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COMPARATIVE EFFICACY OF ORGANIC AND INORGANIC FERTILISERS ON VEGETABLE GROWTH AND YIELD IN SOUTH AFRICA

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Abstract: This study investigates environmentally friendly alternatives to conventional inorganic fertilisers in South African agriculture. Inorganic fertilisers are known to pose risks to human health, environment, and groundwater. It assesses the efficacy of organic alternatives such as vermicompost, bokashi compost, and cow manure, when compared to inorganic fertilisers concerning the growth and yield of spinach, carrots, and peas. The experiment, conducted in a 10.08 m² rural garden plot in Bhongweni, assessed plant height, leaf length, number of leaves, branches, stipules, and pods monthly. Vegetable yields were measured during harvest, focusing on the number of leaves in spinach and carrots and the number of pea pods. Statistical analyses using analysis of variance (ANOVA) and Tukey test were employed to determined significant differences in the growth and yield of the pre-selected vegetables based on fertiliser type. Results indicated significant effects of different fertilisers on spinach height and leaf length. For carrots and peas, organic fertilisers significantly affected growth and yield by the third month. The findings suggest that organic fertilisers, specifically vermicompost, bokashi compost, and cow manure, are promising alternatives for sustainable vegetable production compared to inorganic fertilisers. This study recommends further research to optimise application rates and understand the mechanisms behind improved plant performance with organic fertilisers.

Keywords: bokashi compost, cow manure, crop yield, inorganic fertiliser, sustainable agriculture, vermicompost.

Introduction

Vermicomposting is the process of converting biodegradable organic waste into humus-like vermicast using earthworms (Fernando & Arunakumara, 2021). Vermicomposting has been put forward as one way of helping simmer down organic waste that is directly turned into a composted fertiliser (Singh & Sinha, 2022). As an increasingly popular method, vermicomposting is a recently adopted form of waste management, and vermicast produced through the process has a significant contribution towards improving the fertility of the soil by supplying the plants nutrients and also improves the structure of the soil and is healthy for plant growth (Walia & Kaur, 2024). On the other hand, bokashi is a fermented soil conditioner which has the potential to aid farmers by supplying fertility organic matter directly to the soil (Abo-Sido et al., 2021). As noted by Abo-Sido *et al.* (2021), bokashi's effectiveness in improving soil health has been recognised, yet literature comparing bokashi with vermicompost and inorganic fertilisers is limited (Dhakal *et al.*, 2021). Like compost, bokashi can be made from a variety of different raw materials and adds value to organic materials that would otherwise be considered waste (Olasesan *et al.*, 2022). Its increased use can be attributed to its capacity to quickly ferment organic waste, thereby improving the soil and minimizing the need for synthetic fertilisers (Gashua et al., 2022).

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Soil structure has been impaired due to the increased use of inorganic fertilisers, soil has become acidic, and nutrient content in the soil is either high or low, depending on the type of plant (Bhatt *et al.*, 2019). In this respect, attention has shifted to the application of fertilisers, including organic manure (Aguilera *et al.*, 2021). Given the renewed interest in organic fertilisers, this study aims to investigate how effective the two manufactured composts and fertilisers are compared to inorganic fertilisers in terms of the growth and yield of the selected vegetable crops.

The growing concern of soil degradation as a result of desertification is one of the environmental challenges in South Africa, which is further worsened by the increased population growth which has led to an increased demand for food (Du Preez & Van Huyssteen, 2020). This pressure increases the dependence on traditional agricultural systems as well as the heavy dependence on inorganic fertilisers like ammonium nitrate and potassium chloride, which are known to be health hazards and pose environmental risks (Kakar et al., 2020; Ntoyi, 2020). These fertilisers are associated with complications for example pollution of groundwater and emission of greenhouse gases (Rashmi *et al.*, 2020). For these problems, it becomes quite important to explore alternative eco-friendly substitutes such as organic fertilisers whose sources include worm compost, bokashi compost, and cow dung. Nonetheless, what is still not clear is how these organic sources perform in enhancing crop productivity and food production to a growing population base, to the level of conventional inorganic fertilisers (Qaim, 2020). Current studies suggest that organic sources of fertilisers like vermicompost and bokashi compost are more sustainable than inorganic fertilisers; however, there is a lack of comparative data with respect to the impact on the yield and growth volatility of these innovative techniques.

Although the use of organic fertiliser is rising, there are only limited data on the effect of bokashi compost and vermicompost on the growth of vegetables such as carrot and pea (Aryal et al., 2021; Hou et al., 2022). Though some researchers have already provided evidence of the big potential of vermicomposting on soil structure and nutrient content (Xue et al., 2022), there is limited comparative assessment of the effectiveness of vermicomposting over inorganic fertilisers (Al-Tawarah et al., 2024; Kalika-Singh et al., 2022). Similarly, bokashi compost has been identified as a promising soil conditioner, but its potential to maintain crop yield in vegetable production, particularly under variable conditions of the soil, is not well-documented (Kruker et al., 2023; Olle, 2020).

