Influence of vermicomposted soil amendments on plant growth and dry matter partitioning in seedling production

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The present experiment was undertaken to evaluate the effects of different vermicompost substitutions for vlei soil in seedling nursery production. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Cucumber (Cucumis sativus) seeds were planted in five treatment groups including without vermicompost, 25% vermicompost, 50% vermicompost, 75% vermicompost and 100% vermicompost. Vlei soils were incorporated into the experiment making up the different supplements. There was significant (P<0.05) influence of vermicompost amendments. Tallest seedlings were recorded from V50% (13.2cm) and V75% (12.6cm) and means from treatments V25%, V50% and V75% were significantly higher than treatment V0%. Treatment V100% recorded the highest number of leaves (5.88). Highest root fresh weight was recorded from V50% (2.16g). All treatments revealed a significant difference amongst the treatments with V50% having the highest shoot dry weight of 2.22g. The means for treatments V50% and V75% were significantly higher than the treatment V0%. The highest fresh weight (11.31g) was recorded from V50%. All means for plant dry weight with vermicompost amendments were significantly higher than no vermicompost treatment (V0%). A ratio of 1:1 vermicompost and vlei gave the best results. These findings indicate that instead of using vermicompost alone, its use in mixtures with vlei gives the same effect.

Keywords: Cucumber (Cucumis sativus), vermicompost, amendment, growth, vlei, shoot, root, weight.

INTRODUCTION

The main goal of horticultural nurseries is to produce quality seedlings with target morphological and physiological features that guarantee crop success after transplanting. Post-transplant success after the nursery stage is strongly influenced by plant morphology factors (Lazcano et al., 2009). Progressively more, nursery stock is produced in containers due to market demands and numerous production advantages, including greater production per surface unit, faster plant growth, higher plant quality, and lack of dependence on arable land. Nursery potting media usually contain substantial amounts of peat moss (Sphagnum spp.) (Raviv et al., 1986) or cocopeat (Khayyat et al., 2007; Nazari et al., 2011) since it provides adequate aeration, moisture retention and support for the seedlings.

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The use of peat involves the exploitation of non-renewable resources and the degradation of highly valuable ecosystems like peatlands (Robertson, 1993). However, in recent years, increasing consumer concern about issues such as food quality, environmental safety and soil conservation has lead to a substantial increase in the use of sustainable agricultural practices. For that reason, in order to reduce costs, adopt more environmentally-friendly practices and the parallel increasing concern in waste recycling has led to the proposal of some organic materials of great interest such as compost-like substrates for example vermicompost. The latter is a nutrient-rich, microbiologically-active organic amendment that results from the interactions between earthworms (i.e. *Eisenia fetida* Savigny, *Lumbricus rubellus* Hoffmeister) and microorganisms under non-thermophilic, aerobic conditions (Edwards, 1995). It is a stabilized, finely divided peat-like material with a low C:N ratio, high porosity and high water-holding capacity and is very useful for improving the mechanism and nutrition of the plants (Domínguez, 2004; Kabiri Khosh Sout. 2008; Yadav and Garg, 2015). There are only few research studies that have examined the responses of plants to the use or substitution of vermicompost to soil or greenhouse container media (Buckerfield and Webster, 1998; Karmegam et al., 1999; Edwards et al., 2004; Hashemimajd et al., 2004; Tognetti et al., 2005; Argüello et al., 2006; Mahdavi Damghani et al., 2007; Nazari et al., 2008; Mirzaei et al., 2009; Ahmadabadi et al., 2011). Most of these studies confirmed that vermicomposts have beneficial effects on plant growth. Vermicomposts, whether used as soil additives or as components of horticultural media, improved seed germination and enhanced rates of seedling growth and development (Murumba et al., 2015; Mugwendere et al., 2015). Benefits of using vermicompost as a soilless substrate amendment for container grown horticultural crops has also been reported for a variety of reasons, including increased plant growth and flowering (Hidalgo and Harkess 2002; Gupta et al., 2014) correspondingly improved physical properties (Hidalgo et al., 2006) and water use efficiency of production (McGinnis et al., 2005) as well as to provide liming equivalences (McGinnis, 2007). Vermicompost also provides some, but not all, essential plant nutrients maximize containerized crop growth, thus an additional source of nutrients (i.e. Fertilizer) is needed (Atiyeh et al., 1999; Atiyeh et al., 2000a; Atiyeh et al., 2000b). The slowly and steadily released nutrients by vermicompost into the rhizosphere provide the suitable conditions for plant uptake (Ansari and Sukhraj, 2010). The use of compost in horticulture has occasionally been shown to be limited by the high electrical conductivity and the excessively high amount of certain ions that cause phytotoxicity (Garcia-Gómez et al., 2002), as a consequence of the chemical properties of the initial waste and/or inadequate composting procedures. It is gorged that high levels of vermicompost substitutions may adversely affect plant growth, development and yield, especially at germination and seedling stages, (Arancon et al., 2004; Roberts et al., 2007; Lazcano and Domínguez 2010; Levinsh, 2011). These adverse effects, although possible, are less likely to occur when vermicompost is used as a potting amendment (Chaoui et al., 2003). Therefore, it must be used cautiously for the agricultural and horticultural activities (Levinsh, 2011). So, the determination of desirable and economical growth inducing concentrations of vermicompost for reducing costs of agriculture is critical (Ladan Moghadam et al., 2012). The present experiment was undertaken to evaluate the possible effects of different concentrations of vermicompost on the growth and development of cucumber seedlings.

