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Differential activity of vermicompost and plant growth regulators (GA_3 and IAA) on yield and growth parameters of *Zingiber officinale* rosc

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Abstract

Vermicompost produced by earthworm through fragmentation of organic waste, has a fine particulate structure consisting of five, eleven and seven times higher nitrogen, potassium and phosphorous compared to normal soil and acts as an excellent natural fertilizer and soil conditioner for plant's growth. In this investigation, exo-morphological characteristics and yield of *Zingiber officinale* were studied comparatively by using 50% of vermicompost and two plant growth hormones namely Indole Acetic Acid & Gibberellic Acid (IAA & GA_3). Experiment was performed in pot with 4 separate soil treatments viz: first 50% vermicompost; second GA_3 (0.28 mm); third IAA (0.57 mm) and fourth is control (deionized water). During this study, a significant improvement in various parameters of plant growth like shoot length, number of leaves and total dry & wet weight was noticed in plants treated with 50% vermicompost compared to control, GA_3 and IAA treated plants.The demonstrated results recommend the possible application of vermicompost as an effective biofertilizer in cultivation of various vegetable crops in an ecofriendly manner. Scope of current study is to improve soil strength for better plant development by supporting utilization of biological or organic additives like vermicastin in place of inorganic fecundators to attain higher yields through sustainable agriculture.

Keywords: Vermi or worm compost, Plant development hormones, Indole Acetic Acid, Gibberlic acid, Organic farming

1. Introduction

The consequences of chemical fertilizers application to the soil lead to pollution of hydrosphere, intensified contamination of air, soil acidulation & attrition of minerals [1,2]. At the same time, fertilizer prices are very high, and farmers often cannot purchase them on time for agricultural needs. While, currently, organic manure is readily available in the market at lower costs [3] compared to inorganic chemical fertilizer.

Vermicompost (Vermiculture) is the outcome of organic waste decomposed by earthworms such as red wiggler, white worms or other earthworms and gives vermicast as the final product [4]. Vermicomposting is a low-cost technique used to turn agricultural waste into organic fertilizer, with several interactions in the worm gut between the earthworm and the micro-organisms [5]. Due to advantageous out puts, at present earth worms have been widely used in biodegradable solid waste decomposing [6].

It is a recommended bioconversion process and one of the successful methods of bioremediation that comprises oxidation of organic materials by combined action of earthworms and microbes extensively harnessed for solid waste management [7]. One of the distinctive features of vermicompost is the presence of abundant nutrients in accessible form for easy absorption to promote plant growth and development [8]. Because of these characteristic features vermicompost enhances profuse root formation and better elongation of stems in majority of vegetable crops similar to plant growth hormones [9].

In addition, vermicomposting also plays a crucial role in decreasing nutrient related disorders and fungal diseases like Botrytis rot (graymold) which rises the yield of marketable fruits [10]. In this orientation, it was stated that plants treated with vermicompost developed attractive fruits with high quantities of ascorbic acid and total soluble solids with less acidity [9]. Furthermore, soil augmented with vermicompost yielded best quality vegetables and fruits with minimum content of nitrate or heavy metals than soil supplied with chemical fertilizers [11].

Promising impact of vermicompost involves triggered seed germination in many plant species like petunia [12], pine trees [13] and tomato [14-16]. Moreover it has siginificant result on vegetative growth, root and shoot development [17]. These effects involve modifications in morphology of seedling like enhanced leaf area and root bifurcation [18]. In addition, it was also observed that vermicompost has shown positive impact on stimulation of plant flowering, enhancing the flower number and biomass of the flowers formed [12] besides increased fruit harvest [15,19,20]. Apart from this, vermicompost improves the nutritional aspects of a few vegetables like Chinese cabbage [21], spinach [22], tomatoes [23], lettuce [24], sweet corn [25] and strawberries [20]. Studies conducted by Tomati et al [26] in petunia and coleus by comparing the impact of vermicompost on their growth and development stated that there was solid evidence of hormonal activity induced by the earth worms.