To fill these gaps, this study presents a direct comparison between organic and inorganic fertilisers in specific vegetable contexts and offers an extant understanding of the application of organic options in sustainable agriculture. It evaluates the growth, and the yield obtained from the selected vegetable species (spinach, carrots and peas) applying vermicompost, bokashi compost, cow manure and inorganic fertiliser. These crops were chosen for their nutritional and economic significance. Spinach is known to be rich in essential vitamins and minerals and is widely consumed as a leafy green (Kumar et al., 2020), carrots are a valuable source of beta-carotene and a staple in many diets (Nagraj et al., 2020), and peas are an important leguminous crop that contributes to soil nitrogen fixation while providing a protein-rich food source (Kumar et al., 2023). The study offers practical insights into the efficiency of these composts in sustainable agriculture practices.

The specific objectives are to compare the growth rates of selected vegetables over a three-month growing period using these nutrient sources and to compare the total yield of the selected vegetable varieties produced under the different compost treatments. It is anticipated that the growth rates of certain vegetables will show statistically significant differences when grown with different nutrient sources, namely vermicompost, bokashi compost, cow manure and inorganic fertiliser. Furthermore, the total yield of the selected vegetable varieties is expected to demonstrate statistically significant differences between the different compost treatments that have already been mentioned.

Materials and Methods

The experiment was conducted to assess the effectiveness on the growth and yield of selected vegetables when grown under vermicompost, bokashi compost, cow manure as well as the inorganic fertiliser. Spinach, carrots and peas were chosen as model plants because these vegetables are widely consumed in South African households and have different nutrient demands. Hence, their response to these fertilisers can give a balanced view of the efficacy of these fertilisers in enhancing nutrients in various vegetable types.

Selection of fertilisers and application rates

The vermicompost used in this experiment was sourced from Amele Recycling's worm farm at Ncambedlana, Mthatha. This farm has been noted to produce high-quality vermicompost characterized by a balanced nutritional value and high microbial populations. Wako (2021), Domínguez (2018) and Appelhof and Olszewski (2017) found that nutrient-rich liquid worm faeces can be harvested from a compost bin in two to three months and used as fertiliser for selected vegetable crops. Therefore, the liquid worm castings were used as liquid fertiliser for the vegetables selected for this project. In accordance with the recommendation of Wako (2021), this liquid was diluted with tap water at a ratio of 1:10. The preparation of the vermicompost took 6 months, as Wako (2021) and Domínguez (2018) suggested that the vermicompost can be applied as fertiliser to the plants after 6 months.

The researcher prepared the bokashi compost used in this experiment using food waste and other organic waste matter treated with Effective Microorganisms (EM). The method aims to produce nutrient-rich compost through anaerobic fermentation. The choice of bokashi compost was based on its potential to enrich soil fertility through anaerobic fermentation, providing readily available nutrients and improving soil structure. The excess liquid produced during the fermentation process can hinder the beneficial bacteria, as reported by Ghanem et al. (2017). This liquid was drained every two days as recommended by Lew et al. (2021), and then bottled for analysis. In addition, this liquid was diluted with tap water at a ratio of 1:100, as recommended by Schonbeck (2017). The mixture was applied as a liquid fertiliser to the selected vegetable plants as recommended by Pohan et al. (2018) and Christel (2017).

The cow dung used was obtained from a homestead in Zandukwane. It was carefully selected to be fresh and free from artificial additives so that the organic nature of the material was maintained. The household was selected because it has been practising some form of cattle rearing for more than four years, and thus, it has mature dung as defined by (Rahman *et al.*, 2020). Li *et al.* (2020) and Mahboub *et al.* (2021) recommend that the household must have raised cattle continuously for at least two years to be eligible for selection. Fresh cow manure was selected due to its widespread availability in rural areas and its ability to improve soil organic matter and microbial activity.

Finally, the inorganic fertiliser was purchased from Umtiza Farmers' Corp in Mthatha, a reputable source for agricultural inputs, specifically chosen to represent commonly used synthetic fertilisers that deliver readily available nutrients. Comparative analyses were then carried out for the five treatments: the two composts, the manure, the inorganic fertiliser and no treatment.

Effect of fertilisers

A garden plot measuring 10.08 m^2 (9.6 m x 1.05 m) was secured in Bhongweni to grow the three pre-selected crops: spinach, peas and carrots, as previously reported. The soil was loamy with small stone particles. Soil samples were taken at a depth of 15 cm (topsoil) for chemical analysis before and after the application of fertilisers to take care of any potential variability of the soil. Plants such as Nile flowers (*Agapanthus africanus*) and spider plants (*Chlorophytum comosum*) were last planted in the garden plot three years ago. The garden was worked by hand to prepare it for cultivation.

