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(RESEARCH ARTICLE)

Evaluation of vermicompost on development and yield of beetroot (*Beta vulgaris*)

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Abstract

A greenhouse experiment was conducted at Botswana University of Agriculture and Natural Resources for 10 weeks (19 March – 28 May 2019) under irrigated conditions. The objective of the experiment was to evaluate the effect of vermicompost on the growth and yield of beetroot (*Beta vulgaris*) under (i) four doses of vermicompost, (ii) three doses of mineral fertilizer, and (iii) ordinary soil (as control). A randomized complete design had polyethylene pots with 8 treatments, namely 4 doses (5, 10, 20 and 30 tonne/ha) of vermicompost, 3 doses (50, 100 and 200% of 50 kg bag/ha) of NPK (2:3:2) and ordinary soil (as control), of three replicates. Data on growth and yield parameters were analyzed using the Statistical Analysis Software computer package (SAS version 9.3). Analysis of variance and means were separated using Duncan's multiple range test at 5% confidence level. The results of this study showed that 30 tonne/ha vermicompost treatment gave great potential to increase the performance, growth and yield of beetroot plant and improvement of soil quality. The four doses of vermicompost gave higher significant growth and yield of beetroot than the three doses of NPK [2:3:2] fertilizer and ordinary soil. The minimum quantity of 5 tonne/ha of vermicompost is, therefore, recommended as a natural fertilizer for root crops, vegetable crops and other crops for increased and sustainable agricultural systems.

Keywords: Vermicompost; Beetroot; Growth-and-root yield parameters; Soil quality

1. Introduction

Soil fertility is perhaps the second most important constraint, behind water availability, in limiting crop production to meet food security needs of the burgeoning human population of Sub Saharan Africa (SSA). At the same time, soil degradation is a widespread occurrence in these areas [1], majorly due to loss of crop nutrients from the field resulting from crop harvests [2]. Replacement of the lost nutrients using mineral fertilizer is beyond the economic capacity for most smallholder SSA farmers [3]. A more appropriate solution to this problem could be treating decomposable crop waste using proper methods and utilizing it as fertilizer or soil conditioner. One such treatment method is vermicomposting, an environmentally suitable process and involves using worms to convert organic waste into a humus-like material termed vermicompost [4]. This earthworm-facilitated decomposition process provides newer opportunities for replenishing soil fertility [5] while sustainably managing the environment.

Vermicomposting is a viable, cost-effective, and rapid technique for efficiently managing biodegradable waste [6]. The worms break up the biodegradable waste, thus quickening its decomposition and eventually stabilization [7]. Vermicompost's popularity has significantly increased due to its higher economic return than conventional compost

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because its nutrients are in higher concentration than the fresh waste from which it was derived and are readily accessible for plant growth [8].

These benefits of vermicompost are, nevertheless, scantly known to SSA where farmers relentlessly cultivate the moisture hungry sandy-like soils for livelihoods using mineral fertilizer. Although mineral fertilizer such as N:P:K (2:3:2) does enhance the availability of soil nutrients for plant growth, it also greatly contributes to the deterioration of environment, loss of soil fertility, declining agricultural productivity and soil degradation [9]. Vermicompost, on the other hand, increases organic carbon, microbial populations and dehydrogenase activity in soils; improves pH, soil porosities and water-holding capacities; and decreases bulk density [10]. In SSA countries, where high temperatures accelerate the decomposition of organic matter, annual application of vermicompost would go a long way in maintaining soil fertility.

Botswana produces half of its horticultural produce to meet demand [11]. There is a huge untapped potential in SSA to supply commercial beetroot. Botswana has, for example, only two hectares which produce 34 tonnes of beetroot per year for commercial purposes [11]. Beetroot is a nutritious vegetable root crop which helps to lower blood pressure, reduces the risk of obesity, and possesses a lot of beneficial boron.

