INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
16–0481/2017/19–5–1007–1011
DOI: 10.17957/IJAB/15.0375
http://www.fspublishers.org

***Full Length Article***

# Potential of Chicken Manure Vermicompost as a Substitute for Pine Bark Based Growing Media for Vegetables

**Hupenyu Allan Mupambwa*, Khanyisile Ncoyi and Pearson Nyari Stephano Mnkeni**
*Department of Agronomy, University of Fort Hare, Private Bag X1314, Alice, 5700, South Africa*
*For correspondence: hmupambwa@ufh.ac.za; hamupambwa@gmail.com

## Abstract

Due to the high ammonia concentration associated with chicken manure, there is limited research on how it could be incorporated in horticultural growing media. This study evaluated the influence of substituting pine bark compost (PB) with chicken manure vermicompost (CMV) at 0, 25, 50, 75 and 100%, on media properties and early tomato and cabbage seedling growth. Substitution of PB with CMV at between 25 and 50% resulted in the most appropriate media physical properties which also translated to seedling emergence above 90% for both vegetables. Seedling physical appearance, which is of economic importance was then measured as final leaf area and plant height of the seedlings. Similarly, media with a substitution of between 25 and 50% resulted in a leaf area that was 200% more compared to 100% PB and final plant height that was 100% more than PB alone. Though rich in essential nutrients, chicken manure vermicompost did not prove to be the most ideal medium and its incorporation should be limited to 50% for effective seedling emergence and early development of crops. © 2017 Friends Science Publishers

**Keywords:** Tomato seedling vigor; Growing media; Water holding capacity; Porosity

## Introduction

In recent years, there has been a growing realization on the potential of using earthworms to improve the fertilizer value of both organic and inorganic waste materials. Several researchers have reported the potential of using epigeic earthworm species like *Eisenia fetida*, *E. andrei*, *Lumbricus rubellus* and *Eudrilus eugeniae* among others, in improving the nutrient mineralization of waste materials compared to the traditional composting methods (Dominguez and Edwards, 2011; Mupambwa *et al*., 2015). The product of composting using these different earthworm species is a nutrient rich and stabilized vermicompost, which can act as a viable nutrient and plant growth hormone source. Due to their favourable characteristics, vermicomposts have being evaluated as either horticultural media or as components of other traditional media (Arancon *et al*., 2008).

In South Africa, the traditional horticultural planting medium was sphagnum peat moss mainly due to its positive properties (Mphaphuli *et al*., 2005). This traditional media is a finite resource hence its use is now limited with most horticulturists now using the readily available and infinite pine bark media produced from debarking of pine trees (Mupondi *et al*., 2010). However, though being abundantly available, pine bark has been reported to have poor chemical and physical properties (Mphaphuli *et al*., 2005; Mupambwa *et al*., 2017). As a way of improving these undesirable properties, pine bark media can be substituted at different levels with nutrient rich; physically improved organic materials like vermicomposts (Mphaphuli *et al*., 2005). This potential to improve the physio-chemical properties of planting media with other materials like vermicomposts has prompted several researchers to evaluate the influence of organic fertilizers on the physio-chemical properties of various commercial planting media (Atiyeh *et al*., 2000; Mupambwa *et al*., 2017). In a study, Atiyeh *et al*. (2000) using a commercial media substituted with 10–20% of vermicomposted pig solids or food wastes and a control of the media itself, with all treatments being irrigated with a nutrient solution, reported significantly enhanced seedling growth where the commercial media was substituted compared to the control. In another study, Mupondi *et al*. (2014) evaluated the emergence and growth of tomato seedlings in pine bark compost substituted with cow dung vermicompost reporting optimum results with 60% substitution.

One of the most widely used animal wastes is chicken manure, which is usually applied without any treatment due to its high nutrient contents (Arancon *et al*., 2012). There is limited information available on the vermicomposting of chicken manure, mainly due to the presence of high ammonia concentrations, high density, auto-heating capacity and soluble salts in the chicken manure (Khan, 2003). One way to reduce these effects would be to use bulking materials like waste paper to widen the C/N ratio and lower the ammonia concentrations during the

**To cite this paper:** Mupambwa, H.A., K. Ncoyi and P.N. S. Mnkeni, 2017. Potential of chicken manure vermicompost as a substitute for pine bark based growing media for vegetables. *Int. J. Agric. Biol.*, 19: 1007-1011

vermicomposting process. Due to complications involved in poultry manure vermicomposting, there is paucity of information on the potential of this vermicompost as a horticultural media especially as a component of nutrient deficit media like pine bark. The objective of this study was to determine the influence of substituting pine bark with optimized chicken manure vermicompost on the resultant media physio-chemical properties and growth of cabbage and tomato seedlings.

