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Use of Vermicompost as Supplement to Pine Bark for Seedling Production in Nurseries

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Abstract Vermicompost, used as soil additives or as components of greenhouse bedding plant container media, have been found to improve seed germination, enhanced seedling growth and development, and increased overall plant productivity. As a result, small scale farmers can improve their capacity to produce vegetable seedlings using vermicompost amended potting mixes as it is more available to them than pine bark. The present experiment was undertaken to evaluate the possible effects of different substitutions of vermicompost potting mixes for seedling nursery production as an alternative and supplement to pine bark. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Cabbage (*Brassica oleracea* var. capitata) seeds were planted in six treatment groups including vermicompost of 20%, vermicompost of 50%, vermicompost of 75% and vermicompost of 100%. Pine bark, sand and vlei soils were incorporated into the experiment making up the different supplements. Results revealed that the tallest plants were recorded from pine bark amended mixtures with vermicompost substitution of 20% and 50%. Fresh weight of roots of plants from 100% vermicompost media revealed nonsignificant (P>0.05) difference when compared to treatment with 100% pine bark. However, the same treatment of 100% pine bark gave a significantly (P<0.05) lower fresh weight of leaves in comparison to 100% vermicompost. Seedlings from 100% vermicompost treatment had the highest stem thickness. There were no significant differences for the planting media treatments applied with respect to dry weight of both the leaves and roots. A ratio of 1:1 vermicompost and pine bark gave the best results. These finding indicate that vermicompost at suitable levels may promote plant growth and development probably via the modified nutrition. Instead of using vermicompost alone, its use in mixtures with pine bark, or vlei or sand may give the same effect.

Keywords: *cabbage (Brassica oleracea var. capitata), vermicompost, pine bark, vlei, sand, growth*

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1. Introduction

Planting medium is a source of nutrient for plant growth. Media composition used influences the quality of a seedling. Generally, media for vegetable crop seedlings are composted of soil, organic matter, and sand. The soil is usually used as a basic medium because it is cheapest and easy to get. Sand improves the porosity of the media while while the organic matter provides nutrients for the seedling. There is better relationship between well prepared artificial media and rooting compared to conventional soil mix that often predispose the seedling to soil borne pests and diseases.

To a large extent, nurseries in Zimbabwe use pine bark as their main media. Pine bark has good aeration for gaseous exchange, good moisture retention capacity, free from disease but poor in nutrients to support growth. The Horticulture Research Council Zimbabwe (HRC) mixes 4 parts pine bark, 2 parts compost and 2 parts top soil. The ideal growing media usually contain 50% black (loamy) or top soil and 50% sand by volume [37].

Vermicomposts, used as soil additives, or as components of greenhouse bedding plant container media, have improved seed germination, enhanced seedling growth and development, and increased overall plant productivity [9]. The greatest plant growth responses, and largest yields, usually occurs when vermicomposts are constituted 20–40% of the total volume of a medium mixture, but larger proportions of vermicomposts do not always improve plant growth [9].

Vermicompost is homogenous, retains most of the original nutrients and has reduced levels of organic contaminants with respect to the starting material because they are degraded [25]. Vermicompost can be applied to the soil media to increase organic matter and nutrient content, improve soil structure; and increase cation exchange capacity. However, thermophilic composting is generally a more time-consuming process requiring frequent mixing with possible losses of nutrients like NH_3. Certain species of earthworms fragment organic material residuals rapidly into much finer particles by passing them through a grinding gizzard [24].

Different processes involved in the production of compost and vermicompost is the foundation of the different physical and chemical characteristics that affect nursery media properties and plant growth in diverse ways. Vermicomposting generally converts organic matter to a more uniform size, which gives the final substrate a characteristic earthy appearance. Usually, the material resulting from composting has a more heterogeneous appearance [24,35].

High levels of vermicompost substitutions may adversely affect plant growth, development and yield, especially at germination and seedling stages [5,17]. Vermicompost must be used cautiously for the agricultural and horticultural activities [17]. Desirable and economical growth inducing concentrations of vermicompost for reducing costs of agriculture is therefore absolutely critical [20].

