UTILIZATION OF COMPOSTS AS BEDDING PLANT GROWTH SUBSTRATES

By

John C. Bouwkamp
Xianzhen Li
Department of Natural Resource Sciences and Landscape Architecture
University of Maryland, College Park, Maryland

INTRODUCTION

Peat moss is the most widely used source of organic matter for growing horticultural crops in the United States. The demand for peat as a substrate constituent for bedding and pot plants has remarkably increased in recent years, thus reducing the availability and increasing cost (Nappi and Barberis, 1993). Composts may serve as qualitatively and economically as competitive alternative sources of organic matter.

Composting of organic materials such as animal manure and crop residues has a long history as an agricultural practice. Present environmental concerns and an increase in community generated wastes have accelerated the technological development of waste products composting. Today, composts derived from biosolids, animal manure and yard debris are homogeneous and easy to use.

Many composts are useful in supplying crops with macronutrients such as N, P, K, and S (Barruzunni and Del Zan, 1992; Cortellini et al., 1996; Kuo, S., 1995; Taylor et al., 1978), and also micronutrients such as Cu, Fe, Mn, and Zn (Bomke and Lowe, 1991; Dixon et al., 1995; Giordano et al., 1975). A study by Chaney et al., (1980) demonstrated that digested biosolids compost could provide sufficient trace elements such as Cu, Fe, Zn, and macronutrients P and K for growth of French Marigold (*Tagetes patula* L.) growth, although not enough nitrogen. According to Chen et al., (1988) composted cattle manure and composted grape marc contained high nutrient levels, especially P and K which were slowly released during the growing period. Composts are also useful to formulate potting substrates (Gouin, 1985; and Link et al., 1983, Tomati et al. 1993).

Composts can improve substrate physical properties when they are mixed with peat moss. When peat was used alone, air filled pore space (AFPS) was very low; however if blended with composted cattle manure and composted grape marc respectively, the AFPS and water-holding capacities were close to ideal (Chen et al., 1988). Biosolids composted with bark or biosolids composted with grape stalks had acceptable physical properties (Nappi and Barberis, 1993). Measuring physical properties for compost amended substrates intended for nursery production is insufficient. Not all composts can be expected to have comparable efficacy. Substrates containing composted biosolids and yard debris had superior performance, but not all their physical properties were within the suggested optimum range (Fitzpatrick and Verkade, 1991). According to Bugbee and Frink (1989), composts derived from biosolids, pharmaceutical and food flavoring wastes had rather similar physical properties, but plant performance was different. Composted cattle manure and composted grape marc, and their blends with peat respectively also had similar aeration and water holding capacity (Chen, et al., 1988).

Bedding and pot plants are ideally suited for utilization of composts, because heavy metals and threats to human health are of less concern (Gouin, 1982). However, there is a limited amount of published research on utilization of composts as bedding plant substrates. According to Sawhney (1976), leaf compost is well buffered at about pH 7, which is considered optimum for the growth of many plants. Yard debris compost can be added to a commercially prepared peat-based potting mix for Ageratum (*Ageratum houstonianum* Mill) up to 50% of final volume (MacCubbin and Henley, 1993). Chaney et al. (1980) showed that 33% digested biosolids compost could produce African Marigold (*Tagetes erecta* L.) equal to the complete Cornell mix. Bragg et al. (1993) indicated 30% municipal solid waste or biosolids were suitable to grow Petunia (*Petunia hybrida* Hort.) and Impatiens (*Impatiens wallerana* Hooks). French marigold growth was improved when up to 50 % Canadian sphagnum peat was replaced by composted biosolids or up to 30 % replacement of peat by composted food flavoring waste, and up to 40 % replacement of peat by pharmaceutical or cranberry wastes (Bugbee and Frink, 1989).

The objectives of this research were to determine suitability of compost -amended substrates for five species of bedding plants compared to two commercially available substrates (Sunshine Mix # 1 and Progro 300s). In order

to quantify substrate suitability, the following variables were determined:

- substrate physical properties
- substrate chemical properties
- plant growth and development
- plant tissue nutrient status including macronutrients and micronutrients