## Materials and Methods

### Planting Media Sources

Pine bark used was sourced commercially as described by Mupambwa *et al*. (2017), whilst the chicken vermicompost was obtained from vermicomposting research unit at University of Fort Hare (Alice campus), South Africa. Briefly, chicken manure vermicompost was obtained by mixing chicken manure with paper waste at an optimized C/N ratio of 40, and then vermicomposted using *Eisenia fetida* earthworms as described in detail by Ravindran and Mnkeni (2016).

### Treatments and Experimental Design

The experiment was carried out in a glasshouse with temperature and humidity controls located at University of Fort Hare (Alice Campus). Commercial pine bark media was substituted with mature chicken manure vermicompost at different levels (v/v basis) to give five different media i.e. 0, 25, 50, 75 and 100%, which constituted the treatments in this study. The experiment was laid in a completely randomised design replicated three times. These media combinations were then evaluated for different physical properties, pH and electrical conductivity as outlined below.

### Analysis of Physical Properties of the Growing Media

**Physical properties:** Physical parameters of chicken manure vermicompost-pine bark growing media were analysed as outlined by Atiyeh *et al*. (2001). The following physical properties were determined i.e., bulk density, particle density, total porosity, water holding capacity and air filled capacity, based on equations outlined by Mupambwa *et al*. (2017).

**Electrical conductivity (EC) and pH:** Electrical conductivity and pH were measured potentiometrically in deionized water at a ratio of 1:10 (w/v) (Ndegwa and Thompson, 2001).

### Vegetable Seedling Emergence and Growth

Each treatment combination of PB and VC was filled into polystyrene trays with 20 planting wells each. Cababage and tomato seeds were planted seperately and replicated, giving 15 trays for cabbage and also for tomatoes. The 30 trays were placed in a glasshouse on two separate tables in a random order and irrigated with water on a daily basis. Emergence percentage was recorded as number of emerged seeds on the 20 cavities of seedling trays after one week. Since two seeds had been planted in each cavity, thinning was done to leave one seedling in each cavity after two weeks from planting. Watering was done with tap water as and when needed. Four weeks after emergence, 5 plants from each treatment were randomly selected and growth was measured as plant height (distance from the growing medium level to the top leaf of the plant) and also leaf area per plant.

### Statistical Analysis

A one-way analysis of variance (ANOVA) for a completely randomized design was done using JMP version 12.0.1 statistical software (SAS Institute, Inc., Cary, North Carolina, USA, 2010). Mean separations were done using the least significant differences (LSD) at $p \leq 0.05$ test when ANOVA indicated a significant *p*-value.

## Results

### Effects of Chicken Manure Vermicompost Substitution on Pine Bark of Media Properties

Except for total porosity, substitution of pine bark with chicken manure vermicompost resulted in significant ($P < 0.05$) changes in all physico-chemical parameters (Table 1). It was interesting to observe that, substitution of pine bark with 25, 50 and 75% CMV significantly increased the media water holding capacity by 16.5; 18.9 and 24.6%, respectively. A similar but contrasting trend was also observed on the air space where substitution with chicken manure vermicompost significantly decreased the air space. The pH of the 100% pine bark treatment was highly acidic (3.69) whilst that of 100% CMV was alkaline. Pine bark showed very limited buffering capacity and substitution of PB with CMV significantly neutralised acidity to an average pH of 6.32. Similarly, electrical conductivity (EC) of media significantly ($P < 0.05$) increased when CMV was added at 25, 50 and 75% resulting in a 4.19; 7.02 and 9.5 times difference in EC, respectively compared to 100% PB.

