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Agricultural and Municipal Wastes as Container Media Component for Ornamental Nurseries

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ABSTRACT: This paper deals with the suitability of agricultural and municipal organic wastes as growing media components for ornamental plants. Nine growing media prepared by mixing the main components of peat (P), hazelnut husk (H) and maize straw (M) with the fertilizer sources of municipal solid waste compost (C), bio-solid (B) and poultry manure (Pm) were compared against soil-based (C1) and peat-based (C2) controls. The suitability of such mixtures for use in soilless media was evaluated using their physico-chemical characteristics. To investigate the impact of mixtures on plant growth, two different pot experiments, including the plants of ligustrum (*Ligustrum lucidum*) and cypress (*Cupressus macrocarpa*), were conducted for two years. Physical and physico-chemical properties of mixture indicated that peat and soil were successfully replaced with hazelnut husk, maize straw, MSW-compost, bio-solid and poultry manure. The effect of fertilizer additives on plant growth was more pronounced than that of the main components. Therefore, among the present mixtures, the most suitable one for ligustrum was the mixture containing poultry manure, whereas for cypress was bio-solid, regardless of the main components.

Key words: Hazelnut husk, Maize straw, Bio-solid, MSW-compost, Poultry manure, Nursery plants

INTRODUCTION

Growing media is a key material to produce high quality, container grown plants. Most of nursery producers in Turkey mix their own media with basic ingredients such as peat, perlite, animal manure, and field soil to alter the physical and nutritional properties of the medium and to reduce cost. Approximately 200,000 tons of natural soil is used annually as container substrates by 400 producers in Sakarya, Turkey. However, an excessive amount of soil and manure causes extra weight, handling, soil compaction, and weeding problems, which lead to poor growth and commercial value of the ornamental plants. There is an increasing need for a regular supply of a uniform growth medium that has the ability to support vigorous plant growth for nursery plants. There has been more interest from the researcher in recent years in reducing peat in growing media component (Abad, *et al.*, 2001; Guerin *et al.*, 2001; Hicklenton *et al.*, 2001; Garcia Gomez *et al.*, 2002). Research to date has suggested that peat in container media has been satisfactorily replaced with some organic waste materials including bark and wood fibre, coconut coir and compost. Many different media formulations have been developed from waste materials and successfully introduced to the nursery industries. Such lightweight bio-waste resources, which are more porous than natural soil, are cheaper and more renewable than peat or natural soil (Ingelmo *et al.*, 1998, Hernandez Apaolaza *et al.*, 2005).Among the organic residues, hazelnut husk is one of the promising materials that could be introduced to container media. Hazelnut is predominantly produced in Mediterranean countries and Turkey produced 661,000 t of hazelnut in 2006. Using a 1:3 ratio of dry matter of hazelnut husk to total harvested dry matter of hazelnut, the estimated equivalent dry mass residue

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in 2006 was 300,000 t. Maize straw is another abundant crop residue for container media in Turkey. However, beneficial use of this raw material is limited and hence farmers tend to leave all or part of this material on the field or burn uncontrolled. During media preparation, the main components are usually mixed with nutrient rich wastes such as bio-solid, MSW-compost and poultry manure (Garcia Gomez *et al.,* 2002; Wilson *et al.,* 2002; Hernandez Apaolaza *et al.,* 2005). Recent studies indicated the beneficial effects of nutrient rich wastes on both media properties and plant growth. However, higher doses frequently create adverse effects especially due to the higher electrical conductivity (EC) (Hicklenton *et al.,* 2001; Garcia Gomez *et al.,* 2002).

Most ornamental plants are produced in containers. Therefore, fertilization is particularly critical in containerized plants because roots are confined in a limited amount of soil. Slow-release characteristics of nutrient rich organic wastes may play an important role in fertilization programs of containerized ornamental plants in order to reduce nutrient deficiencies.

