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Full Length Research

Vegetable Growth Medium Components: Effects of Dairy Manure-Waste Paper Vermicomposts on Physicochemical Properties, Nutrient Uptake and Growth of Tomato Seedlings

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A glasshouse experiment was carried out to determine the effects of amending a commercial growth medium (pine bark compost) with dairy manure-paper vermicompost (at the rates of 0%, 20%, 40%, 60%, and 100% by volume) on the physicochemical properties of the medium and plant growth. The study was a 5 x 4 factorial experiment conducted in a randomized complete block design (RBD) with three replicates. Four fertilizer levels, 0, 2, 4, and 6 granules per cavity were used. Tomato (*Lycopersicon esculentum* Mill.) seeds were sown and the seedlings allowed to grow for 4 weeks. The percentage total porosity and percentage air space of pine bark compost decreased significantly following substitution with equivalent amounts of dairy manure-paper vermicomposts whereas their bulk density, particle density, container capacity, pH, electrical conductivity and available N and P levels increased. The highest biomass was obtained from pine bark composts substituted with 60% dairy manure-waste paper vermicomposts and fertilised with 6 granules of fertiliser per cavity. These results suggest that the best medium for planting tomatoes was the 60% vermicompost substitution into pine bark fertilised with 6 granules of fertiliser per cavity.

Keywords: Fertilizer; growth medium; physicochemical properties; pine bark compost; plant growth; vermicompost.

INTRODUCTION

Pine bark compost is the growth medium of choice in South Africa due to its availability, affordability, desired physical properties and good structure. It however has low water holding capacity and available water (Smith, 1985). Pine bark is acidic with a pH of between 4 and 4.3 (Germishuisen, 1988) and lacks sufficient available nutrients to supply plant needs (Roberts, 1987). Thus pine bark compost alone, is a poor growth medium. On the other hand vermicomposts enriched with phosphate rock (PR) have a high pH of 7.9 and more plant available nutrients (Mupondi, 2010) and can thus be used to raise the pH of pine bark compost growth medium and also its nutrient content.

Besides improving the pH of pine bark composts, PR enriched vermicomposts could also improve pine bark compost growth medium's bulk density, particle density and water holding capacity as these

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Table 1. Equations used to determine the physical properties of soilless container media (adapted from Inbar et al., 1993).

Bulk density (BD) (gcm^{-3}) = dry weight/volume
Particle density (PD) ($g\ cm^{-1}$) = 1/ [% organic matter/ (100 x 1.55) + % ash/ (100 x 2.65)][a]
Total porosity (% volume) = (1 - BD/PD) x 100
Water holding capacity (% volume) = [(wet weight- dry weight)/volume] x 100
Air space (% volume) = total porosity - water holding capacity

[a] 1.55 and 2.65 are the average particle densities of soil organic and mineral matter, respectively.

vermicoposts have low bulk densities and high water holding capacities. (Mupondi, 2010). Improving the bulk density of a growth medium could possibly lead to improved aeration. According to Ingram et al., (1993), roots growing in poorly aerated media are weaker, less succulent and more susceptible to micronutrient deficiencies and root rot pathogens such as *Pythium* and *Phytophtora* than those growing in well-aerated media.

The amount of available nutrients in pine bark growth medium is usually not sufficient to support vigorously growing seedlings for long (Mupondi et al., 2006) and this necessitates the use of fertilizer to raise bigger and healthier seedlings. Traditionally seedling producers in South Africa depend on water soluble fertilisers to supply seedlings with nutrients and these are added at each irrigation cycle. On the other hand there is slow release compound fertiliser called Horticote which can be used in place of water soluble fertilisers. Horticote contains nitrogen (N), phosphorus (P) and potassium (K) and has the following formulation: 7: 2: 1 (22) (N: P: K (total nutrient content). Being a slow release fertiliser it is expected to provide nutrients for longer to the growing seedlings and also reduce nutrient losses through leaching when watering is done.

The objectives of this study were to:

(1) Determine the effects of pine bark compost amendment with dairy manure-waste paper vermicomposts on the physical and chemical properties of the resultant growth medium and the growth of tomato seedlings, and;
(2) Determine the optimum rate of fertiliser application to use in raising seedlings in the amended pine bark composts.