### Effects of Substituting Pine Bark Compost with Chicken Manure Vermicompost on Early Seedling Development

Two test crops popularly grown in South Africa were used i.e. tomato and cabbage. There were no significant ($P > 0.05$) differences observed on emergence percentages for tomato seedlings across all treatments including 100% PB (Fig. 1). Though not significantly different, the 100% PB

**Table 1:** Effects of substituting pine bark compost with chicken manure vermicompost on selected physical properties, media pH and electrical conductivity

| Plant media mixtures | Bulk Density | Particle Density | Total porosity | Water holding capacity | Air Space | pH | Electrical conductivity |
|---|---|---|---|---|---|---|---|
| | g $cm^{-3}$ | | | % | | | mS $cm^{-1}$ |
| 100% PB* | 0.358b | 1.65e | 78.33a | 44.90d | 33.48a | 3.69e | 0.52e |
| 75%PB:25%CMV | 0.378ab | 1.74d | 78.28a | 52.30b | 26.00c | 5.82d | 2.18d |
| 50%PB:50%CMV | 0.385ab | 1.83c | 78.95a | 53.40c | 25.55b | 6.23c | 3.65c |
| 25%PB:75%CMV | 0.389a | 1.89b | 79.40a | 55.95b | 23.45bc | 6.90b | 4.94b |
| 100% CMV | 0.397a | 1.95a | 79.70a | 58.66a | 21.05c | 8.35a | 5.87a |
| Coefficient of variation (%) | 3.86 | 1.14 | 0.98 | 1.09 | 5.17 | 1.41 | 8.04 |

*PB – Pine bark; CMV – chicken manure vermicompost

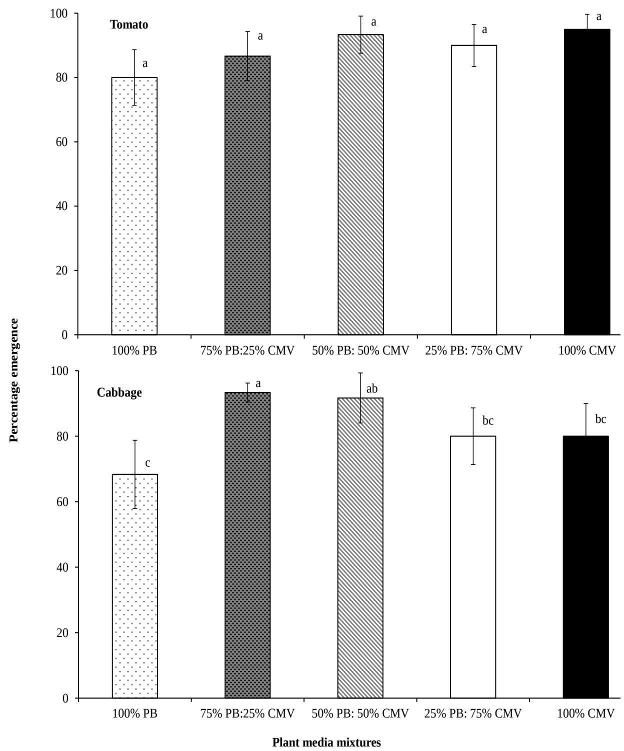


**Fig. 1:** Emergence percentage of tomato and cabbage seedlings after 7 days of planting in pine bark media substituted with different levels of chicken manure vermicompost. Error bars represend standard deviation (*n* = 3). PB – Pine bark; CMV – chicken manure vermicompost

showed the lowest emergence for tomato of 80% with the other treatments showing an average 14% higher emergence compared to 100% PB. Unlike for tomato emergence, there was a significantly different ($P < 0.05$) percentage emergence for cabbage seedlings across the treatments, as shown in Fig. 1. The medium with 25% CMV showed the highest emergence percentage for cabbage of 93.3%, followed by 50% CMV substituted media. Relative to 100% PB, which had an emergence percentage of 68.3%; the substitution of pine bark with 25, 50 and 75% CMV resulted in 36.6, 34.1 and 17.1%, respectively more emergence. Across the two crops, the treatment that recorded the highest emergence percentage was 50% CMV substituted treatment with an average of 92% emergence, whilst 100% PB treatment showed the lowest emergence percentage of 74%.