MATERIALS AND METHODS

Compost Sources and Treatments

Four compost sources were tested in this experiment: Compro ® (C), Leafgro ® (L), poultry litter (P), and Orgro (O). Compro and Leafgro were obtained from Maryland Environmental Service, Annapolis, MD. Compro is made from lime stabilized biosolids, blended with 50% woodchips and composted in a static pile process. It has rather high pH above 7.3-7.5. Leafgro is made from 50% leaves and 50% grass clippings using a turned windrow process. Poultry litter compost was produced by New Earth Service, Cambridge, MD from a mix of 50% wood chips and 50% poultry litter using a turned windrow process. Orgro was obtained from PSG Ecology Baltimore, MD. It is derived from polymer dewatered biosolids blended with 50% woodchips and composted in a static pile process. All two way combinations of the four composts, were blended at 1:1 ratio, to make six compost blends, thus a total of 10 compost sources including the four unblended composts. Composts were diluted with a base mix (peat and perlite at 1:1 ratio). The compost volumes were 25%, 33% and 50%. The ratios of compost: peat : perlite were 2:3:3, 1:1:1 and 2:1:1 respectively. Thus ,there were 30 substrates. Two commercially available substrates, were used as the controls. Sunshine mix #1 (SunGro Horticulture Inc, Bellevue, WA) is made from 70-80% peat and perlite. Progro 300S (Progro Products, McCormick, SC) has about 40% composted bark, much less peat and perlite.

Bedding Plant Species

Five species of bedding plants were tested in this experiment: Ageratum (*Ageratum houstonianum* Mill.) cv 'Blue Puffs', Impatiens (*Impatiens wallerana* Hooks) cv 'Dazzler Red', French marigold (*Tagetes patula* L.) cv 'Bonanza Flame', Petunia (*Petunia hybrida* Hort.) cv 'Madness Red', and Vinca (*Catheranthus roseus* L.) cv 'Cool Peppermint'. All the plants were obtained as plugs (800 plugs/tray) from Tagawa Greenhouses Inc., Brighton, CO.

Greenhouse Experiment

The experiment was conducted in 1996 in a greenhouse at the University of Maryland, College Park. The experimental design was randomized complete block. Each of four benches was used as a replication. For each replication of a substrate treatment, four 4-cellpacks (#804) per species were used with one plant per cell giving 16 plants per substrate per replication. The plants were transplanted on April 11, 1996. The greenhouse temperature was kept 23°C at day and 20°C at night. After 10 days growth, and weekly thereafter, the plants were fertilized with 100 ppm N of 20-20-20 (N-P_2O_5-K_2O) .

Beginning April 19, and weekly for the next 3 weeks, a 4-cellpack of substrate was taken for analyses from each replication of French marigold. The experiment was concluded on May 10. From each plot, plants from a randomly selected 4-cellpack were harvested and dried at 60°C to a constant weight.

Laboratory Analyses

All substrate samples were dried at 60°C for four days. The substrate electrical conductivity (EC) and P were determined from 3g dry samples saturated with 30 ml deionized water. The samples were shaken for 1 hour on a Thermomix Model 1480 (B. Braun, Germany). EC was measured with a Soil Tester (Beckman Instruments Inc.) following vacuum extraction (Hershey, 1989). Soluble P was determined with Spectrophotometer Model 390 (Sequoia-Turner Corporation, Mountain View, CA) at λ = 882 nm (Watanabe and Olsen,1965). Soluble N and pH were determined following mixing 30 ml of 1 M KCl to 3 g of dry sample, shaken for 1 hour on the above described shaker and filtered using Whatman #1 filter paper. Both extractable total N and NH_4^+-N were determined with a Westcan Ammonia Analyzer Model 360 (Alltech, Deerfield, IL). Total N was measured by reducing the sample

NO_3^- fraction to NH_4^+ fraction with 30 mesh zinc before determination of NH_4^+-N.

The substrate samples obtained by weekly sampling were combined, moistened and then lightly packed into one 4-cellpack (#804). The saturated weights were recorded after the cell packs were saturated with water from below for 24 hours. They were weighed again after 24-hour drainage. The substrate dry weight was recorded after 60 °C oven drying till constant weight. Container capacity and bulk density were determined similarly from the weight of oven-dried media. Container capacity was determined by weight of water in the wet substrate after 24 hours drainage.

Kjeldahl-N of plant tissue was determined by the method of Bowman et al (1988). The procedure for determining P, K, Ca, Mg, Cu, Fe, Mn, and Zn of plant tissue was as follows: 0.1-0.2 g dry whole plant tissue samples were ashed at 550°C for 3 hours. The ash was dissolved with 10 ml 3.8N HCl. The ashed solution was filtered with Whatman #40 filter paper. Hot deionized water was used to rinse the crucible and the filter paper. The final volume was brought up to 50 ml. The analyses were performed by the University of Maryland Soil Testing Lab.

