Vermicast and Vermitea Application and its Effects on Growth and Yield, Firmness and Suitability of Tomato (Solanum Lycopersicum L.)

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Abstract

The increasing demand for sustainable tomato production has intensified the search for environmentally friendly nutrient management strategies that can improve crop productivity while maintaining soil health. This study evaluated the effects of different rates and combinations of vermicast and vermitea on the growth, yield, fruit quality, postharvest performance, and profitability of tomato (Solanum lycopersicum L.) under the agroecological conditions of Ilocos Sur, Philippines. The experiment was conducted using a Randomized Complete Block Design (RCBD) with six treatments and three replications. Growth parameters, flowering characteristics, yield components, fruit quality, postharvest attributes, and economic returns were analyzed using Analysis of Variance (ANOVA). Results revealed that vermicast and vermitea significantly influenced all measured parameters ($P \leq 0.01$). The combined application of 80 g vermicast + 1000 ml vermitea per 16 L water (T3) consistently produced the best overall performance, recording the highest final plant height (86.37 cm), height increment (75.43 cm), number of leaves (86.00), flowers (53.00), fruits per plant (41.00), average fruit weight (98.27 g), total fruit yield (4.02 kg plant^{-1}), marketable yield (21.43 t ha^{-1}), and market quality (97.56%). The same treatment also extended shelf life, minimized fruit cracking, and generated the highest gross income (₱642,000.00 ha^{-1}), net income (₱447,596.24 ha^{-1}), return on investment (230.24%), and benefit-cost ratio (3.30). Meanwhile, vermitea applied alone enhanced stem diameter, fruit firmness, fruit size, and accelerated flowering. Overall, integrating vermicast and vermitea proved to be an effective and economically viable organic nutrient management strategy for improving tomato growth, fruit quality, yield, and profitability. The study demonstrates the potential of vermicompost-based amendments as sustainable alternatives to synthetic fertilizers for enhancing tomato production under local farming conditions.

Keywords: tomato, vermicast, vermitea, growth, yield, firmness, profitability

Introduction

Tomato (*Solanum lycopersicum* L.) is among the most widely cultivated vegetable crops worldwide because of its nutritional benefits and economic importance. The fruit is valued as a rich source of vitamins, minerals, antioxidants, and dietary fiber, making it a staple ingredient in many diets and food products. Its growing demand in both local and international markets has encouraged producers to adopt intensive cultivation practices aimed at increasing productivity. While these practices have contributed to higher yields, they have also led to the widespread use of synthetic fertilizers. Over time, excessive dependence on chemical inputs has been associated with declining soil quality, nutrient imbalances, contamination of water resources, and reduced biological activity in agricultural soils, highlighting the need for more sustainable nutrient management approaches.

The search for environmentally responsible farming practices has renewed interest in organic soil amendments that can improve crop productivity without compromising soil health. Among these, vermicast and vermitea have emerged as promising alternatives because of their ability to enhance soil fertility through natural biological processes. Vermicast, produced through the decomposition of organic materials by earthworms, contains readily available plant nutrients, beneficial microorganisms, humic substances, and naturally occurring growth-promoting compounds. These components improve soil structure, increase moisture retention, stimulate microbial activity, and enhance nutrient availability, creating favorable conditions for vigorous root growth and plant development. Vermitea, a water-based extract derived from vermicast, complements these benefits by delivering soluble nutrients, beneficial microbes, enzymes, and bioactive compounds that are readily absorbed by plants. As a result, it promotes nutrient uptake, improves photosynthetic efficiency, and supports overall plant vigor. Numerous studies have demonstrated that vermicompost-based inputs can enhance vegetative growth, flowering, fruit production, and fruit quality in tomato and other high-value vegetable crops, making them viable alternatives to conventional fertilizer programs.

Asia continues to dominate global tomato production, with China, India, and several Southeast Asian countries contributing a significant share of the world's supply. In the Philippines, tomato cultivation provides income for thousands of farming households and plays an important role in ensuring a stable supply of nutritious vegetables. However, tomato growers continue to face challenges brought about by escalating fertilizer prices, declining soil productivity, and increasing environmental concerns associated with intensive farming. These challenges have encouraged greater interest in adopting organic nutrient sources such as vermicast and vermitea as components of sustainable production systems. Although previous investigations have documented the positive effects of vermicompost products on tomato growth and yield, limited information is available regarding the combined application of solid and liquid vermicompost products under Philippine growing conditions.

This research gap is particularly relevant in the Ilocos Region, where tomato production serves as an important source of livelihood for many smallholder farmers. Despite the growing availability of locally produced vermicast and vermitea, scientific evidence supporting their use under the region's specific agroecological conditions remains insufficient. Furthermore, most existing studies have concentrated primarily on plant growth and yield performance, while relatively few have examined fruit quality characteristics, including firmness and marketability, which directly influence consumer preference, shelf life, and farm profitability.

Recognizing these knowledge gaps, the present study assessed the effects of different rates and combinations of vermicast and vermitea on the growth, flowering, yield, and fruit quality of tomato under the agroecological conditions of Ilocos Sur. The study aimed to determine whether integrating solid and liquid vermicompost products could improve crop performance while reducing dependence on synthetic fertilizers. The findings are expected to generate location-specific recommendations that will support farmers, agricultural extension personnel, and policymakers in developing sustainable nutrient management strategies. More broadly, the study contributes to ongoing efforts to promote environmentally sound vegetable production and aligns with the objectives of the United Nations Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger)**,** SDG 12 (Responsible Consumption and Production)**,** SDG 13 (Climate Action)**, and** SDG 17 (Partnerships for the Goals)**.**

Objectives

General Objective

To determine the effects of vermicast and vermitea application on the growth, fruit yield, fruit firmness, fruit quality, and overall suitability of tomato (*Solanum lycopersicum* L.) production under local farming conditions in Ilocos Sur.

Specific Objectives

1. To evaluate the effects of different rates and combinations of vermicast and vermitea on the growth and yield performance of tomato plants in terms of (a) plant height, (b) stem diameter, (c) number of primary branches, (d) number of leaves, (e) days to flowering, (f) number of flowers per plant, (g) number of fruits per plant, (h) average fruit weight, and (i) total fruit yield.
2. To determine the effects of vermicast and vermitea application on the fruit quality and postharvest characteristics of tomato in terms of (a) fruit firmness, (b) fruit size, (c) fruit shape, (d) market quality, (e) shelf life, (f) number of non-marketable fruits, (g) Shelf life, (h) fruit cracking incidence, (i) and weight loss during storage.
3. To identify the most effective rate or combination of vermicast and vermitea for enhancing tomato growth, yield, fruit quality, and overall production suitability, and to assess their potential as sustainable organic nutrient sources under local growing conditions.
4. To evaluate the economic viability of tomato production using vermicast and vermitea application in terms of production costs, gross income, net income, return on investment (ROI), and benefit-cost ratio (BCR).

Time and Place of the Study

This study was conducted at the Ilocos Sur Polytechnic State College Pinakbet Farm, Poblacion Norte, Santa Maria, Ilocos Sur from November, 2022 to July, 2023.

Methodology and Materials

Procurement of Planting Materials and Research Supplies

Hybrid tomato seeds (Victoria F1) used in the experiment were purchased from an agricultural supply store located at the Santa Maria Public Market, Santa Maria, Ilocos Sur. Other materials required for nursery establishment, field management, data collection, and postharvest evaluation included seedling trays, garden soil, carbonized rice hull, animal manure, sprinkler, knapsack sprayer, digital weighing scale, Vernier caliper, penetrometer, tape measure, meter stick, ruler, water pump, shovel, rake, pails, sacks, plastic bags, identification tags, markers, record books, and other standard field and laboratory equipment

Methods and Experimental Design

The study was conducted using a Randomized Complete Block **Design (RCBD)** with three replications to minimize the effects of field variability. Each replication consisted of six treatment combinations arranged randomly within each block. Individual experimental plots measured 3.0 m × 3.5 m (10.5 m²) and contained four rows. Tomato seedlings were established at a spacing of 0.75 m between rows and 0.50 m between plants, while a one-meter alley separated adjacent plots. A two-meter space was maintained between replications to facilitate irrigation, fertilizer application, monitoring, and harvesting activities.

The treatments evaluated in the study were as follows:

T_0 – Control (no vermicast or vermitea)
T_1 – 40 g vermicast per plant + 500 mL vermitea per 16 L water
T_2 – 60 g vermicast per plant + 750 mL vermitea per 16 L water
T_3 – 80 g vermicast per plant + 1,000 mL vermitea per 16 L water
T_4 – 100 g vermicast per plant
T_5 – 1,000 mL vermitea per 16 L water

The assigned treatments were maintained throughout the cropping period to evaluate their effects on tomato growth, flowering, yield, fruit quality, postharvest performance, and economic returns under the agroecological conditions of Ilocos Sur.

CULTURAL MANAGEMENT AND PRACTICES

Land Preparation

One month prior to the study, the site was cleared of weeds and debris. Planting materials, along with the necessary tools and equipment, were prepared in advance. The soil was thoroughly cultivated using a tractor rotavator, with plowing and harrowing performed twice to achieve a fine soil tilth. Each experimental plot measured 3.5 meter × 3.0 meter, covering a total area of 10.5 m². Furrows were spaced 75 cm apart, and seedlings were transplanted at 50 cm intervals per hill. Each plot consisted of four rows, with seven hills per row.

Preparation of Soil Media for Seedling Establishment

To enhance aeration and nutrient availability, the potting medium was formulated using a 1:2:3 ratio of garden soil, animal manure and carbonized rice hull, respectively.

Seedling production

Before sowing, the seeds were soaked in clean water enough to imbibe for faster germination. One seed of tomato was placed in each hole of the seedling tray and covered with sacks to maintain adequate moisture and promote uniform germination. At 25 days after sowing, the seedlings were acclimatized for 5 days, and at 30 days, the seedlings were ready for transplanting.

