



Research Article

Maximizing Vegetable Growth Potential: Evaluating the Synergistic Impact of Vermicompost and NPK Fertilizer Amended Soil

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Abstract | The beneficial effects of Vermicompost (VC) as an organic fertilizer on the growth and yield of plants are well studied. However, studies related to its utilization and effect in combination with reduced chemical fertilizers on plant growth are still limited. Therefore, this experiment was conducted to evaluate the effect of varying levels of VC (0 and 2.5 tons/ha) and NPK (60:80:60 kg/ha or RDF, 75% RDF, 50% RDF, 25% RDF) fertilizers on the growth and yield of spinach, peas, and radish. In a Randomly Complete Block Design (RCBD), the soil for each plot was amended with different VC concentrations before sowing the seeds. The data collected was subjected to ANOVA at 5% level of significance. VC substitution (T_1) in soil was helpful in enhancing the overall growth of all three vegetables as compared to control (T_0). NPK alone (T_2) was more helpful and further enhanced the vegetative growth as well as the yield of the studied vegetable plants. T_3 as a combined VC and NPK treatment caused more enhancement in the growth of vegetable plants. With the increased VC and reduced NPK in T_4 , all three vegetable plants behaved significantly and depicted maximum yield as compared to T_0 . Whereas, T_5 and T_6 showed a gradual decline in the growth and yield of spinach, peas, and radish as compared to T_4 . The results of this experiment suggest that 1.5 tonnes of VC per hectare of land is best suitable for vegetable production in clay loam soils of district Chakwal.

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Keywords | Vermicompost, Inorganic fertilizers, Radish, spinach, Peas, Growth



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Introduction

The use of inorganic fertilizers to enhance crop growth and yield is a widely adopted practice and

is increasing with the increase in demand for food. Recent studies demonstrated that the long-term use of these synthetic fertilizers negatively affects food quality and also soil communities (Chew *et al.*, 2019;

Ye *et al.*, 2020) (Alternatively, organic fertilizers are used which are helpful in enhancing the nutrient content of the food and improving crop production as well (Souri and Sooraki, 2019; Elsa and Desmond, 2021). Organic fertilizers also supply large amounts of inorganic Nitrogen (N) in the form of NH_4^+ and NO_3^- , and Carbon (C) compounds which collectively enhance the activities of various microorganisms (Zhu *et al.*, 2013; Zhang *et al.*, 2015). Therefore, compared with chemical fertilizers, organic fertilizers are more advantageous for soil C and N accumulation. A sole application of organic fertilizer increases available mineral content and their activation efficiency (Liang *et al.*, 2016; Shi *et al.*, 2014). This fertilization-based positive effect on the productivity of *Triticum aestivum* (Hafez *et al.*, 2021), rice (Huang *et al.*, 2015), *Brassica juncea* (Anggraeni *et al.*, 2022) Lettuce and tomato (Arancon *et al.*, 2019) has already been studied.

Organic fertilizers are complex compounds that add numerous micro and macro-nutrients to the soil and also enhance its structure. One of the many advantages of organic fertilizers is also that the source materials are easily available such as farmyard manure (FYM), plant materials, human excreta, food wastes, etc. (Assefa and Tadesse, 2019) These sources are also classified as non-hazardous organic wastes which are eco-friendly and financially favourable raw materials (Samal *et al.*, 2019; Ahmad *et al.*, 2021). This organic waste is processed to prepare composts such as vermicompost. Vermicompost is prepared through a technique called vermicomposting which involves the use of earthworms (*Eisenia fetida*) that convert agricultural organic wastes into valuable nutrients and metabolites (Bhat *et al.*, 2018; Maharjan *et al.*, 2022).

The nutrient content of the VC and its positive effects on the crops are directly related to the type of agricultural waste used during its preparation (Wang *et al.*, 2021). The beneficial effect includes a higher germination rate, efficient growth, protection from diseases and pathogens, enhanced yield, etc (Ahirwar and Hussain, 2015). At the same time, consumers are increasingly aware of the adequate proportions of vitamins, dietary fibres, and various other nutrients in vegetables. Such quality vegetable production requires nutrient-rich soils (Ievinsh, 2011; De Corato, 2020). Some practices to increase the food's nutrient contents include the use of nutrient supplementation, biofortification, organic fertilizers, etc. Organic fer-

tilizers including VC improve the uptake of various essential nutrients such as N, K, P, Ca, Mg, and S as compared to other fertilizers (Singh *et al.*, 2020; Verma *et al.*, 2018).

In light of these findings, limited knowledge is available on the use of VC together with relatively lower doses of NPK and its effect on the growth and production of vegetables. This study aims to determine the effect of VC and NPK fertilizers as well as the effective combination doses of VC and NPK fertilizers. Therefore, the experiment is based on the hypothesis that VC and NPK-amended soils enhance the growth and yield-related attributes of spinach, peas, and radish as compared to non-amended soils by enhancing the biochemical properties of soil and morphological attributes of the vegetables. However, optimizing plant nutrition in fruit crops and their effective management strategies also require more attention.

Materials and Methods

Experimental site and design

The experimental study was carried out on the experimental site of Barani Agricultural Research Institute (BARI) Chakwal (32°55'33"N, 72°43'30"E) from October 2022 to January 2023. The study was conducted to evaluate the effect of VC, alone and in combination with NPK, on the growth of spinach (*Spinacia Oleracea*), peas (*Pisum sativum*), and radish (*Raphanus raphanistrum*) separately. Before the start of the trial, soil samples were collected from 0-15 cm depths and subjected to the analysis of various physio-chemical properties of the soil presented in Table 1.

