Influence of graded levels of vermicompost integrated with FYMe-based fertigation on yield, fruit quality and soil microbial population of strawberry (Fragaria × ananassa Duch.) cv. Winter Dawn

Amit Shah
Punjab Agricultural University
Kuldeep Singh Bhullar
ksbhullar@pau.edu
Punjab Agricultural University
Gulab Pandove
Punjab Agricultural University
Gurmeet Singh Dheri
Punjab Agricultural University

Research Article

Keywords: Drip Irrigation, Farmyard manure extract, Organic Fertigation, Strawberry, Vermicompost

Posted Date: February 12th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8789547/v1

Additional Declarations: No competing interests reported.

Influence of graded levels of vermicompost integrated with FYMe-based fertigation on yield, fruit quality and soil microbial population of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn

[1]Amit Shah, [2]Kuldeep Singh Bhullar, [3]Gulab Pandove and [4]Gurmeet Singh Dheri

[1]Department of Fruit Science, Punjab Agricultural University, Ludhiana (Punjab), India

[2]School of Organic and Natural Farming, Punjab Agricultural University, Ludhiana (Punjab), India

[3]School of Organic and Natural Farming, Punjab Agricultural University, Ludhiana (Punjab), India

[4] Department of Soil Science, Punjab Agricultural University, Ludhiana (Punjab), India

Corresponding author: Kuldeep Singh Bhullar

Email: ksbhullar@pau.edu

Abstract Organic farming is a sustainable alternative to conventional production systems. The present experiment was conducted during 2023-24 and 2024-25 to evaluate the effect of vermicompost integrated with farmyard manure extract (FYMe) fertigation on growth, yield, biochemical attributes, nutrient content and soil microbial population of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn. The experiment was conducted in a randomised complete block design with five treatments and three replications. Treatments comprised vermicompost supplying 60, 80 and 100% of recommended nitrogen as basal dose, supplemented with 20% nitrogen through FYMe, along with vermicompost alone and an untreated control

Results revealed that vermicompost and FYMe fertigation significantly influenced all measured parameters for both the years. Application of 100% nitrogen through vermicompost + FYMe consistently resulted in the highest plant growth, fruit yield, fruit number and fruit weight. Fruit quality attributes, including total soluble solids, total sugars, phenolic content, ascorbic acid and anthocyanin were also significantly enhanced under this treatment. Improved nitrogen, phosphorus and potassium content in the plant and soil along with increased number of beneficial microbes indicated improved nutrient availability and soil biological dynamics. The unfertilized control recorded the lowest value for all parameters. The study demonstrated that vermicompost supplemented with FYMe fertigation is an effective organic nutrient management strategy for enhancing productivity, fruit quality and soil microbial health of strawberry.

Keyword: Drip Irrigation; Farmyard manure extract; Organic Fertigation; Strawberry; Vermicompost

Introduction

Strawberry is a popular fruit known for its sweet flavour and pleasant aroma. It belongs to the genus *Fragaria* in the rose family (Rosaceae). Strawberries are valued for their high vitamin C content, along with dietary fibre, antioxidants, folate and manganese (Giampier et al. 2012). They are grown in the many parts of the world and thrive in cool to moderate climates. Conventional farming systems typically depend on synthetic fertilizers, pesticides, intensive irrigation and mechanization. Although these technologies have enhanced productivity, they have also contributed to pollution, soil degradation and health risks due to excessive use of agrochemicals. As a result, there is growing interest in alternative production systems that rely on biological and organic inputs for nutrient supply and pest management (Garg et al. 2024). Environmental concerns are gaining increasing global attention, prompting researchers and policymakers to promote agricultural practices that minimize ecological damage (Fischer et al. 2025). Organic farming has emerged as a sustainable approach aimed at maintaining soil health, reducing chemical residues and protecting natural resources (Sher et al. 2024). The core principle of organic agriculture is to enhance the growth and functioning of soil microorganisms without depending on synthetic chemical inputs. These microbes are important for maintaining soil fertility. Organic manures such as vermicompost and Farmyard Manure have been reported to increase microbial populations, strengthen microbial community structure and consequently enhance crop productivity (Shah et al. 2018). Vermicomposting is a bioconversion process in which organic waste is decomposed by earthworms (Pathma and Sakthivel 2012). It facilitates the recycling of organic waste into more bioavailable forms with elevated nutrient and mineral content alongside beneficial microorganisms under controlled temperature and aeration conditions (Oyewole et al. 2014). Further, vermicompost is also enriched with nutrients. Due to its high nutrient availability and microbial activity, vermicompost improved soil fertility, stimulated plant growth and suppressed plant pathogens and pest populations (Pathma and Sakthivel 2012). Liquid organic input such as bio-inoculants like Farmyard Manure extract is rich in beneficial microbes and plant growth enhancing compounds. It significantly contributes to improve plant growth, yield and quality, making them highly effective for biofertigation in organic farming (Boraiah et al. 2017). Drip irrigation is a modern irrigation technique in which water is supplied slowly and precisely to the crop root zone through a network of plastic pipes. This system can save 20-50% of water and increase crop yields by 10 to 30%, resulting in significantly higher water productivity compared to conventional flood irrigation (Kadasiddappa et al. 2015; Parthasarathi et al. 2018; Li et al. 2020). Organic fertigation through drip irrigation provides nutrients directly to the roots, reduces losses and improves plant growth and yield. Biofertigation refers to the precise delivery of beneficial microorganisms through micro-irrigation systems, allowing both water and organic inputs to be applied simultaneously and efficiently. Biofertigation can increase cation exchange capacity and promote the proliferation of beneficial microbes, ultimately leading to improved nutrient uptake and root development (Garcia et al. 2018). Despite the growing adoption of organic inputs in horticultural crop production, limited scientific information is available on the combined effect of graded levels of vermicompost applied as a basal dose along with organic fertigation on strawberry growth, yield, fruit quality, biochemical attributes, and soil microbial population under field conditions. Although recent studies have shown that vermicompost and organic amendments can improve strawberry yield and quality parameters and influence nutrient uptake and fruit quality (Quddus et al. 2025), most research has focused on single application strategies or combinations with biofertilizers rather than systematic graded dose responses with fertigation integration. The present study investigated the influence of graded levels of vermicompost (60, 80, and 100%) on plant height, yield attributes, fruit quality, biochemical attributes, nutrient content and soil microbial population, with the objective of establishing the effectiveness of organic fertigation in enhancing nutritional quality and sustainability in strawberry production.