The joint activity of vermicompost and microorganisms generates substantial levels of plant growth hormones and higher quantities of humic substances, which play a major role in plant growth and development [27,28]. Furthermore, it was mentioned that humic acid produced in vermicompost has a vital function in plant growth over commercially available humic acid [29]. So, vermicompost can be utilized as an alternative potting media in agricultural applications on account of its distinguished nutrient level, affordable price and suitable physiochemical characters.

More number of researchers experimentally proved that vermicompost nutrient profile is significantly higher than conventionally prepared compost and in fact, it can physically, chemically and biologically improve soil fertility. Soil treated with vermicompost has greater aeration, porosity, bulk density and water retention [30]. Chemical properties such as pH, electrical conductivity and quality of organic matter are also enhanced by it for better crop production [30]. Effect of vermicomposts prepared from food waste (FWV), cow manure (CMV) and paper sludge (PSV) was examined on root growth during the processing of ginseng production [31] and revealed that the root yield in PSV treatment was increased by 40 t/ha compared with the untreated control.

Worm composting or vermicomposting of organic refuse from two disparate sources (paper fritter & rice straw) were investigated by Sharma et al [32] using *Eisenia fetida* and showed that the vermicompost had higher nitrogen, phosphorus, and potassium (NPK) content. Further, research was carried out to study the impact of vermicompost prepared using effluent obtained from palm oil mill (POME) & palm-pressed fiber (PPF) combinations upon mung bean *Vigna radiata* plants germination, development, relative toxicity and pigments of photosynthetic activity. In this process seeds of mung bean were treated with various concentrations of vermicomposted POME-PPF extracts (50, 60 and 70%) and suggested that at lower concentrations these extracts showed better results compared to higher concentrations [33]. In another study the effect of vermicompost produced by cattle dung and lignocellulosic waste mixture was analysed and identified the raised level of NPK content in the vermicompost and revealed that lignocellulosic waste and cattle dung combination could function as a good source of raw material for manure production using earthworms [34].

Phytohormones (plant growth hormones) are plant derived chemicals that control the plant progress, advancement, propagative progresses, permanence as well as demise. Such diminutive molecules were produced out of subsidiary metabolites & accountable for plants habituation towards ecological impulses.

Foliar plant spray typically involves the application of fertilizer directly to the plant leaves instead of adding to the soil and is generally less concentrated than fertilizers. It is considered as a wonderful short-term solution for stressed plants. However, it is always best to build soil with plenty of organic matter. Foliar spray of fertilizers, although not a replacement for healthy soil, however, it is desirable when a plant has a nutrient deficiency. In this manner Fathima et al [35] conducted foliar spray experiments to study the impact of growth promoters in different combinations upon extrinsic morphological features attributed to *Abelmoschus esculentus* & observed a more rise in plant height, diameter and internode length.

In the current research, effect of vermicompost was analyzed on the growth rate of *Zingiber officinale* compared to artificial plant growth hormones like IAA and GA_3. *Z. officinale* was referred as a herbous perdurable, augments with year wise false stems of around one-meter height with cramped leafage. This plant is loaded with bioactive compounds and nutrients that have impressive benefits to the brain and body. The efflorescence fetches purple & pale yellow flowers and arises promptly out of rhizome upon individual shoots. Rhizome of this plant is largely benefited as a spicery & holistic medicine.

2. Materials and methods

In this experiment, *Z. officinale* Rosc., appertaining to the *Z.* aceae, routinely named as ginger was preferred to study the role of vermicompost on plant growth and yield in comparison with foliar spray of plant growth hormones. To raise plants for experimental analysis, commonly used ginger root was procured from the local vegetable market. Different parametrics of the plant's advancement were analyzed utilizing worm compost compared to foliar spray of plant development substances such as Indole acetic acid and Gibberlic acid (IAA & GA_3).