MATERIALS AND METHODS

The growth media used in this study, consisted of a commercial pine bark compost obtained from Rances Timbers, Sutterheim, South Africa as a control and amendments of the pine bark compost with 20%, 40%, 60% and 100% (by volume) of phosphate - enriched dairy manure-waste paper vermicompost.

Analyses of physical and chemical properties of growth media

The physical properties of various vermicomposts were determined following the procedures described by Bragg and Chambers (1988) and Gabriels et al., (1993), with the equations shown in Table 1. From these measurements, the bulk density, particle density, porosity, and air and water capacities were calculated using the equations of Inbar et al. 1993; (Table 1).

Electrical conductivity (EC) and pH were determined potentiometrically in a 1:10 suspension of sample in distilled water. These suspensions were placed on a mechanical shaker at 230 rpm for 30 minutes prior to the measurements. Mineral nitrogen ((ammonium – N) NH_4^+-N and (nitrate – N) NO_3^--N) was extracted from fresh compost samples with a 0.5 **M** K_2SO_4 solution (Okalebo et al., 2002). The nitrate and ammonium concentrations were determined using a spectrophotometer after development of a yellow colour using 5% salicylic acid in concentrated sulphuric acid for nitrate-N and for ammonium-N a blue colour using salicylate-nitroprusside method (Okalebo et al., 2002). Available phosphorus (P) of organic wastes was estimated using the Bray 1 extractant (Okalebo et

Table 2. Physical Properties of growing media constituted by substituting pine bark compost with different proportions of dairy manure-waste paper vermicompost.

Proportions of pine bark compost and Vermicompost		Bulk density (gcm^{-3})	Particle density ($g\ cm^{-3}$)	Total porosity (%)	Water holding capacity (%)	Air space (%)
Pine bark (%)	Vermicompost (%)					
100	0	0.19 e	1.64 c	88 a	48 e	40 a
80	20	0.23 d	1.76 b	87 b	52 d	35 b
60	40	0.26 c	1.83 b	86 c	62 c	24 c
40	60	0.29b	1.94 a	85d	67 b	17 d
0	100	0.33 a	1.95 a	83 e	74 a	10 e

Means within the same column followed by the same letter are not significantly different at $P \leq 0.05$.

al., 2002). The amount of phosphorus extracted was determined by the molybdenum blue colorimetric method.

Seedling growth experiment

A 5 x 4 factorial experiment in a randomized complete block design (RBD) with three replicates was carried out in a glasshouse which had a controlled environment. Five levels of growth media, consisting of pine bark growth medium and amendments of pine bark growth medium with vermicomposts as follows 0% (control), 20, 40, 60 and 100% (by volume) were used. The test crop used was tomato (*Lycopersicon esculentum* Mill.). Polystyrene trays with 40 cavities per tray were filled with the appropriate medium as per treatment. Four fertilizer levels of 0, 2, 4 or 6 granules per cavity of Horticote (7:1:2 (22)) were applied to each growth medium before sowing. Two tomato seeds were then sown into each cavity. At the end of one week emergence counts were done and used for calculating the emergence percentages for the different growth media. After two weeks the plants were thinned to one plant per cavity. Plants were monitored regularly for deficiency symptoms as well as for possible disease and pest attack. The experiment was terminated after 4 weeks and plant height (distance from potting medium level to the top node) and stem girth were determined. Plants were removed from potting mixtures, separated into shoot and root portions and their fresh and dry weights determined. Dry weights were determined by oven drying samples at 60 ºC for 3 days (Atiyeh et al., 2001). The dried shoots were ground (< 1 mm) and analysed for tissue N, P and K by wet digestion using a mixture of concentrated sulphuric acid, selenium, salicylic acid and hydrogen peroxide as described by Okalebo et al., (2002).

DATA ANALYSIS

Plant height, stem girth, shoot and root dry weights as well as tissue N, P and K were statistically analyzed using the GENSTAT RELEASE 4.24 (Lawes Agricultural Trust, 2008) statistical package and means separation done using the least significant difference (LSD) method at 0.05 level of significance.

RESULTS

Physical properties of growing media

The physical properties of the different growth media are shown in Table 2. Dairy manure-waste paper vermicompost growth medium had a significantly higher bulk density and particle density than pine bark compost medium. Substitution of pine bark compost with dairy manure-waste paper vermicompost resulted in an increase in both bulk and particle densities of the resultant growth medium.