Recent research work into the effects of vermicompost utilization on vegetable crops have been very limited. Joshi and Adarsh [12] reported that the growth, yield and quality parameters of tomato (*Lycopersicum esculentum*) increased significantly in all three cattle dung vermicompost mixtures as compared to soil (control). Similar findings were reported by Tahmineh and Ziveh [13]. Narkhede [14] examined the effect of chemical fertilizer and vermicompost on the growth of sweet pepper (*Capsicum annum*). Significant increase in plant height, leaf length and fruit yield of pepper plants was observed in plots treated with vermicompost. Lari [15] evaluated the effect of cocopeat and vermicompost biofertilizers at different media ratios on qualitative traits of three sweet pepper varieties. The results showed that there were significant differences in amount of Chlorophyll a, Chlorophyll b and carotenoids at 5% level of significance in ratios containing vermicompost. Lazcano [16] assessed the effects of vermicompost on yield and quality of sweet corn (*Zea mays*) hybrids under (i) a conventional fertilization regime, (ii) rabbit manure or (iii) vermicompost. Both vermicompost and manure produced significant increases in plant growth and marketable yield and affected the chemical composition and quality of the marketable ear. The results confirmed that the use of organic fertilizers such as vermicompost has a positive effect on crop yield and quality. Ansari [17] appraised the effect of vermicompost application in reclaimed sodic soils on the productivity of potato (*Solanum tuberosum*), spinach (*Spinacia oleracea*) and turnip (*Brassica campestris*). Among the different dosages of vermicompost applied, there was a significant improvement in the soil quality of plots amended with vermicompost at 6 tonnes per ha. The overall productivity of vegetable crops during the two years of the trial was significantly greater in plots treated with vermicompost at 6 tonnes per ha. The requirement of vermicompost for leafy crops such as spinach was lower (4 tonnes per ha), whereas that for tuber crops like potato and turnip was higher (6 tonnes per ha).

The effects of vermicompost on the growth and yield of beetroot have largely not been assessed in SSA (including Botswana). Therefore, the objective of the present study was to evaluate the effect of vermicompost on the growth and yield of beetroot (*Beta vulgaris* var. Early Wonder) under

- Four doses of vermicompost
- Three doses of mineral fertilizer
- Ordinary soil (as control).

2. Material and methods

The study was conducted at the Botswana University of Agriculture and Natural Resources greenhouse situated at Sebele (24^0 15’ S; 25^0 58’ E; 998 m) about 15 km North-East of Gaborone (Figure 1), for 10 weeks (19 March – 28 May 2019) under irrigated conditions.

The garden soil was used as a medium in the study. A soil sample was air dried, passed through a 4 mm sieve and then used to make 1:1 soil to water mixture for determining electrical conductivity (EC) and pH by digital EC and pH meters, respectively. Soil textural analysis was also determined by sedimentation method. Soil textural analysis, EC and pH were similarly determined for the vermicompost. This vermicompost was made from processing kitchen waste, shredded papers, animal waste and dry tree leaves with the help of red wigglers worms (*Eisenia fetida*).

Twenty-four polyethylene pots were each filled with 3 kg of garden soil and two beetroot (*Beta vulgaris* var. Early Wonder) seedlings transplanted into each pot at field capacity. The randomized complete design (RCD) was subjected to the polyethylene pots with 8 treatments, namely 4 doses (5, 10, 20 and 30 tonne/ha) of vermicompost, 3 doses (50, 100 and 200% of 50 kg bag/ha) of NPK (2:3:2) and ordinary soil (as control), of three replicates. Treatments were administered a week after transplanting.

Data on growth parameters (viz. plant height, leaf height and leaf diameter) were collected weekly beginning three weeks after transplanting. At maturity, root diameter, wet weight and dry mass of both shoots and roots (of beetroot) were determined and recorded. Data on growth and yield parameters were analyzed using the Statistical Analysis Software computer package [18]. Analysis of variance and means were separated using Duncan's multiple range test at 5% confidence level.