Transplanting

Seedlings were irrigated thoroughly before transplanting. Transplanting was done at 30 days on the prepared plots. The planting distance was 0.75 meters between rows and 0.50 meters between hills. Transplanting was done late afternoon to avoid plant stress. Watering was done immediately after transplanting. A follow-up watering was done the following day and every five days thereafter, or as the need arises.

Cultivation was done one month after planting to loosen the soil for proper aeration of the roots of the plants and to control the occurrence of weeds

Preparation and application of vermicast and vermitea as organic liquid fertilizer

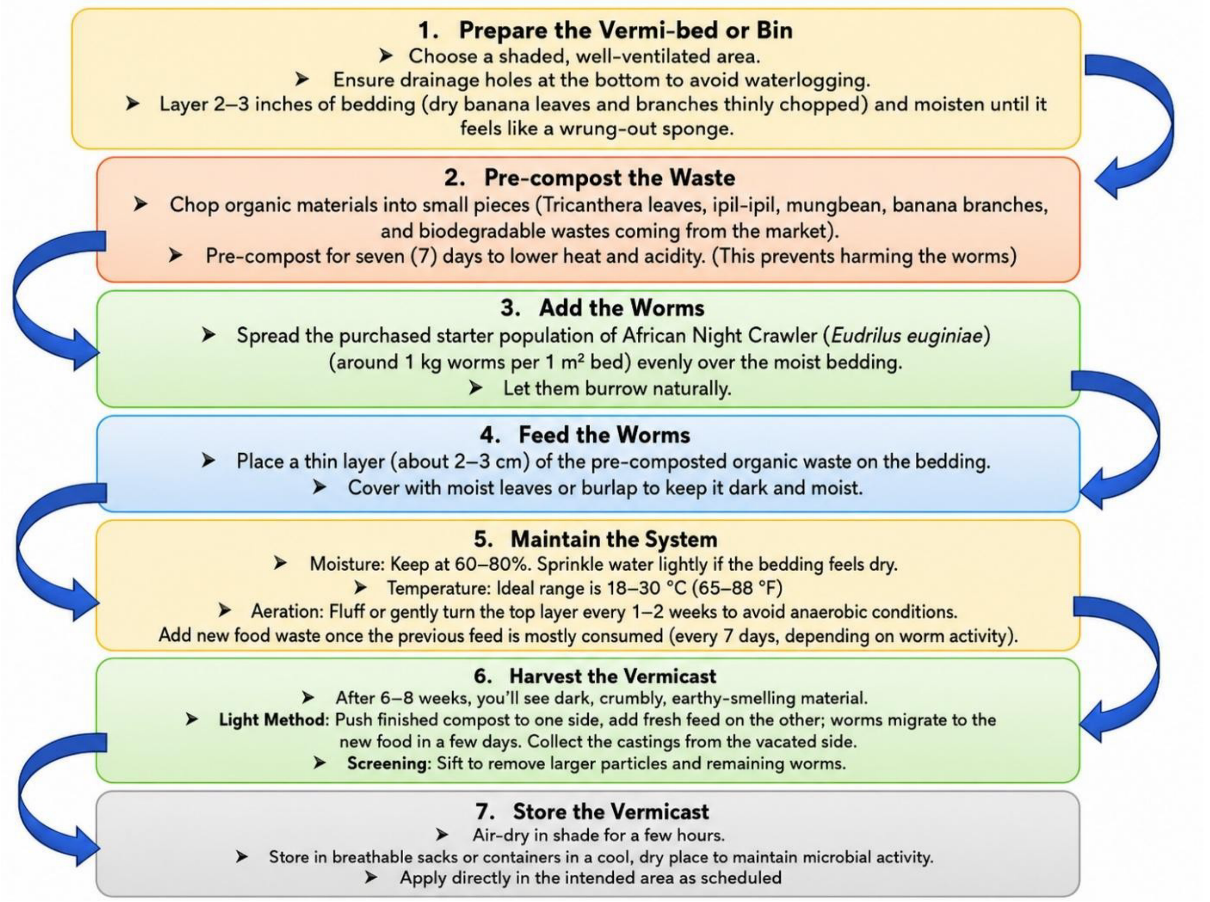

Figure 1. Steps in Vermicast Preparation

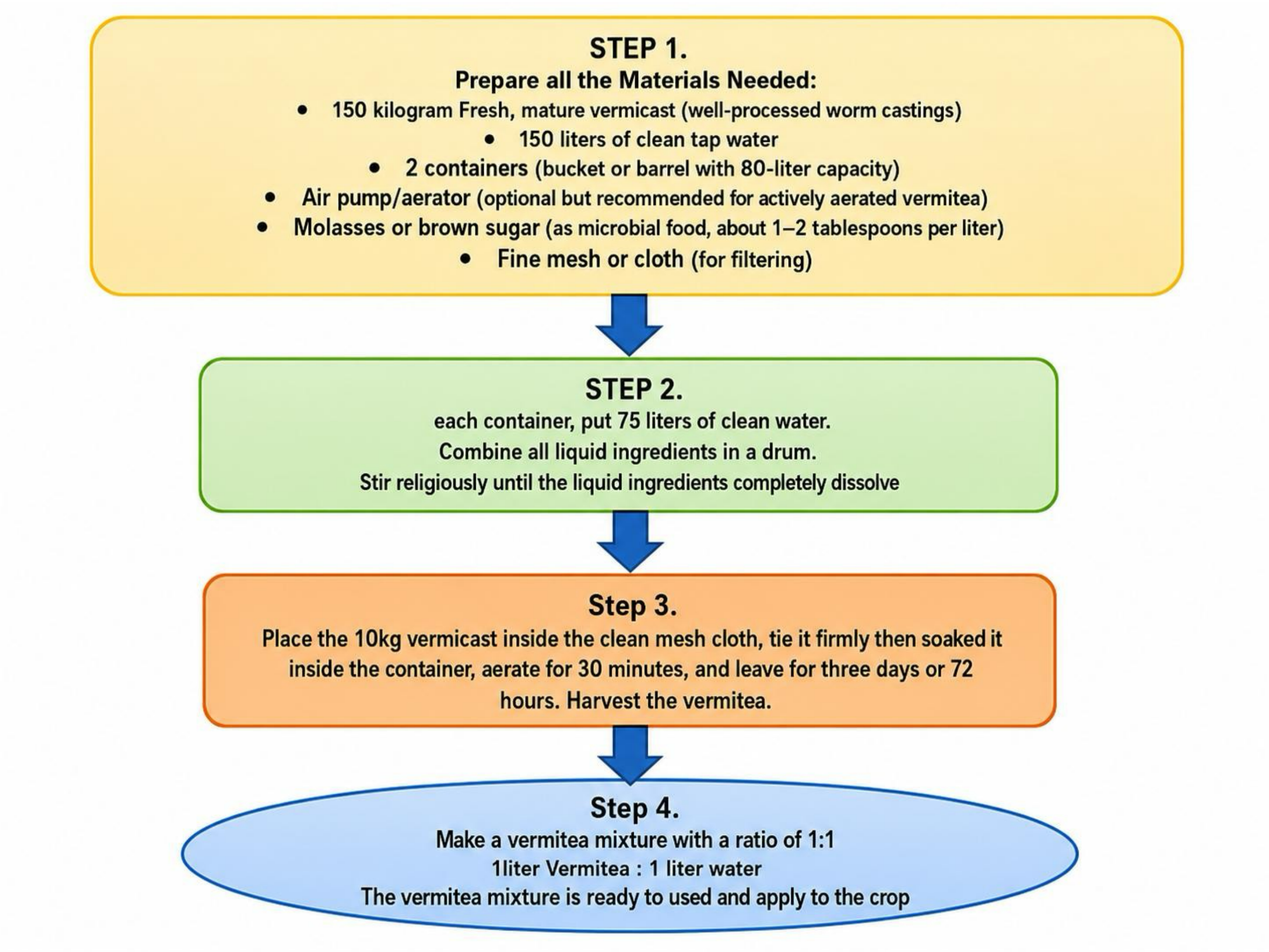

Figure 2: Procedure in making Vermitea

Application of Vermicast and Vermitea

Vermicast and vermitea served as the organic nutrient sources evaluated in this study. Vermicast was applied as a basal amendment by placing it around the base of each tomato plant at the designated treatment rates of 40, 60, 80, and 100 g plant^{-1}**,** which are equivalent **to** 1,066.68, 1,600.02, 2,133.36, and 2,666.70 kg ha^{-1}**,** respectively. Care was taken to distribute the vermicast uniformly around the root zone to facilitate nutrient availability and uptake throughout the growing period.

Vermitea was applied as a foliar spray at the prescribed concentrations of 500, 750, and 1,000 mL diluted in 16 L of water, depending on the assigned treatment. Spraying was carried out once every week during the early morning or late afternoon to minimize evaporation losses and enhance foliar absorption. The first application was made 15 days after transplanting (DAT) and was repeated weekly until 80 DAT, resulting in a total of 10 applications throughout the cropping period.

Irrigation

Adequate soil moisture was maintained throughout the experiment to support optimum plant growth and development. Seedling trays were thoroughly watered two days before transplanting to reduce transplanting shock and promote seedling establishment. Following transplanting, irrigation was provided twice weekly during the first month to ensure adequate moisture during the critical establishment stage. Thereafter, irrigation was applied at weekly intervals, with adjustments made according to prevailing weather conditions and soil moisture status to prevent both moisture stress and waterlogging.

Insect Pest and Disease Management

The experimental area was inspected regularly to monitor the occurrence of insect pests and diseases. Crop observations were conducted every two days to facilitate early detection of pest infestations and disease symptoms. Vermitea was incorporated into the crop management program as a preventive foliar spray because of its reported ability to enhance plant vigor and support natural disease suppression. Applications were initiated during the early stages of crop growth and continued throughout the production cycle to help reduce pest incidence and minimize disease development. Whenever necessary, appropriate cultural management practices, such as the removal of damaged plant parts and field sanitation, were also implemented to maintain healthy crop growth.