Materials and Methods

Experimental site and soil properties

The experiment was conducted during the *Rabi* seasons of 2023-24 and 2024-25 at Punjab Agricultural University, Ludhiana, Punjab, India. Prior to initiating the experiment, representative soil samples were collected from 0-10 cm depth and analyzed for chemical characteristics. The soil of the experimental field was sandy loam in texture, slightly alkaline (pH 7.33-7.35), low in electrical conductivity (0.26-0.28 dS m^{-1}) and organic carbon (0.39-0.41%). Available nitrogen content was low (192-195 kg ha^{-1}), while available phosphorus content (34-35 kg ha^{-1}) and available potassium content (318-320 kg ha^{-1}) were in the medium range. (**Table 1).**

Experimental design and treatments

The experiment was laid out in a randomized complete block design with five treatments and three replications. Strawberry cv. Winter Dawn was transplanted at 30 cm x 30 cm in paired row system under drip irrigation. Treatments consisted of 60% recommended nitrogen through vermicompost as basal dose + FYMe equivalent to 20% nitrogen through fertigation. 80% recommended nitrogen through vermicompost as basal dose + FYMe equivalent to 20% nitrogen through fertigation. 100% recommended nitrogen through vermicompost as basal dose + FYMe equivalent to 20% nitrogen through fertigation. 100% recommended nitrogen through vermicompost as basal dose with drip irrigation (no fertigation). Control (drip irrigation only, no nutrient application)

Table 1 Treatment details

Treatment		Short forms used in the text
T_1	60% Vermicompost equivalent to nitrogen as basal dose + 20% through FYMe Fertigation	60% Vermi BD + 20% FYMe Ferti
T_2	80% Vermicompost equivalent to nitrogen as basal dose + 20% through FYMe Fertigation	80% Vermi BD+ 20% FYMe Ferti
T_3	100% Vermicompost equivalent to nitrogen as basal dose + 20% through FYMe Fertigation	100% Vermi BD + 20% FYMe Ferti
T_4	100% Vermicompost equivalent to nitrogen as basal dose + Drip irrigation	100% Vermi BD + Drip Irrigation
T_5	Drip Irrigation (unfertilized, only drip irrigation)	Control

Water-soluble fertilizers listed in Table 2 (NPK 19:19:19, urea, urea phosphate and muriate of potash) were used to calculate the recommended nutrient requirement of strawberry and to derive nitrogen equivalence for organic nutrient sources. Actual nutrient application in all treatments was made exclusively through organic sources, namely vermicompost and FYMe. The FYMe equivalent to 20% nitrogen was intentionally applied to compensate for lower nitrogen mineralization efficiency of organic sources and to obtain fruit yield near or at par with that typically achieved under 100% recommended nitrogen supplied through chemical fertilizers. The nutrient composition of vermicompost was 1.15-1.92% nitrogen, 0.45-0.50% phosphorus and 0.50-0.85% potassium, whereas FYMe contained nitrogen in the range of 0.22–0.43%, phosphorus 0.19–0.30% and potassium 0.11–0.18%.

Table 2 Organic fertigation schedule and nitrogen input from organic sources

Days after Planting	Water-soluble fertilizers	Fertilizers (kg day^{-1} ha^{-1})	Nitrogen (kg ha^{-1})	N (kg day^{-1})
5-35	NPK (19:19:19)	1.63	9.29	0.13
	Urea Phosphate (17:44:0)	1.98	10.08	0.14
	Urea (46:0:0)	1.28	17.73	0.24
36-60	NPK (19:19:19)	3.31	15.73	0.25
	Urea (46:0:0)	0.44	5.11	0.08
	Urea Phosphate (17:44:0)	1.38	5.88	0.10
61-90	Muriate of Potash (White) (0:0:60)	1.61	0.00	0.00
	Urea (46:0:0)	1.98	27.27	0.37
	Sulphate of Potash (0:0:41)	1.09	0.00	0.00
91-120	NPK (19:19:19)	1.73	9.86	0.13

	Sulphate of Potash (0:0:41)	1.09	0.00	0.00
121-155	0.6725	1.43	8.03	0.09

* Water-soluble fertilizers are shown only for nutrient requirement calculation and nitrogen equivalence. These fertilizers were not applied in the field.

Preparation of vermicompost and FYMe

Vermicompost was prepared using partially decomposed cattle dung that had been pre-composted for 10-12 days to allow cooling followed by inoculation with earthworms (*Eisenia fetida*), following standard vermicomposting procedures. FYMe was prepared using well-rotten FYM fermented with equal amount of water for 7-10 days. Thereafter, it was filtered to make it compatible with drip irrigation system. A representative sample was collected and analysed for nutrient composition prior to field application

Observations recorded

Yield attributes and yield including total yield, number of fruits plant^{-1} and average weight of fruits were recorded at harvest maturity. Quality parameters including total soluble solids (TSS), total sugars, ascorbic acid, anthocyanin and total phenolic content. Furthermore, macronutrient attributes of plant and soil (N, P and K) and soil microbial population *viz.* total bacterial count, total fungal count, total actinomycetes count, total diazotroph count and phosphate solubilizing microorganisms were measured. Plant height was measured regularly from the base of the crown to the tip of the tallest fully expanded leaf, ensuring that plants were in their natural upright position without straining the leaves, and expressed in centimeters (cm). For determination of root shoot ratio, representative plants were uprooted and separated into root and shoot portions. The samples were oven-dried at 65°C to constant weight and weighed separately. The root shoot ratio (R/S) was calculated using the formula:

$$\text{Root shoot ratio}\left(\frac{\text{R}}{\text{S}}\right)=\frac{\text{Dry weight of roots (g)}}{\text{Dry weight of shoots (g)}}$$

Data pertaining to yield attributes and yield were obtained at harvest maturity. Yield attributes and yield *viz.* number of fruits, fruit yield and average weight of fruits were measured at each harvest. The total number of fruits plant^{-1} was recorded at every picking, and the fruit count plant^{-1} was obtained by summing the number of fruits over all harvests until the final picking. Fruit yield plant^{-1} was calculated by adding the weight of fruits harvested at each picking and expressed as g plant^{-1}. In addition, average weight of fruits was using the formula:

$$\text{Average Fruit Weight (g)}=\frac{\text{Total weight of fruits (g)}}{\text{Total number of fruits}}$$

Biochemical attributes such as total soluble solids, total sugars, ascorbic acid, anthocyanin and total phenolic content were determined at peak fruiting stage in mature fruits. The total soluble solids (TSS) of harvested fruits from each treatment were measured using hand refractometer at room temperature according to method described by (AOAC 1990). Briefly a drop of squeezed juice was placed on the clean and dry prism of the instrument and the reading was measured in percent. Total sugars in juice samples were estimated by the method of (Horwitz 1960). A 25 mL aliquot was hydrolysed with concentrated HCl, kept overnight, neutralized with 1 N NaOH using phenolphthalein as an indicator, and the volume was made up to 100 mL. The hydrolysed sample was titrated against Fehling's solution using methylene blue as an indicator until a brick-red end point was obtained.