As ornamental industry grows, the demand for growing media will increase in parallel; thus new alternative materials that are locally available will be needed. Reuse of organic waste as container growing media will reduce the amount of solid waste that is disposed of landfill. Moreover, these materials could be inexpensive solution instead of commercial peat or inconvenient natural soil. Although there is a wide range of wastes that have been studied as growing media, there is no information about the use of hazelnut husk and maize straw and their combination with bio-solid, MSW compost and poultry manure as alternative substrates. Therefore, one of the objectives of this study is to investigate the potential use of hazelnut husk and maize straw as media components by determining their physico-chemical characteristics and their effects on the growth of two ornamental plants, ligustrum and cypress. In addition, this study aims to evaluate the use municipal solid waste as growing media component, and thereby, to reduce the amount of waste that are disposed of into landfills.

MATERIALS & METHODS

The materials used in the substrate mixes were peat (P), naturally decomposed during 8 month hazelnut husk (H), decomposed maize straw (M), municipal solid waste compost (C), dried aerobic digested bio-solid (B) and matured poultry manure (Pm). P, H and M were considered as main components, C, B and Pm as nutrient sources. Nine substrates were prepared using main media component and fertilizer additives (Table 1). Peat and nutrient rich wastes (C, B, Pm) are 25 percent of the total volume of mixture. Commercial peat (C2) and soil+manure mixture (C1), which are widely used materials for nursery ornamentals at site, were tested as controls. Peat containing perlite purchased from a local dealer. Hazelnut husk was initially milled. Maize straw was harvested by silage thresher and decomposed during one and half year. Particle sizes were < 0.125 – 8.00 mm, < 0.125 – 4.00 mm, 0.125 – 8 mm, with geometric mean (dg) of 1.73 mm, 1.99 mm and 2.80 mm for P, H and M respectively.

Matured poultry manure containing rice hull litter was collected from local poultry producer, municipal solid waste compost from Istanbul municipal composting facility, and air dried bio-solid from Adapazari wastewater treatment plant. Initially dry media components were proportionally mixed by dry volume basis and subsequently moistened by distilled water before analysis. Physical properties of mixtures were determined using the method proposed by Verdonck and Gabriels (1992) with two duplicates. Substrate pH and EC were measured in a water-soluble extract 1:5 (w/v). Total organic matter (OM) of prepared growth medium was found after samples were ashed at the temperature of 550 °C. Nitrogen in substrates was determined by the Kjeldahl method. Volume reduction in container was obtained by measuring the difference between the initial media height and the final media height at the end of the experiment.

Two plant species, fast growing shrub *Ligustrum lucidum* and slow growing coniferous *Cupressus macrocarpa,* were tested for the suitability of the substrates. Rooted cutting of cypres and seedling of ligustrum obtained from the local nursery producer were potted in the early

Table 1. Physical properties of growing media prepared from peat (P), hazelnut husk (H), maize straw (M) as main component; biosolid (B), MSW-compost (C), poultry manure (Pm) as nutrient ingredient compared to the soil based (C1) and peat based (P) media

Media	Bulk density (g cm^3)	Particle density (g cm^3)	Total porosity (vol %)	Air Capacity (vol %)	Water Retention (%)
C1	0.78 a*	2.390 a	52.50 d	29.80 c	22.70 g
C2	0.31 b	1.678 f	80.90 c	26.40 cd	54.50 d
PMC	0.33 b	1.791 b	81.57 c	25.25 d	56.32 cd
PHC	0.32 b	1.768 c	82.00 bc	25.39 d	56.61 cd
HMC	0.27 c	1.766 c	84.22 abc	26.05 d	58.46 cb
PMB	0.25 c	1.726 d	85.52 abc	23.99 d	61.53 a
PHB	0.26 c	1.790 b	85.00 abc	25.42 d	59.58 ab
HMB	0.22 d	1.771 c	83.58 abc	27.73 cd	55.85 d
PMPm	0.21 d	1.726 d	88.27 a	40.03 a	50.14 e
PHPm	0.20 d	1.768 c	88.69 a	41.47 a	47.22 f
HMPm	0.20 d	1.693 e	88.19 ab	36.47 b	51.72 e

***Within columns, means followed by the same letter are not significantly different by least significant difference (P>0.05)**

May, and maintained outside in nursery area for two years. Pots were arranged in a random manner, with five single plant replicates and eleven growing substrates. Plants were grown in 1-liter capacity pots in first year and transplanted to 5-liter pots in the second year. Before planting, control (C2) treatment was fertilized with a slow-release fertilizer (15 : 9 : 9 + micronutrients) (Osmocote Plus, 3-4 months) at a rate of 1.5 kgm^{-3} substrate. The pots were hand-watered as needed (2-3 times a week).