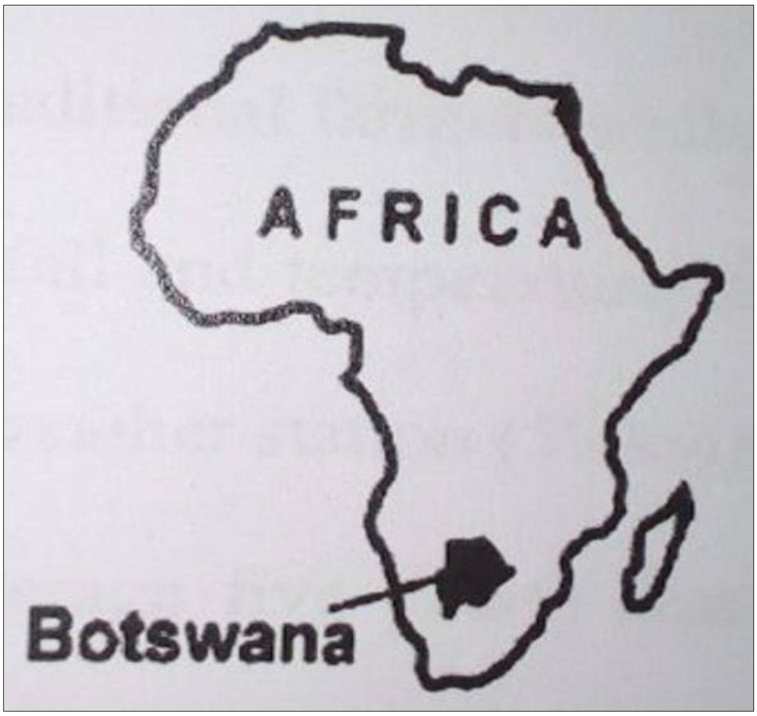

Figure 1 Location of study area in Africa

3. Results and discussion

The growth-medium conditions at onset of the study are given in Table 1.

Table 1 Growth-medium conditions at onset of study

	Soil	**Vermicompost**
Textural class	Sandy loam	Loamy sand
Electrical conductivity (mS/m)	4.6	0.2
Acidity/alkalinity (pH)	7.6	6.2

The plant height, leaf height and leaf diameter of beetroot under ordinary soil (Treat 0), 50% of 50 kg bag/ha of NPK [2:3:2] (Treat 1), 100% of 50 kg bag/ha of NPK [2:3:2] (Treat 2), 200% of 50 kg bag/ha of NPK [2:3:2] (Treat 3), 5 tonne/ha (Treat 4), 10 tonne/ha (Treat 5), 20 tonne/ha (Treat 6) and 30 tonne/ha (Treat 7) of vermicompost during the growing period are shown in Figures 2, 3 and 4, respectively. Treat 4 to 7 out-performed other treatments in these growth parameters.