Table 1: Physico-chemical properties of the soil collected from the experimental area.

Parameter	Unit	Observation
pH		7.8
Electrical conductivity	dS/m	0.74
Organic matter	%	0.28
Nitrogen	mg/kg	3.2
Phosphorus	mg/kg	2.7
Potassium	mg/kg	106
Textural class	Clay loam	

The experiment was laid out in RCBD with 7 treatments and 3 replications in a plot size of 3 x 7 m² for each vegetable. Seven treatments of the fertilizer mix

were as follows:

1. T_0 Control ($VC_0N_0P_0K_0$)
2. T_1 2.5 tons of Vermicompost/ha ($VC_{2.5}$)
3. T_2 60:80:60 kg/ha NPK (Recommended Dose of Fertilizer/RDF)
4. T_3 T_1 + RDF
5. T_4 T_1 + 75% RDF
6. T_5 T_1 + 50% RDF
7. T_6 T_1 + 25% RDF

After 24 hours of the fertilizer mix in the soil, 35 seeds of each vegetable were sown on the top ridges with a row-to-row distance of 30 cm and plant-to-plant distance of 8 cm. Seeds of the spinach (Desi Palak), peas (Barani Matar), and radish (Mino) were provided by The Vegetable Section of BARI Chakwal. Plants were irrigated with the help of bore water as and when needed. All the weeds grown were removed manually. The monthly variation in the climatic conditions during the trial period from 2022 to 2023 is shown in Figure 1. The data for rainfall and the changes in temperature ($^{\circ}C$) throughout a month was recorded by the meteorological system of the BARI Chakwal. It is obvious from the Figure 1. that rainfall was very low during our experimental period as the highest recorded rainfall was 1.2 mm/day during November 2022. Whereas the temperature was continuously decreasing and the highest minimum recorded temperature was $8.75^{\circ}C$ during January 2023.

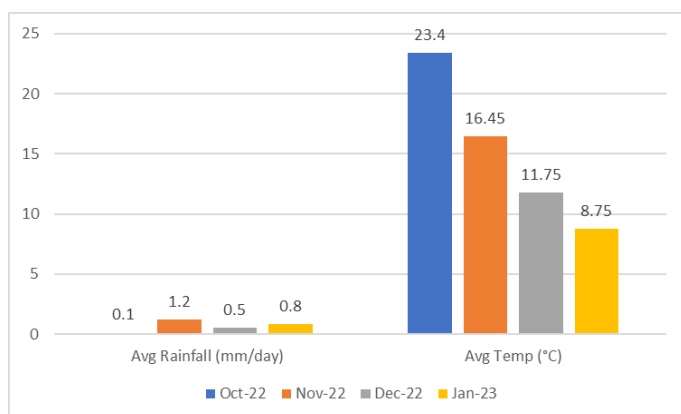


Figure 1: Average Rainfall and Temperature variation during October 2022 – January 2023.

Data collection

For data collection 5 randomly selected plants from each treatment were uprooted for the estimation of the effect of VC and NPK on its growth. For spinach 50 days after sowing (DAS) plant height (cm), plant fresh weight (g), leaf fresh weight (g), number

of primary branches, and yield (kg/ha) were recorded. 80 DAS (mid-December), 5 pea plants were selected independently to measure the plant height (cm), pod fresh weight (g), No. of pods/plant, pod length (cm), 100 seed weight (g), and the yield (kg/ha) were measured. However, the root length (cm), root weight (g), shoot length (cm), leaf weight (g), no. of leaves/plant, and the yield (kg/ha) of radish were measured 115 DAS (End-January).

All the plant heights and lengths were measured with the help of meter tape from ground level to the tip of the plant. The fresh weight of the plants was calculated using a digital weighing balance. The data on the yield was recorded by harvesting the whole plot of $3 \times 7 m^2$ and converted in kg/ha.

Data analysis

The data were collected and recorded in Microsoft Excel (Version 2019). Some simple statistical analyses were also performed using MS Excel. To test the significance of the treatments, ANOVA was applied at a 0.05 level of significance with the help of Statistix 8.1 software. The significant means of the recorded data were differentiated using the LSD test.

Results and Discussion

Effect of vc and npk on the growth of spinach

The data collection for spinach showed that the leaf fresh weight was significantly ($p < 0.01$) influenced under T_4 as compared to the control (Table 2). All the other parameters such as the plant height, plant fresh weight, and no. of primary branches insignificantly differed. The average minimum plant height (12.7 cm), plant fresh weight (2.63 g), leaf fresh weight (2.4 g), and No. of primary branches (4.8) was observed in the control conditions (Table 2). Spinach plants under T_1 showed enhanced growth in all parameters when compared to the growth of control plants. T_1 had the highest effect on No. of primary branches which has disclosed an increase of 33% as compared to T_0 . T_2 was also helpful in further enhancing the overall growth of spinach plants specifically in terms of plant fresh weight (69%) and leaf fresh weight (73%) in comparison to control. T_3 also boosted the average growth of spinach showing a minimum of 32% increase in the plant height and a maximum of 124% in leaf fresh weight. However, the maximum increase in these parameters was recorded under T_4 followed by T_5 . Interestingly, when T_6 was applied, there was

Table 2: Effect of varying doses of Vermicompost and NPK fertilizer on the growth performance of spinach with respect to means $\pm$ SE values.