Harvesting

Harvesting commenced 60 days after transplanting (DAT) when the fruits reached the appropriate stage of physiological maturity. Fruits were harvested during the early morning to minimize field heat and preserve their firmness, freshness, and overall quality during handling. In addition to fruit color, maturity assessment included firmness and external appearance to ensure that only marketable fruits were collected.

Harvesting was performed one to three times per week, depending on fruit maturity and market demand. Fruits at the **breaker stage** and those that had reached full marketable maturity were carefully picked by hand to avoid mechanical damage. Deformed, diseased, insect-damaged, or otherwise unmarketable fruits were harvested separately to prevent the spread of pests and diseases and to maintain the quality of the harvested produce.

Regular harvesting throughout the production period promoted continuous fruit development by reducing competition among developing fruits and preventing overripe fruits from remaining on the plants. This practice also minimized losses caused by fruit borers and other insect pests while helping extend the productive life of the crop and improve overall marketable yield.

DATA GATHERED

All the data gathered were selected at random from 10 sample plants per plot.

Initial plant height (cm). This was gathered 15 days after transplanting (DAT). The height of the plant was measured from the base of the plant to the tip of the highest leaves. A ruler was used to measure the initial height of the plant.

Final height (cm). This was gathered one week before the data gathering was terminated (120 DAT). The height of the plant was measured from the base of the plant to the tip of the highest leaves. Metering stick was used to measure the final height of the plant.

Height Increment. refers to the increase in plant height from transplanting until the final measurement period under each treatment.

Stem diameter is the width or girth of the main stem of the tomato plant**,** indicating how sturdy or robust the plant is.

Number of primary branches. These are the main branches that grow directly from the main stem after the plant's initial growth.
Number of Leaves per plant. These was gathered at 120 days after transplanting (DAT).

Number of days to flower. The date when 50% of the plants per plot flowered. This was used in determining the number of days from transplanting to flowering.

Number of flowers per plant. The total count of flowers produced by a single tomato during its reproductive stage. It is a key indicator of the plant's reproductive potential, as each flower has the possibility of developing into a fruit.

Number of fruits per plant. Refers to the total count of harvested fruits produced by a single tomato plant during the cropping period.

Average Fruit Weight (grams). Refers to the mean weight of individual tomato fruits harvested from a plant or treatment, expressed in grams (g).

Total Fruit Yield (kg/plant). Refers to the total weight of all fruits harvested from a single tomato plant during the entire cropping or harvesting period, expressed in kilograms per plant (kg/plant).
This was computed by using the formula:

Yield per plant = Average Yield per Plant (kg) x Plant Population per ha.

Fruit Firmness. Refers to the resistance of a tomato fruit to pressure or compression, expressed in kilograms per square centimeter (kg/cm^2).

Fruit Size (cm Diameter). Refers to the average width of a tomato fruit (small, medium and large) measured across its widest portion, expressed in centimeters (cm) which determines the market preference and pricing.

Fruit Shape Index (Length/Diameter). Refers to the ratio between the length and diameter of a tomato fruit**,** used to describe its overall shape.

Marketable Quality (%). Refers to the percentage of harvested tomato fruits that meet market standards (good size, shape, color, and free from defects, pests, and diseases) relative to the total harvested fruits.

Number of non-marketable fruits per plant. This was determined by counting the number of fruits damaged by insect, pest and diseases.

Shelf Life (Days). Refers to the number of days tomato fruits remain acceptable for consumption or marketability after harvest before showing signs of spoilage, over-ripening, or quality deterioration.

Fruit Cracking Incidence (%). This refers to the percentage of tomato fruits that show visible cracks (radial or concentric splits) out of the total harvested fruits.

Weight Loss During Storage (%). refers to the percentage reduction in the weight of tomato fruits during storage due to moisture loss, respiration, and physiological degradation.

Marketable Fruit Yield (t/ha). It refers to the total weight of tomato fruits per hectare that are considered suitable for sale (free from defects, pests, diseases, and physical damage), expressed in metric tons per hectare (t/ha).

Economic Analysis refers to the systematic evaluation of the costs and returns from tomato production under different treatments (T0–T5) to determine profitability and economic efficiency. This was assessed using the formula:

Gross income (PhP). This was taken by getting the yield in kilo gram per hectare and valuing it with the farm gate price.
Gross Income = Yield (t/ha)× Php30/kg

Production Cost (PhP). This was taken from the sum total of all expenses incurred during the whole operation and deducted from the total gross income in order to get the net income.

Net income (PhP). This was computed by subtracting the total expenses from the gross sale.
Net Income = Gross Income−Production Cost
Return on Investment (ROI). This was computed by dividing the net returns by the total investment.

$$\textbf{ROI (\%)} = \frac{\text{Net Income}}{\text{Production Cost}} \times 100$$

Benefit-Cost Ratio (BCR). This was computed by dividing the gross income from the total production cost.

$$\textbf{(BCR)} = \frac{\text{Gross Income}}{\text{Production Cost}}$$

Analysis of Data. All the data gathered were arranged, tabulated, and statistically analyzed using the Analysis of Variance (ANOVA) and significant result was further subjected to the least significant different (LSD) test at 0.05 and 0.01 level of significance.

RESULTS AND DISCUSSION
Growth and Yield Performance
Height of Plants

Table 1. Initial Plant Height, Final Plant Height, and Computed Height Increment of Tomato as Influenced by Vermicast and Vermitea Application.

Treatments/Discription	Initial Plant Height (cm)	Final Plant Height (cm)	Computed Height Increment Data
T0 - Control	12.27b	62.43e	50.13d
T1 - 40g VC + 500 ml Vermitea/ 16L Water	12.60a	69.37d	57.90c
T2 - 60g VC + 750ml Vermitea/ 16L Water	12.70a	77.43b	66.00b
T3 - 80g VC + 1000ml Vermitea/16 L water	12.80a	86.37a	75.43a
T4 - 100g Vermicast/plant	12.50ab	72.33c	60.93bc
T5 - 1000ml vermitea/16L water	12.60a	75.77b	60.83bc
F-TEST	**	**	**
CV (%)	0.86	1.02	3.83

Means with the same letter are not significantly different.
*** Highly Significant*

Growth Performance of Tomato

Table 1 presents the initial plant height, final plant height, and computed height increment of tomato plants subjected to different rates and combinations of vermicast and vermitea applications.

Initial Plant Height

The initial height of tomato seedlings ranged from 12.27 to 12.80 cm across all treatments. Although the analysis of variance detected a highly significant difference ($P \leq 0.01$), the observed variation was minimal, reflecting the natural differences in seedling growth that commonly occur even under carefully managed nursery conditions. The tallest seedlings were recorded in T3 (80 g vermicast + 1,000 mL vermitea per 16 L water) with a mean height of 12.80 cm, followed by T2 (12.70 cm), while T1 and T5 both averaged 12.60 cm and did not differ significantly from one another. The control treatment (T0) registered the lowest mean height at 12.27 cm**.**

Despite these statistical differences, the narrow range in seedling height demonstrates that the experimental plants were generally uniform before treatment application. This observation is further supported by the coefficient of variation (CV = 0.86%)**,** which reflects excellent experimental precision and consistency among the planting materials. Such uniformity is essential because it minimizes the influence of pre-existing differences among seedlings, allowing subsequent changes in plant growth to be associated more confidently with the applied treatments rather than inherent variation in the experimental materials.

Comparable observations have been reported in tomato production studies involving vermicompost-based fertilizers. Arancon et al. (2023) noted that slight differences in seedling height before treatment application were unavoidable but had little influence on the overall response of the crop once vermicompost amendments were introduced. As plant growth progressed, the beneficial effects of vermicompost became increasingly evident, resulting in significant improvements in vegetative development. The present findings follow a similar pattern, where the relatively uniform starting condition provided a reliable basis for evaluating the effects of vermicast and vermitea throughout the growing period.

Final Plant Height

Plant height at harvest responded markedly to the application of vermicast and vermitea, as confirmed by the highly significant treatment effect ($P \leq 0.01$). Among all treatments, T3 (80 g vermicast + 1,000 mL vermitea per 16 L water) produced the tallest plants, with an average height of 86.37 cm, exceeding all other treatments. This was followed by T2 (77.43 cm)**,** T5 (75.77 cm)**,** T4 (72.33 cm)**,** and T1 (69.37 cm), whereas the untreated control produced the shortest plants at 62.43 cm. The very low coefficient of variation (CV = 1.02%) demonstrates the consistency of the data and confirms the reliability of the experimental results.

The progressive increase in plant height observed with increasing levels of vermicast and vermitea reflects the positive influence of these organic amendments on tomato growth. The superior performance of T3 highlights the advantage of combining solid and liquid vermicompost products. Vermicast gradually supplies essential nutrients while improving soil structure, aeration, and moisture retention. At the same time, vermitea provides readily available nutrients together with beneficial microorganisms and biologically active compounds that stimulate plant metabolic processes. The complementary action of these two inputs likely enhanced root development, nutrient acquisition, and photosynthetic activity, ultimately promoting more vigorous vegetative growth.

The results are consistent with recent studies demonstrating the effectiveness of vermicompost-based nutrient management in tomato production. Lazcano et al. (2023) reported significant increases in plant height following vermicompost application, attributing these improvements to enhanced nutrient availability and greater microbial activity within the rhizosphere. Likewise, Arancon et al. (2022) observed that vermicompost tea stimulated vegetative growth by enriching populations of beneficial microorganisms and supplying naturally occurring plant growth regulators. Their findings further revealed that combining vermicompost with vermicompost tea produced greater improvements than using either material independently. Similarly, Suthar et al. (2024) documented enhanced tomato growth at higher vermicompost application rates due to improved soil fertility, stronger root systems, and more efficient nutrient uptake. Collectively, these studies reinforce the present findings and demonstrate that integrating vermicast and vermitea provides a favorable growing environment that supports vigorous plant development.