Before cultivating, the garden was divided into fifteen equal rows. Six seedlings were planted in each row. Three rows were treated with vermicompost, three other rows with bokashi compost, three other rows with cow manure, the other three rows with inorganic fertiliser and the last three rows were the control. The distance between the rows was 60 cm and between the plants 15 cm, as recommended (Amare & Gebremedhin, 2020).

The effect of the fertiliser applications was evaluated by measuring the preselected vegetables and soil properties. Plant height and leaf length were measured monthly up to harvest to determine the efficiency of the four fertilisers on plant growth. The number of leaves, the number of branches, the number of stipules and the number of pods were also counted each month until harvest. Thus, at the end of the experiment, the following parameters were measured to determine plant growth: (1) plant height; (2) leaf length; (3) number of leaves; (4) number of branches; (5) number of stipules; (6) number of pods.

Plant height was measured above the ground to the base of the leaf (the part where the leaf is attached to the stem) with the use of a 30 cm mathematical ruler, as suggested by (Jamil *et al.*, 2022). The measurement of leaf length was taken from the base of the complete leaf to the tip of the complete leaf using the 30 cm mathematical ruler as recommended by (Sim *et al.*, 2020). Hand counting of the number of leaves, the number of branches, the number of stipules and the number of pods per plant was done as recommended by Tafesse et al. (2019).

Data analysis

Statistical analysis of the data collected from the experiment was carried out using SPSS software. Data relating to the measured parameters of plant growth were analysed using analysis of variance (ANOVA), similar to the method used by Costan et al. (2020), to determine whether the vermicompost, bokashi compost, cow manure, and inorganic fertiliser had statistically significant differences in their effectiveness on the growth and yield of the chosen vegetables. The Tukey test was used to examine the pairwise differences between the different types of fertilisers.

Results

Plant growth parameters analysis

Effect of fertiliser treatments on spinach growth

Table 1 summarises the results of the effectiveness of the four different fertiliser treatments and the control (no fertiliser) on the growth of spinach over a three-month growth period. Measured parameters to ascertain the effectiveness of fertilisers on spinach growth included plant height, leaf length, and number of leaves, as described in Section 2.

Results for plant height, as shown in Table 1, constantly showed statistically significant differences among all three months of trial for each fertiliser treatment at $p<0.05$. This means the type of fertiliser applied greatly influenced the height of the plant during the trial period. As with plant height, significant differences ($p<0.05$) in leaf length were observed for all the trials throughout the three months of the experiment for all fertiliser treatments. These results rejected the null hypothesis and supported the alternative hypothesis. This underlines that the different fertiliser types had a significant effect on leaf length growth over the entire trial period. Compared with other parameters, the total number of leaves for all fertiliser treatments during the three months of the trial showed no significant difference ($p>0.05$). This indicates that the number of leaves remained relatively constant regardless of the fertiliser used.

Table 1: Parameters measured to determine plant growth of spinach plants for a three-month experiment.

Parameters	First month	Second month	Third month
Plant height	*	*	*
Leaf length	*	*	*
Number of leaves	ns	ns	ns

ns = no significant differences
** = significant differences*

Table 2 and Figure 1 show the mean values of the parameters measured to determine the plant growth of spinach plants in a three-month experiment.

Initially, the Bokashi compost treatment demonstrated better efficacy on the spinach plants than the other treatments in the first month of the study, as evidenced by the highest average values for parameters such as plant height, leaf length, and the number of leaves, which are listed in Table 2 and visualised in Figure 1. However, in the following months, especially during the second month and at harvest time, the results indicated that the application of inorganic fertiliser produced more favourable results for spinach growth than the vermicompost, bokashi compost, and cow manure treatments. These findings are detailed in Table 2 and depicted in Figure 1.

At harvest, the spinach plants fertilised with inorganic fertiliser had a significantly higher plant height (17.4 cm) than the other fertilisers: vermicompost (15.8 cm), bokashi compost (13.4 cm), cow manure (12.2 cm), and the untreated spinach plants (control) (9.5 cm). This treatment also produced the highest mean value for leaf length at 19.2 cm and the highest mean value for number of leaves at 11.3. Conversely, the effectiveness of cow manure in promoting spinach growth was found to be the least effective, as this particular treatment produced the lowest mean values for all measured plant growth parameters during the month of harvest. Overall, the analysis of the data presented in Table 2 and Figure 1 shows that the inorganic fertiliser treatment has the best effect on plant growth compared to the organic fertilisers.

Table 2: Mean values for parameters measured to determine plant growth of spinach plants for a three-month experiment.