**MATERIALS AND METHODS**

**Experimental design and Crop establishment**

The experiment was carried out in the shade house at Africa University Farm (AU) in Mutare, Zimbabwe; located at 18° 53 ‘S, 32° 35'E and 1104m altitude. The seeds of *Cucumis sativus* were used as test crop and the vermicompost was purchased from Mutare Farm and city. Vlei soil was sourced from the university premises. The characteristics of the vlei and the vermicompost media are shown below:

Vermicompost was used at five different amendment levels (0, 25%, 50%, 75% and 100%) and seeds were planted in seedling trays. The vermicompost was amended into the planting media. The duration of the experiment went on for seven weeks. The experiment was laid out in Randomized Complete Block Design (RCBD) with three (3) replications and five (5) treatments as follows;

- **Treatment 1:** $V_0\%$ - no vermicompost,
- **Treatment 2:** $V_{25}\%$ - media amendment with 25% vermicompost,
- **Treatment 3:** $V_{50}\%$ - media amendment with 50% vermicompost,
- **Treatment 4:** $V_{75}\%$ - media amendment with 75% vermicompost,
- **Treatment 5:** $V_{100}\%$ - media 100% vermicompost.

**Data collection**

Destructive sampling was carried out seven weeks from seeding. Six (6) representative seedlings from each treatment were selected randomly. **Plant height:** This parameter was measured on a regular interval which was after every two plants. During measuring, a ruler was used and measuring was done from the root collar to the apex of the plant or the growing point.
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The characteristics of the vlei and the vermicompost media

<table>
<thead>
<tr>
<th>Media</th>
<th>pH</th>
<th>Min. Initial</th>
<th>N (ppm)</th>
<th>P2O5 (ppm)</th>
<th>Exchangeable Cations (meq.% K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vlei</td>
<td>6.1</td>
<td>2.05</td>
<td>16.7</td>
<td>0.31</td>
<td></td>
</tr>
<tr>
<td>Vermicompost</td>
<td>7.4</td>
<td>18.3</td>
<td>274.1</td>
<td>0.28</td>
<td></td>
</tr>
</tbody>
</table>

Figures not sharing a common letter differ significantly at 0.05 probability.

Figure 1: Shows influence of soil media amendments on plant height.

**Number of leaves:** Number of leaves was counted from six plants from each treatment block and an average was obtained.

**Root weight (biomass):** This parameter was measured after the samples had been destroyed as part of the plant’s fresh weight and dry weight. However, in order to measure specific root biomass from every sample crop, the below ground growth was cut from the same point of each sampled crop and the fresh weight was measured for every treatment. Root samples from each treatment were measured together using a sensitive balance.

**Stem thickness:** Stem diameter was measured with a Vernier caliper. All the plants were measured from the same level to avoid redundant differences since the stem grows thinner as the plant grows vertically.

