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Influence of Vermicompost and Biofertilizers on Growth and Yield of Strawberry (*Fragaria x ananassa* Duch.) cv. Camarosa

Rajesh Kumar [a*], Jitendra Kumar [a], Ankita Kumari [a], Mritunjay Rai [a], Kajal Srivastava [b] and Harendra Singh [b]

[a] *Department of Horticulture, Doon (P.G.) College of Agriculture Science and Technology, (Affiliated to Hemvati Nandan Bahuguna Garhwal University), Selaqui, Dehradun, Uttarakhand, 248011, India.*
[b] *Department of Agriculture, Doon (P.G.) College of Agriculture Science and Technology, (Affiliated to Hemvati Nandan Bahuguna Garhwal University), Selaqui, Dehradun, Uttarakhand, 248011, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was carried out during 2023-2024 to find out the effect of vermicompost and biofertilizers on the growth and yield of strawberry (*Fragaria* × *ananassa* Duch.) cv. Camarosa at the Horticultural Research Farm of Doon (P.G.) College of Agriculture Science and Technology, Dehradun, Uttarakhand. The growth and yield parameters of strawberry were significantly

**Corresponding author: Email: rjghasolia343@gmail.com;*

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influenced by different treatments of vermicompost and biofertilizers. The maximum plant height (23.10 cm) and plant spread (24.99 cm) was observed in the treatment T_6 [Vermicompost (50%) + *Azotobacter* (25%) + Arbuscular Mycorrhiza (25%)]. Maximum number of leaves per plant (67.11) and leaf area (96.67 cm^2) were observed in the treatment T_2 [Vermicompost (75%) + *Azotobacter* (50%)]. Treatment T_6 [Vermicompost (50%) + *Azotobacter* (25%) + Arbuscular Mycorrhiza (25%)] exhibited superiority in yield attributing characters like number of runners per plant (7.38), fruit size (15.52cm^2), fruit weight (21.12 g), fruit volume (5.79 ml), number of fruits per plant (27.99) and yield per plant (569.86 g).

Keywords: Vermicompost; biofertilizer; growth; yield; strawberry; Fragaria.

1. INTRODUCTION

Strawberry (*Fragaria* × *ananassa* Duch.) is an important fruit of Rosaceae family. Cultivated strawberry results from the hybridization of two different species *viz., Fragaria chiloensis* Duch. and *Fragaria virginiana* Duch. (Singh et al., 2015). Strawberries have become one of the most popular soft fruits in the world after grapes (Umar et al., 2009). It is delicate in flavor, rich in vitamins and minerals, and gives the quickest returns in the minimum possible time (Singh and Singh, 2009). In India the total area under strawberry cultivation is 3310 ha, production is 19840 MT and productivity is 5.99 MT/ha (Ministry of Agriculture and Farmers Welfare, 2021).

Strawberry is a rich source of vitamin A (60 IU/100 g fresh weight) and low-calorie carbohydrate fruit. Vitamin C is available as ascorbic acid (58.8 mg/100g of edible portion). Strawberry is also rich in fiber and pectin content (0.55%). Regular consumption of strawberries has been reported to prevent cancer and asthma disease (Wange et al., 1998). Anthocyanins and phenolic compounds are other major components among the phytochemicals of the fruit, which provide medicinal properties (*viz.,* antioxidant, anticarcinogenic, anti-inflammatory, anti-neuro degenerative) (Fernandes et al., 2012; D'Urso et al., 2015; Domingues et al., 2018). Strawberry is an herbaceous fruit crop that acts as annual in sub-tropical and perennial in the cool season (Khalid et al., 2020).

