Manganese Binding by Municipal Waste Composts Used as Potting Media[1]

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Abstract

Queen palms (*Syagrus romanzoffiana* (Chamisso) Glassman) grown in several types of sewage sludge compost media developed severe Mn deficiency symptoms. Severity of the symptoms was correlated with DTPA-extractable Mn levels in the media and with leaf Mn content, but not with total media Mn. Compost media tied up over 70% of Mn added to samples within one hour, versus 62% or less for a pine bark, sedge peat, and sand medium. Analysis of autoclaved media samples suggested that some of the Mn tie up in garbage and yard trash composts is caused by microorganisms, but microorganisms had little effect on the binding potential of sludge and manure composts.

Index words: Sewage sludge compost, manure compost, garbage compost, Mn deficiency, palms, *Syagrus romanzoffiana*

Significance to the Nursery Industry

Most of the sewage sludge composts studied bind manganese (Mn) so tightly that susceptible plants growing in them develop Mn deficiency symptoms. Because they also bind most added Mn fertilizers as well, treatment of compost-induced Mn deficiency is difficult. Sewage sludge composts therefore should not be used in media for plants susceptible to Mn deficiency, but garbage compost media can usually be safely used for such plants.

Introduction

The use of waste product composts as horticultural growing media is an attractive idea since it utilizes waste products that have few other useful purposes and are expensive to dispose of. They have been successfully used in the production of a variety of landscape plants (6, 7, 8, 9, 13, 15), but unfortunately not all plants grow well in these composts. Problems with high pH, heavy metal toxicity, high soluble salts, or poor aeration occur in some cases (4, 14), but often manganese (Mn) deficiency is the primary limiting factor in their use (3).

Symptoms of Mn deficiency vary among species, but in dicots usually appear as a spotty or diffuse interveinal chlorosis with marginal and interveinal necrosis on the newest leaves (11). Monocots such as palms are very susceptible to Mn deficiency and symptoms appear on new leaves as a general chlorosis with interveinal or longitudinal necrotic streaking (2). Leaflets of new palm leaves often become frizzled in appearance and if untreated, Mn deficiency often kills palms.

Although personal observations suggested that sludge and manure composts often induce Mn deficiency in plants, this has never been proven. Experience with Mn fertilization of sewage sludge compost-grown plants indicated that Mn fertilization is much less effective on these composts than on typical soils or container media. Chaney, et al. (5) also observed these phenomena on marigolds grown in sewage sludge compost, but did not continue their investigations on the subject. The purpose of this study was to determine if different types of municipal waste product composts cause Mn deficiency when used as growing media, and if so, to examine possible explanations for this phenomenon.

Materials and Methods

In the first experiment, ten single plant replicate queen palm (*Syagrus romanzoffiana*) liners were potted up into 6 liter (2 gal) polypropylene containers on February 18, 1987 using 10 different waste compost media and a pine bark, sedge peat, and sand (5:4:1 by vol) medium as a control. The compositiion, origin, and physical characteristics of the media used in this study are presented in Table 1. Osmocote 17N-3P-10K (17-7-12) was surface applied at 54 g per container at time of potting and six months later. Plants were grown in a shadehouse with 63% light exclusion (max. PFD = 800 $\mu M/m^2/sec$) and were irrigated as necessary with overhead irrigation. After one year plants were measured for total height and graded for severity of Mn deficiency symptoms (0 = dead, 5 = green with no symptoms). Ten replicate leaf samples consisting of central leaflets from recently matured leaves were collected from each treatment for Mn analysis. All leaf samples were digested using H_2SO_4-H_2O_2 (1), with Mn determined by atomic absorption spectrophotometry (AAS). Ten replicate media samples were extracted with DTPA (pH 7.3) (10) to determine extractable Mn.

In the second experiment, five other waste compost media plus the pine bark, sedge peat and sand control media were utilized in a similar experiment starting on Dec. 5, 1988. After 10 months plant height was measured and severity of Mn and Fe deficiency symptoms were rated on a 0 to 5 scale as in the first experiment. Leaf samples were analyzed for total Mn content and ten replicate samples of each medium were extracted with DTPA to determine plant available

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Table 1. Origin, composition, and physical characteristics of composts used in this study.