		Plant height (cm)_M1	Leaf length (cm)_M1	Number of leaves_M1	Plant height (cm)_M2	Leaf length (cm)_M2	Number of leaves_M2	Plant height (cm)_M3	Leaf length (cm)_M3	Number of leaves_M3
		Mean	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**
Treatments	Vermicompost	8.5	9.7	7.8	13.7	13.1	8.8	15.8	17.3	9.7
	Bokashi compost	14.1	11.0	10.0	12.6	13.9	7.7	13.4	16.9	11.2
	Cow manure	6.4	7.2	7.3	10.1	11.4	8.0	12.2	13.5	9.8
	Inorganic fertilizer	9.9	10.8	7.7	14.0	18.0	9.3	17.4	19.2	11.3
	Control	7.1	6.0	5.3	7.8	9.0	6.3	9.5	10.3	7.8

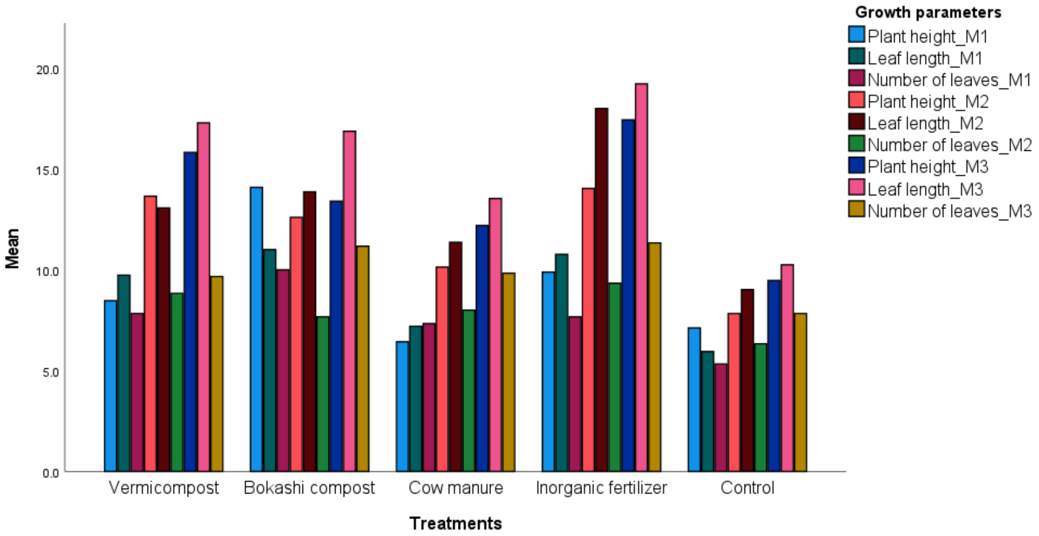

Figure 1: Comparison of mean values for parameters measured to determine plant growth of spinach plant model during the three-month experiment.

Effect of fertiliser treatments on carrot growth

Table 3 shows the results of the carrot growth analysis. Results from the first month of the experiment showed no statistically significant differences in the mean values of parameters measuring carrot growth. Hence, the null hypothesis could not be rejected. The results from the second month reveal significant differences in the effectiveness of various fertilisers in promoting both the growth and yield of carrot plants. Significant differences were observed in plant height ($p<0.05$), leaf length ($p<0.05$), and the number of leaves ($p<0.05$), all below the standard threshold of 0.05 p-values. Therefore, the null hypothesis for the carrot plant models was rejected, and the alternative hypothesis was supported.

In the third month of the experimental trial, all the parameters evaluated in the five carrot plots showed results below the 0.05 significance level. This means that there were significant differences in mean values for all growth and yield parameters, leading to rejecting the null hypothesis and supporting the alternative hypothesis.

Table 3: Parameters measured to determine plant growth of carrot plants for a three-month experiment.

Parameters	First month	Second month	Third month
Plant height	ns	*	*
Leaf length	ns	*	*
Number of leaves	ns	*	*

ns = no significant differences

** = significant differences*

Table 4 and Figure 2 represent the means of the parameters measured to analyse the growth of the carrot plants during the three-month study.

By the end of the first month of growing carrots, the rows with Bokashi compost and inorganic fertilisers treatment showed better growth than other treatments with an average height of 10.7 cm, followed by the application of vermicompost with a 9.9 cm average height. The application of inorganic fertiliser resulted in the best performance, recording the highest mean leaf length of 8.8 cm compared to 7.8 cm recorded when using cow manure and 7.6 cm registered by bokashi compost. Additionally, the inorganic fertiliser treatment achieved the highest average leaf length of 6.3 cm, followed by the cow manure treatment with an average of 6.2 cm. The carrot rows that received vermicompost showed the lowest mean values for both leaf length (6.9 cm) and number of leaves (3.7). On the other hand, the carrot plants treated with cow manure showed the minimum mean height, with a value of 9.83 cm.