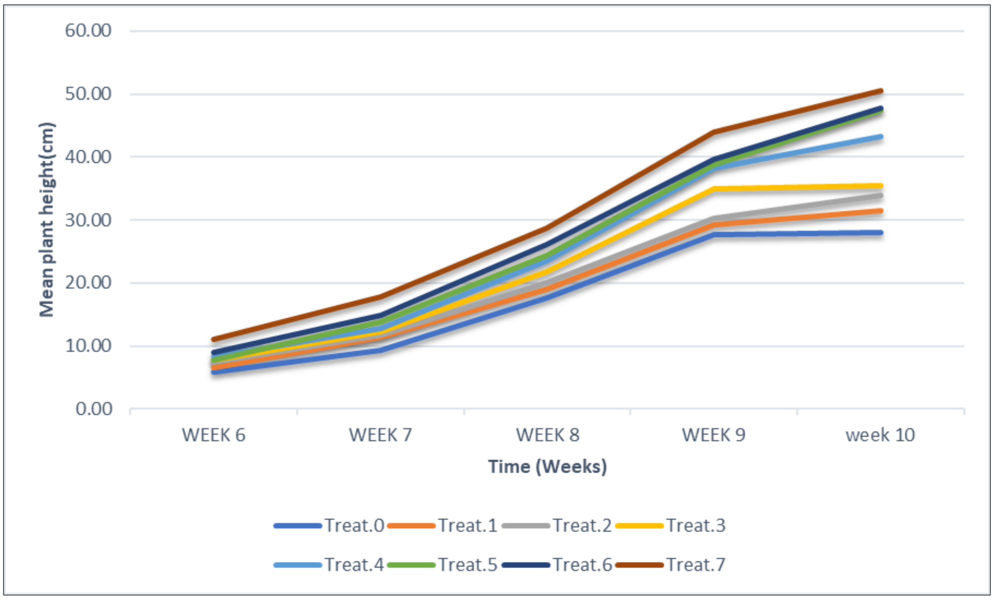

Figure 2 Effect of NPK [2:3:2] and vermicompost treatments on plant height

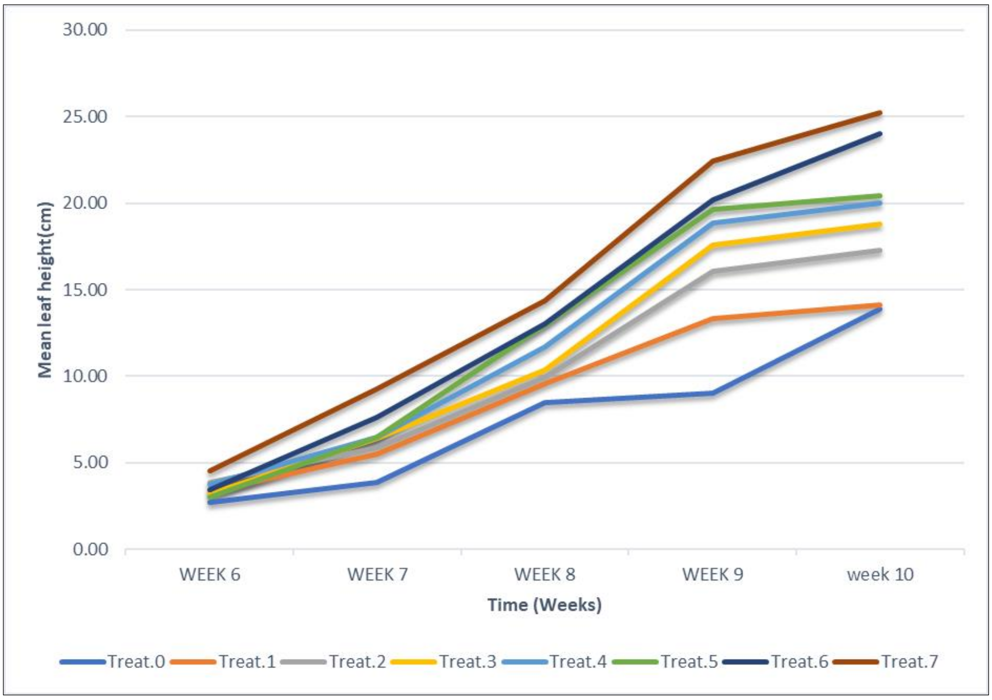

Figure 3 Effect of NPK [2:3:2] and vermicompost treatments on leaf height

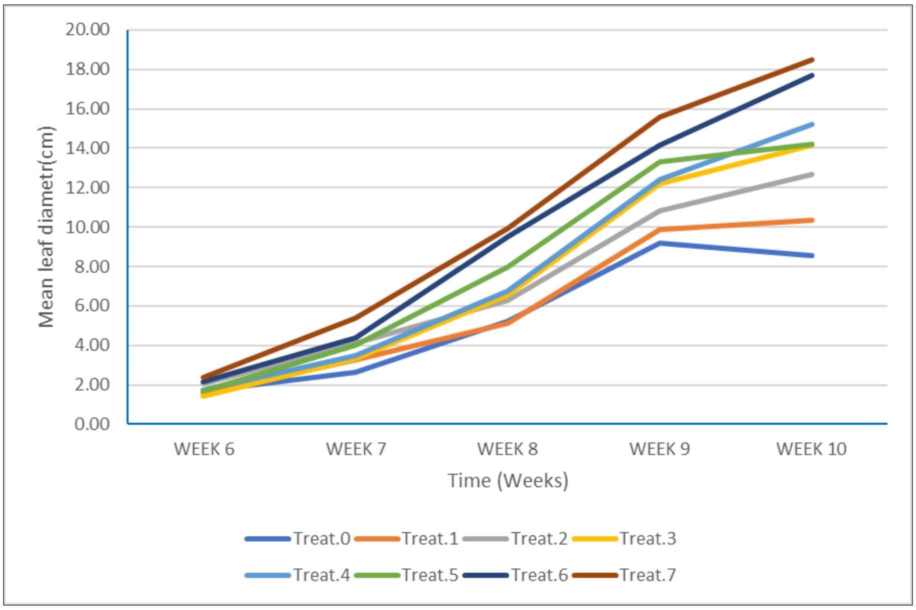

Figure 4 Effect of NPK [2:3:2] and vermicompost treatments on leaf diameter

Variation of root parameters (at time of harvest) as influenced by NPK [2:3:2] and vermicompost treatments is shown in Figures 5, 6 and 7. It is clearly shown that Treat 4 to 7 had the highest values of mean root diameter (Figure 5), mean