Plant nutrition is one of the most important resources that contribute to the better growth, yield and quality of strawberries and has a direct effect on bearing and development of strawberries (Umar et al., 2009). It is well known that the widespread use of chemical fertilizers has an adverse effect on soil health and contributes to reduced crop productivity and quality (Manolikar et al., 2007; Singh et al., 2023). Vermicompost is the result of organic matter decomposition facilitated by worms like red wigglers (*Eisenia andrei* or *Eisenia fetida*), European nightcrawlers (*Eisenia hortensis*), and red earthworms (*Lumbricus rubellus*) (Van Groenigen et al., 2014). The positive impact of earthworm casts and excrement on crop growth has been well recognized (Sheehan et al., 2006). Vermicompost improves soil physical properties, pH, and water-holding capacity, while also adding macro and micronutrients. Thus it increases the nutrient availability and its absorption by plants (Xu and Mou, 2016). Among free living nitrogen-fixing bacteria, *Azotobacter* is the most intensively studied genus. With the ability to fix atmospheric nitrogen, *azotobacter* is also known to synthesize biologically active growth-promoting substances such as indole acetic acid, gibberellic acid and vitamin B in culture media. *Azotobacter* fixes atmospheric nitrogen in the soil and enhances the production of various fruit crops (Kumar et al., 2020). Arbuscular mycorrhizae play an important role in the establishment, growth and productivity of strawberry plants. It can supply phosphorus which affects floral differentiation and growth. Dual inoculation of such fungi with a rhizobium and other bacterium on plants enhances the growth and other beneficial effects (Sadhana, 2014).

Keeping in view the above literature, the present investigation was undertaken to find out the effect of the combined application of vermicompost and biofertilizers on growth and yield of strawberry cv. Camarosa under Dehradun conditions of Uttarakhand.

2. MATERIALS AND METHODS

The present investigation was conducted at Horticultural Research Farm, Department of Horticulture, Doon (P.G.) College of Agriculture Science and Technology, Selaqui, Dehradun (UK), India from 2023-2024. The experimental site is located at an altitude of 515 m above mean sea level between 30.21°N latitudes and 77.50°W longitudes. The average annual rainfall was 207.33 cm with average temperature of 15.5°C and average humidity of 75.25% during the study. The soil of the experimental plot was sandy loam to clay loam with pH ranging from 6.5 to 7.5. The available nitrogen was very low (0.02%), available phosphorus was medium (48.9%) and available potassium was high (2.9%) in the soil of the experimental field. Electrical conductivity of soil ranged from 0.30 to 0.73 dS/m indicating the nature of soil is normal. Moreover, the soil having organic carbon ranged between 0.31% - 0.80%. The experiment was laid out in a Randomized Block Design (RBD) with 7 treatments and 3 replications. Strawberry cultivar 'Camarosa' was used as planting material. Black polythene mulch was used as mulching material which helps in proper crop management. The treatment consisted of vermicompost and biofertilizers singly or in combination assigned to different treatments and indicated as; T_1 [Control], T_2 [Vermicompost (75%) + *Azotobacter* (50%)], T_3 [Vermicompost (75%) + Arbuscular Mycorrhiza (50%)], T_4 [Vermicompost (100%)], T_5 [*Azotobacter* (75%) + Arbuscular Mycorrhiza (75%)], T_6 [Vermicompost (50%) + *Azotobacter* (25%) + Arbuscular Mycorrhiza (25%)] and T_7 [*Azotobacter* (100%)]. The calculated amounts of vermicompost @ 10 t/ha, *Azotobacter* @ 7 kg/ha and Arbuscular Mycorrhiza @ 5 kg/ha were applied before transplanting strawberry runners in the respective plots as per scheduled treatments.

All data about growth and yield components were collected from five plants from each replication in each experimental plot. A random sampling was done from each plot for the determination of growth attributes *viz.,* plant height (cm), plant spread (cm), number of leaves per plant and leaf area (cm^2). After harvesting, yield attributes *viz.,* number of runners per plant, fruit size (cm), fruit weight (g), fruit volume (ml), number of fruits per plant and yield per plant (g) were recorded. Plant height was measured with the help of measuring tape and expressed in centimeters. Plant spread was calculated by taking east-west and north-south spread with measuring tape and averaged. Leaf area was measured by a portable leaf area meter (BST-LM101, Bionics Scientific). Fruit size (cm^2) was calculated by multiplying fruit length (cm) and fruit diameter (cm) and measured by digital vernier callipers (Corceptive Pvt. ltd.). Fruit weight was expressed in grams. Fruit volume was analyzed by water displacement method and expressed in ml. Yield per plant was calculated by weighing all fruits in each treatment, replication-wise at the time of harvesting by using the electric balance of 20 kg capacity. The obtained data was subjected to statistical analysis using the F test according to the procedure of Gomez and Gomez (1984). The critical difference at 5% was calculated to compare the mean value of the determined criteria of different treatments.