Medium	Composition	pH	Initial soluble salts (dS/m)	Air space (%)	Water holding capacity (%)	Source
First experiment						
Control	Pine bark, sedge peat & sand (5:4:1 by vol)	5.95[z]	0.29[z]	28.9	48.6	Atlas Peat & Soil Co., Boynton Beach, FL
Geophile	Household garbage	7.74	1.95	6.8	87.1	Dodge City, KS
Hydro-lite	Household garbage & sewage sludge	7.44	3.52	23.2	66.7	Delaware Reclamation Proj., Wilmington, DE
Broward #1	Sewage sludge & woodchips	7.50	1.91	36.8	37.6	Broward Co. Public Works Dept., Pompano Beach, FL
Glatco-lite	Paper mill waste	7.58	2.63	20.4	68.1	Glatfelder Co., Spring Hill, PA
Septic tank	Septic tank sludge & woodchips	7.64	5.50	9.2	82.0	Broward Co. Public Works Dept., Pompano Beach, FL
Broward #2	Sewage sludge & woodchips	7.42	1.92	30.0	49.1	Broward Co. Public Works Dept., Pompano Beach, FL
Hollywood	Sewage sludge & woodchips	7.02	1.91	38.4	40.3	Waste Treatment Plant, Hollywood, FL
Ft. Lauderdale	Sewage sludge & woodchips	7.73	1.89	44.5	34.5	Waste Treatment Plant, Ft. Lauderdale, FL
Davie	Sewage sludge & woodchips	7.23	11.70	47.6	34.6	Waste Treatment Plant, Davie, FL
Broward #1 (aged 1 yr)	Sewage sludge & woodchips	7.13	0.21	28.4	50.6	Broward Co. Public Works Dept., Pompano Beach, FL
Second experiment						
Control	Pine bark, sedge peat & sand (5:4:1, by vol.)	6.32	0.27	29.0	45.7	Atlas Peat & Soil Co., Boynton Beach, FL
Yard trash	Woodchips, leaves & grass clippings	6.72	0.63	46.8	31.1	Broward Co. Public Works Dept., Pompano Beach, FL
Geophile	Household garbage	7.74	0.68	6.8	87.1	Dodge City, KS
Broward	Sewage sludge & woodchips	7.46	0.78	33.6	40.2	Broward Co. Public Works Dept., Pompano Beach, FL
Stable sweepings	Straw, horse manure & woodchips	6.85	0.72	46.3	33.3	Broward Co. Public Works Dept., Pompano Beach, FL
Hollywood	Sewage sludge & woodchips	6.66	0.72	23.0	51.7	Waste Treatment Plant, Hollywood, FL

[z]Means of three replicate analyses using the saturated paste extract method.

Mn as in the first experiment. All containers were then topdressed with 5 g of Micromax, a micronutrient blend containing 12% Fe and 2.5% Mn. Four months later plants were remeasured and scored, and leaf Mn and extractable media Mn were again determined as above.

Five replicate samples of each medium used in both experiments were digested in aqua regia to determine total elemental content and extracted with DTPA to determine extractable levels of eight metal cations. All metal determinations were made by AAS. Manganese binding studies were performed on five replicate samples of media used in each experiment. Samples of each medium were spiked with 50 ml of 1000 ppm Mn solution (from $MnSO_4$) per 25 ml sample and the mixture was shaken for 30 minutes and vacuum extracted. Samples were re-extracted with deionized water as a rinse and the amount of Mn retained by the sample was calculated. Samples were then extracted with DTPA buffer to determine available Mn and the percentage of the added Mn that was unavailable.

Samples of media used in experiment 2 were also autoclaved and extracted with DTPA to determine if microbial binding was responsible for the Mn tie up. Autoclaved samples were also spiked with Mn as above and extracted with DTPA to determine the effects of microorganisms on the Mn binding potential of each medium. Regression analysis was used to determine relationships among all variables in this study.