The percentage water holding capacity of dairy

Table 3. Chemical properties of a standard growth medium (Pine bark compost) substituted with different concentrations of dairy manure-waste paper vermicompost.

Proportions of pine bark compost and vermicompost		Nitrate (mg/kg)	Ammonium (mg/kg)	Bray 1 P (mg/kg)	pH	EC (dS/m)
Pine bark (%)	Vermicompost (%)					
100	0	46 e	11 d	39 e	4.32 e	6.9 e
80	20	77 d	16 c	93 d	4.71 d	27.8 d
60	40	105 c	26 b	123 c	5.19 c	40.9 c
40	60	163 b	28 b	139 b	6.17 b	80.9 b
0	100	198 a	32 a	152 a	7.59 a	129.5 a

Means within the same column followed by the same letter are not significantly different at $P \leq 0.05$.

manure-waste paper vermicompost (74%) was significantly greater than that of pine bark compost (48%) Table 2. The air filled porosity (10%) of dairy manure-waste paper vermicompost was significantly less than that of pine bark (40%). The percentages of total porosity of the potting mixtures, after the incorporation of 20% up to 60% vermicompost into pine bark compost medium, were reduced by 1.1% to 3.4% whilst air filled porosity was lowered by 12.5% to 57.5%.

Dairy manure-wasted paper vermicompost growth medium and all the resultant media from the substitution of dairy manure-waste paper vermicomposts into pine bark composts had significantly higher water holding capacities than pine bark compost growth medium (Table 2).

Effect of vermicompost on chemical properties of growth medium

The dairy manure-waste paper vermicompost had higher levels of the different chemical parameters analyzed than pine bark compost (Table 3). Substituting pine bark compost with increasing proportions of dairy manure-waste paper mixture vermicompost resulted in significant increases in nitrate and ammonium-nitrogen and Bray 1 phosphorus (P) concentrations in the resulting media (Table 3). The pH followed a similar trend. The pH of the constituted growth media became progressively less acidic with each increment of the vermicompost whose pH was alkaline (pH 7.59). Corresponding increases in the electrical conductivity were also observed.

Effects of vermicompost on seedling emergence

Neither media nor fertilizer levels had an effect on emergence germination for all the seedlings tested (Table 4). The mean tomato emergence percentages, in the five medium were 100% (pine bark compost) - 94.5%; 20% vermicompost - 95.3%; 40% vermicompost - 95.3%; 60% vermicompost - 94.5% and 100% vermicompost – 94%.

Effects of vermicompost and fertilizer application on tomato seedling growth and tissue nutrient content

Stem girth, plant height, shoot and root dry weights of tomato seedlings receiving no fertilizer and grown in 100% dairy manure-waste paper vermicompost were significantly higher than those of seedlings grown pine bark compost alone (Figure 1). Tomato seedling growing in unfertilized growth media showed visible nitrogen (N) and phosphorus (P) deficiency symptoms within a week after germination. Visual observations showed that addition of 2 granules of fertilizer helped alleviate N deficiency symptoms in all growth media but P deficiency symptoms persisted in the Pine bark (PB) compost growth medium. There was an interaction between growth medium type and fertilizer level on the stem girth, plant height, shoot and root dry weights of tomato seedlings. Increase in tomato stem girth, plant height, shoot and root dry weights with fertilizer addition was in the order; pine bark compost < 20% V< 100% V ≤ 40% V< 60% V at the highest fertilizer application rate of 6 granules per

Table 4. Effects of medium and fertilizer levels on tomato seedling emergence.

Fertilizer level (granules/cavity)	Growth medium				
	Control	20% V	40% V	60 %V	100% V
		Seedling emergence (%)			
0	94	96	97	96	95
2	96	93	96	95	94
4	93	95	95	94	93
6	95	96	93	93	96

C – Control 100% Pine bark compost; V – vermicompost.

cavity.