2.1 Preparation of vermicompost

Biodegradable organic wastes like vegetable waste, leaf litter, hostel refuse were collected and are further stored along with cattle dung slurry for the pre-digestion process. Farmyard manure & biogas slush are utilized in the vermicomposting process, later on drying and moist dung must not be employed in the processing of vermicompost. In this process, the materials are partially consumed by the earth worm. A solid support is arranged to deposit squander and proper aeration was provided for the growth of earthworms. Earthworms digest wastes from organic source and convert them into organic materials and thereby providing nutrients essential for the growth of the plant and if any waste is partially digested it is re-digested by the earthworm during the processing of vermicomposting.

Collecting was completed during 70^{th} day, after separating the vermicast from worms. In this experiment, effect of vermicompost on *Z. officinale* plant growth and yield was tested by mixing 50% of vermicompost with loose soil (black soil) in the pots and compared with certain phytohormones and control.

2.2 Plant growth promoter's preparation

Preparation of 0.28 mm GA_3 solution: 1 mg of concentrated GA_3 was dissolved in 10 mL of sterile double distilled water and finally made up to 100 mL with de-ionized water.

Preparation of 0.57 mm IAA solution: Similar to the previous solution, in 10 mL of sterile double distilled water, 1 mg of concentrated IAA was dissolved and finally made up to 100 mL with de-ionized water. Ethyl alcohol is used to dissolve the IAA in 10 mL of water.

2.3 Germination and development of Z. officinale plants for experimental analysis

Z. officinale seedlings were brought up in spacious pots (thickness of pot is 60 cm) in green house. Black soil, barnyard manure & sand in the proportion of 1:1:1 was taken into pots or containers. To cultivate ginger plants in green house, pH of the soil is maintained from 5.0 to 7.0 and before the germination the temperature of the soil is maintained at 22 to 25°C. Moreover, the relationship between light intensity and yield of ginger was inversely proportional. So, after plantation, the pots were placed in warm and humid climate as they don't require considerable amounts of direct, bright sunlight, where they grow well in humid & partial shaded conditions. Additionally, to maintain the moisture of the soil, it was regularly sprayed with mist. Due to underground stem, it took 12 days to start growing. The foliar spray of phytohormones was done at the end of each week. The exo-morphological features of plant like shoot length, number of leaves along with dry and wet weight of all the treatments were noted down at the end of every second week.

2.4 Experimental process

Pot studies were carried out on *Z. officinale* through various treatments including application of vermicompost and plant growth hormones (foliar spray) in separate pots under similar conditions. In addition to the above, purified water was taken as control to evaluate the exoteric morphological characters as well as yield in corresponding to the various treatments. Solution of Teepol (0.01%) was supplemented to the plant growth hormones during foliar spray treatment to function as a surfactant and to improve the adhesion of the plant growth hormone solution to the leaves. Information related to four treatments viz: 50% vermicompost, foliar spray of IAA, GA_3 plant growth regulators and control were mentioned in the Table 1.

Table 1 representing list of treatments and their compositions employed for experimental analysis.

S. No.	Treatment	Composition
1	Control	100mL of deionised water
2	50% Vermicompost	Soil + 50% of vermicompost
3	IAA	10mL IAA + 90 mL deionised water
4	GA_3	10mL GA_3 + 90 mL deionised water

2.5 Exo-morphological features analysis

The exo-morphological results were reported for the control along with treated plants before the foliar spray and for every two weeks after the foliar spray of two phtohormones. The experiment was repeated thrice and the parameters analyzed are: (1) length of the shoot (2) number of leaves (3) dry weight (4) wet weight. Length of the shoot was assessed by a tapeline & number of leaves was counted manually. The dry weight and wet weight of the *Z. officinale* was measured by weighing machine.

2.6 Statistical analysis

Statistical analysis was conducted out on morphological parameters of plant (*Z.officinale* Rosc.). The difference amidst the control and treated plants were analyzed statistically and total data was provided as average and standard error. The significance level is estimated at $\alpha<0.05$. A confident scale of around 95% or statistical significance at 5% is normally interpreted to construe data.

3. Results

Extraterritorial characters such as length of shoot and leaf number were observed for every two weeks (14 days) and finally the values were recorded after 70 days of post treatment in control and treated plants. The impact of vermicompost is prominent and plants supplied with vermicompost exhibited significant increase in growth and yield compared to the plants treated with plant growth hormones and control (Figure 1).