Ascorbic acid contents of fruits for each treatment were determined according to the method described by (Hans 1992). Strawberry pulp (5 g) was blended with 5 ml, 1% hydrochloric acid (w/v) and the homogenate was centrifuged at 10,000 rpm for 10 minutes. The supernatant fluid was collected as vitamin C extract. The absorbance of extract was measured at 243 nm by means of spectrophotometer (OPTIMA, SP-3000-plus). Anthocyanin method suggested by (Rangana 2010) was used to estimate anthocyanin content. Similarly, (Swain and Hills 1959) method was followed for the estimation of total phenol content. Total phenols were expressed in mg $100g^{-1}$.

$$\text{Total Phenols}(\text{mg}100\text{g}^{-1})=\frac{C\times V_t\times 100}{W\times V_s}$$

Nitrogen content was estimated by the Kjeldahl method using the Kjel Plus Nitrogen Estimation System. Nitrogen content was calculated using the formula:

$$\text{Nitrogen}(\%) = \frac{(10\text{-X}) \times 0.0014 \times 100 \times 100}{5}$$

Vanado molybdo phosphoric yellow colour method given by (Chapman and Pratt 1961) was used to estimate phosphorus.

$$\text{Phosphorus}(\%) = \frac{\text{ppm} \times \text{Total dilution}}{100}$$

Flame photometer method (AOAC 1990) was used to estimate Potassium (K) concentration.

$$\text{Potassium}(\%) = \frac{C \times V}{W} \times 100$$

The Total Bacterial Count (TBC), Total Fungal Count (TFC), Total Actinomycete Count (TAC), Total diazotrophs Count (TDC) and Phosphate solubilizing microorganisms (PSM) in the soil was estimated using the pour plate technique on Nutrient Agar (NA), potato Dextrose Agar (PDA), Isolation Agar, Jensen's medium and Pikovskaya's agar medium. The microbial population was expressed as colony forming units (CFU) per gram of soil using the formula:

$$\text{CFUg}^{-1}\text{dry soil}=\frac{\text{Number of colonies}\times\text{Dilution Factor}}{\text{Dry weight of 1g moist soil}}$$

Statistical analysis

The recorded data for different parameters were analyzed using two-way analysis of variance (ANOVA) (Gomez and Gomez, 1984) for RCBD. Microbial population data were $\log_{10}$-transformed prior to analysis. Treatment means were compared using Duncan's multiple range test at $p \leq 0.05$.

Results and Discussion

Growth parameters

The data presented in Table 3 indicate that graded levels of vermicompost integrated with FYMe fertigation significantly influenced plant height and root-shoot ratio of strawberry during both years of experimentation. During 2023-24, the maximum plant height (24.1 cm) was recorded under treatment T_3 (100% vermicompost as basal dose + 20% N through FYMe fertigation), which was significantly higher than all other treatments. The increase in plant height under this treatment may be attributed to improved soil structure, aeration and moisture-holding capacity provided by vermicompost, which enhance root growth and nutrient uptake (Shyam et al., 2023). Similar improvements in strawberry plant height under vermicompost and biofertilizer application have been reported, primarily due to enhanced nutrient availability, increased organic matter content and improved soil conditions that favor shoot elongation and biomass accumulation (Kumar et al., 2024).

Among the remaining treatments, T_2 (19.2 cm) and T_4 (20.2 cm) recorded intermediate plant heights and were statistically at par, whereas T_1 resulted in moderate plant height. The lowest plant height was observed under the control (T_5; 13.4 cm). A similar trend was evident during 2024-25, with T_3 again recording the highest plant height (20.6 cm) and the control exhibiting the minimum value (13.3 cm).

Root–shoot ratio followed a comparable pattern during both years of study. In 2023-24, the highest root–shoot ratio (0.39) was recorded under T_3, which was statistically at par with T_4, while moderate values were observed under T_1 and T_2. The lowest root–shoot ratio (0.33) was recorded in the control. Similar trends were observed during 2024-25. Enhanced root–shoot ratio under vermicompost and FYMe fertigation may be attributed to higher organic matter content, improved soil aeration and water-holding capacity, which promote physiological activity, root development and dry matter accumulation, ultimately resulting in a higher root–shoot ratio (Tani et al., 2021).

Table 3 Influence of vermicompost FYMe fertigation on plant height and root shoot ratio of strawberry.

	Treatments	Plant Height (cm)		Root Shoot Ratio	
		2023-24	2024-25	2023-24	2024-25
T_1	60% Vermi BD + 20% FYMe Ferti	14.87 ± 0.20^{c}	20.6 ± 0.56^{c}	0.35 ± 0.2^{c}	0.38 ± 0.00^{ab}
T_2	80% Vermi BD + 20% FYMe Ferti	19.2 ± 0.17^{b}	22.8 ± 0.20^{b}	0.37 ± 0.3^{b}	0.37 ± 0.00^{bc}
T_3	100% Vermi BD + 20% FYMe Ferti	24.1 ± 1.07^{a}	25.6 ± 0.49^{a}	0.39 ± 0.1^{a}	0.39 ± 0.00^{a}
T_4	100% Vermi BD + Drip Irrigation	20.2 ± 0.57^{b}	22.3 ± 0.32^{b}	0.38 ± 0.12^{ab}	0.39 ± 0.00^{a}
T_5	Control	13.4 ± 0.26^{c}	13.3 ± 0.63^{d}	0.33 ± 0.32^{d}	0.34 ± 0.01^{c}

*Values represent mean ± SE. Means followed by different letters within a column differ significantly at $p \leq 0.05$.

Yield attributes and yield

Data presented in Table 4 show that graded levels of vermicompost in combination with FYMe fertigation significantly influenced fruit yield, number of fruits per plant and fruit weight of strawberry during both years of experimentation. During 2023-24, the highest fruit yield (230 g plant^{-1}) was recorded under treatment T_3 (100% vermicompost as basal dose + 20% N through FYMe fertigation), which was significantly higher than T_4 (204 g plant^{-1}) and T_2 (201 g plant^{-1}). Treatment T_1 recorded a moderate yield (184 g plant^{-1}), whereas the control (T_5) produced the lowest yield (162 g plant^{-1}). A similar trend was observed during 2024-25, with T_3 again recording the maximum yield (256 g plant^{-1}).

For number of fruits per plant, treatment T_3 recorded the highest fruit number during 2023-24 (15.4 fruits plant^{-1}), followed by T_4 (14.8 fruits plant^{-1}) and T_2 (14.2 fruits plant^{-1}), which were statistically at par. In contrast, the lowest fruit number was recorded under the control (11.4 fruits plant^{-1}). During 2024-25, fruit number ranged from 15.6 fruits plant^{-1} under T_3 to 11.3 fruits plant^{-1} under the control.

Fruit weight was also significantly affected by organic fertigation. The highest fruit weight during 2023-24 was recorded under T_3 (16.2 g), which was statistically at par with T_4 (15.8 g) and T_2 (14.7 g), while lower fruit weight was observed under T_1 (14.4 g) and the control (14.2 g). A similar pattern was observed during 2024-25. The improvement in yield and yield attributes under vermicompost and FYMe fertigation may be attributed to enhanced availability of organic nutrients, organic acids and enzymes, which improve nutrient uptake and metabolic activity, thereby supporting better fruit formation (Negi et al., 2021). These findings are in agreement with earlier reports in strawberry and other horticultural crops (Arancon et al., 2004; Athani et al., 2005; Khalid et al., 2013).