3. RESULTS AND DISCUSSION

The present investigation revealed that the vermicompost and biofertilizers significantly impacted the plant growth parameters (plant height, plant spread, number of leaves per plant and leaf area) and yield parameters (number of runners per plant, fruit size, fruit weight, fruit volume, number of fruit per plant and yield per plant) of strawberry fruit cv. Camarosa.

3.1 Growth Characteristics

According to data presented in Table 1 and Fig. 1, maximum plant height (23.10 cm) was reported in the treatment T_6 [Vermicompost (50%) + *Azotobacter* (25%) + Arbuscular Mycorrhiza (25%)] followed by treatment T_3 [Vermicompost (75%) + *Azotobacter* (50%)] which was statistically at par with treatment T_2 and T_4. Rest of the treatments were found significantly lower in plant height. Whereas minimum plant height (16.55 cm) was recorded in treatment T_1 [control] which was statistically at par with treatment T_7. Rest of the treatments recorded significantly higher plant height. The maximum plant spread (24.99 cm) was reported under treatment T_6 [Vermicompost (50%) + *Azotobacter* (25%) + Arbuscular Mycorrhiza (25%)] followed by treatment T_3 [Vermicompost (75%) + Arbuscular Mycorrhiza (50%)], T_2 [Vermicompost (75%) + *Azotobacter* (50%)] and T_4 [Vermicompost (100%)], respectively. Treatment T_4 was statistically at par with T_5. Rest of the treatments were found significantly lower in plant spread. Minimum plant spread (18.41 cm) was recorded in treatment T_1 [control] proceeded by T_7 [*Azotobacter* (100%)] which was statistically at par with T_5 and T_4. Rest of the treatments recorded significantly higher plant spread. The maximum number of leaves per plant (67.11) was reported in the treatment T_2 [Vermicompost (75%) + *Azotobacter* (50%)] which was at par with treatment T_6 [Vermicompost (50%) + *Azotobacter* (25%) + Arbuscular Mycorrhiza (25%)]. Other remaining treatments were significantly lower in number of leaves per plant. And the minimum number of leaves per plant (49.99) was recorded in T_1 [control] which was statistically at par with treatment T_7 [*Azotobacter* (100%)]. Rest of the treatments have significantly higher number of leaves per plant. Leaf area was recorded as maximum (96.67 cm^2) in treatment T_2 [Vermicompost (75%) + *Azotobacter* (50%)] followed by treatment T_3 [Vermicompost (75%) + Arbuscular Mycorrhiza (50%)] and T_7 [*Azotobacter* (100%)], respectively. Treatment T_7 was statistically at par with T_1, T_4, T_5 and T_6. Minimum leaf area (87.35 cm^2) was recorded in treatment T_1 [control], which was statistically at par with the treatments T_4, T_5, T_6 and T_7. The plants absorb more minerals and nutrients, thus increasing the number of leaves and growth of plants. Increasing the number of leaves helps the accumulation of carbohydrates through more photosynthetic activity done by plants which is utilized for fruit development. Hence the number of leaves improves the quantity of flowers and fruits which results in better growth and maximum yield of strawberries as reported by Verma and Rao (2013) and Singh et al. (2015).