Nursery vermicompost can be produced using animal manure as a substrate [11]. Atiyeh et al., [8] assessed growth of tomato plants in three kinds of horticultural potting media mixed with various concentrations of vermicomposted pig manure. Substitution rates of 10, 25, and 50% vermicompost into a horticultural commercial medium (Metro-Mix 360, Sun Gro Horticulture Vancouver,) and cultivation in 100% vermicompost increased plant growth, shoot and root lengths, and shoot biomass [14]. Substituting 10% and 20% vermicompost into peat-perlite or coir-perlite mixtures also improved plant growth significantly compared to non amended medium [14].

The intent of this study was to investigate the effectiveness of vermicompost amended potting mixes on nursery production using *Brassica oleracea* var capitata as a test crop.

2. Materials and Methods

Site description and Experimental design: The experiment was conducted at Africa University Farm located at 18°53'70.3" South and 32°36'27.9" East and at an altitude of 1131m. The experiment was setup on the 2nd of February 2015 and the cabbage variety used was STAR3301 from Starke Ayres. The duration of the seedling stage was up to 5 weeks according to Starke Ayres vegetable production guide. The investigation included 6 treatments with 3 replications in speedling trays. The growing media was substituted with corresponding treatment. The study was conducted in a Randomized Complete Block Design (RCBD).

Vermicompost was used at five different substitution levels (0, 20%, 50%, 75% and 100%). The different application rates for each of the six treatments were made by mixing the different substitution levels of vermicompost with the required amount of top soil and pine bark for the growing media.

The characteristics of the soil and vermicompost media are shown below.

					MELICH 3 EXTRACTION		
Samples	pH	Texture	Min. Initial N (ppm)	P_2O_5 (ppm)	Exchangeable Cations (meq.%)		
					K	Mg	Ca
SAND	5.9	Sandy	9.79	9.67	0.38	1.30	2.49
VLEI	5.7	Sandy	64.2	0.25	0.07	0.20	0.58
PINE BARK	5.9	OM	134.0	39.1	0.59	2.89	6.38
VERMICOMPOST	7.4	-	15.7	240.6	0.23	-	-

Plants were watered as necessary to keep them moist throughout the course of the experiment. Fungicides, Copper Oxychloride (30g) and Dithane M45 (45g) were mixed in 2 liters of water and administered once within the first week of the seedlings emergence to prevent damping off. Fertigation regime comprising of AN (40g), Potassium (40g), DSP (32g) mixed in 15 liters of water was applied twice every week for the duration of the experiment. Treatments as percentage of the total potting media were as shown below.

1). ***Trt 1***: 40%PB : 40%VC : 20%S
2). ***Trt 2***: 50%PB : 50%VC
3). ***Trt 3***: 40%PB : 40%VC : 20%V
4). ***Trt 4***: 75%VC : 25%S
5). ***Trt 5***: VC (100%)
6). ***Trt 6***: P (100%)

Where:

V = vlei; PB = Pine Bark; VC = Vermicompost; S = Sand

Data collection: Data recorded include Plant height; Whole plant fresh weight; Dry weight of leaves; Dry weight of roots; Fresh weight of leaves; Fresh weight of roots; Root length; Stem length and Stem thickness. Data collection was done seven weeks after emergence. Dry weight was obtained by drying the plant material in an oven dryer at 50ºC and weighed on a sensitive balance. All weights were measured using a sensitive balance while plant height was measured using a ruler. Vernier Calipers was used to measure stem thickness.

Data Analysis: The analysis of variance (ANOVA) was done according to Gomez (1976) and means separated using the least significant difference (LSD) at P=0.05.

3. Results

Plant height: The influence of planting media was significant ($P<0.05$) on the plant height (Figure 1). The tallest plants were recorded from treatments Trt2 and Trt3 (6.37 cm and 6.78 cm respectively) while the shortest plants (5.46cm) were from Trt4. Plant height from treatments with 100% vermicompost (Trt5) and 100% pine bark (Trt6) was amongst the shortest plants recorded and were not statistically different from each other. Mean plant height was 5.97cm.

