# Growth Response of Annual Transplants and Physical and Chemical Properties of Growing Media as Influenced by Composted Sewage Sludge Amended with Organic and Inorganic Materials[1]

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**Abstract**

Composted sewage sludge was combined with several other organic and inorganic components to form 19 growing media. Increasing the proportion of sludge compost in media from 25 to 50% increased media pH, electrical conductivity (EC), air-filled pore space (AS), and nutrient levels, and usually increased growth of pansy, snapdragon, and cabbage plants. Of the other organic components, sawdust-based media had the highest pH, EC, and AS; sphagnum peat-based media the highest water holding capacity. Plant fresh weights were highest with bark, which produced media with highest retention of K, Ca, Mg, and Na. Of the inorganic components, pumice produced media with lower AS and lower yields of each crop than did perlite or vermiculite. Inorganic components had no effect on media pH or EC. Yields of all crops were usually higher in media containing compost than in 5 commercial potting mixes but less than in a fertilizer-amended bark medium. High yields appeared to be associated with higher medium AS and higher initial levels of major and minor plant nutrients.

**Index words:** cabbage, pansy, snapdragon, *Brassica oleracea, Viola tricolor, Antirrhinum majus,* air-filled pore space, heavy metal toxicity, peat, bark, sawdust, vermiculite, perlite, pumice, electrical conductivity, composted sewage sludge

## Introduction

Satisfactory growth of annual transplants and nursery crops can occur in soilless media made up of a wide range of components. Peat-vermiculite mixes have been popular for many crops, but the high cost of these components stimulated a search for substitutes. Each geographic area produces waste products which have potential as media components. Bark, woodchips, straw, cinders, nut shells, grain hulls, and many others have been incorporated successfully into growing media. However, the price and availability of these products vary with the economic health of the industry producing the waste. As more communities turn to composting as a means of disposing sewage sludge or municipal solid wastes, interest in using these composts as soil amendments or as components of soilless media increases.

Physical and chemical characteristics desirable in a growing medium have been widely investigated. The importance of a certain range of bulk densities (8, 15), air porosities (4, 15), organic matter (8), cation exchange capacity (8), water holding capacity (4), and particle size distribution (10, 12) has been demonstrated. Composts of sewage sludge and sawdust have many characteristics suitable for use in growing media.

The purpose of this study was to determine the physical and chemical characteristics of media containing compost made of sewage sludge and sawdust in combination with several organic and inorganic components for producing 3 species of transplants.

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## Materials and Methods

A compost was produced from Portland, OR anaerobically digested sewage sludge and conifer sawdust using a closed vessel system.[3] The compost was used to prepare 18 growing media with a factorial combination of either 25 or 50% by volume of compost, 50 or 25% by volume of sphagnum peat, conifer sawdust, or hammer-milled conifer bark, and 25% of vermiculite (Terra-lite, medium grade), pumice, or perlite (Permalite, soil mix grade). Plants growing in these media were compared to plants growing in a medium consisting of 75% compost plus 25% perlite and a medium consisting only of conifer bark plus 12 kg/m$^3$ (20 lb/yd$^3$) of 10N-1.7P-2.5K (10-4-3) fertilizer plus dolomite and Fritted trace elements. Plants were also grown in 5 locally obtained grower mixes. With the exception of the 100% bark medium, no fertilizers or lime were incorporated into media. However, some grower mixes contained fertilizers or lime.

Pansy (*Viola tricolor* 'Super Swiss Mix') and snapdragon (*Antirrhinum majus* 'Floral Carpet Red') were sown on vermiculite on December 10 and transplanted one month later into 5.7 cm-cell 6-pack containers of media which constituted a single replication of the medium treatment. Cabbage (*Brassica oleracea* var. *capitata* 'Golden Acre') seeds were sown directly into media in the above cell packs at the same time the flower seedlings were transplanted. Cell packs of all crop $x$ treatment combinations were randomized in a complete block design with 5 replications. A minimum greenhouse temperature of 7°C (45°F) was maintained until March 1, when the minimum temperature was raised to 13°C (55°F). Average natural daylength during the growing period was 10 hr; supplemental fluorescent lighting was provided from 10 P.M. until 4 A.M.