**Fresh weight (roots and leaves):** Above ground growth (stem and leaves) and below ground growth (roots) was separated and weighed separately and then dried at 65°C in an electric oven for 20 hours to a constant weight to estimate plant component’s dry weights which were then calculated as outlined below:

**Data analysis**

GenStat Discovery 14th Edition was used for Statistical data analysis and means separated using the least significant difference (LSD) at P=0.05.

**RESULTS**

**Plant height:** Data regarding the influence of amending the planting media with vermicompost is shown in Figure 1. The means for the plant height as influenced by soil amendments differed significantly (P<0.05). The tallest plants were recorded from V50% and V75% with a height of 13.2 cm and 12.6 cm respectively. The shortest plants were recorded from soil amendment treatment with no vermicompost (V0%). This means that vermicompost influenced plant height significantly relative to media with no vermicompost amendment. However, at a much higher rate of vermicompost amendment there was a negative influence on plant height. This is shown by a decline in plant height at level V100%. Plant height from treatments V25% and V100% did not differ significantly from one another. Mean plant height from vermicompost amended media was 12.00 cm.

**Number of leaves:** There was significant (P<0.05) influence of vermicompost amendments on the number of leaves as shown in Figure 2. All treatments which were amended with vermicompost produced superior number of leaves compared to no vermicompost application. As the vermicompost increased, the number of leaves increased as well, with V100% recording the highest number of leaves (5.88). This means as the levels of
vermicompost increased the number of leaves increased. The lowest number of leaves (4.80) was recorded from V25% for treatments with vermicompost. The mean number of leaves from vermicompost amended media was 5.22.

**Stem thickness:** Data regarding plant stem thickness is shown in Figure 3. Comparison of means for stem thickness revealed significant (P<0.05) differences in the media treatments applied. Stem thickness in treatments V0% (0.26 cm) and V100% (0.28 cm) were not significantly different from each other. However, the means for treatments V25% (0.31 cm), V50% (0.36 cm) and V75% (0.35 cm) were significantly higher than treatment with no vermicompost amendment (V0%). The application of vermicompost at much higher levels such as V100% has little influence since the means of stem thickness are statistically not significant from vermicompost amendments at levels V0% and V25%. The mean plant stem thickness from vermicompost amended media was 0.32 cm.

**Fresh weight of plant aerial parts:** The comparison of the treatment means revealed significant (P<0.05) differences on the fresh weight of shoots (Table 2). When vermicompost was amended into the growth media there was a positive influence on fresh weight of the shoots. The highest shoot fresh weight was recorded from V75% (8.28g) while the lowest fresh weight was recorded from V0% (5.55g). The mean shoot fresh weight was 7.92g.

**Fresh weight of plant roots:** Data pertaining to fresh weight of the roots as influenced by amendments of vermicompost is shown in Table 2. The comparison of
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Table 1. Characteristics of the vermicompost

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Shoot Fresh weight (Grams)</th>
<th>Shoot Dry weight (Grams)</th>
<th>Root Fresh weight (Grams)</th>
<th>Root Dry weight (Grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V0%</td>
<td>5.55&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.66&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.24&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>V25%</td>
<td>6.40&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.85&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.30&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>V50%</td>
<td>9.15&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.22&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.16&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.79&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>V75%</td>
<td>8.28&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.83&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.82&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.63&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>V100%</td>
<td>7.84&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.25&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.82&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.24&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean&lt;sup&gt;1&lt;/sup&gt;</td>
<td>7.92</td>
<td>1.54</td>
<td>1.76</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Significance: * * * *

LSD<sub>0.05</sub>: 0.76 0.1712 0.4618 0.0949

CV: 5.4 6.7 14.8 11.4

<sup>a</sup>denotes significance at P<0.05. Figures not sharing a common letter in a column differ significantly at 0.05 probability.

<sup>1</sup> this is the average for treatments with vermicompost amendment.

Figure 4. Shows means of influence of treatment on fresh weight of whole plant.

Means on root fresh weight shows significant (P<0.05) differences. Treatments V0% and V25% were not statistically different from each other and produced the lowest root fresh weight of 1.27g and 1.22g respectively. The highest root fresh weight was recorded from V50% (2.16g). However, the means for treatments V75% (1.82g) and V100% (1.820g) did not differ significantly from V50%. These results reveal that there is no benefit that can be derived from media amendment beyond level V50%. The mean fresh weight from vermicompost amended media was 1.76g.