RESULTS AND DISCUSSION

Plant dry weight

Overall, Leafgro and poultry litter compost amended substrates either alone or blended with each other produced large plants, with dry weights either significantly higher or not different from the controls (Table 1). When Orgro was used alone, plant growth was suppressed, more severely at higher volume. Orgro blended with Leafgro or with poultry litter produced plant dry weights which were not significantly different from the controls. The Compro amended substrates gave the poorest response; the only satisfactory substrate was with poultry litter. Not all species responded to the substrates in the same way (Table 2). Petunia had a broad adaptation, it could grow well in various substrates when other species performed poorly; even at 25% Compro alone or Compro blended with Leafgro, or poultry litter at 25-50% compost volume. Other species had slight differences with Compro containing substrates, but few differences with Leafgro, Orgro and poultry litter blends or Leafgro and poultry litter compost only substrates.

Substrate physical properties

The range of values for physical properties of the substrates was small (Table1). The air filled porosity of most substrates is near the optimum range, which is from 10 to 25% (Bugbee and Frink, 1986). The bulk density of all substrates was in the ideal range 0.15-0.50 g/cm^3 (Nappi and Barberis, 1993). According to Bugbee and Frink (1989), composts derived from biosolids, food flavoring wastes and pharmaceutical wastes had similar physical properties, and none of the physical properties we measured were likely to be a major cause of the observed growth responses. None of the substrate physical properties were significantly correlated with plant dry weight (Table 3).

Substrate chemical properties

Substrate pH

Over the 4-week experimental period, there was no significant time by substrate interaction (data not presented). All the substrates containing Compro had pH values above 7.5 (Table 4). However, the plant dry weight of CP @ 25% which had a pH of 7.7 was not significantly different from the Sunshine mix #1 (Table 1). Other treatments had pH values from 5.2 to 6.5. The highest total plant dry weight was from the treatment OL @ 25% which had an average pH of 5.2. The pH range of the experimental substrates was greater than the desirable range from 5.4 to 6.8 (Holcomb, 1994). Average (over the 4 weekly samples) substrate pH was negatively correlated with plant dry weight, (Table 3) mostly due to the high pH levels in the Compro containing substrates.

Table 1. Air filled porosity, container capacity, total porosity, and bulk density of the experimental substrates. and average dry matter accumulation of bedding plants grown in the substrates.

Substrate Compost Source[1]	Air filled porosity (%)	Container Capacity (%)	Total Porosity (%)	Bulk Density (g/cm^3)	Dry Matter (g)
C 25%	11.8	52.4	64.1	0.25	1.06 lm
C 33%	16.4	51.5	67.9	0.26	0.84 mn
C 50%	16.4	50.3	66.7	0.28	0.62 no
CP 25%	14.7	53.5	68.2	0.24	1.85 f-i
CP 33%	12.6	54.0	66.6	0.29	1.71 i-k
CP 50%	14.0	51.3	65.2	0.34	1.73 h-j
CL 25%	15.0	52.7	67.7	0.21	1.48 k
CL 33%	9.4	61.7	71.0	0.24	1.52 jk
CL 50%	11.2	57.8	69.0	0.29	1.14 l
CO 25%	13.6	54.2	67.9	0.23	1.06 lm
CO 33%	17.8	48.3	66.1	0.24	0.72 no
CO 50%	14.8	52.1	66.9	0.34	0.49 o
O 25%	18.5	49.8	68.3	0.20	1.04 lm
O 33%	16.4	53.4	69.8	0.23	1.04 lm
O 50%	17.2	51.1	68.2	0.25	0.49 o
OP 25%	16.5	51.5	68.1	0.22	2.20 a-c
OP 33%	18.0	50.2	68.2	0.24	2.15 b-e
OP 50%	14.0	53.3	67.3	0.29	2.04 c-g
OL 25%	13.6	58.2	71.9	0.21	2.39 a
OL 33%	14.5	56.9	71.4	0.21	2.29 ab
OL 50%	13.6	58.1	71.7	0.25	1.84 g-i
L 25%	18.1	51.1	69.2	0.18	2.04 c-g
L 33%	14.0	55.6	69.6	0.19	2.08 b-f
L 50%	11.0	60.6	71.5	0.22	2.12 b-e
LP 25%	18.8	51.4	70.1	0.20	1.87 f-i
LP 33%	10.9	58.2	69.1	0.24	2.18 ad
LP 50%	17.1	52.4	69.5	0.25	2.05 c-g
P 25%	15.2	54.4	69.6	0.26	1.86 f-i
P 33%	20.2	46.9	67.1	0.24	2.04 e-g
P 50%	19.9	47.9	67.8	0.32	1.97 d-g
Sunshine mix #1	9.3	72.9	82.2	0.11	1.95 e-h
Progro 300S	13.1	57.7	70.9	0.20	2.12 b-e

[1]C = Lime stabilized biosolids; P = Poultry litter; L = Yard debris; O = Polymer dewatered biosolids; 25% = 25% compost, 37.5% peat and 37.5% perlite by volume; 33% = 33% compost, 33% peat and 33% perlite by volume; 50% = 50% compost, 25% peat and 25% perlite by volume.