Tomato tissue nutrient content (N, P and K) was dependent on the type of growth medium and the amount of fertiliser applied per cavity (Figure 2). Combinations of dairy manure-waste paper vermicompost with Horticote fertilizer increased the efficiency of nitrogen, phosphorus and potassium uptake by the plants, as demonstrated by the greater concentrations of tissue N, P and K in tomato plants treated with fertilizer compared with the plants with no fertilizer, and consequently, greater seedling growth (Figure 2). The tissue N, P and K concentrations of tomato seedlings increased with increasing proportions of dairy manure-waste paper vermicompost in the potting mixtures (up to 60%) and increasing fertilizer application rate.

DISCUSSION

South African commercial producers of vegetable transplants consider an emergence percentage of 90% or more as satisfactory and values lower than 90% as low and not acceptable as cited by Mphaphuli et al. (2005). The growth media tested in this study provided optimal conditions since the percentage emergence for all media was greater that the critical level of 90%.

N and P deficiency symptoms were noticed in all unfertilized growth media and this suggested that the growth media used in this study were not able to supply tomato seedlings with sufficient amounts of nutrients. The decreases in plant growth, when the concentration of dairy manure-waste paper vermicompost in the substituted growth medium was increased could possibly be attributed poor aeration. A good growth medium should have air filled porosity (AFP) of between 10 and 20% (Bunt, 1988). The air filled porosity of the 100% vermicompost growth medium (10%) was at the lower end and that may have negatively affected root growth and proliferation and result in reduced plant growth. By contrast when AFP was optimal as was the case with the 20% to the 60% vermicompost substitutions, seedling growth increased progressively. Initially the pH of both pine bark compost (4.32) and dairy manure-waste paper vermicompost (7.59) were both outside the optimum range of between 5.0 and 6.5 (Goh and Haynes, 1977). Upon incorporation of dairy manure-waste paper vermicomposts into pine bark compost the pH of the resultant growth media increased progressively with increasing substitution of vermicompost. This improvement in pH from 4.32 to 6.17 could have improved plant growth by its direct effect on nutrient availability. At high pHs, the availability of all nutrients except for molybdenum is very low whilst at low pHs the availability of nitrogen, phosphorus, potassium and magnesium is low whilst levels of micronutrients can reach toxic levels (Havlin et al., 2005). Similar improvements in plant growth as a result of an improvement in substrate pH were reported by Atiyeh et al., (2001).

Without fertilizer application, there was an improvement in tomato dry matter with increasing proportions of dairy manure-waste paper vermicomposts up to 60%. This was probably due to the high nitrogen (N) content and phosphorus (P) content of the substituted substrates, compared to the pine bark compost growth medium. The dairy