Treatments	Plant Height (cm)	Plant fresh weight (g)	Leaves Fresh weight (g)	No. of Primary branches
T ₀	12.8 $\pm$ 1.2 d	2.6 $\pm$ 0.4 b	2.4 $\pm$ 0.3 c	4.8 $\pm$ 0.7 c
T ₁	14.3 $\pm$ 0.6 cd	3.3 $\pm$ 0.5 ab	2.9 $\pm$ 0.6 c	6.4 $\pm$ 0.6 bc
T ₂	16.0 $\pm$ 1.0 bc	4.5 $\pm$ 0.8 ab	4.2 $\pm$ 0.9 bc	7.4 $\pm$ 0.6 b
T ₃	16.9 $\pm$ 0.7 ab	5.6 $\pm$ 0.6 ab	5.4 $\pm$ 0.6 ab	8.6 $\pm$ 0.9 b
T ₄	19.0 $\pm$ 1.0 a	7.2 $\pm$ 0.9 a	7.0 $\pm$ 1.0 a	12.2 $\pm$ 1.2 a
T ₅	18.6 $\pm$ 0.6 a	6.5 $\pm$ 1.0 ab	6.4 $\pm$ 1.0 a	11.8 $\pm$ 1.2 a
T ₆	15.2 $\pm$ 0.4 bc	5.5 $\pm$ 0.9 ab	5.2 $\pm$ 0.9 ab	8.6 $\pm$ 1.0 b

Table 3: Effect of varying doses of Vermicompost and NPK fertilizer on the growth performance of Peas with respect to means $\pm$ SE values.

Treatments	Plant Height (cm)	Pod fresh weight (g)	No. of Pods per Plant	Pod Length (cm)	100-seed weight (g)
T ₀	42.7 $\pm$ 1.6 b	1.5 $\pm$ 1.5 c	22.6 $\pm$ 1.9 d	6.0 $\pm$ 0.5 d	34.9 $\pm$ 1.5 d
T ₁	50.6 $\pm$ 1.0 c	2.1 $\pm$ 1.6 d	25.6 $\pm$ 1.7 cd	8.3 $\pm$ 0.7 c	42.1 $\pm$ 1.4 c
T ₂	55.0 $\pm$ 2.4 d	1.5 $\pm$ 1.8 c	28.6 $\pm$ 1.0 bc	9.5 $\pm$ 0.4 bc	45.8 $\pm$ 1.4 c
T ₃	58.3 $\pm$ 1.4 b	1.5 $\pm$ 1.6 b	31.2 $\pm$ 0.9 ab	10.8 $\pm$ 0.6 b	52.1 $\pm$ 1.3 b
T ₄	65.6 $\pm$ 0.6 a	1.9 $\pm$ 2.4 a	33.2 $\pm$ 1.2 a	12.4 $\pm$ 0.8 a	57.7 $\pm$ 3.0 a
T ₅	63.8 $\pm$ 0.8 a	1.1 $\pm$ 1.7 ab	30.2 $\pm$ 1.7 ab	12.3 $\pm$ 0.6 a	54.8 $\pm$ 2.4 ab
T ₆	55.2 $\pm$ 1.8 b	2.6 $\pm$ 2.0 c	29.2 $\pm$ 0.8 ab	10.2 $\pm$ 0.2 b	53.4 $\pm$ 2.4 b

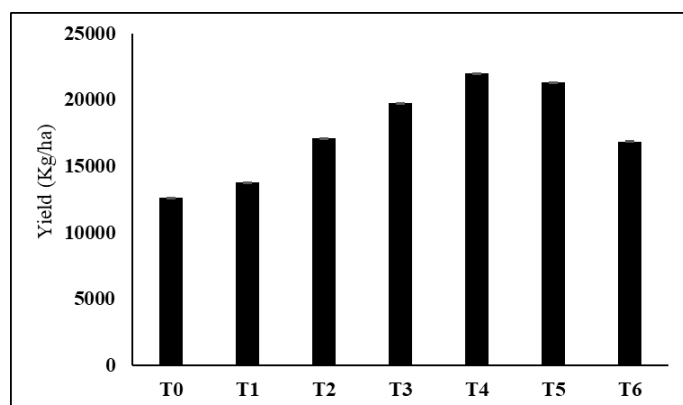


Figure 2: Effect of different doses of Vermicompost and NPK fertilizer on the spinach yield (Kg/ha). Where T₀= Control; T₁= VC@2.5t/ha; T₂= NPK@60:80:60 Kg/ha (RDF); T₃= T₁ + RDF; T₄= T₁ + 75% RDF; T₅= T₁ + 50% RDF; T₆= T₁ + 25% RDF.

a reduction in the plant height (20 and 18%), plant fresh weight (23 and 18%), leaf fresh weight (25 and 18%), and no. of primary branches (29 and 27%) as compared to T₄ and T₅, respectively.

The overall biomass of the spinach was recorded as its yield (kg/ha) presented in **Figure 2**. Increasing dosages of VC depicted an enhancement in the yield as compared to control conditions. ANOVA indicated that the spinach yield behaved highly significantly

(P<0.001) under VC and NPK. It is evident from **Figure 2**, that the highest spinach yield (21996 kg/ha) was obtained from the plots supplied with VC and 50% NPK, closely followed by 21337 kg/ha under T₅. The application of VC and NPK under T₆ reduced the yield (16887 kg/ha under T₆) by 21% as compared to T₅. Generally, the yield under T₁ was enhanced by 8% than control.