[2] Means followed by the same letter are not significantly different (LSD 0.05).

Table 2. Effects of substrate composition on dry weight of each of 5 species as compared to the control substrates. (Sunshine Mix #1 and Progro 300S).

Substrate Compost Source[1]		Ageratum	Impatiens	Marigold	Petunia	Vinca
C	25%	-[2]	-	-	=	-
C	33%	-	-	-	-	-
C	50%	-	-	-	-	-
CP	25%	=	=	=	=	=
CP	33%	=	-	=	=	=
CP	50%	=	-	-	=	=
CL	25%	-	-	-	=	-
CL	33%	-	-	-	=	-
CL	50%	-	-	-	=	-
CO	25%	-	-	-	=	-
CO	33%	-	-	-	-	-
CO	50%	-	-	-	-	-
O	25%	=	-	-	-	-
O .	33%	-	-	-	-	-
O	50%	-	-	-	-	-
OP	25%	=	=	=	+	=
OP	33%	=	=	=	=	=
OP	50%	=	=	-	=	=
OL	25%	+	=	=	=	=
OL	33%	+	=	=	=	=
OL	50%	=	-	-	=	=
L	25%	=	=	=	=	=
L	33%	=	=	=	=	=
L	50%	=	=	=	=	=
LP	25%	=	=	=	=	=
LP	33%	=	=	=	=	=
LP	50%	=	=	=	=	=
P	25%	=	=	=	=	=
P	33%	=	=	=	=	=
P	50%	=	=	=	=	=
Sunshine Mix #1		2.52	2.13	2.97	1.94	1.29
Progro 300S		3.19	1.98	3.26	2.53	1.30

[1] C= Lime stablizied biosolids; P = poultry litter; L = yard debris; O = Polymer dewatered biosolids; 25% = 25% 7.5% peat, 37.5% perlite (v:v:v); 33% = 33% compost, 33% peat, 33% perlite; 50% = 50% compost, 25% peat, 25% perlite.

[2] Indicates significantly (0.05) less dry weight than the lower control substrate; + indicates significantly (0.05) greater dry weight than the higher control substrate; = indicates not different than both control substrates.

[3]Dry weight (g) for each specie following grown in the control media.

Table 3. Coefficients of correlation between mean piant dry weight and substrate physical and chemical properties.

Variable	Correlation coefficients	P value
AFPS[1]	-0.157	0.3917
CC[2]	0.322	0.0720
D_B[3]	-0.329	0.0662
pH	-0.493	0.0041
EC[4]	-0.831	0.0001
P	-0.384	0.0302
NH^+_4	-0.154	0.4004
NO^-_3	-0.309	0.0853

[1] Air filled pore space, [2] Container capacity, [3] Bulk density, [4] Electrical conductivity

Substrate electrical conductivity (EC)

Substrates containing Leafgro or poultry litter compost had lower EC than the other substrates (Table 4). Although the treatment OL @ 50% had an EC of 15 dS/m, the plant dry weight was not significantly different from Sunshine mix # 1. According to Bunt (1976) and Holcomb (1994), this EC is excessive. Over the 4 -week growth period, treatment EC changes occurred in an irregular pattern . However, the EC of most treatments had no significant changes after the first week of growth (data not presented). Among the variables measured, EC was most closely related to plant growth (Table 3).

Substrate phosphorus (P) concentration

The poultry litter compost treatment contained the highest water soluble P concentration (Table 4). All the substrates contained P concentration above 6 ppm. According to Holcomb (1994), the optimum P range is about 6-14 ppm. Substrate water soluble P levels were significantly correlated with plant dry weight perhaps due to the low P levels of the high pH Compro containing substrates (Table 3).

Substrate ammonium (NH_4^+) concentration

Substrates containing Orgro had high NH_4^+ concentration (Table 4). Many plants in Orgro-amended substrate at the highest level (OL @50) died, perhaps due to the high NH_4^+ concentration (Bugbee and Frink, 1989; Jeong and Lee, 1992a and 1992b; Lemaire and Dartigues, 1983,).