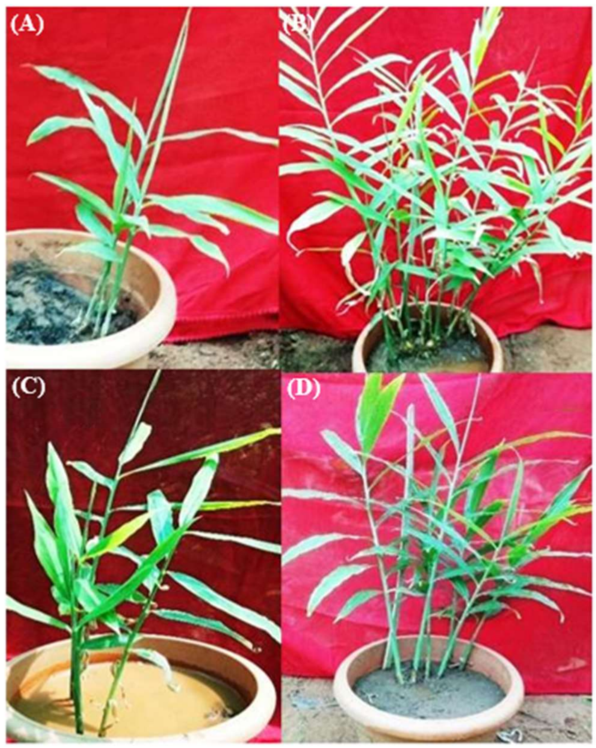

Figure 1 Plants of *Z. officinale* cultivated under four different treatment conditions; (A) Control, (B) Vermicompost, (C) GA_3, and (D) IAA.

3.1 Length of the shoot

Substantial difference was observed between control and treated plants in terms of shoot lengths. Initially, plant shoot lengths were measured after 14 days (two weeks) in three different treatments along with control and recorded as follows: vermicompost 11 cm; IAA 7 cm, GA_3 5 cm and control 3 cm respectively. Finally, values were taken after 70 days of post treatment and it was noticed that there was a considerable increase in shoot lengths of all treated plants compared to control (Figure 2) and corresponding values are as follows; with vermicompost 45 cm; for GA_3 & IAA 36, 34 cm and for control 30 cm respectively. These are illustrated in Table 2 which clearly indicates that administration of vermicompost is significantly effective in better shoot elongation and resulted in enhanced length of shoots compared to the plant growth stimulators and control.

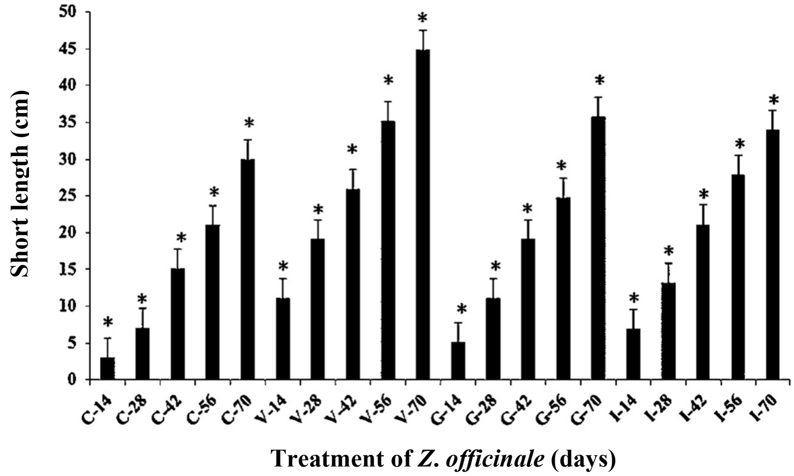

Figure 2 Shoot lengths of treated (vermicomost, GA_3 and IAA) and control *Z. officinale* plants at regular time intervals.

