cost, quality, and availability factors, growers should consider locally available, alternative sources of organic matter, such as yard and municipal solid waste composts, for use as soil amendments and components of container growing media.

Literature Cited

1. Bugbee, G.J. and C.R. Frink. 1989. Composted waste as a peat substitute in peat-lite media. HortScience 24:625–627.

2. Bugbee, G.J., C.R. Frink, and D. Migneault. 1991. Growth of perennials and leaching of heavy metals in media amended with a municipal leaf, sewage sludge and street sand compost. J. Environ. Hort. 9:47–50.

3. Chen, Y. and Y. Inbar. 1993. Chemical and spectroscopical analysis of organic matter transformations during composting in relation to compost. *In*: Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects. H.A.J. Hoitink and H.M. Keener (eds.). Proc. Intern. Composting Res. Symp., March 27–29, 1992. Renaissance Pub., Washington, OH. p. 551–600.

4. Hirai, M.F., A. Katayama, and H. Kubota. 1986. Effect of compost on plant growth. BioCycle 27(4):58–61.

5. Hoitink, H.A.J. and P. Fahy. 1986. Basis for the control of soil borne pathogens with compost. Ann. Rev. Phytopath. 24:93–114.

6. Lumis, G.P. and A.G. Johnson. 1982. Boron toxicity and growth suppression of *Forsythia* and *Thuja* grown in mixes amended with municipal waste compost. HortScience 17:821–822.

7. Rogers, J., T. Vanini, and M. Ventola. 1994. Shredded tires: A new soil amendment. Grounds Maintenance 29(3):42, 44, 48–49.

8. Sanderson, K.C. and W.C. Martin. 1974. Performance of woody ornamentals in municipal compost medium under nine fertilizer regimes. HortScience 9:242–243.

9. Sanderson, K.C. 1980. Use of sewage-refuse in the production of ornamental plants. HortScience 15:173–178.

10. Siminis, H.I. and V.I. Manios. 1990. Mixing peat with MSW compost. BioCycle 31(11):60–61.

11. Smith, E.M. 1994. Research Update: Utilizing landscape waste compost in container production. Perennial Plants 2(4):28–30.

12. Tichnor, R.L., D.D. Hemphill, Jr., and D.J. Flower. 1985. Growth response of *Photinia* and *Thuja* and nutrient concentrations in tissues and potting media as influenced by composted sewage sludge, peat, bark and sawdust in potting media. J. Environ. Hort. 3:176–180.