Effect of vc and npk on the growth of peas

Statistical analysis of the data collected for peas showed that the T₄ had a significant (p< 0.05) effect on all the plant parameters including plant height, pod fresh weight, No. of pods per plant, pod length, 100-seed weight, and pod length (**Table 3**). Whereas plant height and pod length also behaved significantly under T₅ as well. VC alone and in combination with NPK increased the overall pea growth and yield in comparison to control conditions (T₀). Upon the application of T₁, the highest increase of 38% was observed in the pod length whereas a minimum increase of 16% was observed in pod fresh weight as compared to the control condition. Again, pod length showed a maximum increase of 106% in T₄, followed by 105% in T₅. This enhancement in the pea plants was increased with the application of NPK as follows T₄> T₃> T₂> T₁. However, with the increase in VC dose at

the T_5 and T_6 the pea growth-related parameters were slightly decreased in comparison to T_4 . Maximum decrease was observed in T_6 as 16, 19, 10, 17, and 7% decrease in the plant height, pod fresh weight, No. of pods per plant, pod length, and 100-seed weight, respectively, as compared to T_4 .

Pea yield (kg/ha) was calculated as the fresh weight of the pods in each treatment. Pea yield differed significantly ($P < 0.001$) under VC and NPK (Figure 3). The highest pea yield of 16241 kg/ha was recorded under T_4 and 15351 kg/ha under T_5 . Whereas, under no application of VC or NPK the lowest pea yield of 8792 kg/ha was obtained. The average pea yield obtained with alone VC application (T_1) was calculated as 10915 kg/ha which is 24% higher than the control conditions but is reduced by 10% in comparison to T_2 .

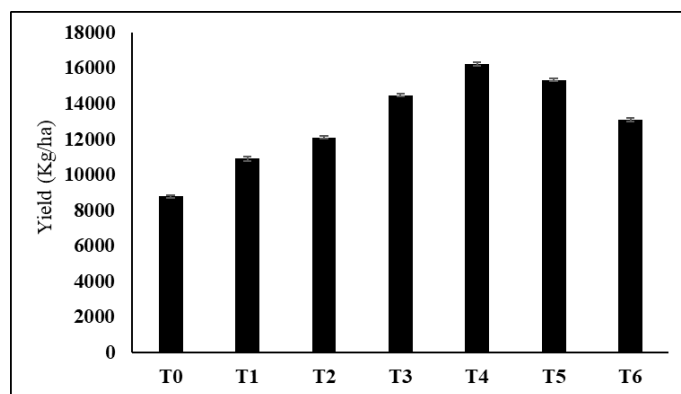


Figure 3: Effect of different doses of Vermicompost and NPK fertilizer on the pea yield (Kg/ha). Where T_0 = Control; T_1 = VC@2.5t/ha; T_2 = NPK@60:80:60 Kg/ha (RDF); T_3 = T_1 + RDF; T_4 = T_1 + 75% RDF; T_5 = T_1 + 50% RDF; T_6 = T_1 + 25%RDF.

Effect of vc and npk on the growth of radish

The data regarding the growth of radish plants revealed that the T_4 caused a highly significant ($P < 0.01$) enhancement in the leaf fresh weight, No. of leaves per plant, and root length. Whereas root weight and shoot length behaved only slightly significantly under T_4 (Table 4). T_1 showed positive results on the overall growth of the radish. An 18, 11, 36, 14, and 17% increase in the root length, root weight, shoot length, leaf fresh weight, and No. of leaves per plant, respectively, as compared to control. The sole addition of NPK (T_2) exhibited enhancement in the growth parameter as compared to T_0 and T_1 . The highest increase (55%), under T_2 , was observed in the shoot length of radish, in contrast to T_0 . As the VC dose increased in the T_3 and T_4 , the average growth rate

of the radish plants also increased, accordingly. The maximum increase under T_3 was observed for shoot length i.e., 98%, and the minimum increase under T_4 was recorded for root weight i.e., 33%, when compared with T_0 . However, with the further increase in VC under T_5 , all of the parameters recorded for radish revealed a reduction which is followed by an even more decrease under T_6 . The reduction in T_5 was observed as follows: Root length 13%, root weight 9%, shoot length 22%, leaf fresh weight 16%, and No. of leaves per plant 23% as compared to T_4 . Similarly, a further decrease of 5, 7, 19, 8, and 10% was recorded in root length, root weight, shoot length, leaf fresh weight, and no. of leaves per plant, respectively, under T_6 as compared to T_5 .

Data revealed that there was a significant ($P < 0.001$) difference in the radish yield (kg/ha) under VC and NPK application (Figure 4). It was observed that the yield obtained from maximum to lowest was 52002, 50217, 49347, 47543, 46662, 43551, and 38229 kg/ha under T_4 , T_5 , T_3 , T_6 , T_2 , and T_1 , respectively. The Fig. 4 shows that the radish yield attained under T_4 was 36% higher as compared to T_0 . However, the minimum increase (14%) in the radish yield was observed in T_1 as compared to control.

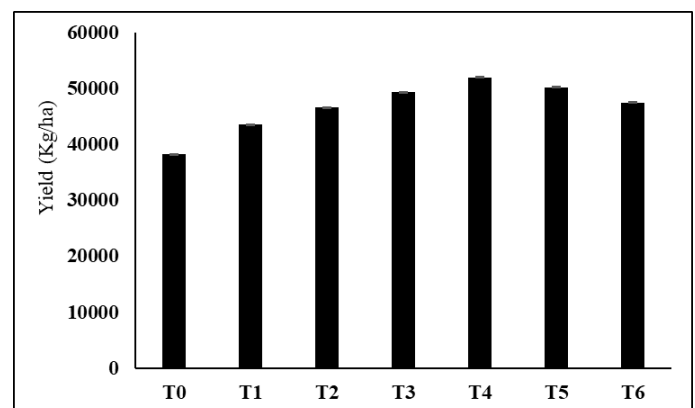


Figure 4: Effect of different doses of Vermicompost and NPK fertilizer on the radish yield (Kg/ha). Where T_0 = Control; T_1 = VC@2.5t/ha; T_2 = NPK@60:80:60 Kg/ha (RDF); T_3 = T_1 + RDF; T_4 = T_1 + 75% RDF; T_5 = T_1 + 50% RDF; T_6 = T_1 + 25%RDF.