All plants were liquid-fed at weekly intervals with Peter's 30N-4.3P-8.3K (30-10-10) (400 ppm N) and

$(NH_4)_2SO_4$ (490 ppm N) until harvest. Harvest dates were March 7, 1983 for cabbage, March 24 for pansy, and March 28 for snapdragon. Shoot fresh weights were measured immediately after cutting. Dry weights were determined from bulked replicates.

Particle size distribution of individual media components was determined by screening through U.S. Standard Sieves of 16, 4.75, 2.00, 1.00, 0.50, 0.25, 0.125, and 0.061 mm. Air-filled pore space of duplicate samples of components and media was determined according to the formula of Buscher and Van Doren (2). Total porosity or water space was calculated by comparing dry weights and weights obtained when a column of medium or component was filled to surface level with water (10). Electrical conductivity (EC) was measured with an RD-26 Solubridge and pH by glass electrode in solutions drained from the columns used for porosity determinations. Separate non-planted samples of all media were irrigated and liquid fertilized as for planted media. When the plants were harvested the unplanted media were dried and ground to pass a 20 mesh screen. Total N in media and compost was determined by the Kjeldahl method. All other elements were determined by inductively-coupled argon plasma emission spectrometry following dry ashing at 500°C (932°F) for six hr. and extraction with 20% $HNO_3$.[4]

## Results and Discussion

*Physical Characteristics of Components and Media*

Sphagnum peat had by far the greatest proportion of small (less than 0.5 mm) particles, the smallest air-filled pore space (AS), and largest water space (WS) of the four organic components (Table 1). Sludge compost was most similar to sawdust in particle size distribution, AS and WS. Of the inorganic components, pumice had the broadest size distribution, with the largest fraction of both small and very large (over 4.75 mm) particles. Pumice tended to pack tightly, with relatively low porosity. Perlite was the most uniform in size and had the largest AS (Table 1).

Media AS ranged from 13 to 34% and media WS from 43 to 67% (Table 2). Increasing the rate of com-

**Table 1. Physical characteristics, pH, and EC of media components.**

| | Sieve size distribution (mm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Component | 0.13 | 0.13-0.50 | 0.50-1.0 | 1.0-2.0 | 2.0-4.75 | 4.75-16 | AS | WS | pH | EC |
| *Organic* | % | | | | | | | | | *dS/m* |
| Bark | 2.5 | 17.5 | 13.3 | 18.8 | 28.5 | 19.6 | 30.0 | 36.8 | 4.13 | 0.25 |
| Peat | 3.2 | 39.4 | 16.4 | 16.4 | 10.5 | 9.0 | 10.3 | 66.0 | 4.00 | 0.18 |
| Sawdust | 0.5 | 6.4 | 15.8 | 39.0 | 29.1 | 9.2 | 39.0 | 37.1 | 5.52 | 0.17 |
| Compost | 2.3 | 7.9 | 13.8 | 33.5 | 39.2 | 3.2 | 39.1 | 37.5 | 5.95 | 2.32 |
| *Inorganic* | | | | | | | | | | |
| Perlite | 0.8 | 3.2 | 6.0 | 25.7 | 63.1 | 1.2 | 39.5 | 30.7 | 6.95 | 0.01 |
| Pumice | 6.7 | 14.9 | 9.4 | 18.2 | 37.5 | 13.5 | 14.8 | 37.5 | 7.07 | 0.01 |
| Vermiculite | 0.8 | 3.3 | 6.4 | 28.8 | 57.9 | 27.5 | 27.5 | 45.9 | 6.90 | 0.10 |