By the end of the second month of the experiment, the plants treated with Bokashi compost showed the highest average height of 16.1 cm. The highest average leaf length of the carrots was recorded at 15.1 cm in the plants treated with inorganic fertiliser. Finally, the inorganic fertiliser treatment also recorded the highest mean value for the number of carrot leaves, at 7.5. The carrot plants that received inorganic fertiliser recorded the lowest average measurement for plant height, pegged at 13.7 cm. The carrot plants treated with vermicompost showed the lowest averages for both the length and number of leaves.

During the time of harvesting, both the Bokashi compost and cow manure treatments showed a more significant effect on carrots compared to vermicompost and inorganic fertiliser. Carrots treated with Bokashi compost achieved the highest average plant height with a value of 18.7 cm. Conversely, the plants treated with cow manure recorded the highest average leaf length of 17.4 cm, followed by inorganic fertiliser and bokashi compost with mean lengths of 15.2 cm and 14.1 cm. The cow manure treatment also yielded the highest average value of 9.3 for the number of leaves, in line with the bokashi compost treatment. This was followed by the vermicompost treatment, with mean values of 6.8 and 6.3, respectively.

Table 4: Mean values of carrot plant growth parameters for four fertiliser treatments over a three-month experiment period.

		Plant height (cm)_M1 Mean	Leaf length (cm)_M1 Mean	Number of leaves_M1 Mean	Plant height (cm)_M2 Mean	Leaf length (cm)_M2 Mean	Number of leaves_M2 Mean	Plant height (cm)_M3 Mean	Leaf length (cm)_M3 Mean	Number of leaves_M3 Mean
Treatments	Vermicompost	9.9	6.9	3.7	14.6	9.7	5.0	14.1	11.3	6.8
	Bokashi compost	10.7	7.6	4.5	16.1	12.5	5.0	18.7	14.1	6.3
	Cow manure	9.8	7.8	6.2	14.7	14.1	7.0	16.9	17.4	9.3
	Inorganic fertilizer	10.7	8.8	6.3	13.7	15.1	7.5	11.5	15.2	9.3
	Control	6.8	5.7	4.0	8.0	7.0	5.7	10.4	9.3	6.7

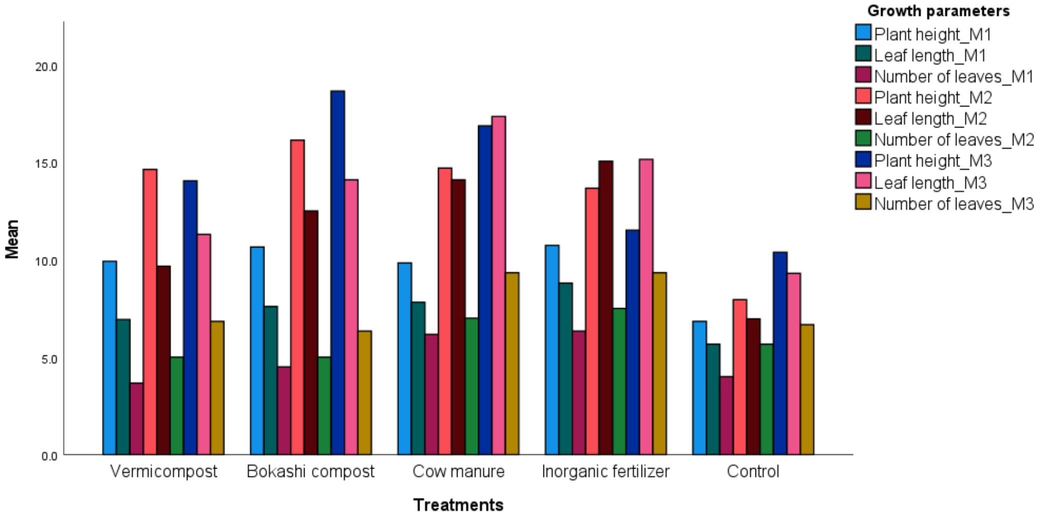

Figure 2: Comparison of mean values for parameters measured to determine plant growth of carrot plants for a three-month experiment.

Effect of fertiliser treatments on pea growth

Table 5 presents the effects of fertiliser treatments on pea plants. The parameters of interest included plant height, the number of branches, the number of stipules, and the number of pods. At the end of the first month of the experiment, statistically significant differences were found in the effectiveness of the different treatments on pea plant growth and yield. For all parameters assessed, the values were below the significance level of 0.05 ($p<0.05$). Consequently, the null hypothesis was rejected, and the alternative hypothesis was supported. This indicates a remarkable difference in the effectiveness of all treatments administered for pea plant growth and yield.