The current study was intended to evaluate the effect of VC and NPK, both alone and in combination, on the growth and yield of spinach, peas, and radish. Generally, the effect of VC (T_1) was highly positive on the growth of vegetables in comparison to control conditions (T_0) but a little negative in relation to NPK fertilizer (T_2). Overall, the growth rate under different treatments was as follows: $T_0 < T_1 < T_2 < T_3$

Table 4: Effect of varying doses of Vermicompost and NPK fertilizer on the growth performance of Radish with respect to means $\pm$ SE values.

Treatments	Root Length (cm)	Root weight (g)	Shoot Length (cm)	Leaf Fresh weight (g)	No. of leaves per plant
T ₀	17.5 $\pm$ 1.4 d	130.8 $\pm$ 2.2 e	11.4 $\pm$ 1.3 d	67.6 $\pm$ 2.7 d	10.6 $\pm$ 0.6 d
T ₁	20.7 $\pm$ 0.8 c	145.0 $\pm$ 2.7 d	15.5 $\pm$ 2.5 cd	77.0 $\pm$ 3.6 cd	12.4 $\pm$ 1.0 cd
T ₂	22.8 $\pm$ 1.0 abc	155.8 $\pm$ 4.5 cd	17.7 $\pm$ 2.1 c	88.6 $\pm$ 5.5 bc	13.8 $\pm$ 0.8 bc
T ₃	24.8 $\pm$ 0.9 ab	167.0 $\pm$ 6.3 ab	22.6 $\pm$ 0.8 ab	94.8 $\pm$ 6.5 ab	15.6 $\pm$ 0.8 ab
T ₄	25.8 $\pm$ 1.2 a	174.2 $\pm$ 2.6 a	24.4 $\pm$ 1.9 a	102.4 $\pm$ 8.1 a	17.2 $\pm$ 1.3 a
T ₅	23.7 $\pm$ 0.8 abc	170.4 $\pm$ 4.6 a	23.3 $\pm$ 2.2 ab	93.4 $\pm$ 3.1 ab	14.6 $\pm$ 1.4 abc
T ₆	22.5 $\pm$ 1.4 bc	150.8 $\pm$ 6.6 bc	18.9 $\pm$ 1.9 bc	86.0 $\pm$ 4.2 bc	13.2 $\pm$ 1.6 bcd

$< T_4 > T_5 > T_6$. This trend suggests that the effect of organic fertilizers such as VC depends on the dose applied.

In the present study, the spinach growth was calculated in terms of plant height, plant fresh weight, leaf fresh weight, and no. of primary branches. The soil VC treatment (T₁) was highly advantageous for the growth of spinach plants as compared to control plants. Increasing the dose of VC and its application in combination with NPK was even more beneficial. But the highest treatments of VC i.e., T₅ and T₆ showed a reduced growth as compared to T₄ (Table 2). Similar results were reported in a study by Raksun *et al.* (2022), in which spinach (*Amaranthus tricolor*) depicted maximum growth up to a specific level (1.8 kg VC/m²) and did not show a significant effect on a higher dose (2.4 kg VC/m²). Another study conducted on tomato has shown that VC-amended soils with higher doses (0.8 g/g) produce plants with a greater number of leaves, taller height, higher plant fresh weight, and increased photosynthesis rate (Zucco *et al.*, 2015).

This improved growth rate is generally attributed to the richness of VC in essential mineral ions also readily available for plant growth. VC also improves the soil structure, porosity, and water-holding capacity (Chatterjee *et al.*, 2020; Olivares *et al.*, 2017). The VC-mixed soils also release various phytohormones, humic substances, leachates, etc. which are extremely effective in plant growth (Ravindran *et al.*, 2016; Amooaghaie and Golmohammadi, 2017). In this study, VC was also beneficial in enhancing the overall spinach yield as compared to the control but NPK had a more promising effect on spinach yield (Figure 2). This can be due to the fact that Nitrogen (N) is most crucial in significantly enhancing the growth and yield of spinach by improving the physiological

and biochemical attributes of the plants (Islam *et al.*, 2020; Leghari *et al.*, 2016).

VC effect has also been studied to stimulate root growth and aid in more nutrient uptake ultimately improving the shoot growth and overall plant biomass (Rehman *et al.*, 2023; Vuković *et al.*, 2021). This finding justifies the significant growth of radish root length and root weight under T₁, T₃, and T₄, in the current experiment (Table 4). Similarly, a higher growth rate in radish under VC treatment was reported by (Akay, 2019; Kumar *et al.*, 2018; Maduwanthi *et al.*, 2021). Maximum radish yield due to VC integration has also been reported by Kumar and Gupta (2018), explaining it due to the advantageous soil microbes observed in the VC-amended soils. A similar effect of VC to increase the radish average biomass has also been reported by (Dulal *et al.*, 2021; Kushwah *et al.*, 2020).