Table 4 Influence of vermicompost and FYMe fertigation on yield, fruit number and average fruit weight of strawberry.

Treatments	Yield plant^{-1} (g)	Fruit Number plant^{-1}	Fruit weight (g)

		2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
T_1	60% Vermi BD + 20% FYMe Ferti	184±1.15^{d}	190±1.15^{d}	12.9±0.23^{c}	12.8±0.15^{cd}	14.4±0.06^{b}	14.73±0.12^{b}
T_2	80% Vermi BD + 20% FYMe Ferti	201±1.76^{c}	200±1.15^{c}	14.2±0.11^{b}	13.1±0.06^{bc}	14.7±0.25^{b}	15.53±0.13^{a}
T_3	100% Vermi BD + 20% FYMe Ferti	230±1.15^{a}	256±1.15^{a}	15.4±0.08^{a}	15.6±0.12^{a}	16.2±0.1^{a}	16.23±0.17^{a}
T_4	100% Vermi BD + Drip Irrigation	204±1.45^{b}	211±1.15^{b}	14.8±0.11^{b}	13.5±0.06^{b}	15.8±0.29^{a}	15.73±0.08^{a}
T_5	Control	162±1.73^{e}	163±1.73^{e}	11.4±0.15^{d}	11.3±0.15^{d}	14.2±0.17^{b}	14.3±0.23^{b}

* Values represent mean ± SE. Means followed by different letters within a column differ significantly at $p \leq 0.05$.

Biochemical Attributes

Graded levels of vermicompost integrated with FYMe fertigation significantly influenced the biochemical attributes of strawberry fruits during both years of study. Application of higher vermicompost levels supplemented with FYMe fertigation resulted in marked improvement in total soluble solids (TSS), total sugars and total phenolic content (Table 5). During 2024-25, treatments receiving 80% and 100% vermicompost equivalent to nitrogen as basal dose along with FYMe fertigation (T_2 and T_3) increased TSS by 29.66% and total sugars by 22.90% over the control. Comparatively lower increases were observed under T_4 (18.48%) and T_1 (9.48%). A similar response pattern was recorded during 2023-24, indicating a consistent enhancement of TSS and total sugars with increasing vermicompost levels.

The improvement in TSS and total sugar content under vermicompost and FYMe fertigation may be attributed to enhanced nutrient uptake and improved metabolic efficiency. Vermicompost improves soil physical properties such as moisture retention and aeration and stimulates microbial activity, which together promote efficient photosynthate synthesis and conversion of starch into soluble sugars, resulting in improved fruit sweetness and quality. Similar enhancements in fruit biochemical attributes under organic nutrient management have been reported in jamun (Khayum, 2021) and dragon fruit (Verma et al., 2019; Siddiqua et al., 2023).

Total phenolic content of strawberry fruits also varied significantly among treatments during both years. During 2024-25, the highest phenolic content was recorded under T_3 (225.53 mg g^{-1}), followed by T_2 (213.63 mg g^{-1}) and T_4 (206.50 mg g^{-1}). Lower phenolic content was observed under T_1 (198.26 mg g^{-1}), while the minimum value was recorded in the control (T_5; 184.46 mg g^{-1}). Increased phenolic accumulation under higher vermicompost levels may be associated with enhanced secondary metabolite synthesis driven by improved nutrient availability and greater microbial activity in the rhizosphere.

The influence of vermicompost and FYMe fertigation on ascorbic acid content of strawberry fruits is illustrated in Fig. 1. Ascorbic acid content was significantly higher under T_3, followed by T_2 and T_4 during both years, whereas moderate values were recorded under T_1 and the lowest under the control. Enhanced ascorbic acid content under organic nutrient treatments may be attributed to improved availability of nutrients and growth-promoting substances, which stimulate metabolic and hormonal activity and promote greater accumulation of photosynthates in fruits (Bhalero et al., 2009).

A similar trend was observed for anthocyanin content (Fig. 2). The highest anthocyanin levels were recorded under T_3, followed by T_2, while T_1 and T_4 also showed higher values than the control during both years of experimentation. The increased accumulation of ascorbic acid and anthocyanins under higher vermicompost levels supplemented with FYMe fertigation may be due to enhanced microbial activity and production of growth-promoting substances, which accelerate physiological processes such as carbohydrate synthesis and secondary metabolite formation (Pirlak and Kose, 2009).

Table 5: Influence of vermicompost and FYMe fertigation on TSS, total sugars of strawberry.

Treatments	TSS (%)		Total Sugar (%)		Total Phenolic content (mg g^{-1})	
	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
T_1 60% Vermi BD + 20% FYMe Ferti	6.91±0.04^{c}	7.16±0.01^{d}	4.88±0.04^{d}	4.98±0.02^{d}	192.7±0.90^{c}	198.26±0.86^{d}
T_2 80% Vermi BD + 20% FYMe Ferti	7.76±0.06^{b}	8.04±0.08^{b}	5.50±0.03^{b}	5.70±0.04^{b}	207.1±0.89^{b}	213.63±0.91^{b}
T_3 100% Vermi BD + 20% FYMe Ferti	8.28±0.11^{a}	8.48±0.02^{a}	6.01±0.01^{a}	6.09±0.03^{a}	211.9±0.35^{a}	225.53±0.98^{a}
T_4 100% Vermi BD + Drip Irrigation	7.42±0.11^{b}	7.77±0.09^{c}	5.27±0.02^{c}	5.39±0.02^{bc}	208.2±1.15^{ab}	206.5±0.75^{c}
T_5 Control	6.38±0.04^{d}	6.54±0.03^{e}	4.09±0.00^{e}	4.39±0.02^{e}	184.5±0.73^{d}	184.46±0.73^{e}

* Values represent mean ± SE. Means followed by different letters within a column differ significantly at p ≤ 0.05.