3.2 Yield Characteristics

Data pertaining to yield characteristics presented in Table 2 and Fig. 2. Plants under treatments T_6 [Vermicompost (50%) + *Azotobacter* (25%) + Arbuscular Mycorrhiza (25%)] produced maximum number of runners per plant (7.38) followed by T_3 [Vermicompost (75%) + Arbuscular Mycorrhiza (50%)] and T_2 [Vermicompost (75%) + *Azotobacter* (50%)], respectively. Treatment T_2 was statistically at par with T_1. Rest of the treatments were significantly lower in number of runners per plant. Minimum number of runners per plant (3.51) was recorded in treatment T_4 [Vermicompost (100%)] preceded by treatment T_7 [*Azotobacter* (100%)]. Treatment T_7 was statistically at par with treatment T_5. Rest of the treatments showed significantly higher number of runners per plants. Biofertilizers and vermicompost combination significantly increased the size of fruits and largest fruits (15.52 cm^2) were produced in treatment T_6 [Vermicompost (50%) + *Azotobacter* (25%) + Arbuscular Mycorrhiza (25%)] which was statistically at par with treatment T_3, followed by T_2 [Vermicompost (75%) + *Azotobacter* (50%)], T_5 [*Azotobacter* (75%) + Arbuscular Mycorrhiza (75%)], T_4 [Vermicompost (100%)] and T_7 [*Azotobacter* (100%)], respectively. Treatment T_7 was statistically at par with T_1 for size of fruits. Whereas minimum fruit size (7.61 cm^2) was recorded in the treatment T_1 [control] which was statistically at par with T_7 [*Azotobacter* (100%)]. Rest of the treatments recorded significantly higher fruit size. Plants under treatment T_6 [Vermicompost (50%) + *Azotobacter* (25%) + Arbuscular Mycorrhiza (25%)] produced fruits of maximum weight (21.12 g) which was statistically at par with treatment T_3 [Vermicompost (75%) + Arbuscular Mycorrhiza (50%)]. Rest of the treatments recorded significantly lower fruit weight. Minimum fruit weight (10.49 g) was observed under treatment T_1 [Control] which was statistically at par with T_4, T_5 and T_7. Rest of the treatments exhibited significantly higher fruit weight. The maximum fruit volume (5.79 ml) was recorded in T_6 [Vermicompost (50%) + *Azotobacter* (25%) + Arbuscular Mycorrhiza (25%)] followed by treatment T_2 [Vermicompost (75%) + *Azotobacter* (50%)] and T_2 was found statistically at par with T_3. Rest of the treatments had significantly lower fruit volume. While minimum fruit volume (3.89 ml) was recorded in the treatment T_1 [control] which was statistically at par with the treatment T_4. Rest of the treatments were found to have significantly higher fruit volume than T_1 [Control]. The maximum number of fruits (27.99) was produced from the treatment T_6 [Vermicompost (50%) + *Azotobacter* (25%) + Arbuscular Mycorrhiza (25%)] which was statistically at par with treatment T_3 [Vermicompost (75%) + Arbuscular Mycorrhiza (50%)]. Rest of the treatments had significantly lower number of fruits per plant. Whereas minimum number of fruits per plant (15.33) was observed in the treatment T_1 [control] which was statistically at par with the treatments T_4 and T_7. And rest of the treatments had significantly higher number of fruits per plant than T_1 [Control].

The maximum yield per plant (569.86 g) was recorded in treatment T_6 [Vermicompost (50%) + *Azotobacter* (25%) + Arbuscular Mycorrhiza (25%)] followed by T_3 [Vermicompost (75%) + Arbuscular Mycorrhiza (50%)], T_2 [Vermicompost (75%) + *Azotobacter* (50%)], T_5 [*Azotobacter* (75%) + Arbuscular Mycorrhiza (75%)] and T_7 [*Azotobacter* (100%)], respectively. Treatment T_7 was statistically at par with treatment T_4 and treatment T_4 was statistically at par with treatment T_1 [Control]. Minimum yield per plant (157.00 g) was found in T_1 [control] which was statistically at par with treatment T_4. Rest of the treatments had significantly higher yield per plant than T_1 [Control]. The improved strawberry yield with multi-inoculation could be attributed to

Table 1. Influence of vermicompost and biofertilizers on growth characteristics of strawberry

Symbols	Treatment Details	Plant Height (cm)	Plant Spread (cm)	Number of leaves per plant	Leaf Area (cm^2)
T_1	Control	16.55	18.41	49.99	87.35
T_2	Vermicompost (75%) + Azotobacter (50%)	20.55	22.10	67.11	96.67
T_3	Vermicompost (75%) + Arbuscular Mycorrhiza (50%)	21.55	23.66	63.33	94.64
T_4	Vermicompost (100%)	19.77	20.83	52.66	88.03
T_5	Azotobacter (75%) + Arbuscular Mycorrhiza (75%)	18.99	20.49	56.33	88.43
T_6	Vermicompost (50%) + Azotobacter (25%) + Arbuscular Mycorrhiza (25%)	23.10	24.99	65.66	88.50
T_7	Azotobacter (100%)	17.44	19.77	51.33	88.69
C.D. @ 5 %		1.592	1.264	2.018	1.473
SE(m)		0.511	0.406	0.648	0.473
C.V.		4.491	3.274	1.932	0.907

Table 2. Influence of vermicompost and biofertilizers on yield characteristics of strawberry