At the end of the second growing season, plant height (from the stem base to the inflorescence tip), stem diameter and fresh weight were recorded for each pot. The fresh shoots were subsequently dried in an air oven at 78 °C until a constant weight was observed, and dry weight was also recorded.Measured data for the growing media and plants were statistically evaluated using the analysis of variance (*F*-test) and means values of the treatments were compared by the Least Significant Difference (*LSD*) at $P = 0.05$.

RESULTS & DISCUSSION

The main physicochemical characteristics of the growing media mixtures from organic wastes are shown in Table 1 and Table 2. Significant statistical differences among mixtures were observed for all properties measured in the present study. Substrate physical and chemical properties were influenced by both main component and nutrient source ingredient. However, the effect of nutrient rich materials, C, B and Pm, on media characteristics was higher than that of the main components; P, H and M. Bulk and particle density in the mixture containing C and B were substantially high since C and B involve more inorganic content than Pm. On the other hand, large particle size of rice hull in poultry manure increased the total pore space and thereby air filled pore as compared to fine texture materials, C and B. The effect of the main components on total pore space was negligible. Hazelnut husk and poultry manure resulted in higher air porosity and decreased water holding capacity of mixtures. On contrary, relatively fine particles of B and C in the mixtures improved the both parameters.

Based on the physical properties' growing media prepared from organic waste mixes had improved substrate properties over soil control (C1) or identical as compared to peat based (C2) media. Bulk density, particle density and total porosity of waste based media were in the range of ideal substrate (Abad *et al.,* 2001). However Pm increased the air porosity over the ideal range and conversely reduced the water retention of growing media. Relatively large particle size of rice hull was responsible for the elevated air porosity and low water retention (Abad *et al.,* 2005), therefore needs frequent irrigation.Peat was containing perlite, therefore OM value was lower in commercial peat controls (C2) and the substrates prepared from peat had values below than the substrates having no peat (Table 2). Particularly C addition to mixture further reduced OM. On the other hand Pm presence in mixture was significantly increased the total OM. In accordance with the nitrogen content, fertilizer additive organic wastes; C, B and Pm increased the nitrogen concentration of mixtures (Table 2). Nitrogen content was higher in maize straw combination whereas it is slightly reduced in hazelnut husk combination.pH was around neutral range in all mixtures (Table 2) and was within the e adequate values for woody ornamental. The EC was significantly lower in hazelnut husk combination because of initial low EC of hazelnut husk (0.756 dSm^{-1}). On the other hand, C, B or Pm addition exceed the EC beyond acceptable range (Abad *et al.,* 2001). The peat control substrate (C2) had more adequate values of pH and EC than the waste-based media (Abad *et al.,* 2001). At the end of the experiment, after 5 months of plant growth volume reduction in container was more apparent in media containing M because of media compaction or volume reduction by steady decomposition rate of M (Bernai *et al.*, 1998). H containing mediums were lower compaction than that M indicating resistance of H to degradation. Hemicelluloses and lignin content of H (11%, 43% resp.) was higher than that of M (27 %, 25 % resp.). The maximum volume reduction was in HMPm with 6.5% in volume of substrate given in Table 2.

Ligustrum growth parameters on soil based medium (C1) was significantly ($p < 0.01$) lower than the organic waste mixtures or peat based media (C2). Slow release fertilizer given plants grown on peat (C2) produced similar plant height and shoot dry weight with the compost (C) treatment but lower than the Pm or B given plants. For the organic waste based medium, the effects of media main components on plant growth parameters were not significant. The determined differences on plant height and dry weight were mainly due to the nutrient ingredient sources ($p < 0.01$). Both plant height and dry biomass was affected by substrate chemical properties generated by fertilizer additive components. According to the multiple regression analysis substrate N content, pH and organic matter were

Table 2. Physico-chemical properties of growing media prepared from peat (P), hazelnut husk (H), maize straw (M) as main component; biosolid (B), MSW-compost (C), poultry manure (Pm) as nutrient ingredient compared to the soil based (C1) and peat based (C2) media