A meta-analysis by Blouin *et al.* (2019) revealed that the plant biomass, root and shoot fresh weights are dependent on the lower to medium doses (20-60%) of VC. This analysis also described that adding >60% can decline the plant growth which might be due to overproduction of the phytohormones and root exudates which results in compacted soil or any other reason for negative plant growth. In our present studies, the further increase in the VC i.e., >50% did not enhance the average growth of spinach, peas, and radish. A slightly negative effect on the growth of all three vegetable plants was observed under T₅ and T₆ (Table 2, 3 and 4). These results are in accordance with the reduced vegetative growth of *Linum usitatissimum* under 60, 80, and 100% VC used (Makkar *et al.*, 2017). In a comparative study between varying doses of vermicompost and urea again suggested that moderate VC doses (50%) result into optimum yields of *Momordica charantia* (Ghimire *et al.*, 2023).

In our study, peas exhibited positive growth behaviour in terms of plant height, pod length and fresh weight, and No. of pods per plant upon application of VC alone (T_1) and in combination with NPK (T_3 and T_4) as compared to T_0 (Table 3). This significant effect of VC on the growth of peas (*Pisum sativum*) has also been investigated by Jolly *et al.* (2022), Akinnuoye-Adelabu *et al.* (2019) and Jiang *et al.* (2023), in *Vigna radiata* and *Vigna mungo* by Bhattacharya *et al.* (2019). However, a decline in the pea growth under T_5 and T_6 as compared to T_4 (Table 3) might be due to the fact that the higher doses of VC cause an increased ammonium content in the soil which hampers root nutrient absorption (Makkar *et al.*, 2017; Atiyeh *et al.*, 2000). It is well known that reduced nutrient uptake ultimately negatively affects plant growth.

Conclusions and Recommendations

Based on the findings of the current study, it can be deduced that

1. Lower to moderate doses of VC are optimum for the growth of spinach, pea, and radish
2. Higher doses of VC improve the overall plant growth than control but is slightly reduced than optimum growth, and
3. All of the growth-related parameters of pea (*Pisum sativum*) exhibited maximum of significant behaviour under VC treatment than spinach and radish. Thus, the use of 45-55% of VC together with a mild inorganic fertilizer is recommended for the maximum growth of vegetables. Consequently, the dose of VC should be carefully chosen before sowing. Therefore it would be helpful in enhancing the average growth and overall yield of vegetables and therefore should be further evaluated for its effect on the quality of the vegetables and other crops.

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Novelty Statement

Integrated application of vermicompost and mineral fertilizers results in improved yield of vegetables.

Author's Contribution

Sairah Syed and Muhammad Arsalan: Conceived the idea, designed and experiment.

Rafia Urooj Saman and Abdul Latif: Conducted experiment and paper writeup.

Madeeha Khan: Data recording, paper writeup, overall management of the article.

Ayesha Manzoor: Data recording, paper writeup.

RehmatUllah, Muhamad Bilal, Rizwan Latif: Overall management of the article.

Rizwan Latif, Ijaz Ahmad, Muhammad Amjid, Muhammad Aslam and Aaima Masood: Statistical analysis of data and arranging figures and tables.

Sair Sarwar and Sabir Hussain Shah: Technical inputs.

Conflict of interest

The authors have declared no conflict of interest.

References

- Ahirwar, C.S., and A. Hussain. 2015. Effect of vermicompost on growth, yield and quality of vegetable crops. *Intl. J. Appl. Pure Sci. Agric.*, d1(8):49-56.
- Ahmad, A., Z. Aslam, K. Bellitürk, N. Iqbal, S. Naeem, M. Idrees, Z. Kaleem, M.Y. Nawaz, M. Nawaz, M. Sajjad, and W.U. Rehman. 2021. Vermicomposting methods from different wastes: an environment friendly, economically viable and socially acceptable approach for crop nutrition: a rev. *Int. J. Food Sci. Agric.*, 5:58-68. <https://doi.org/10.26855/ijfsa.2021.03.009>
- Akay, A. 2019. The effect of NPK fertilizer and vermicompost application on plant growth and the nutrient contents of Radish (*Raphanus Sativus* L.). *Turk. J. Agric. Food Sci., Tech.*, 7(12):2259-2263. <https://doi.org/10.24925/turjaf.v7i12.2259-2263.3029>
- Akinuoye-Adelabu, D.B., S. Steenhuisen, and E. Bredenhend. 2019. Improving pea quality with vermicompost tea and aqueous biochar: Prospects for sustainable farming in Southern Africa. *S. Afr. J. Bot.*, 123:278-285. <https://doi.org/10.1016/j.sajb.2019.03.009>
- Amooaghaie, R., and S. Golmohammad. 2017. Effect of vermicompost on growth, essential oil, and health of *Thymus Vulgaris*. *Compost Sci. Utilization*. 25(3):166-177. <https://doi.org/10.1080/1065657X.2016.1249314>