*Indicates substantial distinction in height or length of shoot amongst plants under treatment & control.Values represented were Mean ± SE (n = 3). Asterisks show considerable variance between control and phytoharmone treated plants at $p \leq 0.05$.

Table 2 Impact of vermicompost and plant growth hormones on *Z. officinale* plant shoot length.

Treatment	Number of days	Average shoot length (cm) mean ± standard error (% of error)
Control	14	3.13 ± 0.39 (±12.68%)
	28	7.1 ± 0.27 (±3.90%)
	42	15.1 ± 0.22 (±1.50%)
	56	21.13 ± 0.34 (±1.64%)
	70	29.96 ± 0.34 (±1.15%)
50% Vermicompost	14	11.06 ± 0.28 (±2.57%)
	28	19.13 ± 0.23 (±1.23%)
	42	26.06 ± 0.39 (±1.52%)
	56	35.20 ± 0.39 (±0.96%)
	70	44.86 ± 0.28 (±0.63%)
GA_3	14	5.13 ± 0.39 (±7.74%)
	28	11.06 ± 0.39 (±3.59%)
	42	19.10 ± 0.29 (±1.57%)
	56	24.83 ± 0.79 (±3.20%)
	70	35.83 ± 0.28 (±0.79%)
IAA	14	6.90 ± 0.22 (±3.28%)
	28	13.20 ± 0.29 (±2.27%)
	42	21.16 ± 0.39 (±1.88%)
	56	27.93 ± 0.28 (±1.02%)
	70	34.03 ± 0.23 (±0.69%)

3.2 Number of leaves

After 14 days of beginning the experiment, total number of leaves produced per plant was counted and is as follows: 4 leaves in vermicompost, 3 leaves in IAA, 2 leaves in GA_3 and 2 leaves in control respectively. Later, the same parameter was evaluated after 70 days of treatment and the data obtained was 16 Nos in vermicompost, 14 Nos in IAA, 12 Nos in GA_3 and 9 Nos in the case of control (Table 3). A considerable increase in the number of leaves was observed among the control and the other three treatments and there is a significant difference in the leaf number raised in the three different treatments in comparison with control (Figure 3).

Table 3 Imp act of vermicompost and plant growth hormones on leaf number of *Z. officinale* plants.

Treatment	Number of days	Average number of leaves mean ± standard error (% of error)
	14	2.33 ± 0.65 (±28%)
	28	5.66 ± 0.65 (±11.53%)
Control	42	7 ± 1.13 (±16.17%)
	56	7 ± 1.13 (±16.17%)
	70	9.33 ± 1.72 (±18.52%)
	14	3.66 ± 0.65 (±17.82%)
	28	7 ± 1.13 (±16.17%)
50% Vermicompost	42	10.66 ± 1.72 (±16.21%)
	56	12.33 ± 0.65 (±5.30%)
	70	16.66 ± 0.65 (±3.92%)
	14	2.33 ± 0.65 (±28%)
	28	4.33 ± 0.65 (±15.08%)
GA_3	42	7 ± 1.13 (±16.17%)
	56	9.33 ± 1.72 (±18.52%)
	70	11.33 ± 1.30 (±11.53%)
	14	3.66 ± 0.65 (±17.82%)
	28	5.33 ± 1.30 (±24.50%)
IAA	42	8.33 ± 1.72 (±20.74%)
	56	9.33 ± 1.30 (±14%)
	70	14.66 ± 2.35 (±16.06%)