One of the most appealing characteristic of seedlings for enhanced marketability is its physical appearance and in this study, this was determined as plant height and leaf area of the seedlings. It was important to note that across the two vegetables, there was a significant difference ($P < 0.05$) between treatments, with 100% CMV and 100% PB showing the lowest plant heights (Fig. 2). For the tomato seedlings, treatment with 25% CMV contributed to highest plant height which was 86.0 and 70.1% more than 100% PB and 100% CMV, respectively. The effect was more pronounced for cabbage plant height, where the treatment with 50% CMV substitution had the highest plant height relative to 100% PB. Compared to 50% CMV substituted treatment, 100% PB treatment had a plant height that was 236.3% less, whilst that of 100% CMV was 56.7% less (Fig. 2). Across all treatments and crops, substitution of pine bark with chicken manure vermicompost from 25 to 75% resulted in an average 104.3 and 50.8%, respectively increase in seedling plant height after four weeks compared to 100% PB and 100% CMV treatments.

There was no significant difference in plant height between 100% PB and 100% CMV treatments in tomato (Fig. 3). However, treatments with different levels of chicken manure vermicompost substitution showed a significant ($P < 0.05$) difference from 100% PB treatment. Final leaf area of tomato seedlings followed the order 25% CMV > 75% CMV > 50% CMV > 100% PB > 100 CMV. The vermicompost treatment (25%) had a leaf area which was 243.7% and 309.7% more than that of 100% PB and 100% CMV treatments, respectively. The cabbage seedlings in 100% PB treatment could not survive for the entire four weeks period hence there was no leaf area to measure (Fig. 3). Similar to tomato seedlings, 25% CMV treatment showed the highest leaf area, though it was not significantly different from that of 50 and 75% CMV treatments. Relative to 100% CMV treatments, the 25, 50 and 75% vermicompost treatments resulted in 207.1, 191.5 and 168.3%, respectively more leaf area.

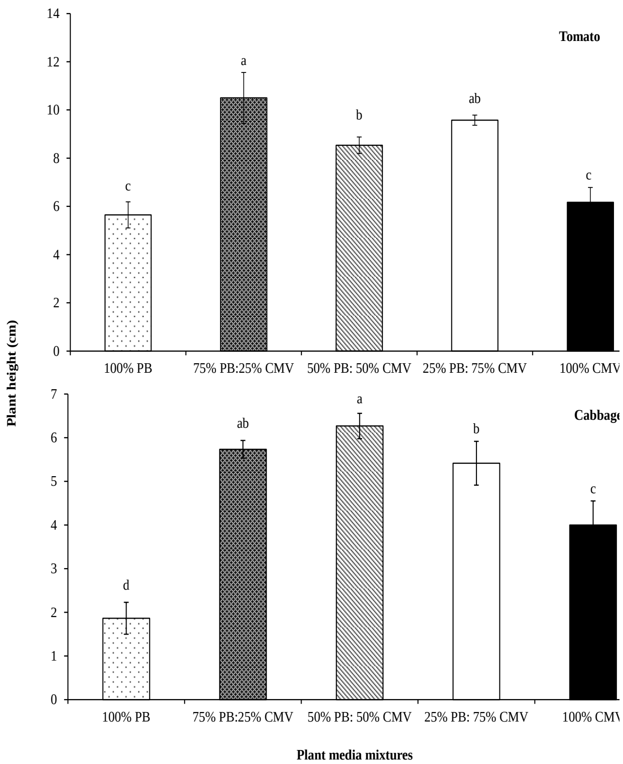


**Fig. 2:** Plant height of tomato and cabbage seedlings after 4 weeks after emergence in pine bark media substituted with different levels of chicken manure vermicompost. Error bars represend standard deviation ($n$ = 3). PB – Pine bark; CMV – chicken manure vermicompost