Substrate nitrate (NO_3^-) concentration

Over the growth period, substrate NO_3^- had no significant substrate with time interaction (data not presented). Average substrate NO_3^- concentration followed same pattern as the NH_4^+ concentration (Table 4). Orgro containing substrate exhibited higher NO_3^- concentration, and the concentrations became significantly lower over the 4-week experiment (data not presented). Substrates containing Leafgro, poultry litter and their blends had the lowest NO_3^- concentration, but the concentrations did not change significantly over the growth period. Neither substrate NH_4^+ nor NO_3^- were significantly correlated with plant dry weight (Table 3).

Plant tissue chemical compositions

Plant tissue N concentration

Plants from Orgro amended substrates had the highest N concentration (Table 5). In contrast, plants from substrates amended with Leafgro, poultry litter and their blends had less than 3 % N concentration. Plant tissue concentration N less than 3% may not be sufficient for many plants (Dight, 1977). However, in this experiment plant growth from those treatments was not reduced. The correlation coefficient between plant dry weight and tissue N concentration was –0.205 (Table6) suggesting that N uptake did not limit growth.

Plant tissue P concentration

Plant tissue P concentration from Compro amended substrates was lower (Table 5). This is because those substrates had pH above 7.5, which probably affected P availability. Most of P concentrations were above 0.3 %, which should be sufficient for plant growth (Holcomb, 1994; Jones, et al., 1991). The correlation coefficient between tissue P concentration and plant dry weight of 0.745, is the highest among the tissue nutrient concentrations (Table 6).

Plant tissue K concentration

Plant K concentration from substrates amended with Orgo and blends of Compro and Orgro were the lowest, about 3.1-3.5 % (Table 5). They should not be deficient in that both Holcomb (1994) and Jones et al. (1991) indicated that K in the range of 1.0 to 5.0 % is sufficient. The lower K of plants growing in substrates amended with Orgro could be due to high NH_4^+ levels of those substrates, which may have suppressed K uptake. The correlation coefficient between tissue K concentration and plant dry weight was 0.700 (Table 6).

Plant tissue Ca concentration

Plant tissues from Compro amended substrates had rather high Ca concentration (Table 6), probably because Compro is produced from lime stabilized biosolids. Other substrates had much lower Ca concentration. They should be in the appropriate range because Ca average concentration in plant dry matter higher than 0.5 % is considered to be sufficient for plant growth (Jones, et al., 1991). The significant negative correlation coefficient is probably due to the very high Ca levels in the lime dewatered biosolids (Table 6).

Plant tissue Mg concentration

Mg concentration from substrates showed a fairly narrow range (0.52 – 0.90%). Mg concentration was above 0.4 % (Table 5), suggesting that Mg was probably not Mg deficient (Holcomb, 1994). The correlation coefficient between tissue Mg concentration and plant dry weight was 0.14 2 (Table 6), suggesting no relationship between plant dry weight and Mg concentration.

Plant tissue micronutrient concentration

The micronutrients, Cu , Fe, Mn, and Zn did not exhibit systematic trends relative to substrates (Table 5). The data indicated no micronutrient deficiency or toxicity. There probably was no Mn toxicity since sweet potato contained up to 1380 ppm Mn before severe toxicity developed (Jones, et al., 1991). The lowest Mn concentration was above 50 ppm in this experiment, which is the lower limit of maximum level for general crops recommended by Holcomb (1994). For other species, Mn concentrations were generally between 100 to 300 ppm. The highest Zn was about 470 ppm (Table 5), which is above maximum upper limit (Holcomb, 1994). Plants from Orgro or Orgro blended substrates had Zn concentration over 100 ppm. Plants from rest of the substrates had Zn concentration from 50 to 100 ppm (Table 5). This range is more than sufficient for plant growth, which is reported to be 15 to 50 ppm (Jones et al., 1991).

Table 4. Substrate pH, EC, water soluble P, NH_4, NO_3 and Total N averaged over the 4 sampling dates.