Height Increment

Height increment differed significantly among treatments ($P \leq 0.01$), indicating that vermicast and vermitea substantially influenced tomato growth throughout the production period. Plants receiving T3 (80 g vermicast + 1,000 mL vermitea per 16 L water) recorded the greatest increase in height (75.43 cm), followed by T2 (66.00 cm). Intermediate responses were obtained from T4 (60.93 cm)**,** T5 (60.83 cm), and T1 (57.90 cm), whereas the untreated control exhibited the smallest increase at 50.13 cm. The coefficient of variation (CV = 3.83%) remained low, confirming good experimental precision and indicating that the observed differences primarily resulted from the treatment effects.

A clear upward trend in height increment was observed as the rate of vermicast and vermitea increased. Plants supplied with the combined organic amendments consistently outperformed those receiving individual applications or no organic inputs. Notably, the height increment achieved under T3 was 50.46% greater than that of the control, demonstrating the substantial contribution of integrated vermicast and vermitea application to vegetative growth.

The enhanced growth response can be explained by the complementary functions of vermicast and vermitea in improving the crop's growing environment. Vermicast contributes a steady supply of macro- and micronutrients while enhancing soil physical properties and stimulating microbial activity. Vermitea supplements these benefits by providing soluble nutrients, beneficial microorganisms, enzymes, and naturally occurring bioactive compounds that accelerate nutrient absorption and physiological processes associated with plant growth. The interaction of these factors creates conditions that favor continuous cell division, stem elongation, and overall biomass accumulation, leading to greater height increment throughout the growing season.

The present findings agree with those reported by Lazcano et al. (2023), who demonstrated that increasing vermicompost application enhanced plant height and biomass through improved nutrient mineralization and greater microbial activity in the root zone. Their study showed that higher vermicompost rates created more favorable conditions for sustained vegetative growth, which closely resembles the growth response observed under T3 in the present investigation. Similar conclusions were reached by Arancon et al. (2022), who found that vermicompost tea significantly increased plant height, leaf expansion, and biomass production by supplying beneficial microorganisms and naturally occurring plant growth-promoting substances. These compounds stimulate nutrient uptake and improve physiological efficiency, thereby supporting rapid vegetative development. The superior growth obtained from the combined application of vermicast and vermitea in this study further demonstrates that integrating both amendments provide greater benefits than applying either material alone.

Table 2. Stem Diameter (mm) and Number of Primary Branches as affected by Vermicast and Vermitea Application.

Treatments	Stem Diameter (mm)	Number of Primary Branches
T1 - 40g VC + 500 ml Vermitea/ 16L Water	8.23e	5.33
T2 - 60g VC + 750ml Vermitea/ 16L Water	8.80d	5.33
T3 - 80g VC + 1000ml Vermitea/16 L water	9.40c	8.33
T4 - 100g Vermicast/plant	9.10cd	10.33
T5 - 1000ml vermitea/16L water	10.30b	9.33
T1 - 40g VC + 500 ml Vermitea/ 16L Water	11.00a	7.67
F-TEST	**	**
CV (%)	1.27	2.93

Means with the same letter are not significantly different.
*** Highly Significant*

Table 2 shows the Stem Diameter (mm) and Number of Primary Branches as affected by Vermicast and Vermitea Application.

Stem Diameter

Table 2 presents the stem diameter and number of primary branches of tomato plants as affected by varying rates and combinations of vermicast and vermitea applications. Stem diameter is an important growth parameter because it reflects the structural strength of the plant, vascular development, nutrient transport efficiency, and the plant's overall capacity to support vegetative and reproductive growth. Analysis of Variance (ANOVA) revealed highly significant differences ($P \leq 0.01$) among treatments, indicating that vermicast and vermitea applications significantly influenced stem thickening and plant vigor. The low coefficient of variation (CV = 1.27%) further indicates experimental accuracy and consistency among observations. The results showed that T5 (1000 ml vermitea/16 L water) produced the thickest stem diameter (11.00 mm), followed by T4 (100 g vermicast/plant) with 10.30 mm. Intermediate values were observed in T2 (9.40 mm), T3 (9.10 mm), and T1 (8.80 mm), while the control treatment (T0) recorded the smallest stem diameter at 8.23 mm.

The significant differences among treatments indicate that vermicast and vermitea positively influenced stem development and overall plant vigor. Plants treated with vermitea alone (T5) produced the thickest stems, suggesting that the readily available nutrients and beneficial microorganisms in vermitea enhanced nutrient uptake and stimulated stem growth. Thicker stems are often associated with improved nutrient transport, stronger plant structure, and better growth performance.

The superior response observed in T5 may be attributed to the rapid availability of nutrients and bioactive compounds supplied by vermitea, while vermicast provides a slower but sustained release of nutrients. The improved stem diameter observed in both treatments indicates enhanced nutrient-use efficiency and plant development, which may contribute to greater productivity.

These findings are consistent with those of Kaur et al. (2024), Qasim et al. (2023), and Elsharkawy et al. (2023), who reported that vermicompost-based amendments improved stem growth, plant vigor, and overall vegetative development through enhanced nutrient availability and microbial activity. The results highlight the potential of vermicast and vermitea as effective and sustainable nutrient sources for tomato production.

Number of Primary Branches

The table presents the number of primary branches produced by tomato plants as affected by different rates and combinations of vermicast and vermitea applications. Branch development is a critical vegetative growth parameter because it directly influences canopy architecture, leaf area expansion, photosynthetic capacity, flowering sites, and ultimately fruit production. The results revealed that the number of primary branches significantly responded to the application of vermicast and vermitea. Analysis of Variance (ANOVA) indicated highly significant differences ($P \leq 0.01$) among treatments, demonstrating that the organic amendments exerted substantial effects on branching characteristics of tomato plants.

Among the treatments, T3 (80 g VC + 1000 ml vermitea/16 L water) produced the highest number of primary branches with a mean of 10.33 branches per plant, followed by T4 (100 g vermicast/plant) with 9.33 branches and T2 (75 g VC + 750 ml vermitea/16 L water) with 8.33 branches. Lower branch numbers were observed in T5 (7.67 branches) and T1 (7.33 branches), while the control treatment (T0) recorded the fewest primary branches at 5.33.

The results clearly demonstrate that increasing rates of vermicast and vermitea enhanced branching development, with the combined application of both organic inputs producing the most favorable response.

The findings further suggest that vermicast and vermitea may have influenced endogenous concentrations of plant growth regulators, particularly cytokinins and auxins. Cytokinins are known to stimulate cell division and promote the development of axillary buds, while balanced auxin-cytokinin interactions regulate branch emergence and growth. The abundance of humic substances and microbial metabolites in vermicompost products may have contributed to these hormonal effects.

The results of the present study are consistent with recent findings highlighting the positive effects of vermicompost-based amendments on branching and vegetative growth in vegetable crops. Arancon et al. (2023) reported that vermicompost application significantly increased branch production in tomato and pepper, which they attributed to improved nutrient availability, enhanced microbial activity, and the presence of growth-promoting compounds such as humic substances and cytokinins. These mechanisms may have contributed to the increased number of primary branches observed in T3 and T4.

Similarly, Lazcano et al. (2023) found that vermicompost enhanced canopy development and overall plant vigor by improving soil biological activity and nutrient-use efficiency. Their study showed that plants receiving higher rates of vermicompost produced more lateral branches than untreated plants, supporting the results obtained in the present investigation.

Likewise, Suthar et al. (2024) reported that vermicompost tea stimulated branching and canopy expansion through increased microbial activity in the rhizosphere and the production of plant growth-promoting substances.

Table 3. Number of Leaves, Days to Flowering, and Number of Flowers per Plant as affected by Vermicast and Vermitea Application.

Treatments	Number of Leaves	Days to Flowering	Number of Flowers per Plant
T1 - 40g VC + 500 ml Vermitea/ 16L Water	56.33f	35.33a	25.00f
T2 - 60g VC + 750ml Vermitea/ 16L Water	66.00e	33.67b	32.00e
T3 - 80g VC + 1000ml Vermitea/16 L water	77.00c	32.33b	41.00c
T4 - 100g Vermicast/plant	86.00a	32.67b	53.00a
T5 - 1000ml vermitea/16L water	71.00d	30.33c	36.00d
T1 - 40g VC + 500 ml Vermitea/ 16L Water	81.00b	29.33c	45.00b
F-TEST	**	**	**
CV (%)	1.71	1.57	1.6

Means with the same letter are not significantly different.
*** Highly Significant*

The data presented in Table 3 illustrates the effect of different vermicast and vermitea treatments on the number of leaves, days to flowering produced by plants, and the number of flowers per plant.

Number of Leaves

As shown in the table, the number of leaves produced by tomato plants was significantly influenced by the application of vermicast and vermitea, as indicated by the highly significant ANOVA result ($P \leq 0.01$). Among the treatments, T3 (80 g vermicast + 1000 ml vermitea per 16 L water) recorded the highest number of leaves (86.00), followed by T5 (1000 ml vermitea per 16 L water) with 81.00 leaves and T2 (75 g vermicast + 750 ml vermitea) with 77.00 leaves. Lower leaf counts were observed in T4 (71.00), T1 (66.00), and the control treatment

(56.33). The low coefficient of variation (CV = 1.71%) indicates a high degree of experimental precision and reliability of the data.

The control treatment (T0) produced the lowest leaf count at 56.33, reflecting the limited growth potential when no organic amendments are applied. In contrast, the combined applications of vermicast and vermitea (T1–T3) consistently enhanced leaf production, with T3 (80 g VC + 1000 ml vermitea per 16 L water) achieving the highest number of leaves at 86.00. Remarkably, vermitea alone (T5) resulted in 81.00 leaves, which was notably higher than vermicast alone (T4, 71.00 leaves). This outcome suggests that liquid extracts may facilitate more efficient nutrient uptake compared to solid amendments.