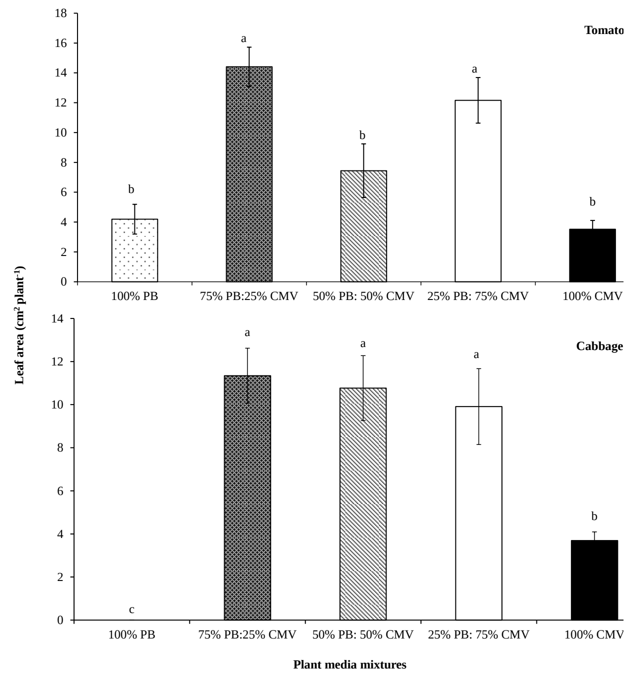


**Fig. 3:** Average leaf area per plant of tomato and cabbage seedlings grown in in pine bark media substituted with different levels of chicken manure vermicompost, 4 weeks after planting. Error bars represend standard deviation ($n$=3). PB – Pine bark; CMV – chicken manure vermicompost

## Discussion

There is limited research on the horticultural potential of chicken manure vermicompost that has been adjusted using carbonaceous materials like waste paper for effective earthworm activity. This study evaluated the influence of incorporating vermicomposted chicken manure into pine bark on early seedling development of tomato and cabbage. One of the main targets of horticulturalists is to get a media that is light weight, gives higher emergence and mature seedlings over the shortest period, which all translates into profit (Arancon *et al*., 2008). Also, a good horticultural medium should be able to adequately supply oxygen and water to plant roots as this will influence seed emergence and subsequent growth, these are mainly affected by media physical properties (Mupambwa *et al*., 2017).

In this study, substitution of pine bark with vermicompost greatly improved the media physical properties. A suitable media has been proposed to have the following optimum physical properties; a minimum of 85% porosity, water holding capacity between 55% and 75%, and air space between 20% and 30% (Atiyeh *et al*., 2001). It was interesting to note that in this study, 100% PB showed results of water holding capacity and air space that were outside the recommended range. The water holding capacity and air spaces are the main parameters that influence water and oxygen supply of media, which greatly affect seedling emergence. This could explain why 100% PB treatment recorded the lowest emergence amongst all the treatments and between the two crops. These results support the fact that addition of vermicomposts to traditional media like pine bark will significantly modify the physical properties creating more ideal conditions for effective emergence (Arancon *et al*., 2008; Mupambwa *et al*., 2017). According to Mupondi *et al*. (2014), an emergence percentage of 90% and above is considered adequate, and in this study, it was shown that this can be achieved by substituting PB with CMV at between 25 and 50%. From a chemistry perspective, addition of the alkaline vermicompost helped to neutralize the acidity of the pine bark, which will have the effect of improving nutrient supply for elements like phosphorus which are fixed at lower pH (Brady and Weil, 2008; Mupondi *et al*., 2014). It would be interesting to further evaluate the nutrient supply properties of substituted media during extended seedling growth.

Similar to emergence results, substitution of the pine bark with chicken manure vermicompost at between 25% and 50% also resulted in the best physically looking seedlings based on the leaf area and plant height. These results corroborate with the studies from several researchers that, though vermicomposts are rich in essential nutrients, for effective seedling growth, they need to be incorporated at levels around 50% (Arancon *et al*., 2008; Lazcano *et al*., 2009; Mupambwa *et al*., 2017). At this level of substitution, it is speculated that, apart from nutrient supply being adequate, there is a balance of humic acids, enzyme activity and the presence of beneficial micro-organisms which all encourage better seedling growth (Mupambwa *et al*., 2017). From an economic point of view, incorporation of chicken manure vermicompost has the potential of reducing the average time required for seedlings to reach the required physical appearance before being transplanted.

## Conclusion

This study clearly showed that pine bark alone is a very poor medium due to its inferior physical and chemical properties. For effective seedling emergence and growth, chicken manure vermicompost can be effective when used as a substitute for pine bark at levels between 25% and 50%. As this study was preliminary in nature, further studies may need to evaluate the potential of nutrient supply from substituted media during extended seedling growth to maturity. Also, the potential for further enhancing the media chemistry by using different fertilizer source may need to be evaluated.