Media	OM (% dry wt)	pH	EC (dSm^{-1})	Total N (% dry wt)	Volume reduction (cm)
C1	16 g*	7.43 a	0.55 e	0.826 f	0.26 d
C2	71 de	6.16 f	1.01 d	0.725 g	0.78 ab
PMC	67 f	6.72 d	3.33 ab	1.721 d	0.81 ab
PHC	68 ef	6.79 cd	3.35 ab	1.508 e	0.65 cd
HMC	76 bc	6.72 d	2.11 b	1.629 d	0.72 ab
PMB	72 d	6.95 b	3.47 a	2.066 bc	0.81 ab
PHB	73 cd	6.91 bc	3.29 ab	1.957 c	0.68 b
HMB	77 b	6.92 bc	2.45 c	2.130 b	0.83 ab
PMPm	78 b	6.66 de	3.24 ab	2.526 a	0.79 ab
PHPm	77 b	6.65 de	3.05 b	2.082 b	0.66 bc
HMPm	82 a	6.58 e	2.46 c	2.440 a	0.85 a

*** Within columns, means followed by the same letter are not significantly different by least significant difference (P>0.05)**

Table 3. Plant height, shoot dry weight and leaf N content of ligustrum (*Ligustrum lucidum*) on different growing media

Media	Plant height (cm)	Shoot Dry Weight (gr)	Leaf N content (% dry wt)
C1	84 e*	21.4 f	1.68 c
C2	99 d	39.06 de	2.40 b
PMC	100 d	42.36 d	2.39 b
PHC	100 d	40.24 de	2.41 b
HMC	100 d	47.56 c	2.40 b
PMB	107 c	47.30 c	2.45 ab
PHB	110 bc	48.24 c	2.50 a
HMB	109 c	48.2 c	2.47 ab
PMPm	116 a	54.5 a	2.52 a
PHPm	110 bc	50.8 b	2.53 a
HMPm	114 ab	52.58 ab	2.53 a

*** Within columns, means followed by the same letter are not significantly different by least significant difference (P>0.05)**

Table 4. Plant height, shoot dry weight and leaf N content of Cypress (*Cupressus macrorarpa*) on different growing media

Media	Plant height (cm)	Shoot Dry Weight (gr)	Leaf N content (% dry wt)
C1	30 d*	10.02 e	1.17 f
C2	42 b	30.92 cd	1.36 ef
PMC	38 c	36.60 b	1.44 bc
PHC	40 b	36.30 b	1.43 d
HMC	37 b	37.46 b	1.48 c
PMB	49 a	46.32 a	1.59 b
PHB	49 a	44.86 a	1.59 b
HMB	46 a	45.78 a	1.65 a
PMPm	38 b	32.00 cd	1.39 ed
PHPm	40 bc	33.40 c	1.39 ed
HMPm	37 c	30.78 d	1.36 ef

***Within columns, means followed by the same letter are not significantly different by least significant difference (P>0.05)**

responsible great extent for plant height and dry weight.

Ligustrum height = 150.314 + 13.59 N – 10.38 pH (R^2 = 0.844; p ≤ 0.001)

Ligustrum dry weight = 9.61 + 7.12 N + 0.33 OM (R^2 = 0.961; p ≤ 0.001)

Ligustrum plants showed positive responses to excessive substrate N availability. Both plant height and shoot dry weight was higher in the high N growing media group. Therefore plants grown on poultry manure were significantly greater shoot dry weight than in all other treatments (Table 3). Nitrogen concentration in leaves showed significant relationships with substrate N values and plant dry weight. Nitrogen rich Pm and, in a lesser extent B in growing media significantly increased N concentration in leaves. No differences were found in C given and slow release fertilizer amended plant (C2).For cypress, better plant height and shoot dry weight were recorded for the growing media based on the B and followed by the C treatment (Table 4). B and to the later extent C amended plants had also larger canopy and dark green appearance than other treatments. There were no significant differences in cypress plant height in the other treatments except soil based media (C1). On the other hand, plants grown on Pm mixture produced less shoot dry weight than the B and C but similar with peat based media (C1). Soil based media produced significantly less growth parameters than the rest of the treatments. The effect of waste-based substrates on leaf N concentration was in general positive in relation to the peat-based substrate (Table 4). N concentrations in leaves of plants of poultry manure-based substrates were smaller than those in bio-solid and MSW-compost, although poultry manure-based substrates were greater N presence.