Symbols	Treatment Details	Number of runners per plant	Fruit size (cm^2)	Fruit weight (g)	Fruit volume (ml)	Number of fruits per plant	Yield per plant (g)
T_1	Control	5.44	7.61	10.49	3.89	15.33	157.00
T_2	Vermicompost (75%) + Azotobacter (50%)	5.54	14.07	16.24	5.18	23.44	372.80
T_3	Vermicompost (75%) + Arbuscular Mycorrhiza (50%)	6.73	14.80	18.76	4.89	24.99	448.23
T_4	Vermicompost (100%)	3.51	9.87	11.46	4.07	16.66	181.96
T_5	Azotobacter (75%) + Arbuscular Mycorrhiza (75%)	5.00	12.76	14.08	4.56	21.11	258.66
T_6	Vermicompost (50%) + Azotobacter (25%) + Arbuscular Mycorrhiza (25%)	7.38	15.52	21.12	5.79	27.99	569.86
T_7	Azotobacter (100%)	4.67	8.22	11.02	4.39	18.44	198.33
C.D. @ 5 %		0.405	1.060	3.788	0.377	3.349	39.201
SE(m)		0.130	0.340	1.216	0.121	1.075	12.583
C.V.		4.118	4.980	14.285	4.474	8.809	6.976

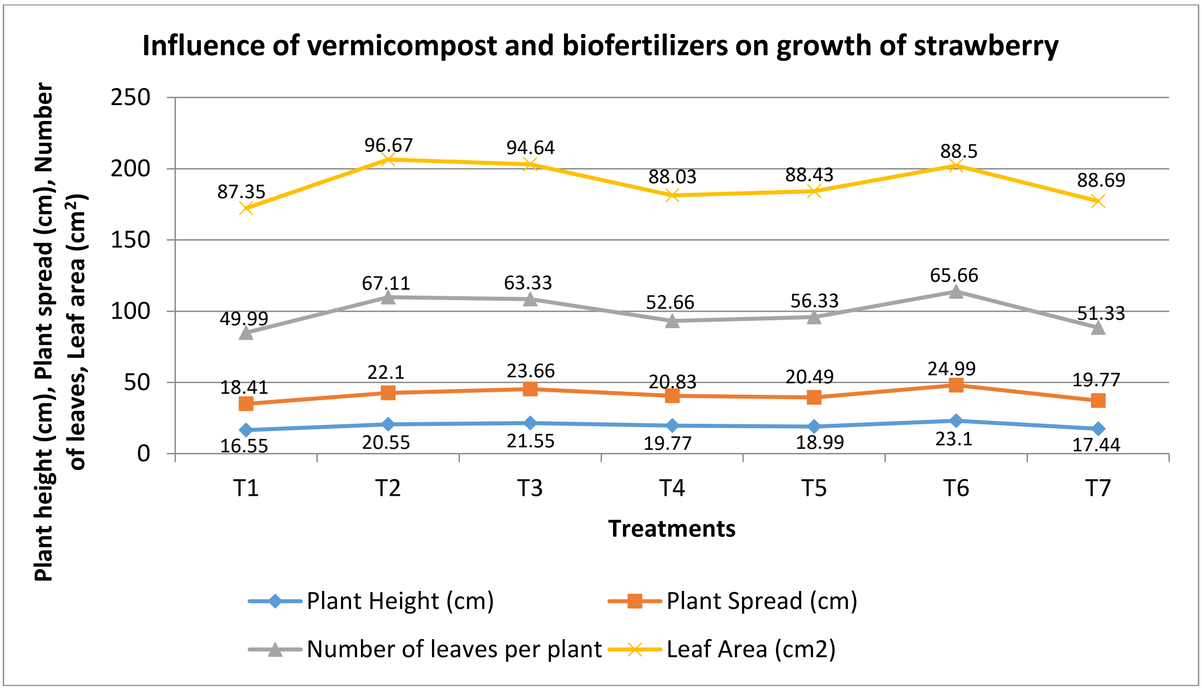

Fig. 1. Influence of vermicompost and biofertilizers on plant height, plant spread, number of leaves per plant and leaf area of strawberry