The findings emphasize the potential of integrating vermicast and vermitea in crop management to stimulate vegetative growth. Vermitea provides readily available nutrients and beneficial microorganisms, while vermicast contributes to long-term soil fertility. Their combination appears to optimize nutrient availability and plant physiological responses, leading to enhanced leaf production.

Recent studies corroborate these results. For instance, Arancon et al. (2022) reported that vermicompost enhances plant growth by improving soil structure and nutrient release. Similarly, Sugino Souffront et al. (2022) emphasized, that vermitea applications increase microbial activity and nutrient solubility, thereby promoting leaf expansion. More recent work by Singh et al. (2024) highlighted that integrated organic inputs, particularly vermicast combined with liquid biofertilizers, significantly improve vegetative parameters compared to single applications. These findings align with the present study, reinforcing the role of vermitea and vermicast synergy in sustainable crop production.

The results demonstrate that vermicast and vermitea applications significantly enhanced leaf production in tomato plants. A general increase in leaf number was observed as the rate of vermicast and vermitea increased, with the combined application in T3 producing the greatest response. This suggests that the integration of vermicast and vermitea created favorable conditions for vegetative growth by improving nutrient availability and promoting physiological processes associated with leaf formation.

Increased leaf production is particularly important because leaves are the primary sites of photosynthesis, and a larger leaf canopy can enhance light interception, carbohydrate production, and overall plant productivity.

The highly significant result implies that leaf development in tomato is highly responsive to vermicompost-based nutrient management. The increased number of leaves observed in treated plants suggests improved nutrient-use efficiency and enhanced vegetative vigor, which may subsequently contribute to better flowering, fruit set, and yield performance. These findings highlight the potential of vermicast and vermitea as sustainable organic inputs for improving tomato growth and productivity.

The present results are supported by recent studies on vermicompost-based amendments. Kaur et al. (2024) reported that the combined application of vermicompost and vermicompost tea significantly increased leaf production and vegetative growth in tomato due to enhanced nutrient availability and microbial activity. Similarly, Rehman et al. (2023) noted that vermicompost promotes plant growth by improving nutrient uptake, stimulating beneficial soil microorganisms, and supplying plant growth-promoting substances. Furthermore, Qasim et al. (2023) found that tomato plants treated with vermicompost exhibited greater leaf development and overall vigor compared with untreated plants. These studies support the present findings and suggest that the enhanced leaf production observed under T3 was likely associated with improved nutrient supply and biological activity in the root zone.

Days to Flowering

The number of days required for flowering was significantly influenced by the application of vermicast and vermitea, as indicated by the highly significant ANOVA result **(**$P \leq 0.01$**).** Tomato plants grown without any amendment (T0) took the longest time to flower, requiring an average of 35.33 days. In contrast, all vermicast- and vermitea-treated plants flowered earlier. The earliest flowering was observed in T5 (1000 ml vermitea per 16 L water) at 29.33 days, followed closely by T4 (100 g vermicast per plant) at 30.33 days**.** Treatments T2 (32.33 days), T3 (32.67 days), and T1 (33.67 days) also flowered significantly earlier than the control. The low coefficient of variation (CV = 1.57**%**) indicates high experimental precision and consistency among observations.

The results demonstrate that the application of vermicast and vermitea accelerated the onset of flowering in tomato plants. Compared with the control, plants receiving vermicompost-based amendments reached the reproductive stage several days earlier, suggesting that these organic inputs enhanced physiological processes associated with plant development. Early flowering is often an indication of improved plant nutrition and vigor, allowing plants to transition more efficiently from vegetative growth to reproductive growth.

Remarkably, vermitea applied alone (T5) resulted in the earliest flowering among all treatments. This response may be attributed to the readily available nutrients, beneficial microorganisms, and bioactive compounds present in vermitea, which can be rapidly absorbed and utilized by plants. Likewise, the favorable performance of T4 indicates that vermicast alone can effectively support plant development by gradually supplying nutrients and improving soil biological activity. The earlier flowering observed in these treatments suggests that both vermicast and vermitea contributed to creating optimal growing conditions that promoted faster crop development.

The highly significant ANOVA result highlights the strong influence of vermicompost-derived amendments on flowering behavior. From a production perspective, earlier flowering is advantageous because it can shorten the crop cycle, hasten fruit set, and potentially allow earlier harvesting and market availability. This may provide economic benefits to growers, particularly in intensive vegetable production systems where crop timing is critical.

The present findings are consistent with recent studies on vermicompost-based amendments in horticultural crops. Kaur et al. (2024) reported that vermicompost and vermicompost tea accelerated flowering and reproductive development in tomato by improving nutrient availability and stimulating plant metabolic activity. Similarly, Rehman et al. (2023) noted that vermicompost enhances plant growth and developmental processes through increased nutrient uptake, microbial activity, and the presence of natural growth-promoting compounds. Furthermore, Qasim et al. (2023) observed that tomato plants treated with vermicompost reached key growth stages earlier than untreated plants due to improved physiological performance and nutrient-use efficiency.

Number of Flowers per Plant

The number of flowers produced per plant was markedly influenced by the application of vermicast and vermitea. Tomato plants treated with 80 g vermicast + 1000 ml vermitea per 16 L water (T3) recorded the highest number of flowers, with a mean of 53.00 flowers per plant, followed by T5 (1000 ml vermitea per 16 L water) with 45.00 flowers and T2 (60 g vermicast + 750 ml vermitea) with 41.00 flowers. Lower flower production was observed in T4 (36.00 flowers) and T1 (32.00 flowers), while the control treatment produced the fewest flowers (25.00 flowers). The different letter groupings indicate that flower production varied significantly among treatments, demonstrating the positive effect of vermicast and vermitea on the reproductive development of tomato plants.

The results show a clear improvement in flower production as the level of vermicast and vermitea increased. Adequate nutrient supply, particularly nitrogen, phosphorus, potassium, and micronutrients, together with the beneficial microorganisms present in vermicompost-based products, may have enhanced photosynthetic activity and assimilate production, allowing plants to allocate more resources toward flower formation.

The relatively high number of flowers observed in T5 further indicates that vermitea alone can effectively stimulate reproductive growth. Because vermitea contains readily available nutrients and plant growth-promoting substances, plants may respond more quickly, leading to enhanced flower initiation and development. However, the greater flower production recorded in T3 suggests that combining vermicast and vermitea provides both immediate and sustained nutritional benefits, resulting in a stronger flowering response.

From an agronomical perspective, increased flower production is important because flowers serve as the foundation for fruit development. A higher number of flowers generally increases the potential number of fruits that can be produced, provided that pollination and fruit set are successful.

The findings of the present study are consistent with recent reports on the benefits of vermicompost-based amendments in horticultural crops. Kaur et al. (2024) found that the combined application of vermicompost and vermicompost tea significantly increased flowering and reproductive growth in tomato due to improved nutrient availability and microbial activity. Similarly, Qasim et al. (2023) reported enhanced flowering and plant vigor in tomatoes treated with vermicompost, attributing these effects to improved nutrient uptake and physiological performance. In a comprehensive review, Rehman et al. (2023) also highlighted that vermicompost-derived products promote flowering and yield formation through their rich nutrient content, beneficial microorganisms, and naturally occurring growth-promoting compounds.

Table 4. Number of Fruits Per Plant, Average Fruit Weight (grams), and Total Fruit Yield (kg/plant) as affected by Vermicast and Vermitea Application.

Treatments	Number of Fruits per Plant	Average Fruit Weight (grams)	Total Fruit Yield (kg/plant)
T0 - Control	19.00e	68.27f	1.87f
T1 - 40g VC + 500 ml Vermitea/ 16L Water	24.00d	75.53e	2.47e
T2 - 60g VC + 750ml Vermitea/ 16L Water	31.00b	84.33c	3.12c
T3 - 80g VC + 1000ml Vermitea/16 L water	41.00a	98.27a	4.02a
T4 - 100g Vermicast/plant	28.00c	79.27d	2.82d
T5 - 1000ml vermitea/16L water	33.00b	87.37b	3.42b
F-TEST	**	**	**
CV (%)	3.05	0.1485	2.34

with the same letter are not significantly different.
*** Highly Significant*

Table 4 presents the Number of Fruits Per Plant, Average Fruit Weight (grams), and Total Fruit Yield (kg/plant) as affected by Vermicast and Vermitea Application.

Number of Fruits per Plant

The number of fruits per plant was significantly influenced by the application of vermicast and vermitea, as indicated by the highly significant ANOVA result ($P \leq 0.01$). Plants treated with T3 (80 g vermicast + 1000 ml vermitea per 16 L water) produced the highest number of fruits (41 fruits per plant), significantly exceeding all other treatments. This was followed by T5 (33 fruits) and T2 (31 fruits), while T4 and T1 produced 28 and 24 fruits, respectively. The control treatment recorded the lowest fruit number (19 fruits per plant). The low coefficient of variation (CV = 3.05%) indicates good experimental precision and consistency of the observed responses.

The results demonstrate that vermicast and vermitea enhanced fruit production, with the combined application producing the greatest response. The superior performance of T3 (80 g vermicast + 1000 ml vermitea per 16 L water) suggests that integrating solid and liquid vermicompost products created favorable nutritional and biological conditions that supported flower retention, fruit set, and fruit development. A greater number of fruits reflects improved plant vigor and reproductive efficiency, both of which are essential for increasing tomato productivity.

These findings are consistent with Kaur et al. (2024)**,** who reported that the combined application of vermicompost and vermicompost tea significantly increased fruit number in tomato by improving nutrient availability and stimulating beneficial microbial activity. Similarly, Qasim et al. (2023) observed that vermicompost enhanced fruit set through improved nutrient uptake and plant physiological performance. The present results confirm that integrating vermicast and vermitea can effectively increase fruit production under sustainable tomato production systems.