**Table 2. Physical characteristics, pH, and EC of media before planting.**

| Compost rate[z] | Components Organic | Inorganic | AS | WS | pH | EC |
|---|---|---|---|---|---|---|
| % | | | % | | | *dS/m* |
| 25 | Peat | Vermiculite | 17 | 64 | 4.0 | 0.75 |
| 50 | | | 28 | 52 | 4.7 | 1.06 |
| 25 | | Perlite | 20 | 60 | 4.2 | 0.59 |
| 50 | | | 24 | 52 | 4.7 | 1.01 |
| 25 | | Pumice | 13 | 60 | 4.4 | 0.34 |
| 50 | | | 19 | 55 | 4.8 | 0.90 |
| 25 | Bark | Vermiculite | 17 | 51 | 4.8 | 0.90 |
| 50 | | | 28 | 47 | 5.3 | 0.89 |
| 25 | | Perlite | 23 | 48 | 4.7 | 0.55 |
| 50 | | | 28 | 47 | 5.2 | 1.08 |
| 25 | | Pumice | 13 | 51 | 4.9 | 0.53 |
| 50 | | | 16 | 48 | 5.1 | 0.95 |
| 25 | Sawdust | Vermiculite | 34 | 45 | 5.8 | 0.71 |
| 50 | | | 33 | 46 | 5.9 | 1.04 |
| 25 | | Perlite | 32 | 45 | 5.6 | 0.75 |
| 50 | | | 34 | 43 | 5.7 | 1.24 |
| 25 | | Pumice | 22 | 50 | 5.6 | 0.56 |
| 50 | | | 23 | 48 | 5.8 | 1.15 |
| 0 | Bark | None | 25 | 43 | 4.9 | 3.40 |
| 75 | None | Perlite | 28 | 46 | 6.2 | 1.75 |
| | | LSD (0.05) | 5 | 4 | 0.2 | 0.18 |

[z]Proportion of compost (% v/v) incorporated into final medium.

post from 25 to 50% increased AS from 21% to 26% when averaged over all other media components, but since sawdust and compost had essentially the same AS (Table 1), increasing the compost rate did not increase the AS of media containing sawdust (Table 2). Air-filled pore space averaged 30% in mixes containing sawdust but only 21% in mixes containing peat or bark. Mixes containing pumice averaged 18% AS compared to 27% for vermiculite or perlite. A high degree of aeration is desirable in media which are maintained with a high level of moisture. However, increased AS may reduce bedding plant growth when plants are allowed to wilt before watering (16).

*Chemical Characteristics of Components and Media*

All organic components were acidic in reaction, but compost and sawdust were more than an order of magnitude less acidic than were bark and peat (Table 1). All inorganic components were nearly neutral in pH. The EC of all components except sludge compost was low. The high initial EC of the compost (Table 1) reflects its high soluble trace element and nutrient content.

Increasing the compost rate usually increased media pH and EC, but did not significantly affect the pH of most media containing sawdust (Table 2). Media pH averaged 5.7 with sawdust, 5.0 with bark, and 4.5 with peat as organic component. As expected, the inorganic component had no effect on media pH or EC. After 6 weeks or irrigation with pH 7.0 water and application of liquid fertilizer, media pH averaged 5.8 and did not vary significantly with rate of sludge compost or inorganic component. The pH of media containing peat averaged 5.3 compared to 5.8 and 6.4 for media containing bark and sawdust, resp. The pH of all media increased with time. Media EC averaged 0.15 dS/m after 6 weeks and did not vary significantly with any component.

Media components affected postharvest media levels of all elements analyzed (Table 3). Increasing the rate of sludge compost decreased the level of N retained (primarily $NH_4^+$) by the media, but increased the extractable concentrations of all other nutrients and trace elements analyzed except Fe and Na. Retention of N was highest in media containing peat; extractable Al levels were also highest in peat-containing media. Media containing bark had the highest levels of extractable K, Ca, Mg, Na, and As. Zinc and Ni levels were highest in media containing sawdust. Inorganic components had very little effect on extractable element levels in media (Table 3) as the extraction procedure did not digest and solubilize the inorganic components.