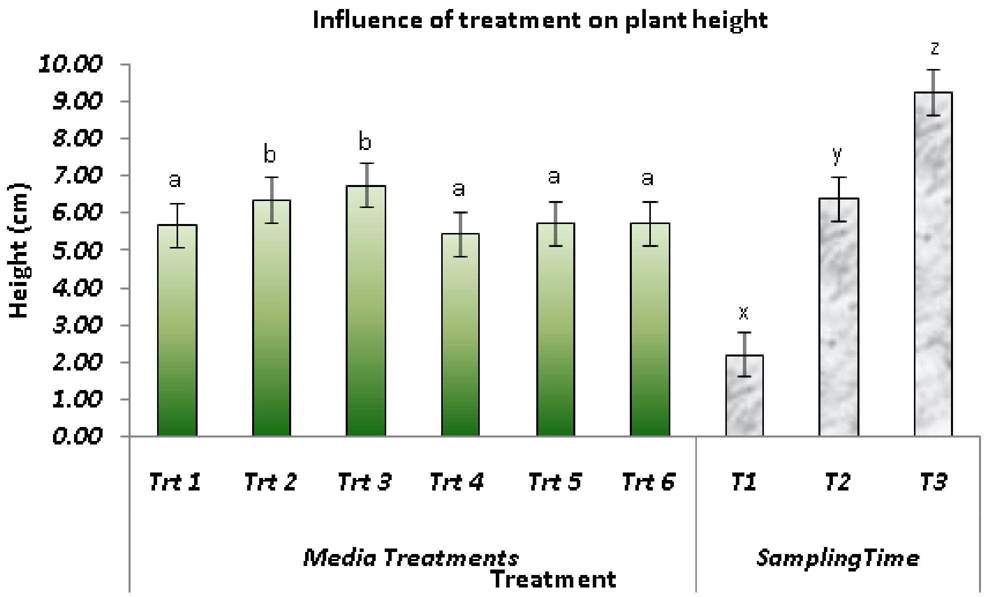

Figure 1. Shows the means of the effect of treatment and days on plant height

Effect of sampling time on plant height revealed significant differences (P<0.05). As time progressed from T1 to T3, plant height increased by more than 300%. Furthermore, significant interaction was recorded indicating that media influenced plant height differently depending on sampling time.

Table 1. Shows the means of characteristics as affected by media treatment

Treatments	Stem		Root			Leaves		Whole plant fresh weight
	Length	*Thickness*	*Length*	*Fresh weight*	*Dry weight*	*Fresh weight*	*Dry weight*	
Media^{M}								
Trt *1*	10.37^{ab}	2.90^{a}	12.33^{c}	0.22	0.05	1.74^{a}	0.18	1.94^{a}
Trt *2*	11.40^{bc}	3.07^{a}	11.07^{b}	0.20	0.05	2.41^{c}	0.25	2.61^{c}
Trt *3*	10.57^{bc}	3.03^{a}	9.60^{a}	0.23	0.06	2.24^{bc}	0.22	2.47^{bc}
Trt 4	10.80^{bc}	3.03^{a}	11.10^{b}	0.22	0.05	1.98^{ab}	0.19	2.20^{ab}
Trt *5*	11.53^{c}	3.47^{b}	9.47^{a}	0.21	0.06	2.38^{c}	0.25	2.59^{c}
Trt *6*	9.43^{a}	2.83^{a}	11.03^{b}	0.21	0.05	2.03^{b}	0.22	2.24^{ab}
Mean	*10.68*	*3.06*	*10.77*	*0.21*	*0.05*	*2.13*	*0.22*	*2.34*
Significance	*	*	*	ns	ns	*	ns	*
LSD	1.134	0.354	1.006	0.024	0.019	0.269	0.076	0.340
CV	5.8	6.4	5.1	6.1	19.7	6.9	19.1	8.0

*denotes significance at P<0.05. **ns** denotes non-significance.

Stem length: Data regarding influence of media treatment on stem length is shown in Table 1. Media treatments revealed significance difference (P<0.05) with Trt6 having the lowest stem length (9.43cm). Results also show that media supplemented with vermicompost performed better than pine bark alone. Treatment with 100% vermicompost (Trt5) had the highest stem length (11.53cm) while the treatment without vermicompost supplement (Trt6) had a stem length below the mean by 1.25 cm (11.70%). Mean stem length was 10.68 cm.

Stem thickness: Data regarding stem thickness showed significant (P<0.05) difference for the media treatments (Table 1). Treatment with 100% vermicompost had the highest stem thickness of 3.47 mm of all the treatment amendments investigated. Stem thickness for Trt1 and Trt6 were smaller than the mean thickness by 0.16mm and 0.23mm respectively. The mean stem thickness was 3.06 mm.