Average Fruit Weight

Average fruit weight was also significantly affected by vermicast and vermitea application, as shown by the highly significant ANOVA result ($P \leq 0.01$). The heaviest fruits were produced by T3 (80 g vermicast + 1000 ml vermitea per 16 L water), with a mean weight of 98.27 g, followed by T5 (87.37 g**)** and T2 (84.33 g). Lower fruit weights were obtained from T4 (79.27 g) and T1 (75.53 g), whereas the T0 (control) produced the lightest fruits (68.27 g). The very low coefficient of variation (CV = 0.15%**)** indicates excellent experimental precision and a high level of confidence in the treatment effects.

The increase in fruit weight suggests that vermicast and vermitea enhanced nutrient accumulation during fruit development. The combined application likely provided a continuous supply of essential nutrients while improving nutrient absorption through enhanced microbial activity, resulting in larger and heavier fruits. Increased fruit weight is an important indicator of improved fruit quality and contributes directly to higher market value and profitability.

These findings agree with those of Rehman et al. (2023)**,** who reported that vermicompost improves nutrient uptake and photosynthetic efficiency, leading to increased fruit size and biomass accumulation. Likewise, El-Sayed (2024) found that vermicompost-based amendments significantly increased tomato fruit weight by improving soil fertility and plant nutrient status. The present study therefore demonstrates that combining vermicast and vermitea can effectively improve fruit quality through increased fruit weight.

Total Fruit Yield

Total fruit yield per plant was significantly influenced by the different vermicast and vermitea treatments, as indicated by the highly significant ANOVA result ($P \leq 0.01$**).** Treatment T3 recorded the highest yield (4.02 kg per plant), followed by T5 (3.42 kg), T2 (3.12 kg), T4 (2.82 kg), and T1 (2.47 kg). The control treatment produced the lowest yield at 1.87 kg per plant. The low coefficient of variation (CV = 2.34%) demonstrates the reliability and consistency of the experimental data.

The substantial increase in yield observed in T3 reflects the combined positive effects of increased fruit number and greater fruit weight. These results indicate that the integrated application of vermicast and vermitea enhanced both vegetative growth and reproductive development, ultimately translating into greater yield. Compared with the control, T3 more than doubled fruit yield, highlighting the effectiveness of combining vermicast and vermitea as an organic nutrient management strategy.

Agronomicaly, higher fruit yield directly improves farm productivity and profitability while reducing dependence on synthetic fertilizers. The findings further suggest that vermicompost-based amendments not only improve crop performance but also contribute to more sustainable and environmentally responsible tomato production.

The present findings are supported by Kaur et al. (2024), who reported significant increases in tomato yield following the combined application of vermicompost and vermicompost tea due to improved nutrient availability and enhanced microbial activity. Similarly, Qasim et al. (2023) found that vermicompost significantly increased tomato yield through enhanced nutrient-use efficiency and improved physiological performance. Furthermore, Rehman et al. (2023) concluded that vermicompost-based amendments improve crop productivity by enhancing soil fertility, microbial diversity, and plant growth. These studies corroborate the present findings and reinforce the value of vermicast and vermitea as sustainable nutrient sources capable of increasing tomato yield while promoting long-term soil health.

Fruit Quality and Postharvest Characteristics

Table 5. Fruit Firmness (kg/cm^2), Fruit Size (cm Diameter), and Fruit Shape Index (Length/Diameter) as affected by Vermicast and Vermitea Application.

Treatments	Fruit Firmness (kg/cm^2)	Fruit Size (cm Diameter)	Fruit Shape Index (Length/Diameter) (cm)
T0 - Control	3.90e	4.53e	1.11e
T1 - 40g VC + 500 ml Vermitea/ 16L Water	4.20d	5.03d	1.14d
T2 - 60g VC + 750ml Vermitea/ 16L Water	4.50c	5.30c	1.18c
T3 - 80g VC + 1000ml Vermitea/16 L water	4.40cd	5.10cd	1.16cd
T4 - 100g Vermicast/plant	5.03b	5.80b	1.21b
T5 - 1000ml vermitea/16L water	5.40a	6.20a	1.25a
F-TEST	**	**	**
CV (%)	2.21	1.48	0.8368

Means with the same letter are not significantly different.
*** Highly Significant*

Table 5 presents the Fruit Firmness (kg/cm^2), Fruit Size (cm Diameter), and Fruit Shape Index (Length/Diameter) as affected by Vermicast and Vermitea Application.

Fruit Firmness (kg/cm^2)
Fruit firmness was significantly affected by the application of vermicast and vermitea, as indicated by the highly significant ANOVA result ($P \leq 0.01$). Among the treatments, T5 (1000 ml vermitea per 16 L water) produced the firmest fruits with a mean value of 5.40 kg/cm^2, followed by T4 (100 g vermicast per plant) at 5.03 kg/cm^2**.** Intermediate values were observed in T2 (4.50 kg/cm^2), T3 (4.40 kg/cm^2), and T1 (4.20 kg/cm^2), while the control treatment recorded the lowest fruit firmness (3.90 kg/cm^2). The low coefficient of variation (CV = 2.21%) indicates high experimental precision and consistency of the treatment effects.

The results suggest that vermicompost-based amendments improved fruit firmness, with vermitea showing the greatest influence. Firmer fruits are generally associated with stronger cell walls, improved calcium utilization, and better tissue integrity, characteristics that enhance fruit quality, storage life, and resistance to mechanical damage during harvesting and transport. The superior performance of T5 indicates that the readily available nutrients and beneficial microorganisms present in vermitea may have enhanced nutrient uptake and physiological processes responsible for fruit tissue development.

From instance, increased fruit firmness is an important quality attribute because it improves postharvest handling, extends shelf life, and enhances market acceptability. These findings indicate that vermitea can serve as an effective organic amendment for producing tomatoes with better postharvest quality while reducing reliance on synthetic inputs.

The present findings agree with those of Kaur et al. (2024)**,** who reported that vermicompost tea significantly improved tomato fruit quality, including firmness, through enhanced nutrient availability and microbial activity. Likewise, Rehman et al. (2023) found that vermicompost-based amendments improved fruit quality by increasing nutrient uptake and strengthening plant physiological functions. Similarly, Qasim et al. (2023) observed that vermicompost application enhanced fruit firmness through improved mineral nutrition and better fruit development.

Fruit Size (cm Diameter)
Fruit size was also significantly influenced by vermicast and vermitea application ($P \leq 0.01$). The largest fruits were obtained from T5 (1000ml vermitea), with a mean diameter of 6.20 cm, followed by T4 (5.80 cm). Treatments T2 (5.30 cm), T3 (5.10 cm), and T1 (5.03 cm) produced moderately sized fruits, while the control recorded the smallest fruits (4.53 cm). The low coefficient of variation (CV = 1.48%) indicates excellent reliability of the experimental results.

The increase in fruit diameter demonstrates the positive effect of vermicast and vermitea on fruit development. The superior response observed in T5 suggests that vermitea provided readily available nutrients and growth-promoting compounds during the fruit enlargement stage, allowing fruits to attain greater size. Larger fruit size is often associated with improved nutrient accumulation, efficient photosynthesis, and enhanced carbohydrate translocation to developing fruits.

These findings have important implications for commercial tomato production because larger fruits generally command higher market prices and improve consumer preference. The results suggest that vermitea can be an effective organic input for enhancing fruit quality while supporting sustainable production practices.

These observations are consistent with the findings of Kaur et al. (2024), who reported significant increases in tomato fruit size following vermicompost and vermicompost tea application. Similarly, Elsharkawy et al. (2023) found that vermicompost improved fruit development through enhanced nutrient uptake and increased photosynthetic activity. Qasim et al. (2023) likewise reported larger tomato fruits in plants receiving vermicompost due to improved nutrient-use efficiency and better physiological performance.

Fruit Shape Index (Length/Diameter)
The fruit shape index was likewise significantly affected by vermicast and vermitea application, as indicated by the highly significant ANOVA result ($P \leq 0.01$). The highest fruit shape index was obtained from T5 (1.25), followed by T4 (1.21). Treatments T2 (1.18), T3 (1.16), and T1 (1.14) recorded intermediate values, while the control produced the lowest fruit shape index (1.11). The very low coefficient of variation (CV = 0.84%) indicates a high degree of uniformity and precision in the experimental data.

The improvement in fruit shape index suggests that vermicast and vermitea positively influenced fruit development and uniformity. Balanced nutrient availability and enhanced physiological activity likely promoted more consistent cell expansion and fruit growth, resulting in well-developed fruits with desirable market characteristics. Although fruit shape is largely controlled by genetics, adequate nutrition plays an important role in expressing desirable fruit morphology.

From a production perspective, uniform fruit shape is a valuable quality trait because it improves grading, packaging efficiency, consumer acceptance, and market value. The superior performance of T5 indicates that vermitea may be particularly effective in improving external fruit quality, making it a useful component of sustainable tomato production systems.

The present findings agree with Rehman et al. (2023), who reported that vermicompost-based amendments improved tomato fruit quality by enhancing nutrient availability and fruit development. Similarly, Kaur et al. (2024) observed improvements in fruit morphology and market quality following vermicompost tea application. Furthermore, Qasim et al. (2023) concluded that vermicompost significantly enhanced fruit quality attributes through improved soil fertility and plant physiological performance.

Table 6. Market Quality (%), Number of Non-Marketable Fruits per Plant, and Marketable fruits(t/ha) as affected by Vermicast and Vermitea Application.