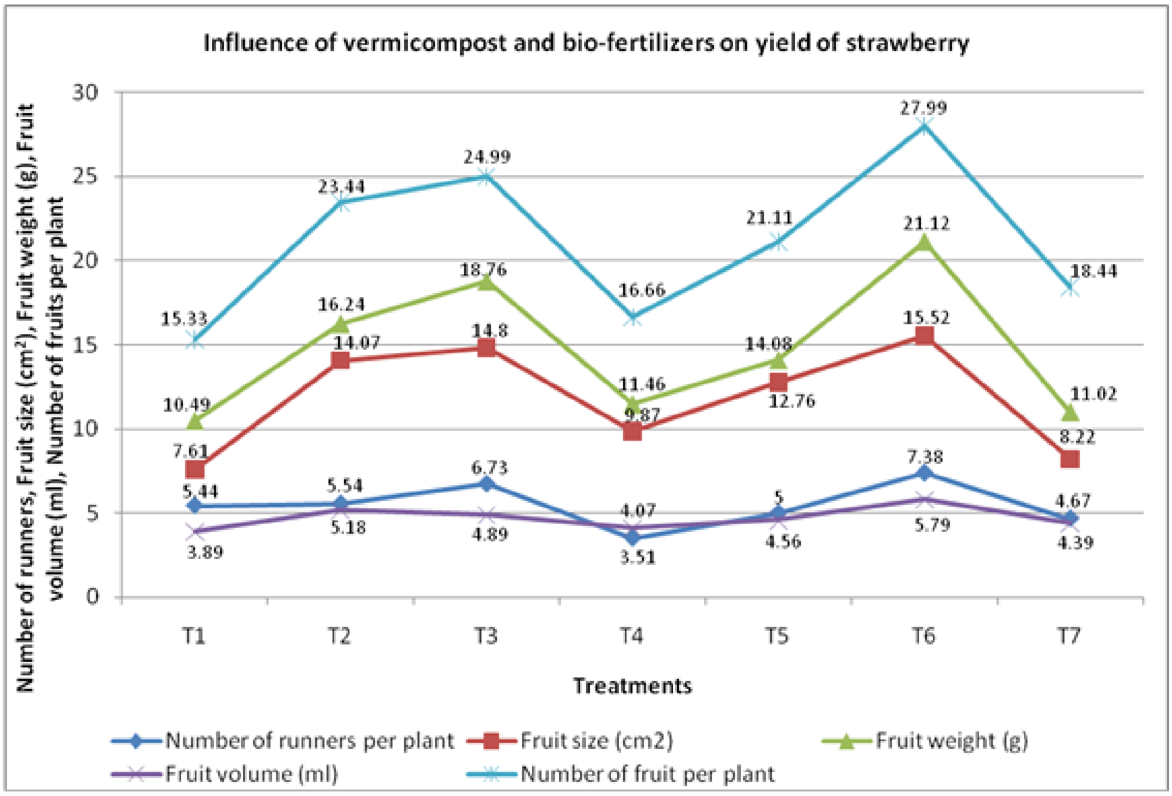

Fig. 2. Influence of vermicompost and biofertilizers on the number of runners per plant, fruit size, fruit weight, fruit volume and number of fruits per plant of strawberry

Plate 1. Fruiting stage of strawberry at experimental site

enhanced N availability in soil from biological N-fixing bacteria and increased P facilitated by phosphate solubilizing bacteria (PSB) (Rana and Chandel, 2003). Synergism among *Azospirillum* along with PSB and *Azotobacter* with PSB might have resulted better in strawberry yield as against single inoculation (Singh et al., 2010). The combined application of organic manure and biofertilizers has shown better results in crop yield (Negi et al., 2021).

4. CONCLUSION

From the results obtained during the present investigation with different treatment combinations of biofertilizers and vermicompost on vegetative growth and yield characters of strawberry cv. Camarosa, it is concluded that plants treated with Vermicompost (50%) + *Azotobacter* (25%) + Arbuscular Mycorrhiza (25%) significantly increased the plant height, plant spread, number of runners, fruit size, fruit weight, fruit volume, number of fruits per plant and yield per plant. Whereas number of leaves per plant and leaf area was maximum in Vermicompost (75%) + *Azotobacter* (50%) treated plants. Based on the above findings it may be concluded that to get substantially better growth and higher yield of berries with more propagating materials, the plants of strawberry may be treated with Vermicompost (50%) + *Azotobacter* (25%) + Arbuscular Mycorrhiza (25%) under Dehradun conditions of Uttarakhand.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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