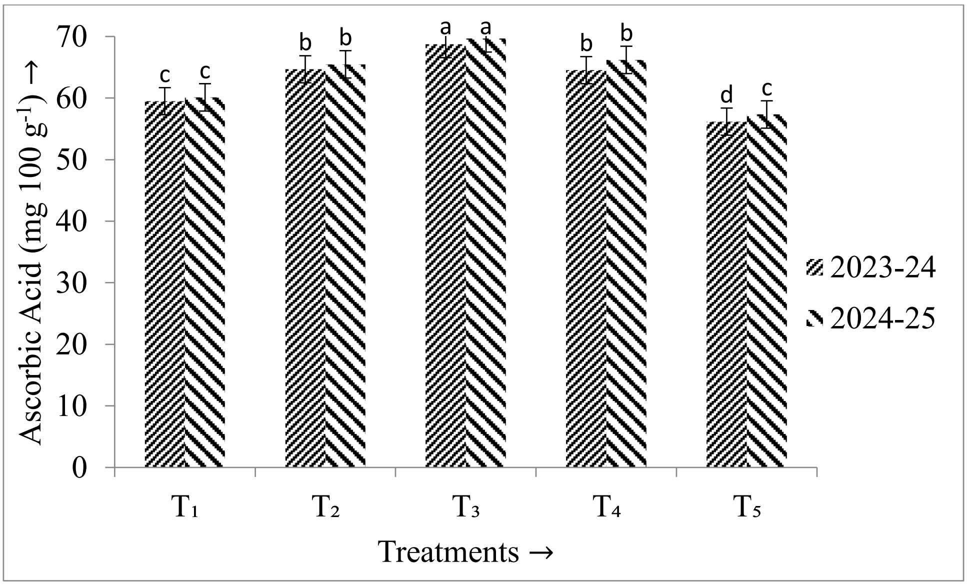

Fig. 1 Influence of vermicompost and FYMe fertigation on Ascorbic acid. Values represent mean ± SE; bars with different letters differ significantly at p ≤ 0.05.

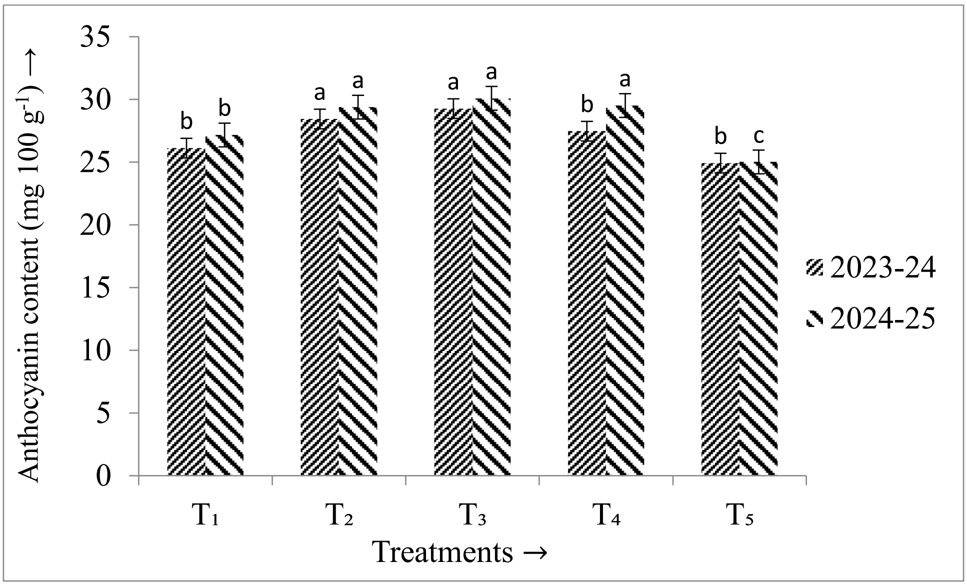

Fig. 2 Influence of vermicompost and FYMe fertigation on Anthocyanin content. Values represent mean ± SE; bars with different letters differ significantly at $p \leq 0.05$.

Macronutrient of Plant

Different levels of vermicompost integrated with FYMe fertigation significantly influenced plant nitrogen, phosphorus and potassium content during both years of study (Table 6). Among the treatments, application of 100% vermicompost as basal dose supplemented with FYMe fertigation (T_3) consistently resulted in the highest nitrogen, phosphorus and potassium content in plant tissues across both seasons. Nitrogen content under T_3 reached 2.09% during 2023-24 and 2.12% during 2024-25, which was significantly higher than all other treatments. A similar trend was observed for phosphorus and potassium content. Treatment T_2 (80% vermicompost as basal dose + FYMe fertigation) ranked second and was statistically at par with T_3 for potassium content during both years. Treatment T_4 (100% vermicompost as basal dose with drip irrigation) also recorded significantly higher nutrient content compared with the control, although values remained lower than those observed under T_2 and T_3. The lowest nitrogen, phosphorus and potassium content was consistently recorded under the control treatment (T_5), indicating that native soil nutrient supply alone was insufficient to meet crop demand.

The increase in plant nitrogen content under vermicompost and FYMe fertigation may be attributed to improved root growth and enhanced nutrient uptake efficiency. Vermicompost application improves soil structure, aeration and moisture-holding capacity, which collectively promote better root development and higher nitrogen absorption. In addition, organic inputs stimulate soil microbial activity, leading to increased nitrogen mineralization and greater availability of plant-available nitrogen in the rhizosphere. Similar improvements in plant nitrogen content under organic nutrient management have been reported earlier (Mohite et al., 2024).

Enhanced phosphorus content under vermicompost-based fertigation may be associated with increased activity of beneficial microorganisms and improved mycorrhizal associations, which facilitate phosphorus solubilization and uptake (Andrade-Sifuentes et al., 2024). Higher potassium content observed under organic fertigation treatments may be due to improved soil moisture retention and reduced potassium leaching, ensuring sustained potassium availability in the root zone. Vermicompost supplies potassium gradually through mineralization, while the increase in soil organic matter improves cation exchange capacity, enabling potassium ions to remain in plant-available forms (Pathariya et al., 2022).

Table 6 Influence of vermicompost and FYMe fertigation on nitrogen, phosphorus and potassium content of plant.

Treatments		Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)	
		2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
T_1	60% Vermi BD + 20% FYMe Ferti	1.71±0.20^{d}	1.72±0.26^{c}	0.27±0.00^{bc}	0.27±0.00^{c}	2.02±0.01^{c}	2.04±0.01^{c}
T_2	80% Vermi BD + 20% FYMe Ferti	1.90±0.01^{b}	1.92±0.05^{b}	0.29±0.01^{b}	0.30±0.01^{b}	2.24±0.02^{ab}	2.24±0.01^{ab}
T_3	100% Vermi BD + 20% FYMe Ferti	2.09±0.1^{a}	2.12±0.02^{a}	0.34±0.02^{a}	0.32±0.00^{a}	2.31±0.08^{a}	2.33±0.09^{a}
T_4	100% Vermi BD + Drip Irrigation	1.76±0.02^{c}	1.80±0.01^{c}	0.29±0.00^{b}	0.29±0.00^{b}	2.17±0.01^{b}	2.18±0.00^{bc}
T_5	Control	1.26±0.01^{e}	1.27±0.05^{d}	0.24±0.01^{c}	0.25±0.00^{d}	1.67±0.04^{d}	1.69±0.05^{d}

* Values represent mean ± SE. Means followed by different letters within a column differ significantly at $p \leq 0.05$.

Macronutrient of soil

Organic fertigation treatments significantly influenced soil available nitrogen, phosphorus and potassium contents during both years of experimentation (Table 7). Across treatments, application of 100% vermicompost as basal dose supplemented with FYMe fertigation (T_3) consistently resulted in the highest availability of soil nitrogen, phosphorus and potassium in both 2023-24 and 2024-25. The lowest availability of these nutrients was recorded under the control, indicating that native soil nutrient supply alone was insufficient to sustain optimal nutrient availability.