In the second month of the trial, a significant difference was observed in the efficacy of the different treatments on the growth and yield of the pea plants. Consequently, the null hypothesis for the parameters of the pea plants was rejected and the alternative hypothesis was confirmed. Simply put, the effectiveness of all treatments on the peas was significantly different.

In the third month of the experiment, all five plots with pea plants showed results below the significance level of 0.05 for all measured parameters (Table 5). This indicates a significant difference in the effectiveness of the different fertiliser treatments in promoting the growth and yield of the pea plants. In view of this, all null hypotheses for this study period were rejected for pea plants, and alternative hypotheses were supported. This conclusion results from the fact that the observed significant differences in plant height, leaf length and number of leaves all had values below the p-value of 0.05.

Table 5: Measured growth parameters of pea plants over a three-month experiment.

Parameters	First month	Second month	Third month
Plant height	*	*	*
Leaf length	*	*	*
Number of leaves	*	*	*

ns = no significant differences

** = significant differences*

Table 6 and Figure 3 show the mean values of the parameters measured to determine the plant growth and yield of the pea plants in a three-month experiment.

In the first month of the experiment, the pea plants treated with cow manure had the highest average plant height of 63.4 cm. On the other hand, the plants treated with Bokashi compost had the highest average number of branches (11.3), while the plants treated with vermicompost had the highest average number of stipules (58.7). On the contrary, the pea plants treated with inorganic fertiliser showed the lowest average values for all measured plant growth parameters.

In the second month of the experiment, the mean height of the pea plants treated with cow manure was the highest, at 92.0 cm. The Bokashi compost-treated plants, on the other hand, attained the highest average number of branches, which was 13.7. For the parameter number of pods, the pea plants treated with Bokashi compost had the highest mean value of 8.2. In contrast, the pea plants treated with inorganic fertiliser showed the lowest mean values for all the assessed plant growth parameters.

At the time of harvest, the pea plants treated with Bokashi compost had the highest height at 116.3 cm. These plants also had the highest average number of branches (17.8). In terms of the number of pods, the pea plants treated with cow manure had the highest average value of 11.8. Conversely, the pea plants treated with inorganic fertiliser had the lowest average values of all the parameters measured.

Table 6: Mean values for parameters measured to determine plant growth of pea plants for a three-month experiment.

		Plant height (cm)_M1	Number of branches (cm)_M1	Number of stipules_M1	Plant height (cm)_M2	Number of branches_ M2	Number of pods_M2	Plant height (cm)_M3	Number of branches_ M3	Number of pods_M3
		Mean	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**
Treatments	Vermicompost	57.6	9.3	58.7	81.2	12.3	6.7	92.0	15.2	8.7
	Bokashi compost	55.1	11.3	54.0	86.7	13.7	8.2	116.3	17.8	10.3
	Cow manure	63.4	10.5	52.5	92.0	13.5	6.8	111.8	16.5	11.8
	Inorganic fertilizer	20.7	4.5	24.2	45.9	5.2	.7	22.3	6.3	.8
	Control	38.5	7.2	42.5	67.2	9.8	3.2	72.4	12.8	4.2

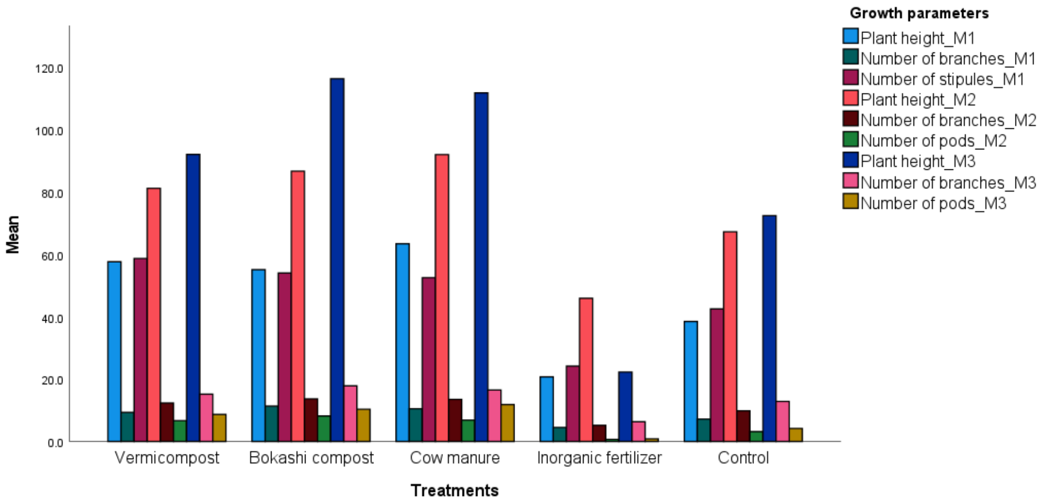

Figure 3: Comparison of mean values for pea plant growth parameters across fertiliser treatments in a three-month experiment.