*Media Effects on Transplant Yields*

Moisture content of plants did not vary significantly with treatment (data not shown); only fresh yield data are presented. Fresh yields of all three bedding plants varied by two to nearly three-fold when comparing the most and least productive media (Table 4). Plant growth was always greatest in the 100% bark medium. This was probably due in part to the lime and fertilizer incorporated into this medium and to favorable AS and WS (Table 2). However, irrigation and fertilizer schedules were also formulated based on experience with this medium. Media with substantially different water and nutrient holding capacities and AS might have produced higher yields with a change in watering or fertilization practices.

Growth of plants in compost-based media was usually greater than in the 5 commercial mixes (Table 4). Several of these commercial media had very low AS or extremely low or high pH (data not shown).

The germination of cabbage seed varied considerably among media and was generally poor in the commercial media (Table 4). This may again be related to extremes of pH or insufficient aeration. The number of snapdragon flower buds present at time of harvest varied considerably with treatment (Table 4). Media producing larger plants also produced higher numbers of flower buds.

Increasing the rate of compost increased the growth of all three crops (Table 5). Bark was the best of the organic components for all three crops. Vermiculite was the best inorganic component for cabbage and pansies, while perlite produced the best growth of snapdragons (Table 5).

Higher yields of all crops usually occurred in media characterized by high initial nutrient and trace element levels, lower retention of N, and higher pH, EC, and AS. However, bark, which was usually the most favorable organic component in media containing compost and produced excellent growth when used alone, had a very low initial pH. Thus, the initial pH of the media, except for extremes of less than 4.5 or greater than 7, did not appear to be a major factor in plant growth.

**Table 3. Main effects of media components on elemental concentrations of irrigated and fertilized media at termination of experiments.**

| Component | Rate or material | N | P | K | Ca | Mg | S | Na | Fe | Cu | Zn | Mn | Al | Ni | As | Cd | B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % | | | | | | | mg/kg | | | | | | | | |
| Sludge compost | 25% | 0.81a[z] | 1.27b | 4.2b | 2.2b | 0.59b | 0.40b | 0.18a | 239a | 18b | 952b | 460b | 90b | 3.7b | 5.6b | 0.63b | 44b |
| | 50% | 0.65b | 1.36a | 5.1a | 2.8a | 0.70a | 0.81a | 0.18a | 247a | 23a | 1675a | 570a | 118a | 6.5a | 7.3a | 0.92a | 49a |
| Organic | Peat | 0.83a | 1.33a | 4.4b | 1.9c | 0.61c | 0.47a | 0.18a | 243a | 19b | 1111b | 365b | 119a | 3.8c | 5.9b | 0.74a | 47a |
| | Bark | 0.73b | 1.34a | 5.0a | 2.8a | 0.69a | 0.48a | 0.19a | 238a | 21a | 1350a | 571a | 94b | 4.8b | 7.0a | 0.78a | 47a |
| | Sawdust | 0.63c | 1.27a | 4.5b | 2.6b | 0.65b | 0.46a | 0.15b | 248a | 21a | 1479a | 609a | 98b | 6.7a | 6.5ab | 0.81a | 45a |
| Inorganic | Vermiculite | 0.70a | 1.30a | 4.9a | 2.6a | 0.71a | 0.50a | 0.15b | 268a | 21a | 1411a | 546a | 93a | 5.2a | 6.7a | 0.79a | 46a |
| | Perlite | 0.75a | 1.32a | 4.4a | 2.3b | 0.60b | 0.43a | 0.18a | 244ab | 20a | 1222a | 469a | 107a | 4.9a | 6.1a | 0.73a | 47a |
| | Pumice | 0.74a | 1.32a | 4.6a | 2.5a | 0.63b | 0.48a | 0.19a | 217b | 21a | 1308a | 529a | 111a | 5.2a | 6.7a | 0.80a | 46a |

[z]Means within a column followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test.