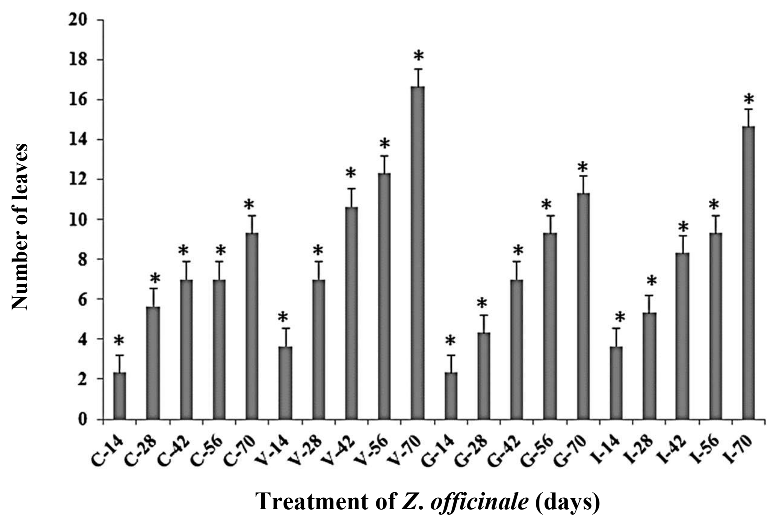

Figure 3 Number of leaves in vermicompost and plant growth harmones treated *Z. officinale* plants in relation to control.

*Indicates remarkable discrepancy of leaf number among treated plants & control. Values depicted were Mean ± SE (n = 3). Asterisks denote significative disparity in comparison with untreated control and phytoharmone sprayed plants at $p \leq 0.05$.

Table 4 Comparative analysis of dry & wet weights of *Z. officinale* root grown under various treatments.

Treatment	Wet weight of ginger root (g)	Dry weight of ginger root (g)
Control	18.73	12.49
Vermicompost	79.26	76.61
GA_3	43.57	39.43
IAA	58.48	54.28

3.3 Dry weight and wet weight of Z. officinale root

After 70 days of post treatment plants were uprooted to measure the dry and wet weights of *Z. officinale* roots (Figure 4). The observed values of dry weight and wet weight of *Z. officinale* plants treated with vermicompost was 76.61 g and 79.26 g, GA_3 is 39.43 g and 43.57 g, IAA was 54.28 g and 58.48 g and finally control was 12.49 g and 18.73 g respectively (Table 4). Based on the results, it is evident that the dry weight and wet weight of zinger root developed from vermicompost treated plants is significantly high compared to the growth hormone (GA_3, IAA) treated plants and control (Figure 5,6). According to the relative weights of all the trea

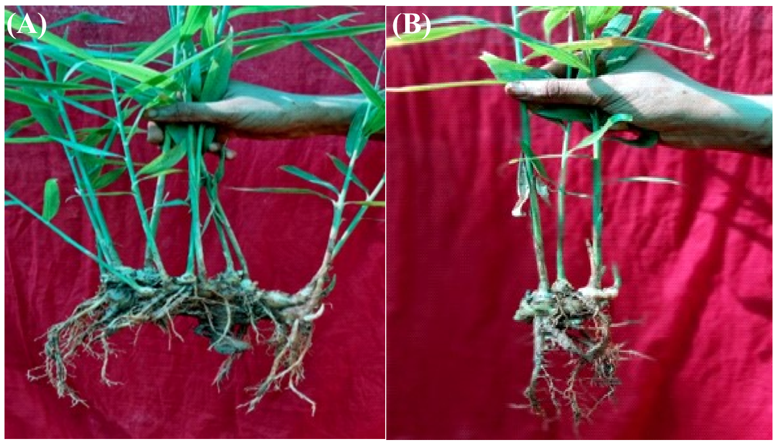

Figure 4 Freshly harvested roots of *Z. officinale* plants treated with vermicompost along with control; (A) dry weight, and (B) wet weight.