The interpreted results prove the effectiveness of organic fertilisers such as Bokashi compost and cow manure, among others. That such organic treatments provided improved results also underscores their potential as substituents for inorganic fertilisers, just as it brings environmental concerns to the fore. They promote effective soil physical properties and improve microbial inoculation and nutrient supply, which are slowly released, thus reducing cases of nutrient leakages. This is even more important in conservation agriculture, which focuses on the productivity of soil and the reduction of chemicals moving with water.

Discussion

According to Hasnain et al. (2020), inorganic fertilisers are widely used in agriculture as they help to increase crop yields, but environmental pollution and soil degradation have worsened where inorganic fertilisers are used excessively and on a long-term basis (Ayilara et al., 2020). Therefore, the alternate use of compost helps to maintain a healthy soil structure and improve plant growth. As noted by Olasesan et al. (2022)**,** compost serves as a natural organic fertiliser, making inorganic fertilisers superfluous (Ayilara et al., 2020). Vermicompost and bokashi compost were used in this study and were found to be effective for crop yield in all three vegetable varieties used as plant models in this study.

Bokashi compost proved to be a very effective fertiliser in this study as the growth of the pea plants was higher than any of the other fertiliser treatments. It was also effective on the carrot plants as it improved the plant height of the carrots (see Table 4). These results are consistent with the findings of a study by Sharma et al. (2019), which concluded that composts (organic-based fertilisers) add organic matter to the soil and improve its fertility and structure. Singh et al. (2022) also reported that the application of organic fertiliser to soil improves several properties, including soil aeration, drainage and water holding capacity, which ultimately promotes healthier root development, plant height and overall plant growth. The most commonly used organic fertilisers are forest litter, compost, green manure and cattle manure (Henry et al., 2020).

The use of cow manure as an organic fertiliser has been attributed to increased agricultural yields, thus corroborating assumptions made by Hashimi et al. (2020) and Adekiya et al. (2020) on the potential of cow dung in increasing soil fertility and crop productivity while decreasing the negative environmental impacts associated with cow waste. This is attributed to the high nutrient value in cow manure that encourages long-term fertility of the soil (Mahboub et al., 2021). The use of cow manure was mostly effective when it was used as a fertiliser for the pea plants, as shown in Table 6. In the third month of the trial, cow manure also proved to be effective on carrots, as leaf length and average number of carrot leaves were highest on the cow manure-treated plants, as shown in Table 4.

Statistical analyses showed that vermicompost, bokashi compost and cow manure had a significantly better performance in comparison with inorganic fertilisers about the height of spinach plants ($p<0.05$). This may be due to the slow-release nature of organic fertilisers, which gradually release nutrients, allowing plants to absorb them consistently over time (Kakar et al., 2020). The performance of inorganic fertiliser was quite significant for the number of leaves compared to other treatments. The mean value of 11.3 was obtained at the end of the experiment and was higher than all the other treatments. This result is consistent with the statement from an earlier referenced study by Oyetunji et al. (2022), which states that inorganic fertilisers provide nutrients to plants in a form that is immediately available, hence suitable for correcting nutrient deficiencies and promoting rapid growth. However, excessive or improper use of inorganic fertilisers can lead to nutrient imbalances, soil degradation and environmental pollution (Kumar et al., 2019).

As for the yield of crops, it was found that vermicompost, bokashi compost, and cow dung significantly increased the pea yield as compared to inorganic fertiliser ($p<0.05$), as depicted in Table 5 and Table 6. This is supported by the highest mean values recorded for the number of pods on pea plants treated with cow manure, followed by those treated with bokashi compost and vermicompost. All the fertiliser treatments used during the trial period yielded no significant differences in the first month of the trial ($p>0.05$), while the treatment yielded significant differences in the second and final month of the trial ($p<0.05$), as shown in Table 3 for carrots. This is in line with the reports of a review study by Bhatt et al. (2019), which highlights that the effectiveness of organic and inorganic fertilisers in releasing the nutrients required for plant growth is different.

These findings imply that the efficiency of the applied fertilisers depends on the given crop and specific growth parameters. This variation may be because of the different requirements of each crop in using nutrients; for example, peas may need more from nitrogen, generously supplied by cow manure, while carrots might need more from improvements in soil structure, which can be provided by bokashi compost. Olasesan et al. (2022) indicated that the choice of fertiliser may be influenced by the unique nutrient demand of each crop. Bokashi compost and cow manure appear to be more effective in promoting the growth and yield of spinach, carrots and peas. In contrast, inorganic fertilisers are generally fast-dissolving and provide plants with nutrients immediately, as they deliver precise and readily available nutrients. These characteristics make inorganic fertilisers extremely ideal for those crops that need instant nutrient uptake, such as spinach. Therefore, they are also more effective, especially when used in a controlled manner to avoid the negative effects on the environment mentioned earlier (Basavegowda & Baek, 2021). From the results, it can be deduced that inorganic fertilisers foster growth and productivity in spinach and carrots, but the impact is not observed in pea plants.