Root length: As indicated in Table 1, there was significant difference (P<0.05) for the media treatment with regard to root length. Trt3 and Trt5 had significantly the lowest root lengths (9.60cm and 9.47cm respectively) and both treatments recorded a root length which was 10.86% and 12.07% below the mean respectively. Trt1 significantly had the longest roots (12.33cm) compared to all the media treatments investigated. The mean root length was 10.77 cm.

Dry weight of roots: The comparison of the treatment means regarding root dry weight was nonsignificant (P>0.05) at all levels of vermicompost amendments (Table 1). Regarding root dry weight, 100% pine bark and 100% vermicompost did not give any significant statistical differences. Trt3 and Trt5 recorded figures above the mean though not significant statistically. Mean root dry weight was 0.05g.

Dry weight of leaves: There were no significant (P>0.05) differences for planting media treatments applied with respect to dry weight of the leaves (Table 1). The dry weight of leaves for Trt1 and Trt4 was below the mean although not statistically different. Trt2 and Trt5 recorded the highest figures (0.25g for both treatments) for dry weight of leaves although no statistical difference was shown. Mean dry weight of leaves was 0.22g.

Whole plant fresh weight: Data pertaining to whole plant fresh weight revealed that there was significant ($P<0.05$) differences among the means for the treatments investigated (Table 1). Trt1 recorded the lowest figure (1.94g) while the highest figure (2.61g) was recorded for Trt2. Comparison of 100% vermicompost to 100% pine bark revealed that the whole plant fresh weight from vermicompost treatment (Trt5) was significantly higher by 15.63% than the pine bark treatment (Trt6). Mean whole plant fresh weight was 2.34g.

Fresh weight of roots: The comparison of the treatment means revealed nonsignificant ($P>0.05$) difference on fresh weight of roots (Table 1). These results show that when vermicompost was amended into other growth media there was no positive influence on fresh weight of the roots. Treatment with 100% vermicompost compared to treatment with 100% pine bark also revealed a nonsignificant difference on fresh weight of the roots.

Fresh weight of leaves: There was significant influence of vermicompost supplements to other growth media (Table 1). The lowest fresh weight (1.74g) was recorded from Trt1. Treatment with 100% pine bark gave a significantly lower fresh weight of leaves by 14.71% in comparison to 100% vermicompost. Also, the fresh weight of leaves from a treatment of 100% pine bark was below the treatment average by 4.70%. The average fresh weight of leaves was 2.13g.

4. Discussion

Applied vermicompost affected root length, plant height, stem thickness and fresh weights suggesting a positive influence of the vermicompost to growth and development. Amendments of the growth media with vermicompost had an influence on the nutritional aspect of the media. More nutrients could have been added to the media such that the plants had more uptake of the growth nutrients such as nitrogen. Pour et al., [27] attributed the physiological changes observed in vermicompost treated plants to the humic substances and nutrients. Dominguez et al., [12]; Atiyeh et al., [7] and Sahni et al., [32] also confirmed that vermicompost contains considerable amounts of humic substances and had improving effects on the plant nutrition Vermicompost utilization is also known to induce various physiological changes.

Root length was not strongly significant different with vermicompost amendments. This is in contrast to Alvarez and Grigera, [2] who eluded that vermicompost represented hormone-like activity and increased root growth, thereby, enhancing nutrient uptake as well as plant growth and development. Atiyeh et al., [6] showed that the contributions of vermicomposts, when incorporated into soilless greenhouse container media and supplied with all needed nutrients, consistently exceeded the potential that vermicomposts may have to improve nutrient availability in the container medium and improve physical conditions of the container medium that favor root growth. Furthermore, the root to shoot ratios of seedlings increased significantly with increasing concentrations of humic acids in the soilless container medium, indicating greater resource allocation towards the roots. Paszt et al., [26] observed that the organic fertilizers induced a considerable branching of the root system, as derived from the high total root length and number of tips. Similar results with application of vermicompost having favorable effects on the growth, development and physiology on *Lilium asiatic* hybrid var. *Navona* were obtained by Ladan Moghadam et al., [20]. Srivastava et al., [34] reiterated that the physical and biological properties may be modified in the vermicompost amended soils. The vermicompost enhances plant growth because it modifies physiochemical and microbiological characteristics of the soil, increasing availability of macro and micro nutrient elements [4].