Results and Discussion

Although heavy metal toxicity is often reported to be a major drawback in the utilization of composted wastes as growing media (4, 13), all of the composts used in this study had very low levels (<.5 ppm) of total and extractable Cd and Cr, low levels (<12 ppm) of extractable Pb, and moderate levels (2–82 ppm) of extractable Zn (data not shown). Symptom severity was not correlated with extractable or total levels of any element except Mn. Manganese deficiency ratings on queen palms in the first experiment ranged from severe ($\bar{x}<2.0$) for 3 sludge composts to moderate ($\bar{x}=2.0-3.5$) for one sludge compost and 2 garbage compost media (Table 2). The control medium produced plants completely free of Mn deficiency symptoms. Plant height was directly correlated with Mn deficiency rating ($P<.001$), as was leaf Mn content ($P=.016$). Palms with less than 20 ppm Mn in the foliage showed moderate to severe Mn deficiency symptoms. Although critical values for Mn in queen palm foliage have not been established, leaf Mn concentrations below 40 ppm are considered to be deficient for *Chrysalidocarpus lutescens* H. Wendl., *Howea forsterana* (C. moore & F. Muell.) Becc., and *Chamaedorea* Willd. spp. (2).

Total Mn in the media varied from a low of 32 ppm for the control medium to 1144 ppm for a garbage compost medium. There was no correlation between total Mn content

Table 2. Effects of compost media on growth, quality, and Mn content of queen palms. Experiment 1.

Medium	Compost type	Medium: Total Mn (ppm)	Medium: DTPA Mn (ppm)	Medium: % of added Mn bound	Queen palms: Leaf Mn (ppm)	Queen palms: Mn rating[y]	Queen palms: Height (cm)
Pine bark	control	32 ± 1.0[z]	3.1 ± 0.20	57.0 ± 1.5	22.2 ± 2.2	5.0 ± 0.0	284 ± 15.6
Geophile	garbage	68 ± 0.5	3.4 ± 0.07	73.0 ± 0.6	27.9 ± 3.8	4.4 ± 0.4	292 ± 5.9
Hydro-lite	garbage/sludge	478 ± 5.0	19.7 ± 0.47	70.7 ± 1.9	34.5 ± 3.9	4.9 ± 0.1	291 ± 8.3
Broward #1	sludge	66 ± 0.5	0.9 ± 0.05	75.7 ± 0.3	16.5 ± 1.3	1.9 ± 0.3	236 ± 12.4
Glatco-lite	paper mill waste	1144 ± 2.2	8.3 ± 0.72	72.0 ± 0.6	74.7 ± 11.8	4.1 ± 0.6	228 ± 21.2
Septic Tank	sludge	67 ± 1.0	0.4 ± 0.02	71.7 ± 0.3	15.3 ± 0.7	2.9 ± 0.6	252 ± 13.3
Broward #2	sludge	58 ± 0.3	0.4 ± 0.03	72.7 ± 0.3	15.1 ± 1.5	1.8 ± 0.6	213 ± 12.2
Hollywood	sludge	45 ± 0.2	0.7 ± 0.11	74.7 ± 0.9	14.6 ± 1.3	1.9 ± 0.5	245 ± 15.7
Ft. Lauderdale	sludge	33 ± 0.3	0.4 ± 0.03	74.7 ± 0.7	20.6 ± 2.7	3.0 ± 0.5	216 ± 14.0
Davie	sludge	65 ± 0.2	2.4 ± 0.13	70.0 ± 0.6	26.2 ± 2.7	4.8 ± 0.2	268 ± 14.4
Broward #3	sludge	513 ± 4.0	1.2 ± 0.03	78.3 ± 0.7	19.8 ± 2.4	3.5 ± 0.6	257 ± 15.4

[z]Means ± S.E.