Treatments	Market Quality (%)	Number of Non-Marketable Fruits per Plant	Marketable Fruits (t/ha)
T0 - Control	81.05d	3.67a	12.50c
T1 - 40g VC + 500 ml Vermitea/ 16L Water	87.49c	3.00a	16.80b
T2 - 60g VC + 750ml Vermitea/ 16L Water	93.54b	2.00b	18.67b
T3 - 80g VC + 1000ml Vermitea/16 L water	97.56a	1.00c	21.43a
T4 - 100g Vermicast/plant	89.28c	3.00a	19.27ab
T5 - 1000ml vermitea/16L water	93.94b	2.00b	17.90b
F-TEST	**	**	**
CV (%)	1.22	9.64	4.94

Means with the same letter are not significantly different.
*** Highly Significant*

Table 6 exhibited the Market Quality (%), Number of Non-Marketable Fruits per Plant, and Marketable Fruit Yield (t/ha) as Affected by Vermicast and Vermitea Application

Market Quality (%)
As can be seen in the table, Market quality was significantly influenced by the application of vermicast and vermitea, as indicated by the highly significant ANOVA result ($P \leq 0.01$). The combined application of 80 g vermicast + 1000 ml vermitea per 16 L water (T3) produced the highest market quality (97.56%), followed by T5 (93.94%) and T2 (93.54%). Lower percentages were obtained from T4 (89.28%) and T1 (87.49%), while the control treatment recorded the lowest market quality (81.05%). The low coefficient of variation (CV = 1.22%) indicates excellent experimental precision and consistency.

The results show that vermicast and vermitea substantially improved the proportion of marketable fruits. The superior performance of T3 suggests that combining solid and liquid vermicompost products enhanced fruit development and reduced quality defects. Improved nutrient availability, beneficial microbial activity, and the presence of naturally occurring plant growth regulators likely contributed to the production of fruits with better size, firmness, and appearance. From a practical perspective, higher market quality translates into greater economic returns because a larger proportion of the harvest meets commercial standards.

These findings are consistent with Qasim et al. (2023), who reported that vermicompost significantly improved tomato fruit quality by enhancing nutrient uptake and plant physiological performance. Likewise, Kaur et al. (2024) observed that vermicompost and vermicompost tea increased marketable yield through improved fruit development and balanced plant nutrition.

Number of Non-Marketable Fruits per Plant

The number of non-marketable fruits per plant was likewise significantly affected by vermicast and vermitea application ($P \leq 0.01$). Treatment T3 recorded the fewest non-marketable fruits (1.00 fruit per plant), followed by T2 and T5 with 2.00 fruits each. Treatments T1 and T4 produced 3.00 fruits, while the control had the highest number (3.67 fruits per plant). Although the coefficient of variation (CV = 9.64%) was relatively higher than the other parameters, it remained within the acceptable range for biological experiments.

The reduction in non-marketable fruits indicates that vermicompost-based amendments promoted healthier fruit development and minimized the occurrence of defective or undersized fruits. Improved nutrient balance and enhanced microbial activity likely strengthened plant growth and reduced physiological disorders, resulting in better fruit quality. Fewer non-marketable fruits not only reduce postharvest losses but also increase production efficiency and farm profitability.

The present findings agree with Rehman et al. (2023), who emphasized that vermicompost improves crop quality by enhancing soil fertility, nutrient-use efficiency, and plant health. Similarly, Kaur et al. (2024) reported that vermicompost-based amendments reduced fruit defects and increased the proportion of marketable produce in tomato.

Marketable Fruit Yield (t/ha)

Marketable fruit yield was significantly influenced by the different vermicast and vermitea treatments, as shown by the highly significant ANOVA result ($P \leq 0.01$). Treatment T3 produced the highest marketable yield (21.43 t/ha), significantly outperforming all other treatments. This was followed by T4 (19.27 t/ha), T2 (18.67 t/ha), T5 (17.90 t/ha), and T1 (16.80 t/ha), while the control recorded the lowest yield (12.50 t/ha). The coefficient of variation (CV = 4.94%) indicates acceptable experimental precision and dependable treatment responses.

The higher marketable yield observed in T3 reflects the combined effects of improved vegetative growth, enhanced fruit set, greater fruit weight, and superior fruit quality. The findings suggest that integrating vermicast and vermitea can improve both productivity and fruit quality while reducing dependence on synthetic fertilizers, making it a practical approach for sustainable tomato production.

The present results are supported by Qasim et al. (2023), who found that vermicompost significantly increased tomato yield through improved nutrient-use efficiency and enhanced physiological performance. Similarly, Kaur et al. (2024) reported that the combined application of vermicompost and vermicompost tea resulted in higher marketable yields due to better fruit quality and reduced disease incidence. Rehman et al. (2023) likewise concluded that vermicompost-based amendments enhance crop productivity by improving soil health, nutrient availability, and plant physiological processes.

Table 7. Shelf-Life Days, Fruit Cracking Incidence (%), and Weight Loss During Storage as affected by Vermicast and Vermitea Application.

Treatments	Shelf Life (Days)	Fruit Cracking Incidence (%)	Weight Loss During Storage
T0 - Control	10.33d	21.49a	87.77b
T1 - 40g VC + 500 ml Vermitea/ 16L Water	10.33d	14.12b	90.23ab
T2 - 80g VC + 750ml Vermitea/ 16L Water	12.33bc	7.50d	92.77ab
T3 - 80g VC + 1000ml Vermitea/16 L water	14.67a	2.44e	95.90a
T4 - 100g Vermicast/plant	11.33cd	10.69c	88.23b
T5 - 1000ml vermitea/16L water	13.33ab	5.96d	93.47ab
F-TEST	**	**	**
CV (%)	3.91	10.03	2.63

Means with the same letter are not significantly different.
*** Highly Significant*

Table 7 shows the Shelf Life, Fruit Cracking Incidence, and Weight Loss During Storage as Affected by Vermicast and Vermitea Application

Shelf Life (Days)

Shelf life was significantly influenced by the application of vermicast and vermitea, as indicated by the highly significant ANOVA result ($P \leq 0.01$). Tomato fruits from T3 (80 g vermicast + 1000 ml vermitea per 16 L water) had the longest storage life (14.67 days), followed by T5 (13.33 days) and T2 (12.33 days). Fruits from T4 and both the control (T0) and T1 exhibited shorter shelf lives, ranging from 10.33 to 11.33 days. The low coefficient of variation (CV = 3.91%) indicates that the observed differences were reliable and consistent across treatments.

The results indicate that vermicast and vermitea effectively prolonged tomato shelf life. The superior performance of T3 suggests that the combined application improved fruit structural integrity and delayed deterioration. This response may be associated with better nutrient balance, particularly calcium and potassium, together with enhanced physiological activity promoted by vermicompost-derived bioactive compounds. Longer shelf life is an important postharvest trait because it reduces storage losses, extends marketability, and increases the value of fresh produce.

These findings agree with Kaur et al. (2024), who reported that vermicompost and vermicompost tea improved tomato shelf life by enhancing fruit quality and delaying senescence. Likewise, Rehman et al. (2023) concluded that vermicompost enhances postharvest quality through improved nutrient uptake, antioxidant activity, and overall fruit physiology.

Fruit Cracking Incidence (%)

Fruit cracking incidence was also significantly affected by vermicast and vermitea application ($P \leq 0.01$). The highest incidence of fruit cracking was recorded in the control treatment (21.49%), whereas T3 had the lowest value (2.44%), representing nearly a 90% reduction compared with the untreated plants. Treatments T5 (5.96%) and T2 (7.50%) also substantially reduced fruit cracking, while T4 (10.69%) and T1 (14.12%) showed intermediate responses. Although the coefficient of variation (CV = 10.03%) was higher than the other parameters, it remained within the acceptable range for biological studies

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The marked reduction in fruit cracking indicates that vermicast and vermitea improved fruit integrity and resistance to physiological disorders. Adequate nutrient availability, particularly calcium, together with improved water regulation and stronger cell walls, may have contributed to the lower cracking incidence observed in treated plants. Reducing fruit cracking is economically important because cracked fruits are more susceptible to pathogen infection, have lower market value, and contribute to postharvest losses.

The present findings are supported by Qasim et al. (2023), who reported that vermicompost improved fruit quality and reduced physiological disorders through enhanced nutrient balance and improved plant health. Similarly, Kaur et al. (2024) observed lower fruit defects in tomato following vermicompost-based treatments due to improved fruit development and stronger tissue structure.

Weight Loss During Storage (%)

Weight loss during storage was significantly influenced by vermicast and vermitea application ($P \leq 0.01$). Fruits harvested from T3 recorded the highest value (95.90%), followed by T5 (93.47%) and T2 (92.77%), whereas the control and T4 had lower values of 87.77% and 88.23%, respectively. The coefficient of variation (CV = 2.63%) indicates good experimental precision.

The significant differences among treatments indicate that vermicompost-based amendments influenced postharvest moisture retention and fruit quality during storage. Assuming this parameter represents the remaining marketable weight after storage, the higher values observed in T3 suggest better maintenance of fruit quality and lower deterioration throughout the storage period. Improved nutrient status and stronger fruit tissues likely reduced physiological breakdown and helped preserve fruit freshness for a longer time.

These findings support the earlier observations on shelf life and fruit firmness, indicating that vermicast and vermitea not only enhanced fruit production but also improved postharvest quality. Better storage performance reduces postharvest losses, increases marketing flexibility, and provides greater economic returns to growers.
Similar results were reported by Rehman et al. (2023), who found that vermicompost improved postharvest quality by enhancing fruit physiological stability and reducing deterioration during storage. Likewise, Elsharkawy et al. (2023) demonstrated that vermicompost application improved fruit biochemical characteristics associated with longer storage life and better postharvest performance.

Overall, the combined application of 100 g vermicast and 1000 ml vermitea per 16 L water (T3) consistently produced tomatoes with superior postharvest quality. Fruits from this treatment exhibited the longest shelf life, the lowest incidence of fruit cracking, and the best storage performance, demonstrating that integrating vermicast and vermitea can effectively improve both fruit quality and marketability under sustainable tomato production systems.

Economic Analysis
At Farm gate price of ₱30/kg = ₱30,000/ton
Costs include labor, materials, vermicast/tea inputs, and application

Table 8. Yield (t/ha), Gross Income (₱), Production Cost (₱/ha), Net Income (₱), Return on Investment

(ROI)(%), and Benefit Cost Ration (BCR).

