Physical and Chemical Properties of Substrates Containing Earthworm Castings and Effects on Marigold Growth

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Abstract. The effects of various substrates with or without earthworm [Eisenia fetida (Savigny, 1826)] castings on growth of marigolds were evaluated. In addition, the physical and chemical properties of such substrates were determined. Castings had a greater nutrient content than the remaining substrates. The 4 pine bark: 1 sand treatment (v/v) (PBS) had higher P, K, and Zn than 7 peat moss: 3 perlite (v/v) (PP). PP had the lowest nutrient content of all substrates. Castings (C) had the highest pH followed by 1 PBS: 1 C (v/v), 2 PBS: 1C (v/v) and 3 PBS: 1C (v/v). Sunshine Mix 1 and PP had the lowest pH. EC (ER) was increased by castings, which had high EC. Castings and PP had the greatest percentage pore space. Water-holding capacity was greatest for 2 PBS: 1C (v/v) compared with Sunshine Mix 1 followed by castings. Earthworm castings increased plant growth index, stem diameter, root growth, dry weight, and flower number of marigolds compared with PP, Sunshine Mix 1, and PBS. All mixtures of castings (C) with PP, PBS, except 3 PBS: 1C (v/v), increased the growth index of plants. 1 PP: 1 C (v/v), increased flower number compared with all substrates without castings. Castings alone increased number of open flowers, but did not differ from 1 PP: 1 C or 3 PP:1 C.

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were analyzed by analysis of variance using SAS (SAS Institute, Cary, N.C.). Treatment means were separated using Duncan’s multiple range test, 5% probability.

Results and Discussion

Substrate nutrient analysis showed that castings had a greater nutrient content than the remaining substrates. As anticipated, when castings were mixed with other substrates, nutrient content decreased as a result of dilution. The 4 pine bark: 1 sand (v/v) treatment (PBS) had higher P, K, and Zn than 7 peat moss: 3 perlite (v/v) (PP). PP had the lowest nutrient content of all substrates (Table 1). Similar to our findings, Parkin and Berry (1994) found that earthworm castings were enriched in mineral N, relative to surrounding soil, and the amount of N accumulated in earthworm castings was a reflection of the N content of the organic matter used as a food source by the earthworms. It was previously reported that sheep or cattle castings had greater initial nutrient content than castings from horse manure and substrates with castings (Hidalgo and Harkess, 2002b).

Earthworm castings (C) had the highest pH followed by 1 PBS: 1 C (v/v), 2 PBS: 1 C (v/v), and 3 PBS: 1 C. Sunshine Mix 1 and PP had the lowest pH. Research with poinsettia showed that leachate pH of earthworm castings and peat: perlite substrates ranged from 4.69 to 8.0 depending on the type and amount of castings (Hidalgo and Harkess, 2002a). In this experiment, PP without castings had a pH between 3.85 and 4.69.

Earthworm castings had a greater amount of soluble salts as indicated by EC compared with the control (Sunshine Mix 1) followed by 1 PBS: 1 C (v/v), 1 PP: 1 C (v/v), and 2 PP: 1 C (v/v) (Table 2). Substrates with low EC were PBS and PP. These results are associated with higher nutrient levels (Table 1) in the treatments with castings. As previously reported, electrolyte conductivity (EC) was increased by castings based on the type of castings and EC decreased with time after transplanting (Hidalgo and Harkess, 2002a).

Earthworm castings, 1 PBS: 1 C, and PP had the greatest percentage pore space followed by 2 PBS: 1 C, 2 PPC: 1 C, and Sunshine Mix 1 (control). PBS, 3 PBS: 1 C, and 1 PP: 1 C had the smallest percentage pore space (Table 2). Percent air space was greatest for PP followed by earthworm castings as compared with Sunshine Mix 1. Mixtures 3 PBS: 1 C, and 2 PPC: 1 C had the smallest percentage air space. These are expected results, because perlite is a good substrate to improve aeration of container mixes (Davidson et al., 1994).

Water-holding capacity was greatest for 1 PBS: 1 C as compared with Sunshine Mix 1 followed by earthworm castings. PBS and 1 PP: 1 C had the least water-holding capacity. All treatments containing pine bark: sand had the highest values for bulk density, followed by 1 PP: 1 C, 2 PP: 1 C, and earthworm castings. Sunshine Mix 1 and 7 peat moss: 3 perlite had the lowest bulk density. Davidson et al. (1994) stated that peat moss is difficult to wet, but when wetting, it possesses good water-holding capacity and good aeration. In this study, treatments containing peat moss showed reduced water-holding capacity, possibly as a result of a short wetting period of 30 min. Syers and Springett (1983) found that earthworm castings generally have higher water-holding capacity compared with soil without castings.

Castings alone and 1 PP: 1 C resulted in the greatest growth index (GI), but did not differ from 2 PP: 1 C or 1 PBS: 1 C (Table 3). All treatments except PP and 3 PBS: 1 C resulted in a greater GI compared with Sunshine Mix 1 (control). PBS resulted in the lowest growth index. Greater amount of nutrients, higher pH, and increased water-holding capacity found in castings may have resulted in a greater plant growth index of plants. In plant growth trials with vegetables, fruits, and ornamental plants, vermicompost outperformed both traditional compost and commercial plant growth substrates in almost every experiment. The author stated that this may be explained, partially by circumstantial evidence, that vermicomposts have better structure and may contain plant growth hormones, enhanced levels of soil enzymes, and high microbial populations (Edwards, 1995).