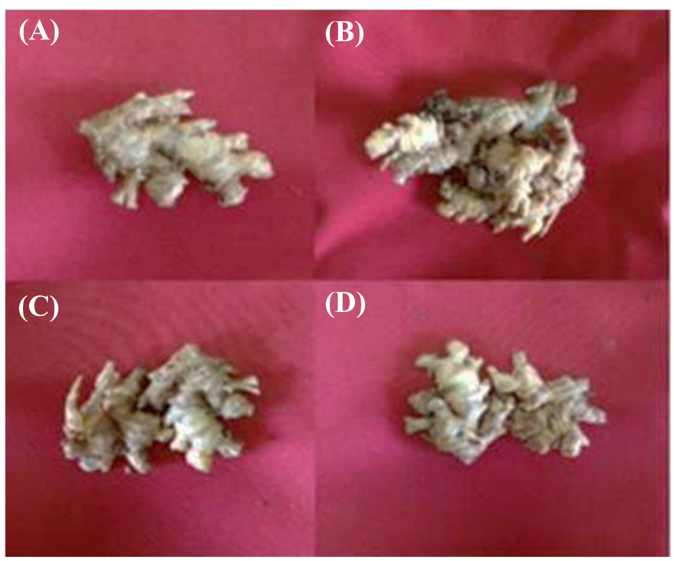

Figure 5 Dry roots of *Z. officinale* plants subjected to four different treatments; (A**)** Control, (B) Vermicompost, (C) GA_3, and (D) IAA.

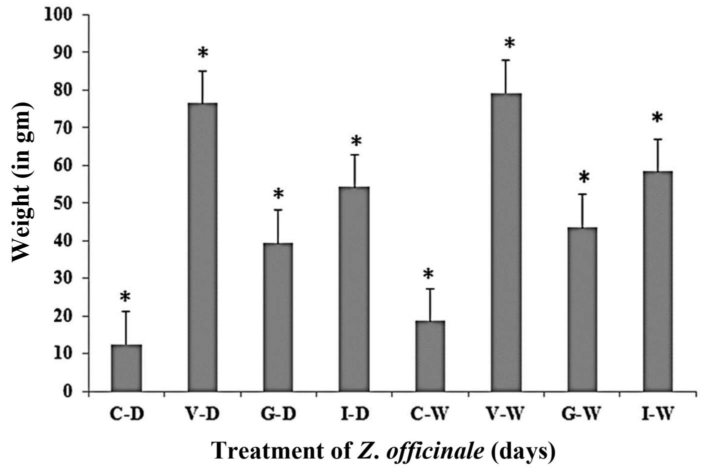

Figure 6 Dry weight and wet weight of vermicompost and phytoharmone treated *Z. officinale* plants in comparison with control.
*Indicates significant difference between control and treated plants in terms of dry and wet weights.Values given were Mean ± SE (n = 3). Asterisks demonstrate noticeable dissonance in values within control and phytohormone treated plants at $p \leq 0.05$.

4. Discussion

The present study illustrates enhanced growth, development and yield of *Z. officinale* plants with the application of 50% vermicompost to the potted plants compared to foliar spray of plant growth hormones such as GA_3, IAA and control. When compared to other amended soils, the NPK content of vermicompost amended soil was shown to be higher. The growth of plants treated with vermicompost was shown to be significantly enhanced. The needed nutrients are provided by vermicompost-amended soil, which are not available in chemically treated soil. Application of vermicompost with Plant Growth Promoting Rhizobacteria (PGPR) to promote shallot development and yield is an effort to reduce climate change. In this experiment, plants were given treatment in three different approaches using vermicompost, GA_3, IAA and compared with control. Data regarding shoot length, number of leaves, dry as well as wet weights of *Z. offficinale* plants was procured after regular intervals of treatment. From the second week of treatment distinct variation was identified in the parameters of shoot length, leaf number, wet weight and dry weight. Out of three treatments, the maximum length of shoots was achieved in plants treated with 50% vermicompost compared to plants foliar sprayed with GA_3, IAA and control. Plant height was significantly affected by the vermicompost which is clearly observed during treatment (Table 2). According to this study, the height of the plant is significantly related to the dose of the vermicompost applied, which may be due to the presence of growth regulators such as auxins, cytokinins, GA_3 and humic acid in vermicompost. Comparatively after 70 days, shoot length was notably increased to 60% in vermicompost amended plants compared to GA_3, IAA and control, where it was noticed only 44, 43 and 40% respectively. A significant level of variation was observed among the shoot lengths of these plants. The observations in the current study are in line with the earlier findings, where increase in the harvest of few vegetables like okra, tomato and brinjal were disclosed by Elumalai et al [36], Guerrero et al [37], Sinha et al [38] and Gupta et al [39].