The increase in soil available nitrogen under vermicompost integrated with FYMe fertigation may be attributed to the slow and sustained mineralization of organic nitrogen, enhanced microbial activity and improved nitrogen retention within soil organic matter fractions. Organic inputs promote microbial-mediated nitrogen transformations, leading to greater availability of mineral nitrogen in the soil over time (Blouin et al., 2019; Geisseler and Scow, 2021).

Soil available phosphorus content varied among treatments during both years of experimentation (Table 7). The highest available phosphorus was recorded under T3; however, it was statistically at par with treatments T2 and T4 during both years. The control treatment (T5) recorded the lowest available phosphorus content. The higher phosphorus availability under organic fertigation may be attributed to enhanced microbial activity, secretion of organic acids and phosphatase enzymes, which convert insoluble phosphorus into plant-available forms (Sharma et al., 2013; Rawat et al., 2021; Pang et al., 2024).

Soil available phosphorus was also significantly higher under T_3 and was statistically at par with T_2 and T_4. Enhanced phosphorus availability under organic fertigation may be attributed to increased rhizosphere microbial activity, secretion of organic acids and phosphatase enzymes, which facilitate the conversion of insoluble phosphorus forms into plant-available forms. Decomposition of FYMe releases organic acids that aid phosphorus solubilization, while vermicompost supports beneficial microbial populations and mycorrhizal associations, further enhancing phosphorus availability (Sharma et al., 2013; Rawat et al., 2021; Pang et al., 2024).

A similar response pattern was observed for soil potassium availability, with the highest values recorded under T_3, followed by T_2 and T_4 during both years. Increased soil potassium availability under vermicompost and FYMe fertigation may be due to the gradual release of exchangeable potassium from organic residues, improved soil aggregation and enhanced cation exchange capacity resulting from increased soil organic matter content. Improved soil structure and moisture retention under organic fertigation further reduce potassium leaching losses, ensuring greater potassium availability in the root zone (Zuo et al., 2018; Pathariya et al., 2022; Bhanwaria et al., 2022).

Table 7 Influence of vermicompost and FYMe fertigation on nitrogen, phosphorus and potassium content in soil.

Treatments		Nitrogen content (kg ha^{-1})		Phosphorus content (kg ha^{-1})		Potassium content (kg ha^{-1})	
		2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
T_1	60% Vermi BD + 20% FYMe Ferti	195±4.04^{d}	196±5.29^{a}	34.6±1.2^{c}	35.6±0.88^{c}	340.6±5.13^{c}	343.6±4.50^{b}
T_2	80% Vermi BD + 20% FYMe Ferti	202±5.68^{ab}	203±6.80^{a}	37.6±2.4^{bc}	40.6±1.85^{b}	351.3±3.21^{b}	353.3±7.57^{b}
T_3	100% Vermi BD + 20% FYMe Ferti	208±1.52^{a}	210±0.57^{a}	42.6±1.2^{a}	45±1.15^{a}	365.3±2.30^{a}	366.3±2.51^{a}
T_4	100% Vermi BD + Drip Irrigation	196±4.72^{c}	197±5.29^{a}	36.6±1.45^{b}	40±0.57^{b}	351.3±3.21^{b}	353.5±0.57^{b}
T_5	Control	167±2.081^{e}	168±4.50^{b}	27.3±0.88^{d}	30.6±1.20^{d}	318.3±3.51^{d}	320.3±0.57^{c}

* Values represent mean ± SE. Means followed by different letters within a column differ significantly at $p \leq 0.05$.

Soil Microbial population

The data presented in (Table 8) indicate that organic fertigation treatments exerted a significant influence on soil microbial population including total bacterial count (TBC), total fungal count (TFC), total actinomycetes count (TAC), total diazotroph count (TDC), and phosphate solubilizing microorganisms (PSM) during both years of study. Among the treatments, T_3 recorded the highest microbial populations across all microbial groups in both years. During 2023-24 and 2024-25, T_3 recorded maximum TBC values of 7.37 and 7.47 $\log_{10}$ cfu g^{-1} respectively. Similarly, the highest TFC (3.96 and 4.06 $\log_{10}$ cfu g^{-1}), TAC (3.58 and 3.65 $\log_{10}$ cfu g^{-1}), TDC (2.28 and 2.92 $\log_{10}$ cfu g^{-1}) and PSM (2.37 and 2.43 $\log_{10}$ cfu g^{-1}) were observed under this treatment. Treatments T_2 and T_4 recorded intermediate microbial count and were statistically comparable with each other, though slightly lower than T_3. The control treatment (T_5) recorded lowest microbial population for all parameters across both years. Vermicompost contains abundant organic matter and humic substances that support saprophytic fungal growth, while FYMe enhances microbial diversity by adding fermentative fungi and nutrient-rich substrates (Fernández-Gomez et al. 2010). Similarly, actinomycetes thrive in soils enriched with stable organic matter, and vermicompost provides an ideal environment due to its fine texture and high carbon content (Mahmud et al. 2018). In addition, vermicompost is naturally rich in beneficial microbes, including decomposers, nitrogen fixers, and phosphate solubilisers, which improve soil fertility and nutrient cycling (Tian et al. 2024).

Previous studies have reported that vermicompost stimulates microbial production of organic acids, phosphatases and chelating compounds that convert insoluble phosphorus into plant-available forms (Yashasvi et al., 2022). In addition, application of FYMe further stimulates PSB activity by supplying additional organic substrates and promoting a diverse microbial environment (Farooq et al. 2025).

Table 8 Influence of vermicompost and FYMe fertigation on soil microbial population.

Treatments	TBC ($\log_{10}$ cfu g^{-1})		TFC ($\log_{10}$ cfu g^{-1})		TAC ($\log_{10}$ cfu g^{-1})		TDC ($\log_{10}$ cfu g^{-1})		PSM ($\log_{10}$ cfu g^{-1})	
	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
T_1	7.18 ± 0.01^{ab}	7.25 ± 0.03^{b}	3.53 ± 0.05^{b}	3.61 ± 0.03^{b}	$3.34\pm0.05^{\cancel{bc}}$	3.44 ± 0.07^{ab}	2.74 ± 0.04^{ab}	2.87 ± 0.00^{a}	2.09 ± 0.03^{c}	2.17 ± 0.01^{b}
T_2	7.25 ± 0.02^{ab}	7.28 ± 0.01^{ab}	3.62 ± 0.06^{ab}	3.75 ± 0.02^{b}	3.37 ± 0.03^{ab}	3.49 ± 0.02^{ab}	2.69 ± 0.02^{b}	2.77 ± 0.03^{b}	2.18 ± 0.01^{b}	2.26 ± 0.01^{b}
T_3	7.37 ± 0.12^{a}	7.47 ± 0.06^{a}	3.96 ± 0.09^{a}	4.06 ± 0.04^{a}	3.58 ± 0.03^{a}	3.65 ± 0.00^{a}	2.82 ± 0.03^{a}	2.92 ± 0.01^{a}	2.37 ± 0.02^{a}	2.43 ± 0.00^{a}
T_4	7.32 ± 0.02^{ab}	7.37 ± 0.06^{ab}	3.64 ± 0.03^{ab}	3.74 ± 0.05^{b}	3.46 ± 0.06^{ab}	3.58 ± 0.08^{a}	2.57 ± 0.03^{c}	2.69 ± 0.00^{c}	2.07 ± 0.03^{c}	2.15 ± 0.05^{b}
T_5	7.08 ± 0.1^{b}	7.20 ± 0.01^{b}	3.98 ± 0.08^{c}	3.09 ± 0.00^{c}	3.15 ± 0.04^{c}	3.25 ± 0.03^{b}	2.38 ± 0.04^{d}	2.41 ± 0.00^{d}	1.89 ± 0.01^{d}	1.92 ± 0.03^{c}