[y]0 = dead; 5 = green with no symptoms.

of the media and Mn deficiency ratings of the palms. However, Mn ratings and leaf Mn content were highly correlated (P = .006) and (P = .004), respectively, with DTPA-extractable Mn levels in the media samples. Media with 1.3 ppm or more of DPTA-extractable Mn produced plants with little or no Mn deficiency symptoms in this experiment.

Media pH for the control medium averaged 5.95, while all compost media had pH levels between 7.0 and 8.0 (Table 1). There was no correlation between media pH and severity of the Mn deficiency symptoms, even though Mn availability is known to be greatly reduced at high soil pH levels (11). The pH of the DTPA buffer (7.3) used to extract Mn is close to that of most of the compost media and therefore should not underestimate available Mn in these media, as it might for the control medium (pH 5.95). Extraction of ten replicate samples of each medium with 1 N NH_4OAc (pH 7.0) yielded Mn levels very similar to those obtained by DTPA extraction, but extraction with NH_4OAc (pH 5.3) resulted in extractable Mn levels over 1.3 ppm for all media (data not shown). This suggests that although pH does not appear to be the primary cause of the Mn tie up in these media, pH reduction may represent one possible solution for overcoming the Mn-binding problem in composted waste media. However, extractable Pb concentrations also increased 5-fold as extraction pH was decreased from 7.0 to 5.3 (data not shown).

In the second experiment palm Mn deficiency ratings were positively correlated with palm height (P = .0002), leaf Mn content (P = .0002), and DTPA-extractable Mn in the media (P = .004) (Table 3). Palm leaf Mn content and palm height were also correlated with DTPA-extractable Mn in the media (P = .01) and (P = .002), respectively. Total Mn content was not correlated with palm Mn deficiency ratings. One material, yard trash compost, showed no Mn deficiency symptoms despite leaf Mn levels of 20 ppm and low DTPA-extractable Mn levels in the medium. Palms grown in this medium all showed severe Fe deficiency symptoms (2), and Fe appeared to be the primary growth limiting factor rather than Mn. Analysis of the yard trash compost medium showed very low levels of available and total Fe, and that Fe was not being bound by this medium in the same manner as Mn (data not shown).

When micronutrients were added to the media in the second experiment after 10 months, Mn deficient palms in most media showed signs of recovery for 2–3 months, but after 4 months Mn deficiency ratings were not significantly dif-

Table 3. Effects of compost media on queen palm growth, quality, and Mn content. Experiment 2.

Medium	Compost type	Medium, Raw sample: Total Mn (ppm)	Medium, Raw sample: DTPA Mn (ppm)	Medium, Raw sample: % of added Mn bound	Medium, Autoclaved sample: DTPA Mn (ppm)	Medium, Autoclaved sample: % of added Mn bound	Queen palms: Leaf Mn (ppm)	Queen palms: Mn rating[y]	Queen palms: Fe rating[y]	Queen palms: Height (cm)
Pine bark	control	49 ± 1.6[z]	1.6 ± 0.08	61.7 ± 0.9	6.1 ± 0.6	66.3 ± 3.8	23.2 ± 0.6	5.0 ± 0.0	5.0 ± 0.0	266 ± 7.5
Yard trash	trash	20 ± 0.4	0.5 ± 0.08	70.7 ± 0.7	1.5 ± 0.5	66.3 ± 1.5	20.5 ± 1.4	5.0 ± 0.0	2.2 ± 0.3	204 ± 14.1
Geophile	garbage	647 ± 6.6	1.2 ± 0.03	71.7 ± 0.3	21.1 ± 1.1	66.3 ± 0.9	30.0 ± 6.9	4.9 ± 0.1	4.9 ± 0.1	295 ± 13.5
Broward	sludge	46 ± 0.1	0.4 ± 0.01	76.0 ± 0.6	2.4 ± 0.1	76.7 ± 0.7	15.8 ± 1.1	1.5 ± 0.4	5.0 ± 0.0	222 ± 19.4
Stable sweepings	manure, wood, straw	56 ± 0.8	1.0 ± 0.07	66.5 ± 1.2	4.3 ± 0.4	66.0 ± 0.6	25.1 ± 1.8	5.0 ± 0.0	4.7 ± 0.2	252 ± 6.7
Hollywood	sludge	46 ± 1.8	0.4 ± 0.01	75.0 ± 0.6	3.5 ± 0.2	74.0 ± 0.0	15.1 ± 0.6	2.1 ± 0.3	5.0 ± 0.0	244 ± 10.3

[z]Means ± S.E.