Substrate Compost Source [1]		pH	EC dS/m	P ppm	NH_4 ppm	NO_3 ppm
C	25%	7.5	14.5	7	5	87
C	33%	7.6	18.0	6	5	84
C	50%	7.8	22.2	6	5	110
CP	25%	7.7	10.4	18	6	59
CP	33%	7.6	13.1	17	4	104
CP	50%	7.7	11.0	17	3	61
CL	25%	7.6	16.8	19	5	80
CL	33%	7.6	16.2	9	5	52
CL	50%	7.6	20.4	10	4	62
CO	25%	7.5	19.7	7	93	182
CO	33%	7.5	24.2	6	103	181
CO	50%	7.6	25.8	6	148	192
O	25%	5.2	14.2	28	2879	374
O	33%	5.3	15.0	17	4232	565
O	50%	5.5	22.5	14	4722	860
OP	25%	5.3	8.4	94	1745	286
OP	33%	5.4	7.6	113	1473	217
OP	50%	5.7	11.9	120	1590	354
OL	25%	5.2	8.1	42	1469	185
OL	33%	5.4	12.4	32	2000	192
OL	50%	5.6	15.0	29	2039	314
L	25%	5.6	4.4	179	69	59
L	33%	5.9	6.0	264	34	17
L	50%	6.4	7.1	262	10	13
LP	25%	5.4	4.2	474	59	14
LP	33%	5.9	5.8	449	35	15
LP	50%	6.5	6.8	434	7	27
P	25%	5.5	5.0	668	48	25
P	33%	5.8	4.9	632	28	19
P	50%	6.3	6.1	580	9	37
Sunshine Mix#1		6.0	6.8	120	63	145
Progro 300S		5.9	6.7	103	64	277
LSD 0.05		0.2	3.2	50	212	151

[1] C= Lime stablizied biosolids; P = poultry litter; L = yard debris; O = Polymer dewatered biosolids; 25% = 25% 7.5% peat, 37.5% perlite (v:v:v); 33% = 33% compost, 33% peat, 33% perlite; 50% = 50% compost, 25% peat, 25% perlite.

Table 5. Plant tissue (average of 5 species) nutrient concentration.

Substrate Compost Source[1]		N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Cu ppm	Fe ppm	Mn ppm	Zn pp
C	25%	3.76	0.44	4.32	4.64	0.73	22.8	427	215	65
C	33%	3.41	0.34	4.02	4.70	0.74	21.7	482	225	62
C	50%	3.45	0.30	3.80	5.07	0.77	22.5	798	245	65
CP	25%	3.09	0.62	5.57	3.34	0.63	23.4	326	146	70
CP	33%	3.20	0.55	5.62	3.40	0.67	22.8	327	147	68
CP	50%	3.16	0.55	6.00	3.14	0.72	25.1	436	139	78
CL	25%	3.26	0.49	5.47	3.75	0.64	17.6	226	238	64
CL	33%	3.42	0.51	5.70	3.70	0.65	17.5	294	255	68
CL	50%	3.48	0.48	5.76	3.68	0.74	21.7	459	249	71
CO	25%	4.01	0.43	3.41	4.36	0.74	18.9	396	203	75
CO	33%	4.08	0.38	5.44	4.42	0.74	19.8	588	211	77
CO	50%	4.31	0.34	3.11	4.13	0.73	22.2	1066	203	74
O	25%	6.65	0.90	3.46	0.78	0.68	26.7	960	452	164
O	33%	6.84	0.86	3.16	0.77	0.65	28.0	1213	406	151
O	50%	7.28	0.70	3.11	0.83	0.66	29.4	1564	344	140
OP	25%	5.67	1.17	5.19	1.06	0.86	30.0	714	617	217
OP	33%	5.69	1.13	5.47	0.97	0.82	32.5	775	465	210
OP	50%	5.73	1.11	5.35	1.11	0.90	31.9	908	460	209
OL	25%	5.39	1.10	5.38	1.12	0.85	23.2	733	698	164
OL	33%	5.79	1.04	5.70	1.04	0.82	24.0	804	728	168
OL	50%	5.84	0.87	5.60	1.00	0.70	23.2	704	431	138
L	25%	2.67	0.89	6.32	1.37	0.61	14.1	218	336	91
L	33%	2.66	0.91	7.08	1.14	0.55	13.5	164	329	96
L	50%	2.81	0.88	8.04	1.09	0.55	14.8	187	370	96
LP	25%	2.64	1.02	6.13	1.17	0.64	18.3	219	323	90
LP	33%	2.90	1.01	7.00	1.00	0.60	20.6	215	229	113
LP	50%	2.99	0.96	8.10	0.82	0.52	22.1	172	177	100
P	25%	2.79	1.22	6.12	0.93	0.64	21.9	185	201	97
P	33%	2.84	1.13	6.67	0.80	0.61	21.6	178	147	97
P	50%	2.98	1.10	7.21	0.59	0.54	25.9	166	100	95
Sunshine Mix #1		2.50	0.84	3.56	1.62	1.06	13.2	156	305	03
PG 300S		3.24	0.94	5.28	2.47	1.00	12.5	172	116	110
LSD 0.05		0.32	0.06	0.34	0.20	0.06	2.5	137	49	13

[1] C =Lime stablizied biosolids; P = poultry litter; L = yard debris; O = Polymer dewatered biosolids; 25% = 25% 7.5% peat, 37.5% perlite (v:v:v); 33% = 33% compost, 33% peat, 33% perlite; 50% = 50% compost, 25% peat, 25% perlite.