Table 4. Effects of media on growth of cabbage, pansy, and snapdragon.

| Compost rate (%)[z] | Component: Organic | Component: Inorganic | Fresh wt.: Cabbage | Fresh wt.: Pansy | Fresh wt.: Snapdragon | Cabbage emergence (%) | Number of snapdragon flower buds/ 30 plants |
|---|---|---|---|---|---|---|---|
| | | | ——— | g/plant | ——— | | |
| 25 | Peat | Vermiculite | 2.2 | 3.8 | 2.2 | 90 | 3 |
| 50 | | | 1.9 | 3.8 | 2.8 | 77 | 8 |
| 25 | | Perlite | 1.6 | 2.1 | 1.6 | 75 | 4 |
| 50 | | | 1.7 | 3.7 | 2.2 | 79 | 6 |
| 25 | | Pumice | 1.7 | 2.5 | 1.6 | 94 | 2 |
| 50 | | | 1.8 | 1.9 | 2.0 | 77 | 5 |
| 25 | Bark | Vermiculite | 2.3 | 3.5 | 2.4 | 79 | 5 |
| 50 | | | 2.4 | 5.0 | 3.0 | 83 | 14 |
| 25 | | Perlite | 1.9 | 2.5 | 1.7 | 73 | 0 |
| 50 | | | 2.2 | 3.8 | 2.8 | 96 | 8 |
| 25 | | Pumice | 1.7 | 2.9 | 1.9 | 79 | 0 |
| 50 | | | 2.4 | 4.4 | 2.8 | 94 | 16 |
| 25 | Sawdust | Vermiculite | 1.9 | 3.2 | 2.0 | 92 | 4 |
| 50 | | | 2.2 | 5.0 | 2.8 | 81 | 12 |
| 25 | | Perlite | 1.6 | 2.2 | 1.5 | 88 | 1 |
| 50 | | | 2.0 | 3.0 | 2.6 | 81 | 8 |
| 25 | | Pumice | 1.9 | 2.3 | 1.5 | 90 | 1 |
| 50 | | | 2.2 | 3.9 | 2.6 | 83 | 10 |
| 0 | Bark | None | 3.0 | 5.8 | 3.2 | 85 | 10 |
| 75 | None | Perlite | 2.2 | 3.9 | 2.9 | 88 | 17 |
| 0 | Various[y] | Various | 1.7 | 2.0 | 1.5 | 57 | 1 |
| | | LSD (0.05) | 0.4 | 1.6 | 0.6 | 5 | — |

[z]Proportion of compost (% v/v) incorporated into final medium.
[y]Means of 5 commercial media.

Table 5. Main effects of media components on growth of cabbage, pansy and snapdragon

| Component | Rate or material | Fresh wt.: Cabbage | Fresh wt.: Pansy | Fresh wt.: Snapdragon | Cabbage emergence (%) | Number of snapdragon flower buds/30 plants |
|---|---|---|---|---|---|---|
| | | ——— | g/plant | ——— | | |
| Sludge compost | 25% | 1.9b[z] | 2.8b | 1.8b | 84a | 2b |
| | 50% | 2.1a | 3.8a | 2.6a | 84a | 10a |
| Organic | Peat | 1.8b[y] | 3.0b | 2.1b | 82a | 5a |
| | Bark | 2.1a | 3.7a | 2.5a | 84a | 7a |
| | Sawdust | 1.9b | 3.3ab | 2.2b | 86a | 6a |
| Inorganic | Vermiculite | 2.1a | 4.1a | 2.1b | 84a | 8a |
| | Perlite | 1.8b | 2.9b | 2.5a | 82a | 5a |
| | Pumice | 1.9b | 3.0b | 2.1b | 86a | 6a |

[z]Means within a column followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test.

The lower N retention by media containing 50% as compared to 25% compost may have been caused by the lower water holding capacity of these media, saturation of binding sites by other elements, or increased loss of N in gaseous form due to greater microbial activity. Greater plant uptake was not involved since only non-planted media were sampled for analysis.