[y]0 = dead; 5 = green with no symptoms.

Table 4. Growth, quality, and Mn composition of queen plams grown in municipal waste compost media amended with micronutrients.

Medium	DTPA Mn (ppm)	Leaf Mn (ppm)	Mn rating[y]	Fe rating[y]	Height (cm)
Pine bark	4.1±0.2[z]	24.6±1.3	5.0±0.0	5.0±0.0	306±10.2
Yard trash	10.8±0.5	27.1±3.8	5.0±0.0	2.6±0.2	240±10.6
Geophile	0.5±0.0	31.3±3.4	5.0±0.0	4.9±0.1	303±11.6
Broward	2.4±0.1	15.9±1.4	2.2±0.4	5.0±0.0	261±25.1
Stable sweepings	2.5±0.1	26.4±2.3	5.0±0.0	4.7±0.1	283± 5.6
Hollywood	2.3±0.1	19.1±0.7	1.8±0.2	5.0±0.0	261± 7.6

[z]Means ± S.E.

[y]0 = dead; 5 = green with no symptoms.

ferent from those of the same plants prior to micronutrient fertilization (Table 4). Leaf Mn content and media Mn levels showed similar trends, although the absolute levels of DTPA-extractable Mn were higher following micronutrient fertilization. This suggests that some of the added Mn is initially available to the palms, but eventually most of it becomes tightly bound by these media. These results are similar to those of Chaney, et al. (5) who grew marigolds in sewage sludge compost.

Although production of ornamental plants in container media having more than 50% compost is generally not recommended, the palms in this study were intentionally grown in 100% compost to eliminate any potential confounding effects due to other media amendments. Chaney, et al. (5), however, showed that the reduced Mn uptake in marigolds was similar in media containing 33% or 100% sewage sludge compost.

When samples of composts in the first experiment were spiked with Mn and extracted with DTPA, between 70 and 78% of the added Mn was rendered unavailable within 1 hr of the spiking (Table 2). In contrast, only 57% of the added Mn was tightly bound by the pine bark, sedge peat and sand medium. Palm Mn deficiency ratings were correlated with the percentage of added Mn that was bound by the media ($P = .012$). Results from the second experiment composts showed a similar trend, although the control medium used in this experiment bound slightly more Mn than the one used in the first experiment (62 vs. 57%) (Table 3).

Autoclaved media samples from the second experiment typically had at least 3 times as much DTPA-extractable Mn as raw samples (Table 3). Extractable Mn levels remained lower for the sludge composts, despite their having total Mn levels similar to that of the control medium. When autoclaved samples were spiked with Mn and extracted with DTPA, the percentage of added Mn that was unavailable remained above 74% for sludge composts and 66% for stable sweepings compost, but was reduced to about 66% for other types of composts (Table 3). This suggests that microorganisms may be responsible for some of the tie up of Mn by garbage and yard trash composts, but do not significantly affect the binding of Mn by sewage sludge and manure composts. This is not surprising since media temperatures encountered during the composting process are usually high enough to kill many types of microorganisms (12).

In conclusion, most sewage sludge and some manure composts bind Mn so tightly that queen palms growing in them develop Mn deficiencies. Mn tie up appears to be much less of a problem in garbage compost products and they may be safely used as a container medium for these plants. In general, sludge and manure composts should not be used to grow plants susceptible to Mn deficiency since additional applied Mn is quickly tied up by these media. Yard trash compost media suffer from very low levels of total Fe and Mn and supplemental micronutrient fertilization will be needed to compensate for their low inherent levels of Mn and Fe. The nature of the chemical or physical mechanisms responsible for this Mn binding in composts remains unknown.

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