Conclusion

The findings of this paper compare the efficiency of vermicompost, bokashi compost, cow manure and inorganic fertiliser for plant growth using spinach, carrots and peas as model crops. The experiment was conducted from June 2022 to August 2022. The vermicompost used for this experiment was obtained from Amele Recycling, a worm farm at Ncambedlana, Mthatha. The bokashi compost used in this study was prepared by the researcher. The cow dung was obtained from one of the households in Zandukwane after asking for permission from the owner of the cows. The inorganic fertiliser was bought from Umtiza Farmers' Corp at Mthatha. To determine whether there was a significant difference between the four different fertilisers used in this study, SPSS was used, and the measured plant growth parameters were subjected to analysis of variance at $p=0.05$.

It can be concluded from the results of this study that vermicompost, bokashi compost, cow manure and inorganic fertilisers have advantages in promoting plant growth. In addition to slow-release nutrients, organic amendments like vermicompost and cow manure help with the improvement of soil fertility, soil structure and microbial activity. Bokashi compost offers similar benefits through anaerobic fermentation. Inorganic fertilisers provide precise and readily available nutrients but may not contribute as much to long-term soil health. What fertiliser to apply strictly depends on factors such as the plant species, soil conditions, nutrient requirements and the desired long-term effects on soil health.

In this comparative field study, it has been determined that vermicompost, bokashi compost and cow manure have different levels of efficacy in terms of plant growth stimulations and yield enhancement for spinach, carrots and peas. These organic fertilisers offer favourable alternatives to inorganic fertilisers for sustainable vegetable cultivation. Compost types that are more favourable to the desired crop and soil properties can be selected by farmers based on the results, thereby optimising growth and yield. Vermicompost is resourceful across a range of crops, as its benefits are noticeable in both root and leafy vegetables. Vermicompost is ideal for farmers aiming to enhance soil health and plant vitality over time. Bokashi compost is efficient for increasing the height and branching of plants; therefore, it is beneficial for crops like carrots and spinach, which require robust root and leaf systems. Farmers growing leafy vegetables or root crops might find bokashi compost to be an ideal choice. Cow manure proved to be well suited for leguminous crops like peas and increased pod yield and growth as it releases balanced nutrients and improves soil condition. Farmers growing legumes and other nutrient-demanding crops can benefit from cow manure's slow nutrient release.

However, there are some limitations in the present study which need to be noted. Firstly, the experiment was carried out on a small plot size which might not translate well to larger scale farming norms in specific. Secondly, the study only focused on three crop types, and hence, the results may not be inferred from other vegetables or crop species with different nutrient requirements and parameters.

It is recommended that organic-based fertilisers be used as an alternative to inorganic fertilisers. Vermicompost, bokashi compost and cow manure are recommended in this study as they are ecologically friendly as compared to the inorganic fertilisers hence enhancing a good soil structure, improving the organic matter content and promoting beneficial soil microorganisms. They help to create a fertile soil environment that supports plant growth and maintains long-term soil productivity. In addition, the balanced nutrient content and improved soil conditions provided by vermicompost, bokashi compost and cow manure promote healthy plant growth and development. This study has proven that they lead to higher crop yields and better crop quality.

The studied three types of organic-based fertilisers are recommended to farmers as they enable the recycling of organic waste that would otherwise end up in landfills. This, in turn, makes for the minimum waste production, fosters and goes well with circular economic principles, as well as improved waste management. Lastly, vermicompost, bokashi compost, and cow manure are among the groups of fertilisers that entail significantly lower costs than inorganic fertilisers, particularly when they are locally sourced or produced. Vermicompost and bokashi compost can be produced from organic household or farm waste, which supports recycling efforts and reduces costs. Inorganic fertilisers are relatively expensive than organic-based fertilisers due to manufacturing and distribution costs. Accordingly, where local sources were employed in this study, the cost of using cow manure sourced from neighbouring households had comparatively the least direct costs. Vermicompost and bokashi compost, which were made in-house, required minimal financial investment. This cost-effectiveness of organic composts makes them viable, long-term solutions for cost-conscious and environmentally mindful farmers. Further research is needed to investigate the long-tern impacts of these organic fertilisers on soil health, particularly regarding microbial diversity and soil structure over multiple growing seasons.

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Declaration of Interest Statement

The authors declare that they have no conflict of interest.

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