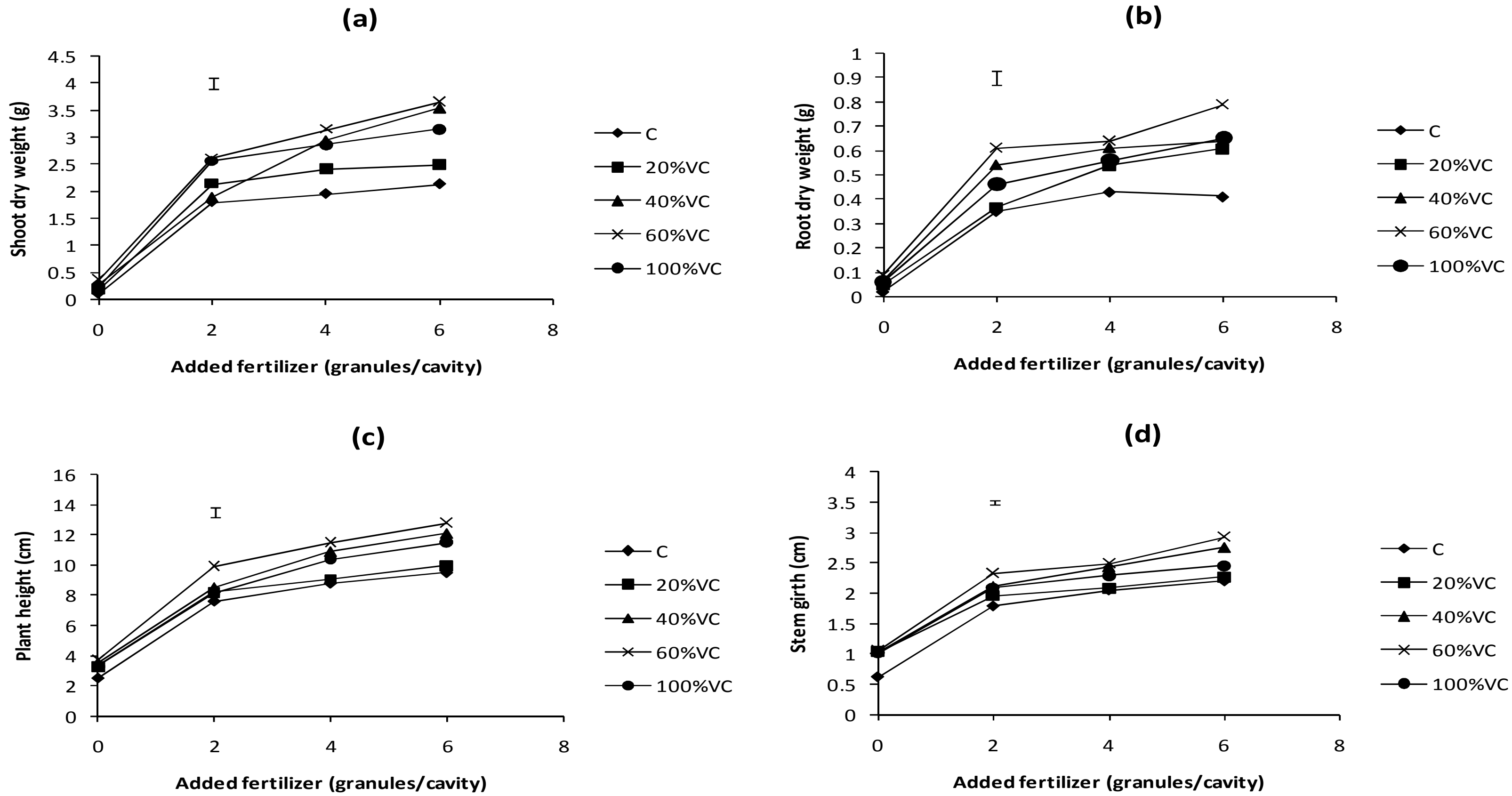

Figure 1. Effects of growth medium and fertilizer on (a) shoot dry weight, (b) root dry weight, (c) plant height and (d) stem girth. Error bars represent LSD ($p \leq 0.05$).

manure-waste paper vermicompost contained more nitrates and more available P, than pine bark compost. This was in agreement with results of Atiyeh et al., (2001) who reported increase in nutrient levels with increased substitution of vermicomposts into a peat based growth medium.

Fertilizer application improved the growth and nutrient uptake of tomato seedlings in all the growth media used in this study. This suggested that these growth media alone were not able to supply tomato seedlings with