## Acknowledgements

The authors would like to thank the famers in Nkonkobe local municipality, Alice, South Africa, for generously allowing us to collect chicken manure used for vermicomposting. The authors also acknowledge the Govan Mbeki Research and Development Centre at University of Fort Hare and the National Research Foundation (NRF) of South Africa through its incentive research funding to rated scientists, for funding this study.

## References

Arancon, N.Q., A. Pant, T. Radovich, N.V. Hue, J.K. Potter and C.E. Converse, 2012. Seed germination and seedling growth of tomato and lettuce as affected by vermicompost water extracts (teas). *Hort. Sci.,* 47: 1722–1728

Arancon, N.Q., C.A. Edwards, A. Babenko, J. Cannon, P. Galvis and J.D. Metzger, 2008. Influences of vermicomposts, produced by earthworms and microorganisms from cattle manure, food waste and paper waste, on the germination, growth and flowering of petunias in the greenhouse. *App. Soil Ecol.,* 39: 91–99

Atiyeh, R.M., C.A. Edwards, S. Subler and J.D. Metzger, 2001. Pig manure vermicompost as a component of a horticultural bedding plant medium: Effects on physicochemical properties and plant growth. *Bioresour. Technol*., 78: 11–20

Atiyeh, R.M., S. Subler, C.A. Edwards, G. Bachman, J.D. Metzger and W. Shuster, 2000. Effects of vermicomposts and composts on plant growth in horticultural container media and soil. *Pedobiologia,* 44: 579–590

Brady, N.C. and R. Weil, 2008. *The Nature and Properties of Soils,* 14th edition. Pearson Publishers, Hoboken, New Jersey, USA

Dominguez, J. and C.A. Edwards, 2011. Biology and ecology of earthworm species used for vermicomposting. *In*: *Vermiculture Technology: Earthworms*, *Organic Wastes and Environmental Management*, pp: 53–66. Edwards, C.A., N.Q. Arancon and R. Sherman (eds.). CRC Press Taylor and Francis Group, New York, USA

Khan, A.A., 2003. Vermicomposting of poultry litter using *Eisenia foetida*. *MSc thesis*. Faculty of the Graduate College of the Oklahoma State University, USA

Lazcano, C., J. Arnold, A. Tato, J.G. Zaller and J. Dominguez, 2009. Compost and vermicompost as nursery pot components: Effects on tomato plant growth and morphology. *Span. J. Agric. Res.,* 7: 944–951

Mphaphuli, N.S., W. Van Averbeke and R. Bohringer, 2005. Pine litter as substrate for propagation of vegetable transplants in trays. *S. Afr. J. Plant Soil,* 22: 223–228

Mupambwa, H.A., S.N. Lukashe and P.N.S. Mnkeni, 2017. Suitability of fly ash vermicompost as a component of pine bark growing media: Effects on media physicochemical properties and ornamental marigold (*Tagetes spp*.) growth and flowering. *Compost Sci. Util*., 25: 48–61

Mupambwa, H.A., E. Dube and P.N.S. Mnkeni, 2015. Fly ash vermicomposting to improve fertilizer value – A review. *S. Afr. J. Sci.,* 111: 1–6

Mupondi, L.T., P.N.S. Mnkeni and P. Muchaonyerwa, 2010. Effect of pine bark goat manure medium on seedling growth and N, P, K concentration of various vegetables. *S. Afr. J. Plant Soil,* 27: 305–311

Mupondi, L.T., P.N.S. Mnkeni and P. Muchaonyerwa, 2014. Vegetable growth medium components: effects of dairy manure-waste paper vermicomposts on physicochemical properties, nutrient uptake and growth of tomato seedlings. *ASJ Int. J. Agric. Sustain. Food Suff.,* 2: 23–31

Ndegwa, P.M. and S.A. Thompson, 2001. Integrating composting and vermicomposting in the treatment and bioconversion of biosolids. *Bioresour. Technol.,* 76: 107–112

Ravindran, B. and P.N.S. Mnkeni, 2016. Bio-optimization of the carbon-to-nitrogen ratio for efficient vermicomposting of chicken manure and waste paper using *Eisenia fetida. Environ. Sci. Pollut. Res*., 23: 16965–16976

**(Received 30 August 2016; Accepted 06 March 2017)**