* Values represent mean ± SE. Means followed by different letters within a column differ significantly at $p \leq 0.05$.

Conclusion

The study concluded that vermicompost-based fertigation supplemented with FYMe significantly enhanced growth, yield, fruit quality, nutrient availability and soil microbial activity in strawberry. The integrated use of the solid and liquid organic nutrient sources improved the availability of the nitrogen, resulted in high yield performance and enhanced biochemical attributes compared to the vermicompost alone and the unfertilized control. Improved nitrogen, phosphorus and potassium of plants and soil, along with increased population of beneficial soil microorganisms, indicates better soil health and nutrient dynamics under organic fertigation. Overall, the present study demonstrates that vermicompost integrated with farmyard manure extract-based fertigation represents a viable and sustainable organic nutrients management strategy for strawberry cultivation.

Acknowledgement The authors are thankful to Dr. Sohan Singh Walia (Principal Agronomist-cum-Director, School of Organic and Natural Farming) for providing farm inputs during the current investigation and Dr Surjit Singh Manhas for suggestions.

Author contribution A.S. was involved in conducting the experiment, collecting data, and drafting the manuscript. K.S.B. was responsible for the experimental design, conceptualization of the study, and supervision of field operations. K.S.B., G.P. and G.S.D. contributed to the overall design and critical revision of the manuscript. All authors reviewed the manuscript.

Funding Punjab Agricultural University, Ludhiana (India) has provided financial support for this research work.

Data availability No datasets were generated or analysed during the current study.

Declaration

Ethical Approval This article does not contain any studies with human participants or animals performed by any of the authors.

Competing Interests The authors declare no competing interests.

References

AOAC (1990) Official method of analysis. Association of analytical chemists. Virginia, Arlington, USA.

Arancon N Q, Edwards C A, Bierman P, Welch C, Metzger J D (2004) Influences of vermicomposts on field strawberries: 1 Effects on growth and yields. Bioresource Technology 93: 145-153. https://doi.org/10.1016/j.biortech.2003.10.014

Andrade-Sifuentes A, Peña-Uribe G D J, Sáenz-Mata J, Quezada-Rivera J J, Palacio-Rodríguez R and Muro-Pérez G (2024) The Integration of phosphorus-solubilizing rhizobacteria, eisenia fetida and phosphorus rock improves the availability of assimilable phosphorus in the vermicompost. Sustainability 16: 7576.

Athani, S I, Ustad A I, Prabhuraj H S, Swamy G S K, Patil P B, Kotikal Y K (2005). Influence of vermi-compost on growth, fruit yield and quality of guava cv. Sardar. International Guava Symposium 735: 381-385. 10.17660/ActaHortic.2007.735.54

Bhalerao V P, Patil N M, Badgujar C D, Rana D S (2009). Studies on integrated nutrient management for tissue cultured banana cv. Grand Naine. Indian Journal of Agricultural Research 43: 107–112.

Bhanwaria R, Singh B and Musarella C M (2022) Effect of organic manure and moisture regimes on soil physiochemical properties, microbial biomass Cmic: Nmic: Pmic turnover and yield of mustard grains in arid climate. Plants 11: 722.

Bilalis D, Krokida M, Roussis I, Papastylianou P, Travlos I, Cheimona N, Dede A (2018) Effects of organic and inorganic fertilization on yield and quality of processing tomato (*Lycopersicon esculentum Mill.*). Folia

Hot. 30: 321-332.
Blouin M Hodson M E, Delgado E A, Baker G, Brussaard L, Butt K R, Dai J, Dendooven L, Peres G, Tondoh J E, Cluzeau D and Brun J J (2019) A meta-analysis of the effects of vermicompost on plant growth. Agro for Sust Develop 39: 34.
Boraiah B, Devakumar N, Shubha S, Palanna K B (2017) Effect of panchagavya, Jeevamritha and cow urine on beneficial microorganisms and yield of capsicum (*Capsicum annuum* L.). Int. J. Curr. Microbiol. App. Sci 6: 3226-3234.
Chapman H D and Pratt P F (1961) Methods of analysis of soils, plants and waters. Univ California Division of Agric Sci 66**:** 103-12.
Farooq M A, Gurmani A R, Khan S, Rafique M, Mehmood A, Ahmed Z (2025) Effect of phosphate-solubilizing bacteria inoculated with vermicompost on yield and quality of tomato. Pak. J. Agri. Sci 62: 151-158.
Fernández-Gómez M J, Nogales R, Insam H, Romero E, Goberna M (2010) Continuous-feeding vermicomposting as a recycling management method to revalue tomato-fruit wastes from greenhouse crops. Waste management, 30: 2461-2468.
Fischer K, Vico G, Röcklinsberg H, Liljenström H, Bommarco R (2025) Progress towards sustainable agriculture hampered by siloed scientific discourses. Nature sustainability 8: 66-74.
García-Gaytán V, Hernández-Mendoza F, Coria-Téllez A V, García-Morales S, Sánchez-Rodríguez E, Rojas-Abarca L, Daneshvar H (2018) Fertigation: Nutrition, stimulation and bioprotection of the root in high performance. *Plants* 7: 88.
Garg, K, Dhar S, Sharma V K, Azman E A, Meena R P, Hashim M, Kumar S (2024). Optimizing agricultural sustainability: enriched organic formulations for growth, yield, and soil quality in a multi-crop system. Frontiers in Plant Science 15: 1398083.
Geisseler D, Smith R, Cahn M and Muramoto J (2021) Nitrogen mineralization from organic fertilizers and composts: Literature survey and model fitting. Jrnl of environ quality 50: 1325-1338.
Giampieri F, Tulipani S, Alvarez-Suarez J M, Quiles J L, Mezzetti B Battino M (2012) The strawberry: Composition, nutritional quality and impact on human health. Nutrition 28: 9-19.
Gomez K A, Gomez A A (1984) *Statistical procedures for agricultural research*. New York
Hans Y S H (1992) The guide book of food chemical experiments. Pekin Agricultural University Press, Pekin
Horwitz W (1960) Official and Tentative Methods of Analysis. Washington, D C 314–320.
Kadasiddappa M, Rao V P, Yella R K, Ramulu V, Uma D M, Reddy S (2015) Effect of drip and surface furrow irrigation on growth, yield and water use efficiency of sunflower hybrid DRSH-1. *Prog Res* 10: 5-7.
Khalid S, Qureshi K M, Hafiz I A, Khan K S, Qureshi U S (2013) Effect of organic amendments on vegetative growth, fruit and yield quality of strawberry. Pak. J. Agri Res 26: 104.
Khayum, A. (2020). Physico-chemical profiling of jamun (*Syzygium cuminii Skeels.)* genotypes and development of jamun seed powder chewable tablets (Doctoral dissertation, University of Horticultural Sciences, Bagalkot.(College of Horticulture, Bengaluru).
Kumar, R., Kumar, J., Kumari, A., Rai, M., Srivastava, K., & Singh, H. (2024). Influence of Vermicompost and Biofertilizers on Growth and Yield of Strawberry (*Fragaria x ananassa Duch*.) cv. Camarosa. Asian Journal of Advances in Agricultural Research, 24(12), 20-27.
Li, H., Mei, X., Wang, J., Huang, F., Hao, W., & Li, B. (2021). Drip fertigation significantly increased crop yield,