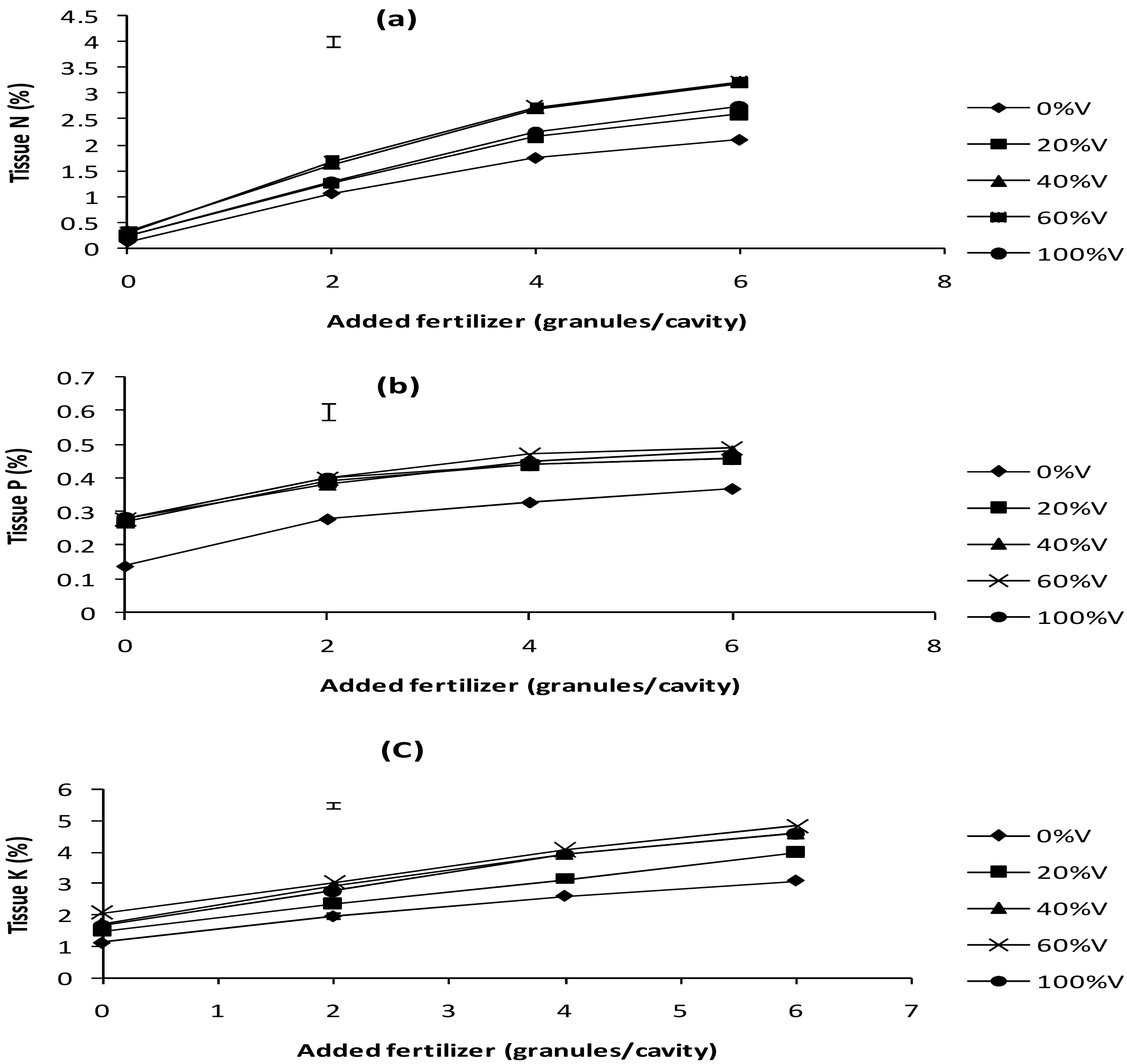

Figure 2. Effects of medium and fertilizer level on (a) N (b) P and (c) K tissue content in tomato tissue. Errors bars represent LSD ($p \leq 0.05$).

sufficient amounts of readily available nutrients and that the addition of Horticote fertilizer increased tomato seedling growth further. Similar results of increased seedling growth with fertilization of growing medium were reported by Atiyeh et al., (2001).

The growth of tomato seedlings treated with fertilizer was greatest in potting mixtures substituted with 60% dairy manure-waste paper vermicompost, probably as a result of combined improved physical conditions and nutritional factors of the growth medium. The highest application rate of 6 granules of fertilizer per cavity resulted in the greatest growth and nutrient uptake across all media.

Results of this study revealed that the best media for raising tomato seedling were the 40 to 60% vermicompost substituted pine bark media. This is similar to the studies reported by Atiyeh et al.

(2000), where the greatest plant growth responses and largest yields have usually occurred when vermicomposts constituted only a relatively small proportion (20 to 40%) of the total volume of a greenhouse container medium mixture, with greater proportions of vermicomposts substituted into the plant growth medium not always improving plant growth further.

CONCLUSION

Progressive substitution of pine bark compost with dairy manure-waste paper vermicompost increased the bulk density, particle density and water holding capacity whilst total porosity and air space of the pine bark compost were reduced. Significant increases in nitrate, ammonium, available phosphorus, pH and EC were also observed with increase in the proportion of the dairy manure vermicompost in the substituted growth medium.

Progressive substitution of pine bark with dairy manure-waste paper vermicomposts increased seedling growth up to 60% dairy manure-waste paper vermicompost substitution. The application of fertilizer to all the growing media greatly improved tomato plant growth as well as nutrient uptake. A 40 to 60% substitution of dairy manure-waste paper vermicompostinto pine bark compost produced the best growing media.

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