Treatments	Yield (t/ha)	Gross Income (₱)	Production Cost (₱/ha)	Net Income (₱)	ROI (%)	BCR
T0 - Control	12.50a	375000.00a	189370.40a	185,629.60a	98.02f	1.98f
T1 - 40g VC + 500 ml VT/ 16L Water	16.80a	504000.00b	192437.08ab	311,562.92c	161.94e	2.62a
T2 - 60g VC + 750ml VT/ 16L Water	18.60b	558000.00b	193420.42ab	364,579.58c	188.49c	2.88c
T3 - 80g VC + 1000ml VT/16 L water	21.40d	642000.00d	194403.76ab	447,596.24d	230.24a	3.30a
T4 - 100g VC/plant	19.20c	576000.00b	193137.10ab	382,862.90c	198.23b	2.98b
T5 - 1000ml VT/16L water	17.90a	537000.00b	193470.40ab	343,529.60c	177.56d	2.77d
F-TEST	**	**	**	**	**	**
CV (%)	0.168	1.65	2.42	1.325	0.0350	0.1268

Means with the same letter are not significantly different.
*** Highly Significant*

Table 8 Presents the Yield, Gross Income, Production Cost, Net Income, Return on Investment (ROI), and Benefit-Cost Ratio (BCR) as Affected by Vermicast and Vermitea Application

Yield (t/ha)

Tomato yield was significantly influenced by the application of vermicast and vermitea, as indicated by the highly significant ANOVA result ($P \leq 0.01$). The highest yield was obtained from T3 (80 g vermicast + 1000 ml vermitea per 16 L water) with 21.40 t/ha, followed by T4 (19.20 t/ha) and T2 (18.60 t/ha). Lower yields were recorded in T5 (17.90 t/ha) and T1 (16.80 t/ha), while the control produced the lowest yield (12.50 t/ha). The very low coefficient of variation (CV = 0.168**%**) indicates excellent experimental precision and reliability.

The higher yield obtained under T3 reflects the combined benefits of vermicast and vermitea in improving plant growth, fruit development, and nutrient-use efficiency. The integrated application likely provided a balanced and continuous supply of nutrients while enhancing microbial activity and root development, enabling plants to sustain higher productivity. These findings suggest that combining vermicast and vermitea is an effective organic nutrient management strategy for increasing tomato yield under sustainable production systems.

The results agree with Qasim et al. (2023), who reported significant yield improvements in tomato following vermicompost application due to enhanced nutrient uptake and plant physiological performance. Likewise**,** Kaur et al. (2024) found that combining vermicompost and vermicompost tea significantly increased tomato yield by improving soil fertility and promoting healthier plant growth.

Gross Income (₱)

Gross income differed significantly among treatments ($P \leq 0.01$). Consistent with its superior yield performance, T3 generated the highest gross income (**₱**642,000.00/ha), followed by T4 (**₱**576,000.00/ha) and T2 (**₱**558,000.00/ha). The control treatment produced the lowest gross income (**₱**375,000.00/ha). The low coefficient of variation (CV = 1.65%) indicates dependable treatment responses.

The increase in gross income directly reflects the higher marketable yield obtained from vermicast- and vermitea-treated plants. This demonstrates that improving crop productivity through organic nutrient management can substantially enhance farm revenue. For tomato growers, increased gross income provides greater financial returns without relying solely on synthetic fertilizer inputs.

These findings support those of Rehman et al. (2023), who emphasized that vermicompost-based nutrient management improves crop productivity and economic performance through enhanced soil fertility and plant growth. Similar economic gains from vermicompost application were also reported by Kaur et al. (2024)**.**

Production Cost (₱/ha)

Production costs were also significantly affected by the treatments ($P \leq 0.01$), although the differences among vermicast- and vermitea-treated plots were relatively small. Production costs ranged from ₱189,370.40/ha in the control to ₱194,403.76/ha in T3, with a coefficient of variation of 2.42%.

The slight increase in production cost observed in treatments receiving vermicast and vermitea reflects the additional investment required for organic inputs. However, the relatively small increase in production expenses was more than compensated by the substantial gains in yield and income. This indicates that investing in vermicompost-based amendments is economically justifiable because the additional costs are offset by improved productivity and profitability.

Net Income (₱)

Net income was significantly influenced by vermicast and vermitea application ($P \leq 0.01$). Treatment T3 generated the highest net income (₱447,596.24/ha), followed by T4 (₱382,862.90/ha) and T2 (₱364,579.58/ha). The control recorded the lowest net income (₱185,629.60/ha). The low coefficient of variation (CV = 1.33%) indicates consistent economic responses across treatments.

The substantial increase in net income under T3 demonstrates that the combined application of vermicast and vermitea not only improved crop performance but also enhanced overall farm profitability. Although production costs increased slightly, the higher yields generated sufficient returns to produce significantly greater profits. These findings highlight the economic advantage of integrating organic nutrient sources into tomato production.

Similar results were reported by Qasim et al. (2023), who found that vermicompost application significantly increased farm profitability through higher yields and improved fruit quality.

Return on Investment (ROI)

The return on investment was highly significant among treatments ($P \leq 0.01$). Treatment T3 achieved the highest ROI (230.24%), followed by T4 (198.23%) and T2 (188.49%). In contrast, the control recorded the lowest ROI (98.02%). The extremely low coefficient of variation (CV = 0.035%) demonstrates exceptional consistency of the economic data.

The high ROI obtained from T3 indicates that every peso invested in vermicast and vermitea generated substantially greater returns than the other treatments. This finding confirms that the integrated application is not only agronomically effective but also economically viable. High ROI is particularly important for farmers because it reflects efficient resource utilization and lower financial risk.

These findings agree with Rehman et al. (2023), who reported that vermicompost-based production systems improve both biological productivity and economic efficiency. Likewise, Kaur et al. (2024) concluded that integrating vermicompost products provides higher financial returns than conventional nutrient management practices.

Benefit-Cost Ratio (BCR)

The benefit-cost ratio also differed significantly among treatments ($P \leq 0.01$). Treatment T3 recorded the highest BCR (3.30), followed by T4 (2.98) and T2 (2.88), while the control had the lowest value (1.98). The coefficient of variation (CV = 0.13%) indicates highly reliable economic measurements.

A Benefit Cost Ration (BCR) greater than 1.0 indicates that the enterprise is profitable, and the values obtained in all treatments confirm that tomato production remained economically feasible. However, the markedly higher BCR of T3 demonstrates that combining vermicast and vermitea generated the greatest economic return per unit cost. This suggests that farmers adopting the integrated application can maximize profitability while promoting environmentally sustainable production practices.

The present findings are consistent with those of Kaur et al. (2024) and Qasim et al. (2023), who both reported improved economic returns from vermicompost-based nutrient management due to increased yield, better fruit quality, and higher marketable production.

Overall, the economic analysis clearly demonstrates that the combined application of 100 g vermicast and 1000 ml vermitea per 16 L water (T3) is the most profitable treatment. It consistently produced the highest yield, gross income, net income, return on investment, and benefit-cost ratio, indicating that integrating vermicast and vermitea is both an agronomically effective and economically sustainable nutrient management strategy for tomato production.

Conclusions

The application of vermicast and vermitea significantly improved the growth, reproductive development, fruit quality, yield, postharvest performance, and economic returns of tomato under the agroecological conditions of Ilocos Sur. All measured parameters showed highly significant responses to the different treatments, confirming that vermicompost-based amendments effectively enhanced plant growth and productivity.

Among the treatments evaluated, the combined application of 80 g vermicast and 1000 ml vermitea per 16 L water (T3) consistently produced the best overall performance. It resulted in the greatest plant height, leaf production, flowering, fruit number, fruit weight, marketable yield, and superior postharvest quality while generating the highest gross income, net income, return on investment, and benefit-cost ratio. Although vermitea applied alone was more effective in improving stem diameter, fruit firmness, fruit size, and promoting earlier flowering, integrating vermicast and vermitea produced the most balanced improvements across all agronomic, quality, and economic parameters.

The findings demonstrate that vermicast and vermitea complement each other by providing both a sustained and readily available supply of nutrients while enhancing beneficial microbial activity and overall soil health. Consequently, the integrated use of these organic inputs offers a sustainable and profitable nutrient management strategy that can reduce dependence on synthetic fertilizers, improve tomato productivity, and support environmentally responsible vegetable production.

Recommendations/implications

Based on the findings of the study, the combined application of 100 g vermicast per plant and 1000 ml vermitea per 16 L water is recommended for tomato production under conditions similar to those of Ilocos Sur because it consistently produced the highest growth, yield, fruit quality, and economic returns. Farmers are encouraged to adopt this nutrient management practice as a sustainable alternative to conventional fertilizer programs to improve productivity while maintaining soil fertility.

Agricultural extension workers, local government units, and development agencies may use these findings in designing training programs that promote the production and utilization of locally available vermicast and vermitea. Wider adoption of vermicompost-based nutrient management can contribute to lower production costs over time, reduced environmental impacts associated with excessive chemical fertilizer use, and improved farm profitability.

Future studies should evaluate the long-term effects of repeated vermicast and vermitea application on soil health, nutrient dynamics, and microbial diversity under different soil types and climatic conditions. Further research may also investigate their integration with reduced rates of inorganic fertilizers, other organic amendments, or biofertilizers to develop more efficient integrated nutrient management strategies. In addition, studies involving different tomato varieties, cropping seasons, and multi-location field trials are recommended to validate the consistency of the results and broaden the applicability of the technology across diverse production environments.

The findings contribute to sustainable agriculture by demonstrating that vermicompost-derived products can simultaneously improve crop productivity, fruit quality, profitability, and environmental stewardship, thereby supporting resilient vegetable production systems and reducing dependence on synthetic fertilizers.

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