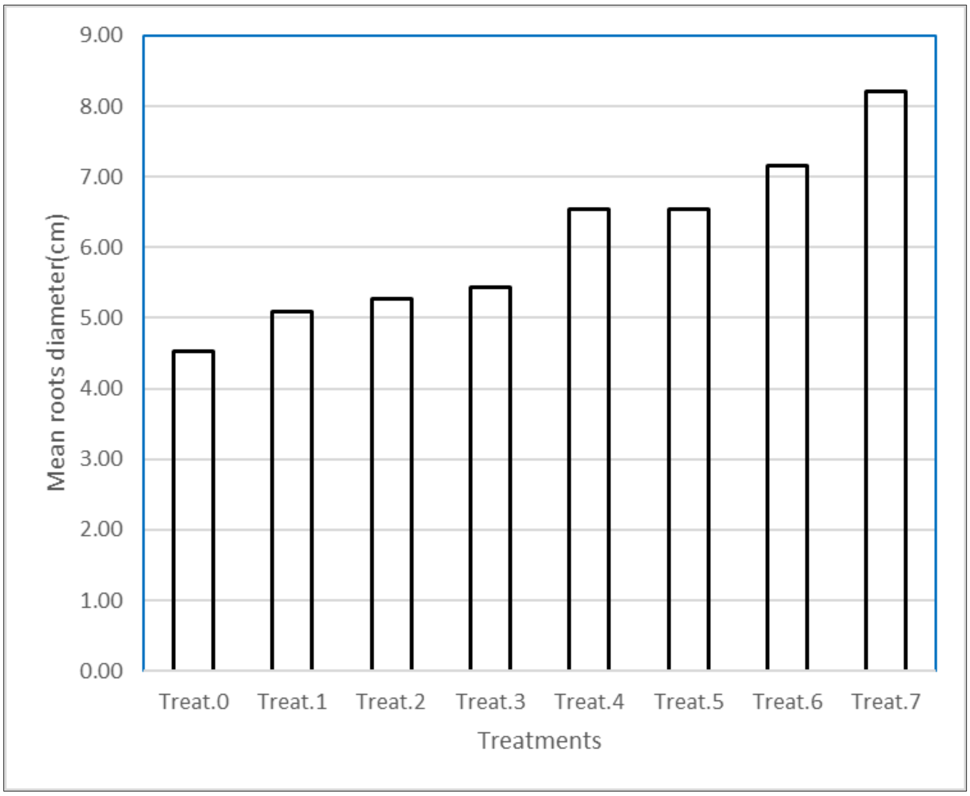

Figure 5 Effect of NPK [2:3:2] and vermicompost treatments on mean root diameter

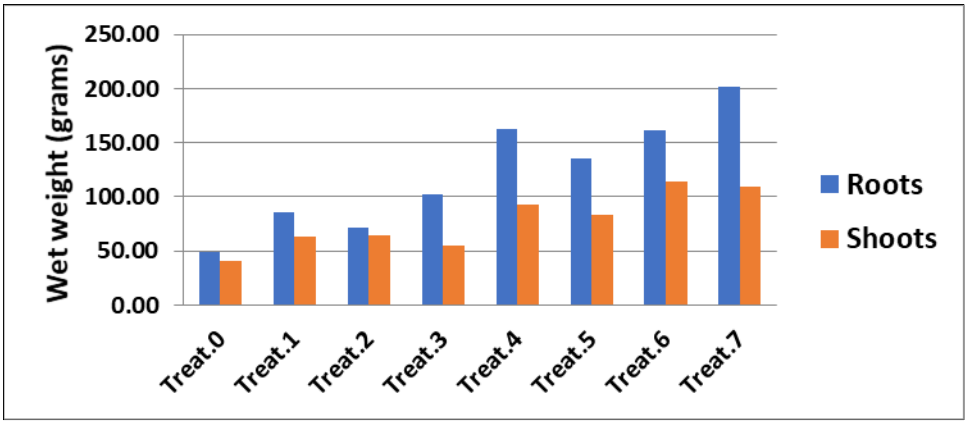

Figure 6 Effect of NPK [2:3:2] and vermicompost treatments on mean fresh weight of roots

fresh root weight (Figure 6) and mean dry root matter (Figure 7) compared to other treatments. The root of the beetroot is the most valuable (and marketable) part of the crop.