water productivity and nitrogen use efficiency with respect to traditional irrigation and fertilization practices: A meta-analysis in China. Agricultural Water Management, 244, 106534.

Mahmud M, Abdullah R, Yaacob J S (2018) Effect of vermicompost amendment on nutritional status of sandy loam soil, growth performance, and yield of pineapple *(Ananas comosus var. MD2*) under field conditions. Agronomy 8: 183.

Mohite D D, Chavan S S, Jadhav V S, Kanase T, Kadam M A and Singh A S (2024) Vermicomposting: a holistic approach for sustainable crop production, nutrient-rich bio fertilizer and environmental restoration. Discover Sustainab 5: 60.

Negi Y K, Sajwan P, Uniyal S, Mishra A C (2021) Enhancement in yield and nutritive qualities of strawberry fruits by the application of organic manures and biofertilizers. Scientia Horticulturae 283: 110038.

Oyewole C I, E S Akogu, E S Attah (2014) Response of eggplant (Solanum melongena L.) to nutrient sources and rates of application: I. Yield components and fruit yield. Int. J. Agric. Biosci., 3: 166-172.

Pang F, Li Q, Solanki M K, Wang Z, Xing Y X and Dong D F (2024) Soil phosphorus transformation and plant uptake driven by phosphate-solubilizing microorganisms. Front Microbiol 15: 1383813.

Parthasarathi T, Vanitha K, Mohandass S, Vered E (2018) Evaluation of drip irrigation system for water productivity and yield of rice. Agronomy Journal 110: 2378-2389.

Pathariya P, Dwivedi B S, Dwivedi A K, Thakur R K, Singh M and Sarvade S (2022) Potassium balance under soybean wheat cropping system in a 44 year old long term fertilizer experiment on a Vertisol. Comm Soil Sci Plant Analy 53: 214-26.

Pathma J, Sakthivel N (2012) Microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential. Springer Plus 1: 1-19.

Pırlak, L., & Köse, M. (2009). Effects of plant growth promoting rhizobacteria on yield and some fruit properties of strawberry. Journal of plant nutrition, 32(7), 1173-1184.

Quddus M A, Ahmed R, Islam M, Haque M E, Islam M A, Alam A, Hossain A (2025) Organic and inorganic fertilizers influence the productivity, fruit quality and nutrient use efficiency of strawberry (*Fragaria* × *ananassa Duch*.). Scientific Reports 15: 26252-26273.

Rangana S (2010) Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw-Hill, New Delhi.

Rawat P, Singh R, Kumar V and Sharma S (2021) Role of phosphate-solubilizing microorganisms in enhancing phosphorus availability for sustainable agriculture. Microorganisms 9: 1152.

Shah Z H, Rehman H M, Akhtar T, Alsamadany H, Hamooh B T, Mujtaba T and Chung G (2018) Humic substances: Determining potential molecular regulatory processes in plants. Front. Plant Sci. 9: 263-275.

Sharma S B, Sayyed R Z, Trivedi M H and Gobi T A (2013) Phosphate solubilizing microbes' Sustainable approach for managing phosphorus deficiency in agricultural soils. Springer Plus 2: 587.

Sher A, Li H, ullah A, Hamid Y, Nasir B, Zhang J (2024) Importance of regenerative agriculture: Climate, soil health, biodiversity and its socioecological impact. Discover Sustainability 5: 462-485.

Shyam A, Sharma D P, Dogra R K, Kaushal R (2023) Improved soil physico-chemical characteristics, soil moisture and plant growth properties through vertical mulching in a plum orchard. Biological Agriculture & Horticulture 39: 283-304.

Siddiqua A, Mukunda G K, Srinivasappa K N (2021) Effect of organic manures and bio-fertilizers on plant growth and yield of dragon fruit (Hylocereus undatus (Haworth) Britton & Rose.) and (Hylocereus polyrhizus (FAC Weber) under eastern dry zone of Karnataka. Mysore J. Agric.Sci. 55: 223-229.

Swain T and Hillis W E (1959) The phenolic constituents of Prunus domestica the quantitative analysis of phenolic constituents. *J Sci Food Agri* 10: 63–68.

Tani M, Panigrahi H K, Sarkar A, Thakur G, and Tahelyani R (2021) Studies on the effect of different growing media on survivability, root and shoot growth of dragon fruit (Hylocereus polyrhizus L.) cuttings. The Pharma Innovation Journal 10: 1497-1503.

Tian M, Yu R, Guo S, Yang W, Liu S, Du H, Zhang X (2024) Effect of vermicompost application on the soil microbial community structure and fruit quality in melon (*Cucumis melo*). Agronomy 14: 2536-2554.

Verma R S, Lata R, Ram R B, Kumar S, Verma S S and Prakash S (2019) Effect of organic, inorganic and bio-fertilizers on physico-chemical attributes of dragon fruit (*Hylocereus undatus L*.) under Lucknow conditions. Ind. J. Pure App. Biosci 7: 67-70.

Yashasvi G N, Tripathi D V, Awasthi V, Anushi A (2022) Impact of PSB and vermicompost on growth, yield and quality of strawberry. Biological Forum- An International Journal 13: 314-318.

Zuo Y, Zhang J, Zhao R, Dai H and Zhang Z (2018) Application of vermicompost improves strawberry growth and quality through increased photosynthesis rate, free radical scavenging and soil enzymatic activity. Sci Horti 233: 132–140. https://doi.org/10.1016/j.scienta.2018.01.023w