**Shoot Dry weight**: Data regarding shoot dry weight is shown in Table 1. The analysis of the means shows a significant (P<0.05) difference in shoot dry weight. All treatments revealed a significant difference amongst the treatments with V50% having the highest shoot dry weight of 2.22g. Beyond this level (V50%) of media amendment there is no further benefit can be derived towards shoot dry matter. The lowest shoot dry weight among the treatments with vermicompost amendments was V25% which recorded a mean dry weight of 0.85g. Treatment V0% had an average shoot dry weight of 0.66g. Mean shoot dry weight from vermicompost amended media was at 1.54g.

**Dry weight of root**: Comparison of the treatment means regarding root dry weight was significant (P<0.05). The data for the root dry weight is presented in Table 1. The means for treatments V50% (0.79g) and V75% (0.63g) were significantly higher than the treatment with no vermicompost amendment V0%. However, means for treatments V25% (0.30g) and V100% (0.24g) did not differ significantly from treatment V0%. These results reveal that at lower levels of media amendments (V25%) and much higher levels (V100%) have no influence on dry weight of plant roots. Mean root dry weight from vermicompost amended media was 0.49g.
Whole plant fresh weight: There were significant (P<0.05) differences among the means for the treatments investigated (Figure 4). Treatment V0% and V25% were not statistically different and they recorded the lowest fresh weight of 6.82g and 7.62g respectively. The highest fresh weight was recorded from V50%. Means for the fresh weight of treatment V100% and V75% were not statistically different from each other. The mean fresh weight from vermicompost amended media was 9.67g. These results reveal that lower levels (V25%) of media amendment has no positive influence on whole plant fresh weight while beyond level V50% the influence will start to decline.

Whole plant dry weight: Data for means of whole plant dry weight is shown in Figure 5. Comparison of the means for the whole plant dry weight shows that there were significant (P<0.05) differences. All means for plant dry weight with vermicompost amendments were significantly higher than no vermicompost treatment (V0%). The highest plant dry weight was recorded from treatment V50% (3.01g) followed by treatment V75%, V100% and V25% which recorded plant dry weight of 2.46g, 1.49g and 1.15g respectively. Mean plant dry weight from vermicompost amended media was 2.03g.

DISCUSSION

The results have revealed the significant impact of vermicompost on the growth and development of cucumber shoots as measured within a period of seven weeks. Data from this experiment and that in the literature reviewed affirm to the fact that vermicompost has a positive impact on whole plant fresh and dry weight, stem thickness, plant height and the number of leaves among other parameters measured.

Vermicompost affected the leaf characteristics including the number of produced leaves. V100%, treatment had the highest number of leaves which is in line with Dintcheva and Trinkoska (2012) who alluded that all vermicomposts cause greater production of leaves than the control. Mugwendere et al. (2015) ascribed a lower cumulative number of leaves in treatments with no vermicompost amendment media to the low nitrogen level. The number of leaves was proportional to the increase in vermicompost concentration. Rakesh (2010) also concluded that the mean plant heights of the treatments of vermicompost were significantly greater than the mean plant height of the control, in this case V0%. This supports results revealed in Figure 1 where all mean plant heights are significantly (P<0.05) different in favour of vermicompost. However, these results contrast with those reported by Moreno-Reséndez et al. (2005) who did not record differences in height of tomato plants var. Flora - Dade, developed on substrates with different levels of vermicompost and sand, when compared with sand fertilized with nutrient solution.

The amendment with vermicompost on the growth media supplies additional nutrients for plant growth. Atiyeh et al. (2001) reported greater growth in the tomato seedlings grown in substrate containing 50% of vermicompost without application of synthetic fertilizers. Pour et al. (2013) attributed the physiological changes observed in vermicompost treated plants to the humic substances and nutrients. Sahni et al. (2008) also confirmed that vermicompost contains considerable amounts of humic substances and had improved effects on the plant nutrition. With respect to plant height, Rodriguez et al. (1998) highlight that greater height promotes the development of a greater number of leaves and chlorophyll.