When vermicompost is applied at higher concentrations (beyond optimum) it reduces the growth and development of plants [16]. The vermicompost amended into the growth media improved the fresh weight of the leaves and the whole plant fresh weight. . Treatments with vermicompost had improved performance compared to pine bark alone for fresh weight probably because vermicompost contains most nutrients in plant available forms such as nitrates, phosphates, exchangeable calcium and soluble potassium. The large particle surface area provides many microsites for microbial activity and for the strong retention of nutrients for plant growth. Possibly the rhizobacteria and other plant growth influencing materials like auxins, cytokinins, and humic substances produced by microorganisms in the vermicompost had a positive influence on fresh weigh of the seedlings [1,33].

Stem thickness from 100% vermicompost was very significant different from the rest of the amendment treatments and pine bark. The significantly improved growth could be due to the slowly and steadily released nutrients by vermicompost into the rhizosphere thus providing the suitable conditions for plant nutrient uptake leading to better stem thickening [3]. Low nitrogen supply adversely affect plant photosynthetic processes thereby reducing plant development and growth [23] as observed in Trt3.

The composted materials could have had an impact on soil biological properties, such as increased microbial biomass and activity [19], as well as changes in the activity of soil enzymes [13,30] and in the structure of the soil microbial community [30] all combined to improving stem thickness.

Despite a significant result observed on fresh weight of the leaves from vermicompost supplemented treatments, the vermicompost did not positively influence the fresh weight of the roots and subsequently the dry weights of both aboveground and belowground structures. This contradicts Khan and Ishaq [18] who provided evidence that vermicompost increases the root length and dry and fresh root weight of pea. Gutierrez-Miceli et al. [15] also reported an increase in the dry root weight of maize and Reddy and Ohkura, [31] reported increased root biomass of sorghum (*Sorghum bicolor*). However, Mugwendere et al., [23] observed a low fresh weight from vermicompost amended treatments while working with rape (*Brassica napus*). They ascribed the results to low nitrogen supply which affected the net photosynthetic rate of all crop plants thereby a non significant increasing plant growth rate and dry matter yield. The adverse influence on the photosynthesis processes leading to reduced fresh yield mass as a result of the low nitrogen content could also be attributed to the wastes used to make the vermicompost, their processing time and maturity [10]. Roberts et al., [28] and Lazcano and Domínguez, [21] also reported that vermicomposts may decrease growth and even cause plant death in tomatoes and ornamental plants. McGinnis, [22] while working with verbena concluded that the top and root growth was not affected by increasing vermicompost rate. Rodda et al., [29], Roberts et al., [28]; Warman and AngLopez, [36] also noted similar variability in the effects of vermicompost and ascribed this to probably the cultivation system into which it was incorporated, as well as on the physical, chemical and biological characteristics of the vermicompost, which vary widely depending on the original feedstock and the earthworm species used.

5. Conclusion

This experiment, together with others reported in the literature; demonstrate that vermicomposts have considerable potential for improving plant growth significantly, when used as components of horticultural soil or container media. The success of vermicompost amendment could be as a result of nutrient nitrogen which positively influenced the net photosynthesis of the plants. The application of vermicompost at suitable levels may promote plant growth and development probably through the modified soil biological properties, such as increased microbial biomass and activity as well as changes in the activity of soil enzymes and in the structure of the soil microbial community all combined to improving development of the plant. Plant growth was increased by treatments of the growth media with supplements of vermicompost, but root growth was adversely influenced probably due to very high concentrations of humic acids from the vermicompost in the container medium. Accordingly, the use of vermicompost supplements alone in a small scale nutrient management plan adversely influenced plant growth, development and yield, especially at cabbage seedling stages as when compared to mixed treatments. Vermicompost must therefore be used cautiously for the agricultural and horticultural activities. Nursery growers can use vermicompost and pine bark in the ratio of 1:1 for the best results. Instead of using vermicompost alone, nursery growers can benefit from using the vermicompost mixed with vlei or sand soils as these gave the same effect as observed in most characteristics studied in this investigation.

Further work to investigate the amendment of vermicompost with other growth media at different ratios to determine how wide it can be applied in nurseries by smallholder producers cannot be over emphasized.

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