Castings alone resulted in greater marigold stem diameter each week after transplanting as compared with the remaining substrates (Table 3). Greater nutrient content of the castings when compared with the rest of substrates may explain the increase in stem diameter. PBS resulted in smallest stem diameter. Earthworm castings and Sunshine Mix 1 resulted in greater number of roots and were equally effective compared with the remaining treatments (Table 3). The number of roots in Sunshine Mix 1 did not differ from pine bark castings mixtures (PBS: C).

Earthworm castings increased plant dry weight followed by 1 PP: 1 C, 1 PBS: 1 C, and 2 PP: 1 C when compared with Sunshine Mix 1 (control). PP and PBS resulted in least dry weight of marigolds. The remaining treatments showed intermediate values not different from the control (Table 3).

Earthworm castings increased the number of flowers compared with the remaining substrates (Table 3). When substrates were mixed with castings at 1:1, 2:1, or 3:1 (v/v), performance was related to the amount of castings in the mixtures; the greater the amount of castings, the greater the growth response. This improvement could have been associated with increasing amount of nutrients obtained when castings were increase in the mixture in addition to the physical and chemical properties of castings. Castings had a greater nutrient content that the other substrates, particularly nitrogen. PP had the lowest nutrient content of all substrates. In addition, castings had the highest pH and EC and contributed to greater air space and water-holding capacity, thus resulting in improved plant growth. Castings were found

**Table 1. Extractable nutrient levels of the treatment substrates used to grow marigolds.**

| Substrates               | N   | P   | K   | Ca  | Mg  | Zn  |
|-------------------------|-----|-----|-----|-----|-----|-----|
| Sunshine                | 4.0 | 23.0| 89.5| 818.5| 252.5| 13.8|
| Castings                | 65.0| 165.5| 567.5| 2431.5| 577.5| 17.9|
| 4 Pine bark: 1 sand     | 0.5 | 15.0| 91.35| 789.5| 79.5| 2.7 |
| 7 Peat                  | 0.5 | 2.5 | 10.5| 193.0| 55.5| 1.1 |

*Means in column separated by Duncan’s multiple range test, 5% significance level.

**Table 2. Percentage pore space, air space, water-holding capacity, bulk density, pH, and EC of the different substrates used to grow marigold plants.**

| Substrate               | Pore Space (%) | Air Space (%) | Water-Holding Capacity (%) | Bulk Density (g cm⁻¹) | pH     | EC (mhos cm⁻¹) |
|-------------------------|----------------|--------------|----------------------------|-----------------------|--------|---------------|
| Sunshine Mix 1          | 66.0           | 33.0         | 53.0                       | 0.10                  | 5.67   | 0.42          |
| Castings                | 82.0           | 18.0         | 60.0                       | 0.22                  | 7.59   | 0.90          |
| 4 Pine                  | 45.0           | 55.0         | 39.0                       | 0.47                  | 6.59   | 0.12          |
| 7 Peat                  | 80.0           | 20.0         | 44.0                       | 0.13                  | 5.80   | 0.15          |

*Means in columns separated by Duncan’s multiple range test, 5% significance level.
to be a suitable substrate amendment for growing potted marigolds.

**Table 3. Growth index (GI), root growth, plant dry weight, stem diameter, number of flowers per plant, and number of flowers opened per plant of marigold as influenced by substrates 9 weeks after transplanting.**

| Substrates              | GI (cm<sup>3</sup>) | Root Growth (1–5)<sup>a</sup> | Dry Weight (g) | Stem Diameter (mm) | Flowers (#) | Open Flowers (#) |
|-------------------------|---------------------|--------------------------------|----------------|--------------------|--------------|------------------|
| Sunshine                | 2164.7<sup>b</sup>  | 4.0 ab                         | 4 cd           | 5 ef               | 3 a          | 0.0 c            |
| Castings                | 3449.2 a            | 4.8 a                          | 10 a           | 7 a                | 3 a          | 0.8 a            |
| 4 Pine bark: 1 sand (PBS)| 1461.7 e           | 2.6 cd                         | 2 e            | 4 g                | 0 e          | 0.0 c            |
| Peat moss: 3 perlite (PP)| 2253.1 d           | 2.6 cd                         | 3 de           | 4 de               | 1 de         | 0.0 c            |
| 1 PP: 1 C               | 3450.1 a            | 2.8 cd                         | 6 b            | 6 b                | 3 ab         | 0.6 ab           |
| 2 PP: 1 C               | 3078.1 ab           | 2.2 d                          | 5 c            | 6 bcd              | 2 bcd        | 0.2 bc           |
| 3 PP: 1 C               | 2884.9 bc           | 2.0 d                          | 4 cd           | 5 de               | 2 abc        | 0.0 c            |
| 1 PBS: 1 C              | 3031.0 ab           | 3.8 b                          | 6 b            | 6 bc               | 2 bcd        | 0.4 abc          |
| 2 PBS: 1 C              | 2721.8 bc           | 3.6 c                          | 5 bc           | 5 cde              | 1 cde        | 0.0 c            |
| 3 PBS: 1 C              | 2418.1 cd           | 3.6 bc                         | 4 c            | 5 de               | 2 bcd        | 0.0 c            |

<sup>a</sup>Means in columns separated by Duncan’s multiple test, 5% significance level.<sup>b</sup>Visual scales from 1 to 5 in which 5 = excellent number of roots and 1 = poor number of roots.

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