High initial EC of the media had no deleterious effect on yield as high yields were obtained with the 100% bark medium and media containing 50 or 75% compost. The high initial EC was a temporary condition; leaching by irrigation water and plant nutrient uptake reduced EC of all media to low levels at time of harvest (Table 4). However, growth of marigold *(Tagetes erecta)* in sludge compost-amended media was limited by high EC when leachate was returned to the media (3). Reductions in growth of snapdragon and geranium *(Pelargonium hortorum)*, possibly caused by high EC, were also noted in media containing sewage-municipal refuse compost (11).

Media producing good growth, with few exceptions, had AS of at least 20%. Yield was significantly correlated with AS for pansy ($r_{xy}=0.38$, $P=0.05$) and snapdragon ($r_{xy}=0.43$, $P=0.03$) but not for cabbage ($r_{xy}=0.25$, $P=0.18$). Bilderback et al. (1) found that decreased AS in media based on peat, bark, and peanut hulls correlated with reduced growth of azalea *(Rhododendron indicum)*. In contrast, yield of marigold was negatively correlated with AS of compost-containing media when watering was less frequent (16). The relatively poor growth of all crops in pumice-containing media (Table 5) may have been due to its low AS (Tables 1 and 2). Spomer (12) has pointed out that materials with a wide range of particle sizes, such as pumice (Table 1), make poor amendments because the fine particles fill the media interpores.

Media containing incorporated trace elements, such as the 100% bark, and media with high rates of compost produced the highest yields. The importance of high initial levels of nutrient and trace elements was also evidenced by the reduced incidence of leaf bronzing and chlorosis in media containing incorporated fertilizers or high rates of sludge. Since media with high AS also usually had high initial nutrient levels, separation of these effects is not possible. A sludge-woodchip compost in media containing peat and perlite supplied all P, Ca, Mg and trace elements needed by tomato *(Lycopersicon esculentum)* and lettuce *(Lactuca sativa)* transplants and sufficient N and K for 1 to 2 weeks (6). Similarly, addition of 33% sludge compost to unfertilized peat-vermiculite media provided all marigold nutrient needs except N and K (3).

Growth suppression of *Forsythia intermedia, Thuja occidentalis,* and *Chrysanthemum morifolium* has been noted in compost-amended media containing very high (50 to 225 mg/kg) initial levels of B (7, 9). Zinc and Cu toxicity have also been reported on vegetable transplants grown in a high metal compost (13). The mean Zn content of media containing sludge compost was 1314 mg/kg, compared to 134 mg/kg for the five commercial mixes and 147 mg/kg for the 100% bark medium. However, no visual symptoms of trace element toxicities were observed in this study.

Possible heavy metal toxicity to consumers of edible portions of vegetable crops grown from transplants started in compost-amended media could be of some concern. However, Sterrett et al. (14) reported that tomato, cabbage, and muskmelon *(Cucumis melo)* transplants grown in media amended with either low or high metal sludges differed in their metal contents, but that the market yield of the crops did not vary with medium and medium metal level had little or no effect on metal concentrations in leaves or edible portions of the market crops. Similarly, media containing 50% of a compost of a low metal sludge and wood chips did not affect Cd and Zn uptake by leaves or fruit of greenhouse cucumber *(Cucumis sativus)* over a medium pH range of 4.1 to 7.1 (5).

## Significance to the Nursery Industry

Successful growth of annual transplants can occur in media containing a wide range of components. Maximum return to the grower will depend on producing a quality plant with the least cost outlay for media, watering, and fertilizers. This study demonstrated that locally produced products, such as bark, sawdust, and, particularly, sewage sludge compost, may be substituted completely or in part for more expensive components such as sphagnum peat. Plant growth in compost-based media was equal to or better than growth in several commercial media and no symptoms of heavy metal toxicities were noted. Problems with extremes of pH or electrical conductivity can usually be corrected inexpensively. The key to successful production lies in maintaining appropriate nutrient, aeration and moisture levels in the chosen medium. Irrigation and fertilizer applications will need to be altered when making changes in media.

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