According to the multiple regression analysis, bulk density (BD), organic matter (OM), EC and air pore space (AP) of growing media were responsible for the plant height and dry weight.

Cypress height = 272.6 – 242 BD – 5.5 EC – 1.87 OM – 0.78 AP (R^2 = 0.922; p ≤ 0.001)

Cypress dry weight = 250.8 – 235.1 BD – 1.63 OM – 1.08 AP (R^2 = 0.844; p ≤ 0.001)

For slow growing coniferous plant cypress, media physical and nutritional properties were equally important but plants were responded to physical properties particularly higher bulk density and lower air space. Poultry manure adversely affected this plant even though substrates had more N, but plant had pale green appearance and narrow canopy as compared to B or C treatment. Substrate main component effects on plant height and shoot dry weight were negligible or even not detected most of the case for growing media prepared by mixing organic residues. The main variation on plants growth parameters were due to the materials that used for the fertilizer ingredient. However these materials also significantly altered the physical properties of the growing media (Table 1). Ligustrum was predominantly responded to nitrogen presence in substrate whereas cypress was affected by both physical and physico-chemical properties of growing media.

Positive response of ornamental plants to nutrient rich organic wastes has been previously reported both for broad leaf and coniferous species (Hickleton *et al.*, 2001; Guerrero *et al.*, 2002; Hernandez Apaolaza *et al.*, 2005). An increase in N availability of growing media increased plant height, dry biomass and leaf N content of ligustrum plants, regardless of the main substrate components. Higher or similar plant performance on organic waste material over peat (C2) control indicated that nutrient rich organic materials had also advantage as slow release fertilizer (Huett, 1997). Moreover, the higher nitrogen release rate of Pm than B or C could be reason for better response of ligustrum to Pm (Adegbidi and Briggs, 2003). The leaf tissue N concentrations (Table 3) associated with maximum growth were within the range of values typically reported in ornamental woody species (Mills and Jones, 1996). However, none of the treatment reached the critical leaf nitrogen value 3.35%, reported for ligustrum (Stratton *et al.*, 2001).Most reports shown that as N increase, biomass production is enhanced to a point and remain constant or depressed in spite of the available N (Marschner, 1995). Leaf N concentration of coniferous plants was reported, in general, lower than the broad leaf evergreen species (Guerrero *et al.,* 2002, Benito *et al.,* 2005). Cypress plants were also responded to nitrogen but higher nitrogen presence in Pm together with low BD because of higher air porosity, depressed the plant growth of this species. Cypress is susceptible to transplanting; high air porosity beyond the optimum range (Abad *et al.,* 2001) could be reason for poor plant growth on treatment containing Pm. Toxic effects of ammonia volatilization from Pm might be further reduced the dry weight production in cypress plants (Gupta and Kelly 1992). On the other hand, the lower N presence and higher BD in mixes containing B and lesser extent in C compared to Pm were significantly increased the dry weight of cypress plants, even thought the plant height is not significantly different in peat control (C2) and mixes containing C and Pm. Leaf N concentrations were also higher in plant grown on mixes B and C. This is consistent with reports in other *Cupressus* species, where maximum growth has been observed with bio-solid receiving treatment (Guerrero *et al.,* 2002; Hernandez Apaolaza *et al.,* 2005; Benito *et al.,* 2005).

CONCLUSION

For the recycling of organic waste, all the investigated materials were within the recommended range for both media characteristics and plant growth, except poultry manure for coniferous cypress. Hazelnut husk and maize straw improved physical properties of growing media mixture; therefore, they can be beneficially used as substitutes for peat and natural soil. Similarly, bio-solids and MSW-compost adequately supplied nutrients to the plants, and when they fulfill quality standards, they can be used as slow release fertilizer source for ornamental plants. Because of toxicity problems of poultry manure to cypress; it is not convenient media ingredient for slow growing coniferous species. It should be pointed out that hazelnut is promising growing media component because of its low volume reduction and longer stand in container. Nutrient rich organic wastes together with locally available main substrate component such as hazelnut husk and maize straw could provide an opportunity to reduce costs as alternative nutrient source and to recycle municipal wastes.

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