The significant p-value for the whole plant fresh weight implies that the impact of vermicompost amendment on vlei soil was positive. Zaller (2007) states that adequate root and aerial biomass of tomato transplants guarantee
an improved ability to exploit soil resources and higher photosynthetic capacity. The potential consequences are enhanced crop yield and improved fruit quality. Trinkoska and Dintcheva (2012) also advances that, the best shoot fresh weights and lengths were due to amending the medium with Bio humus MM which is more like vermicompost. More than a few studies which are in concurrence with the findings of the current study have been done to find the influence of vermicompost on plant biomass (Singh et al., 2010; Wang et al., 2010; Warman and AngLopez, 2010; Arancon et al., 2008). Since vermicompost contains considerable amounts of humic substances (Atiyeh et al., 2002) and had improved effects on the plant nutrition (Sahni et al., 2008), its utilization may induce various physiological changes. The humic substances present in vermicompost could contribute to improved germination, seedling elongation, biomass allocation, fruit morphology and chemical properties of three tomato varieties (Zaller, 2007) and cucumber (Atiyeh et al., 2002).

Instead of using vermicompost alone, nursery growers can benefit from using the vermicompost mixed with vlei or sand soils as these bequeathed the same effect (Murimba et al., 2015). Results from this current investigation also show that best characteristics were obtained from both substrates for optimum productivity which is observed in the treatment $V_{50\%}$. A similar study by Gondek (2003) revealed that the highest dry shoot yields of rape grown were produced in the objects where vermicomposts and untreated tannery sludge were applied, implying that the two substrates have to be mixed to improve growth of the crop. An apparent increase in winter rape root dry mass yield (as compared to yields from mineral treatment and farmyard manure) was found as the consecutive effect of untreated tannery sludge and vermicompost. A study by Edwards (1995) revealed that earthworm cast increases plant dry biomass. This correlates to results observed where increase vermicompost was directly proportional to biomass assimilated. However, in this case, nutrient assimilation is increasing at a decreasing rate at higher vermicompost proportions as shown by the decline in dry weight in treatments $V_{75\%}$ and $V_{100\%}$. Above 50% concentration of vermicompost. Karmegam and Daniel (2010) observed a decrease in effect on most of the parameters. For instance, whole plant fresh weight, stem thickness and plant height decreased at high levels of vermicompost confirming its deleterious effects on crop grown in large quantities. Singh et al. (2010) reported similar findings in tomato and lettuce where specific leaf weight showed decreasing pattern by increasing the amounts of vermicompost. Shoot dry weight decreased at an increasing rate of vermicompost with the biggest value attained at $V_{50\%}$ subsequently decreasing to $V_{75\%}$ and $V_{100\%}$.

Borji et al., (2014) also showed that treatment with 50% vermicompost and 75% vermicompost had the greatest impact on plant stem diameter compared with other treatments. $V_{50\%}$ and $V_{75\%}$ are statistically in same level as in the case of $V_{9\%}$ and $V_{100\%}$, revealing the significance of using vermicompost to ameliorate soil media. Vijayakumari and Hiranmai (2012) divulges that vermicompost in the form of poultry manure has an edge over the control which used inorganic fertilisers because application of organic manures might have supplied N, P and K nutrients through-out the crop growth period as slow released nutrients. Nethra et al. (1999) observed that the maximum plant height and number of leaves of China aster (Callistephus chinensis) were high after application of 10 t/ha vermicompost. This is attributed to better growth of plants and higher yield by slow release of nutrients for absorption with additional growth promoters like gibberellin, cytokinin and auxins, when using organic inputs like vermicompost. This is also representative of what is in the results as the maximum leaf number and height is directly proportional to increase in vermicompost concentration.

CONCLUSION

The enhanced plant growth may be attributed to various direct and indirect mechanisms, including biologically mediated mechanisms such as the supply of plant-growth regulating substances, and improvements in soil biological functions. Stimulation of plant growth may depend mainly on the biological characteristics of vermicompost, the plant species used and the cultivation conditions. With reference to results obtained, it seems that the application of vermicompost at suitable quantities is beneficial and advantageous for plant growth and development. The integration of vlei soil and vermicompost at optimum levels resulted in the formation of substrate that enhances growth and development of nursery plants. Vermicompost is part of the answer to promote plant growth and development probably via the modified nutrition and metabolism and reduced time to transfer seedlings from nursery to field. Smallholder farmers can therefore integrate vermicompost and vlei soil at the level of 50% as the most effective treatment to improve growth and development of seedlings higher high levels may have adverse effects.

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