- Anggraeni, A.Y., A. Raksun, and I.G. Mertha. 2022. The effect of vermicompost and NPK fertilizer on the growth of green Mustard (*Brassica Juncea* L.). J. Biol. Tropis. 22(2):525-533. <https://doi.org/10.29303/jbt.v22i2.3381>
- Arancon, N.Q., J.D. Owens, and C. Converse. 2019. The effects of vermicompost tea on the growth and yield of lettuce and tomato in a non-circulating hydroponics system. J. Plant Nutr., 42(19):2447-2458. <https://doi.org/10.1080/01904167.2019.1655049>
- Assefa, S., and S. Tadesse. 2019. The principal role of organic fertilizer on soil properties and agricultural productivity -A Rev. Agric. Res. Tech., Open Access J., 22(2):556. <https://doi.org/10.19080/ARTOAJ.2019.22.556192>
- 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. Pedobiol., 44(5): 579-590. [https://doi.org/10.1078/S0031-4056\(04\)70073-6](https://doi.org/10.1078/S0031-4056(04)70073-6)
- Bhat, S.A., J. Singh, and A.P. Vig. 2018. Earthworms as organic waste managers and biofertilizer producers. Waste Biomass Valorization, 9(7):1073-1086. <https://doi.org/10.1007/s12649-017-9899-8>
- Bhattacharya, S., S. Debnath, S. Debnath, and A.K. Saha. 2019. Effects of vermicompost and urea on the seed germination and growth parameters of *Vigna mungo* L. and *Vigna radiata* L. Wilzek. J. Appl. Nat. Sci., 11(2):321-326. <https://doi.org/10.31018/jans.v11i2.2052>
- Blouin, M., J. Barrere, N. Meyer, S. Lartigue, S. Barot, and J. Mathie. 2019. Vermicompost significantly affects plant growth. A meta-analysis. Agron. Sustain. Dev., 39(4): 34. <https://doi.org/10.1007/s13593-019-0579-x>
- Chatterjee, R., A. Debnath, and S. Mishra. 2020. Vermicompost and Soil Health. In: Giri, B., and A. Varma (eds.). Soil Health. Springer Nature, Switzerland. p. 69-88. https://doi.org/10.1007/978-3-030-44364-1_4
- Chew, K.W., S.R. Chia, H.W. Yen, S. Nomanbhay, Y.C. Ho and P.L. Show. 2019. Transformation of biomass waste into sustainable organic fertilizers. Sustainability, 11(8):2266. <https://doi.org/10.3390/su11082266>
- Dulal, D., D. Baral, A. Poudel, K. Kafle, and B. Shrestha. 2021. Effect of different doses of vermicompost on growth, yield and quality of radish (*Raphanus sativus* L. cv. Mino Early). Archives Agric. Environ. Sci. 6(3):354-359. <https://doi.org/10.26832/24566632.2021.0603014>
- Elsa, C., and G.M. Desmond. 2021. Vermicompost soil amendment influences yield, growth responses and nutritional value of Kale (*Brassica oleracea* Acephala group), Radish (*Raphanus sativus*) and Tomato (*Solanum lycopersicum* L.). J. Soil Sci. Environ Manage., 12(2):86-93. <https://doi.org/10.5897/JSSSEM2021.0873>
- Ghimire, S., D. Dhami, A. Shrestha, J. Budhathoki, M. Maharjan, S. Kandel, and B.P. Chhetri, B. 2023. Effectiveness of different combinations of urea and vermicompost on yield of bitter melon (*Momordica charantia*). Heliyon, 9(8):e18663. <https://doi.org/10.1016/j.heliyon.2023.e18663>
- Hafez, E.M., A. E.D., Omara, F.A. Alhumaydhi, and M.A.E. Esawi. 2021. Minimizing hazard impacts of soil salinity and water stress on wheat plants by soil application of vermicompost and biochar. Physiol. Plant, 172(2): 587-602. <https://doi.org/10.1111/ppl.13261>
- Huang, J., Y. Zhang, J. Gao, W. Zhang, and S. Liu. 2015. Variation characteristics of soil carbon sequestration under long-term different fertilization in red paddy soil. Chin. J. Appl. Ecol., 26(11): 3373-3380.
- Levinsh, G. 2011. Vermicompost treatment differentially affects seed germination, seedling growth and physiological status of vegetable crop species. Plant Growth Regul., 5(1): 169-181. <https://doi.org/10.1007/s10725-011-9586-x>
- Islam, M., Akther, S. Ahmed, A. Karim, and K. Rahman. 2020. Effects of vermicompost and PK on growth and protein content of spinach (*Spinacia oleracea* L.). Bangladesh J. Bot., 49(1): 141-146. <https://doi.org/10.3329/bjb.v49i1.49121>
- Jiang, X., C. Lu, R. Hu, W. Shi, L. Zhou, P. Wen, Y. Jiang, and Y.M. Lo. 2023. Nutritional and microbiological effects of vermicompost tea in hydroponic cultivation of maple peas (*Pisum sativum* var. arvense L.). Food Sci. Nutrition. 11(6):3184-3202. <https://doi.org/10.1002/fsn3.3299>
- Jolly, S., H.S. Yadav, and V. Sharma. 2022. Response of integrated nutrient management (INM) on growth and yield parameters of Pea (*Pisum sativum*) crop. The Pharm. Innov. J., 11(5):

2481-2485.