The usage of vermicompost with PGPR is one of the approaches for promoting shallot growth and production. This is due to the fact that vermicompost can reduce the population of fungal pathogens while increasing beneficial microbes such as *Trichoderma* and *Paecilomyces lilacinus*, hence increasing shallot bulb yield [40]. Vermicompost provides adequate quantity of nutrients to enrich the soil that promotes plant uptake [41,42] as well as facilitates active growth of microorganisms responsible for plant growth and development [43]. Interestingly, it was noticed that in plants supplemented with vermicompost (50%), the total number of leaves were more in number and recorded greater wet as well as dry weights compared to others types of treated plants along with control. Leaf number, wet and dry weights in plants supplied with 50% vermicompost were significantly enhanced to 65, 81 and 86% respectively compared to GA_3, IAA and control. Significant growth was observed in plants subjected to vermicompost treatment because of favourable environment, perfect temperature & counter balance of inorganic & organic nutriments in worm compost that improves the growth of the plant [44]. The addition of 5 t/ha^{-1} vermicompost enhanced the growth in garlic plant [45]. Soil research indicated that vermicompost is an abundant source of growth regulators, useful microorganisms and nutrients such as nitrates, exchangeable form of phosphates, soluble calcium, potassium and magnesium in available form, which improves plant nutrients intake and enhances the concentration of dry weight and plant nutrients [46]. For this reason,vermicompost amended soil has more production capacity than the soil supplied with chemical fertilizers [47,48].

Previous literature on vermicompost stated that carotenoids content was significantly increased in chickpea when vermicompost was used as a fertilizer instead of chemical fertilizer [49]. It was mentioned that soil provided with vermicompost exhibited more dehydrogenase activity compared to other form of inorganic fertilizers that might be because of proper nutrient utilization from organic materials by microorganisms that finally results in enhanced plant development [50]. So, vermicompost application aids in beneficial outcomes to agriculture, environment, industry and the country's economic condition. Similar to vermicompost, sheep manure is one of the choices for processing organic material to improve agricultural production [51,52]. It was revealed that vermicompost was a better fertilizer than sheep manure due to its high ratio of carbon to nitrogen (C/N), acceptable acidic and saline conditions [53].

In the studies carried out to determine the effect of various fertilizers such as Diammonium phosphate (DAP), farm yard manure (FYM) and vermicompost on different morphological parameters of two essential leguminous plants, *Pisum* sp., *Cicer* sp. and on the *in vitro* growth of N_2 fixing bacterial colonies, it was reported that plants cultivated in soil pretreated with worm compost exhibited maximum increase of morphological parametrics such as twig length and root, number pertaining to stem and root branches, number of flowers, leaves, pods and root nodules compared to untreated, DAP treated and FYM treated soils [54]. It stated that *Passifloraa latacurtis* seeds grown in soils augmented with vermicompost (0.15 kg) exhibited improved primary and secondary metabolites production [55]. In *Cajanus* leaves, notable improvements related to unrefined protein, solvable carbohydrates, ash quantity, whole flavonoid components and bactericidal & antioxidative attributes were reported in case of treatments with vermi or worm compost [56]. Using Life Cycle Assessment (LCA) management system it was reported that vermicompost showed better performance over other systems in terms of eutrophication potential and global warming [57].

All these results demonstrate that vermicompost is capable of improving growth and yield of *Z. officinale* plant compared to growth moderators like IAA & GA_3. Hence, it is essential to endorse usage of organic based vermicompost for agricultural practice to produce better yields by sustainable method of farming.

5. Conclusion

In this investigation, we address the importance of organic agriculture as a method of supplying good quality and safe food within the constraints of an ecosystem. The results of the present experiment displayed that 50% vermicompost showed promising results in view of growth and yield of ginger plant compared to the plant growth hormones and improved the quality of the soil. Further, this analysis provides a clear sign of the value of organic or biological agriculture, where vermi compost was conceivably recommended in the form of an organic fecundator to various market-garden crops to attain higher yields and for sustainable agriculture.

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