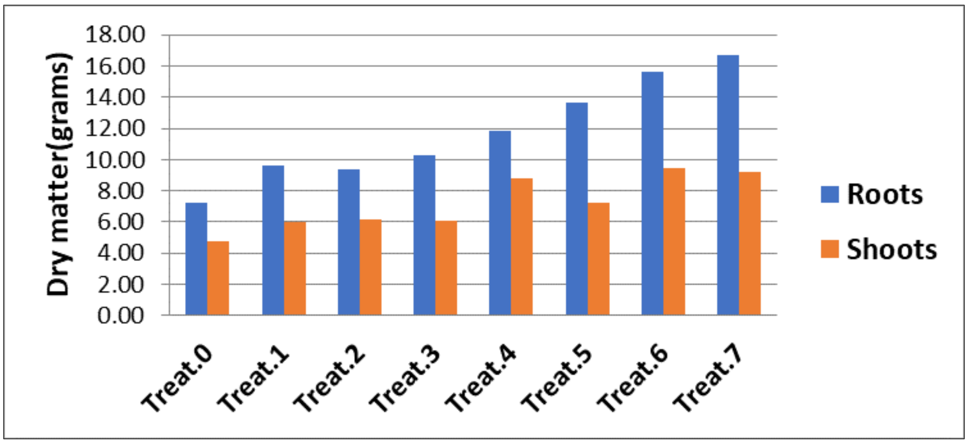

Figure 7 Effect of NPK [2:3:2] and vermicompost treatments on mean dry matter of roots

The statistical analysis of beetroot plant parameters (at harvest) against NPK [2:3:2] and vermicompost treatments is shown in Table 2. The means of plant height, leaf height, leaf diameter, root diameter and fresh weight for Treat 7 – 6

Table 2 Effect of NPK [2:3:2] and vermicompost treatments on plant growth//yield parameters

Treatments	Plant height (cm)	Leaf diameter (cm)	Leaf height (cm)	Moisture Content Roots (%)	Roots Diameter (cm)	Fresh-weight Roots(g)
Treat 0	28.1^{D}	8.533^{D}	13.9^{D}	89.097^{C}	4.5^{D}	49.23^{ED}
Treat 1	31.5^{CD}	10.333^{D}	14.1^{D}	87.313^{BC}	5.1^{CD}	81.73^{CDE}
Treat 2	33.833^{C}	12.667^{C}	17.27^{C}	85.138^{C}	5.3^{CD}	64.83^{ED}
Treat 3	35.467^{C}	14.133^{BC}	14.8^{D}	89.79^{AB}	5.433^{CD}	102.53^{CDE}
Treat 4	43.233^{B}	14.2^{BC}	20^{B}	89.22^{AB}	6.3^{BC}	114.07^{BCD}
Treat 5	47.4^{AB}	15.233^{B}	20.43^{B}	89.913^{AB}	6.533^{BC}	135.27^{BC}
Treat 6	47.733^{AB}	17.8^{A}	24.04^{A}	90.43^{A}	7.2^{AB}	161.27^{AB}
Treat 7	50.467^{A}	18.5^{A}	25.2^{A}	91.633^{A}	8.2^{A}	201.53^{A}

Letters denote significance at 5% level using Duncan's new multiple range test. Means with same letter are not significantly different.

were significantly higher than those for Treat 5 – 4. The descending order of treatment means was as follows: Treat 7 – 6 > Treat 5 – 4 > Treat 3 – 1 > Treat 0.

The conspicuous plant growth and yield response of beetroot from vermicompost treatments could be due to: (i) vermicompost possessing plant growth hormones (e.g. indole acetic acid, gibberellins and cytokinins) and other plant growth regulators which promote increased microbial activities by earthworms [19]; (ii) increased availability of most macronutrients in neutral to slight acidic soils ([20], Table 1); (iii) favourable temperature, moisture and balance of organic and inorganic nutrients in the vermicompost which significantly increased the growth of plants [21].

The results in Table 2 indicate that Treat 4 (viz. 5 tonne/ha of vermicompost) provides a higher significant plant growth/yield response than the highest dose (viz. 200% of 50 kg bag/ha) of NPK [2:3:2] fertilizer. The implication of this finding is that a resource-constrained farmer can apply this low dose of vermicompost to one's horticultural plot and be assured of good yield without the use of expensive mineral fertilizer thus improving soil physical-and-chemical properties for sustained economic returns.

4. Conclusion

The results of this study showed that 30 tonne/ha vermicompost treatment gave great potential to increase the performance, growth and yield of beetroot plant and improvement of soil quality. The four doses of vermicompost gave higher significant growth and yield of beetroot than the three doses of NPK [2:3:2] fertilizer and ordinary soil. The study positively highlighted the importance of organic farming. Therefore, vermicompost may be put to good use as a natural fertilizer for root crops, vegetable crops and other crops for increased and sustainable agricultural systems.

Recommendation

Practically the quantity of 30 tonne/ha of vermicompost may seem to be too high for the farmer to apply on one's fields. The minimum quantity recommended is, therefore, 5 tonne/ha as it also resulted into higher growth rate and yield of beetroot than from artificial fertilizer or ordinary soil.

Compliance with ethical standards

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Disclosure of conflict of interest

We the authors of this paper hereby declare that there are no competing interests in this publication.

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