- Kumar, A. and R.K. Gupta. 2018. The effects of vermicompost on growth and yield parameters of vegetable crop radish (*Raphanus sativus*). J. Pharmacogn. Phytochem., 7(2):589-592.
- Kushwah, L., R.K. Sharma, S.S. Kushwah, and O.P. Singh. 2020. Influence of organic manures and inorganic fertilizers on growth, yield and profitability of radish (*Raphanus sativus* L.). Ann. Plant Soil Res., 22(1):14-18.
- Laghari, S.J., N.A. Wahocho, G.M. Laghari, A.H. Laghari, G.M. Bhabhan, K.H. Talpur, T.A. Bhutto, S.A. Wahocho, and A.A Lashari. 2016. Role of nitrogen for plant growth and development: A rev. Adv. Environ. Biol., 10(9): 209-219. <https://doi.org/10.1038/srep30350>
- Liang, F., J. Li, X. Yang, S. Huang, Z. Cai, H. Gao, J. Ma, X. Cui, and M. Xu. 2016. Three-decade long fertilization-induced soil organic carbon sequestration depends on edaphic characteristics in six typical croplands. Sci., Rep. 6(1): 30350.
- Maduwanthi, A., B. Karunarathna, and I. Wickramasingha. 2021. impact of vermicompost as a base fertilizer for radish (*Raphanus sativus* L.) cultivation. J. Trop. Forestry Environ., 11(1): 61-68.
- Maharjan, K.K., P. Noppradit, and K. Techato. 2022. Suitability of vermicomposting for different varieties of organic waste: A systematic literature review (2012-2021). Org. Agric., 12(4):581-602. <https://doi.org/10.1007/s13165-022-00413-2>
- Makkar, C., J. Singh, and C. Parkash. 2017. Vermicompost and vermiwash as supplement to improve seedling, plant growth and yield in *Linum usitatissimum* L. for organic agriculture. Intl. J. Recycl. Org. Waste Agric., 6(3): 203-218. <https://doi.org/10.1007/s40093-017-0168-4>
- Olivares, F.L., J.G. Busato, A.M. de Paula, L. da Silva Lima, N.O. Aguiar, and L.P. Canellas. 2017. Plant growth promoting bacteria and humic substances: crop promotion and mechanisms of action. Chem. Biol. Tech. Agric., 4(1): 30. <https://doi.org/10.1186/s40538-017-0112-x>
- Raksun, A., I.W. Merta, I.G. Mertha, and M.L. Ilhamdi. 2022. The effect of vermicompost and NPK fertilizer on the growth of Spinach (*Amaranthus tricolor*). J. Pijar Mipa., 17(5): 691-695. <https://doi.org/10.29303/jpm.v17i5.3464>
- Ravindran, B., J.W.C. Wong, A. Selvam, and G. Sekaran. 2016. Influence of microbial diversity and plant growth hormones in compost and vermicompost from fermented tannery waste. Bioresour. Technol., 217: 200-204. <https://doi.org/10.1016/j.biortech.2016.03.032>
- Rehman, S., F. De Castro, A. Aprile, M. Benedetti and F.P. Fanizzi. 2023. Vermicompost: Enhancing plant growth and combating abiotic and biotic stress. Agronomy, 13(4):1134. <https://doi.org/10.3390/agronomy13041134>
- Samal, K., A.R. Mohan, N. Chaudhary, and S. Moulick. 2019. Application of vermitechnology in waste management: A review on mechanism and performance. J. Environ. Chem. Eng., 7(5):103392. <https://doi.org/10.1016/j.jece.2019.103392>
- Shi, J., Y., Zhang, N. Zhang, and S. Zhang. 2014. Effects of long-term fertilization on forms and availability of phosphorus in mountain red soil. Acta. Pedol. Sin., 51(2):351-359.
- Singh, A., V. Kumar, S. Verma, M. Majumdar, and S. Sarkar. 2020. Significance of vermicompost on crop and soil productivity: A review. Int. J. Chem. Stud., 8(5): 1529-1534. <https://doi.org/10.22271/chemi.2020.v8.i5u.10517>
- Souri, M.K., and F.Y. Sooraki. 2019. Benefits of organic fertilizers spray on growth quality of chili pepper seedlings under cool temperature. J. Plant Nutr., 42(6): 650-656. <https://doi.org/10.1080/01904167.2019.1568461>
- Verma, S., A. Singh, S. Pradhan, and J. Singh. 2018. Effects of organic formulations and synthetic fertilizer on the performance of pigeonpea in eastern region of Uttar Pradesh. Bangladesh J. Bot., 47(3): 467-471. <https://doi.org/10.3329/bjb.v47i3.38713>
- Vuković, A., M. Velki, S. Ečimović, R. Vuković, I. Štolfa Čamagajevac, and Z. Lončarić. 2021. Vermicomposting - facts, benefits and knowledge gaps. Agronomy, 11(10): 1952. <https://doi.org/10.3390/agronomy11101952>
- Wang, F., X. Wang, and N. Song. 2021. Biochar and vermicompost improve the soil properties and the yield and quality of cucumber (*Cucumis sativus* L.) grown in plastic shed soil continuously cropped for different years. Agric., Ecosyst. Environ., 315: 107425. <https://doi.org/10.1016/j.agee.2021.107425>
- Ye, L., X. Zhao, E. Bao, J. Li, Z. Zou, and K. Cao. 2020. Bio-organic fertilizer with reduced rates of chemical fertilization improves soil fer-

- tility and enhances tomato yield and quality. *Sci. Rep.*, 10(1): 177. <https://doi.org/10.1038/s41598-019-56954-2>
- Zhang, J., C. Müller, and Z. Cai. 2015. Heterotrophic nitrification of organic N and its contribution to nitrous oxide emissions in soils. *Soil Biol. Biochem.*, 84: 199-209. <https://doi.org/10.1016/j.soilbio.2015.02.028>
- Zhu, X., L.C.R. Silva, T.A. Doane, N. Wu, and W.R. Horwath. 2013. Quantifying the effects of green waste compost application, water content and nitrogen fertilization on nitrous oxide emissions in 10 agricultural soils. *J. Environ. Qual.*, 42(3): 912-918. <https://doi.org/10.2134/jeq2012.0445>
- Zucco, M.A., S.A. Walters, S.K. Chong, B.P. Klubek, and J.G. Masabni. 2015. Effect of soil type and vermicompost applications on tomato growth. *Intl. J. Recycl. Org. Waste Agric.*, 4(2): 135-141. <https://doi.org/10.1007/s40093-015-0093-3>