Table 6. Correlation coefficients between mean plant dry weight and average nutrient concentrations of plant tissue growing in experimental substrates.

Nutrients	Correlation coefficients	P Value
N	- 0.205	0.2597
P	0.745	0.0001
K	0.700	0.0001
Ca	- 0.578	0.0005
Mg	0.142	0.4375
Mn	0.314	0.0800
Zn	0.404	0.0217
Cu	- 0.112	0.5404
Fe	- 0.495	0.0040

All treatments except Leafgro had higher Cu concentrations than the two controls (Table 5). Most plants had about 10 to 20 ppm Cu concentration except those plants from Orgro or Orgro blended substrates, and which had 20 to 40 ppm Cu. The range from 20 to 40 ppm could be approaching the toxicity level (Jones, et al., 1991). There was a wide range in Fe concentration among treatments. Holcomb (1994) did not mention an upper limit of this element. The highest Fe concentration is 1564 with OL@5% substrate. Most substrates containing Leafgro, poultry litter or Leafgro blended with poultry litter had Fe concentration lower than 250 ppm, but most of the other substrates had more than 250 ppm Fe. Jones et al. (1991) only mentioned rice could have Fe toxicity if its concentration is up to several hundred ppm, but some other species could have up to 1000 ppm without Fe toxicity. No microelement tissue concentration was significantly correlated with plant dry weight (Table 6).

CONCLUSIONS

Overall, yard debris (Leafgro), poultry litter and their blends produced good results for bedding plants. They can partially replace peat and perlite by 25 to 50%. Polymer dewatered biosolids (Orgro) blends, either with Leafgro, or with poultry litter, from 25 to 50% volume, are excellent substrates. Plant dry weight from those substrates were either equal to or greater than those from Progro 300S which was the better substrate for most species. However, when Orgro was used alone, even at 25% volume, plant growth was very poor. Many plants died at 50% volume. Overall Compro is not recommended for bedding plants. Most of the plants grew poorly when Compro was used alone or blended with Orgro, Leafgro or poultry litter. The best combination was with poultry litter at 25% volume where plant dry weight was not significantly different from Sunshine mix #1. Blends of composts from two sources often exhibited performance superior to either component alone.

Most of compost-amended substrates had similar air filled porosity, container capacity, and bulk density. Therefore, these properties were probably not major causes of variations in plant performance.

Substrate chemical properties were quite different in terms of pH, EC, P, NH_4^+ NO_3^- , and total N concentration. Orgro had very high NH_4^+ concentration and this could be the reason why some plants died with Orgro amended substrates. The good performance of some substrates could be due to the combination of proper range of pH and EC, which were 5.2 to 6.5 and 5-8 dS/m respectively; and also due to the adequate amount of P concentration and no detrimental , NH_4^+ concentration. Those composts in which plants performed poorly may have been due to the combination of detrimental factors.

Our data do not suggest that plants from poorly performing substrates have nutrient deficiencies or toxicities because most plant tissue N, P, K, Ca, Mg, Mn, Zn, Cu, and Fe concentrations are within optimum ranges. The plants from Leafgro, poultry litter and their blends amended substrates may have lower N and Ca concentrations compared to those from Compro and Compro related substrates.

REFERENCES

Barruzini, L. and Del Zan, F. 1992. Soil fertility improvement and pollution risks from use of composts referred to N, P, K, and C balance. Acta Hort. 302: 51-62.

Bomke, A. A. and Lowe, L.E. 1991. Trace element uptake by two British Columbia forages as affected by poultry manure application. Can. J. Soil Sci. 71: 305-312.

Bowman, D. C., Paul, J. L., and Carlson, R.L. 1988. A method to exclude nitrate from Kjeldahl digestion of plant tissues. Commun. Soil Sci. Plant Anal. 19: 205-213.

Bragg, N. C., Walker,J.A.R., and Stentiford, E. 1993. The use of composted refuse and sewage as substitute additive for container grown plants. Acta Hort. 342: 155-165.

Bugbee, G. J. and Frink, C,R. 1986. Aeration of potting media and plant growth. Soil Sci. 141: 438-441.

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

Bunt, A. C. 1976. Modern Potting Composts. Penn. State Univ. Press, University Park ,PA.

Chaney, R. L., Munns,J B., and Cathey, H.M.. 1980. Effectiveness of digested sewage sludge compost in supplying nutrients for soilless potting media. J. Am. Soc. Hort. Sci. 105: 485-492.

Chen, Y., Inbar, Y., and Hadar, Y.. 1988. Composted agricultural wastes as potting media for ornamental plants. Soil Sci. 145: 298-303.

Cortellini, L., Toderi G., Baldoni, G., and Nassisi, A.. 1996. Effects on the content of organic matter, nitrogen, phosphorus and heavy metals in soil and plants after application of compost and sewage sludge. In: de Bertoldi, P,M., Lemmes, Sequi B., and Papi, T .(editors.). The Science of Composting. Blackie Academic & Professional Chapman and Hall. London. pp. 457-468.

Dight, R. J. W. 1977. Nutritional requirements of bedding plants. Expl. Hort. 29: 63-71.

Dixon, F. M., Preer, J.T., and Abdi, N. 1995. Metal levels in garden vegetables raised on biosolids amended soil. Compost Sci. & Util. 3(2): 55-63.

Fitzpatrick G. E. and Verkade, S.D. 1991. Substrate influence on compost efficacy as a nursery growing medium. Proc. Fla. State Hort. Soc. 104: 308-310.

Giodano, P. M., Mortvedt, J.T., and Mays, J.T. 1975. Effects of municipal wastes on crop yields and uptake of heavy metals. J. Environ. Qual. 4: 393-399.

Gouin, F. R. 1982. Using composted waste for growing horticultural crops. Biocycle 23(1): 45-47.

Gouin, F. R. 1985. Growth of hardy Chrysanthemums in containers of media amended with composted municipal sewage sludge. J. Environ. Hort. 3(2): 53-55.

Hershey, D. R. 1989. Improved equipment for vacuum extraction of saturated growing media. HortScience 24: 155.

Holcomb, E.J. 1994. Bedding Plants IV. Ball publishing. Batavia, Illinois.

Jeong, B. R. and Lee, C.W. 1992a. Ammonia and nitrate nutrition of 11 bedding plant species. Acta Hort. 319: 505-510.

Jeong, B. R. and Lee, C.W. 1992b. Growth suppression and raised tissue Cl^- contents in NH_4^+ fed marigold, petunia, and salvia. J. Am. Soc. Hort. Sci. 117: 762-768.

Jones, J. B. Jr., Wolf, B., and Mills, H.A. 1991. Plant Analysis Handbook: A Practical Sampling , Preparation, Analysis and Interpretation Guide. Micro-Macro Publishing, Inc. Athens, GA.

Kuo, S. 1995. Nitrogen and phosphorus availability in groundfish waste and chitin-sludge composts. Compost Sci. Util. 3(1): 19-29.

Lee, Y. S. and Bartlett, R.J. 1976. Stimulation of plant growth by humic substances. Soil Sci. Soc. Am. J. 40: 876-879.

Lemaire, F., and Dartigues, A. 1983. Influence of $CaCO_3$ added to the substrate on the nitrogen nutrition of *Pelargonium hortorum* mother plants. Acta Hort. 150: 203-217.

Link, C. B., Gouin,F.R., and Shanks, J.B. 1983. Composted sewage sludge and woody ornamental crops. Acta Hort. 133: 199-204.

MacCubbin, T. J. and Henley, R.W.. 1993. Evaluation of a yard waste compost as a potting medium amendment for production of potted ageratum. Proc. Fla. State. Hort. Soc. 106: 302-305.

Nappi. P. and Barberis, R.. 1993. Compost as growing medium: chemical, physical and biological aspects. Acta Hort. 342: 249-256.

Sawhney, B. L. 1976. Leaf compost for container-grown plants. HortScience 11: 34-35.

Taylor, J. M., Sikora,L.J., Tester,C.J., and Parr, J.F. 1978. Decomposition of sewage sludge compost in soil: II. Phosphorus and sulfur transformations. J. Environ. Qual. 2: 84-89.

Tomati, U., Galli, E., Buffone E., Rosique, J.C., and Roig, A.. 1993. Composts in floriculture. Acta Hort. 342: 175-181.

Watanabe, F. S. and Olsen, S.R.. 1965. Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extract from soil. Soil Sci. Soc. Amer. Proc. 29: 677-678.