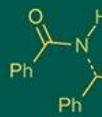


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## Influence of growing media on vegetative growth attributes of strawberry (*Fragaria × ananassa* Duch.) cv. winter dawn under protected condition

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**Abstract**

The present investigation was carried out to elucidate the effect of different growing media combinations including T<sub>0</sub>: (control) soil + sand, T<sub>1</sub>: soil + sand + FYM, T<sub>2</sub>: soil + sand + perlite, T<sub>3</sub>: soil + sand + poultry manure, T<sub>4</sub>: soil + sand + peat moss, T<sub>5</sub>: soil + sand + goat manure, T<sub>6</sub>: soil + sand + vermicompost and T<sub>7</sub>: soil + sand + vermiculite on vegetative growth attributes of strawberry (*Fragaria × ananassa* Duch.) cv. 'Winter Dawn'. The results showed that T<sub>6</sub> had the maximum survival percentage of runners (96.67%) and exhibited maximum plant height at 30, 60, 90 and 120 days after planting (DAP), reaching 8.89, 16.08, 20.18 and 23.67 cm respectively. Maximum number of leaves per plant was also observed in treatment T<sub>6</sub> across the same day intervals, yielding 6.91, 13.56, 18.41 and 24.06 leaves per plant respectively. At the final evaluation stage (120 DAP), T<sub>6</sub> achieved the maximum leaf area (101.44 cm<sup>2</sup>), plant spread (25.81 cm in N-S and 26.32 cm in E-W direction), maximum number of crowns per plant (4.54) and runners per plant (6.18). The highest root length at 120 DAP was also recorded in T<sub>6</sub> (19.73 cm). The overall findings of the study stated that the treatment T<sub>6</sub> was superior in vegetative growth parameters as compared to control T<sub>0</sub>.

**Keywords:** *Fragaria × ananassa* Duch., growing media, survival percentage, vermicompost, vegetative growth

**1. Introduction**

Strawberry (*Fragaria × ananassa* Duch.) is a perennial, monoecious, octoploid (2n = 56) herbaceous fruit crop of the family Rosaceae, originating from a natural cross between *Fragaria chiloensis* and *Fragaria virginiana* (Islam *et al.*, 2023) [14]. It was first introduced to India in the early 1960s at the NBPGR regional station, Shimla, Himachal Pradesh (Maheshgowda *et al.*, 2017) [18] and cultivation was historically confined to the temperate hill regions of Himachal Pradesh, Jammu and Kashmir, Uttarakhand and Darjeeling. However, in recent years the commercial cultivation has expanded into subtropical and semi-arid plains such as Maharashtra, Haryana and Punjab and is progressively spreading to developing horticultural states like Chhattisgarh, aided by the introduction of day-neutral and short-day cultivars and improved microclimate management (Chadha, 2022) [6]. The area under strawberry cultivation in the country increased from 3.03 thousand hectares in 2023-24 to 4.29 thousand hectares in 2024-25, with a corresponding rise in production from 21.10 thousand metric tonnes to 26.95 thousand metric tonnes during the same period (Anon., 2025) [1], with Maharashtra and Haryana emerging as the leading strawberry-growing states of the country, reflecting the rapid year-on-year growth of the crop across both traditional hill regions and newer subtropical growing areas.

Among the cultivars driving this expansion, 'Winter Dawn', a short-day cultivar noted for vigorous vegetative growth, early and abundant flowering, high yield potential and resistance to *Colletotrichum* crown rot, has become especially popular with Indian growers (Rathore *et al.*, 2023) [22], performing well under protected shade-net conditions (Tarafdar *et al.*, 2023) [24]. The plant grows optimally at daytime temperatures of 22-25 °C and night temperatures of 7-13 °C (De and Bhattacharjee, 2012) [8], and is propagated true-to-type through runners (Hartmann *et al.*, 1997) [13].

Open-field strawberry production remains highly vulnerable to weather extremes, which cause flower abortion and yield loss (Menzel, 2025) [20], making protected structures essential for regulating the aerial microclimate and reducing pest pressure (Weber, 2021) [27]. The continuous soil-based cultivation suffers from soil-borne pathogens and nematode build-up (Lieten *et al.*, 2004) [17], prompting growers to amend or replace soil with organic and inorganic substrates such as sand, cocopeat, perlite, farmyard manure (FYM) and vermicompost (Ayesha *et al.*, 2011) [4]. Vermicompost, in particular, has been shown to promote plant growth (Arancon *et al.*, 2004) [3], while vermicompost-perlite-cocopeat combinations improve shoot growth in container systems and perlite alone enhances yield in bag culture (Godara and Sharma, 2016) [11]. Organic amendments generally improve soil structure, pH and nutrient availability and sustain higher microbial biomass (Reganold *et al.*, 2010) [23]. FYM enhances vegetative growth, while vermicompost supplies readily available NPK and micronutrients that stimulate microbial and enzymatic activity (Chaoui *et al.*, 2003) [7].

Despite the well-established benefits of amended growing media, the ideal substrate composition varies with local agro-climatic conditions and cultivar response (Diel *et al.*, 2018) [10], and commercial substrates are often cost-prohibitive for small growers. There is therefore a need to standardize locally available, low-cost growing media suited to region-specific conditions. For regions like Chhattisgarh, where climate challenges persist, using protected cultivation methods and optimizing growing media is essential for successful strawberry cultivation. Keeping the above in view, the present investigation was carried out with an objective of influence of growing media on vegetative growth attributes of strawberry (*Fragaria × ananassa* Duch.) cv. winter dawn under protected condition.

## 2. Materials and Methods

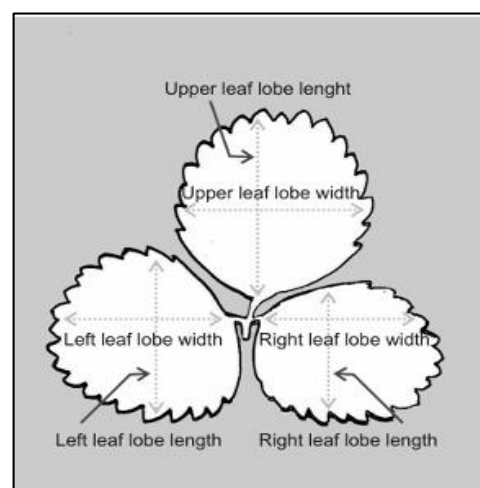
The present investigation was carried out at PFDC (Precision Farming Development Centre), Department of Fruit Science, College of Agriculture, IGKV, Raipur (C.G.) located at a height of 298.15 metres above mean sea level and located at a latitude of 21.25°N and 81.62°E longitude during the year 2025-26. The experiment was laid out in Completely Randomized Design (CRD) with 8 treatment combinations viz. T<sub>0</sub>: (control) soil + sand, T<sub>1</sub>: soil + sand + FYM, T<sub>2</sub>: soil + sand + perlite, T<sub>3</sub>: soil + sand + poultry manure, T<sub>4</sub>: soil + sand + peat moss, T<sub>5</sub>: soil + sand + goat manure, T<sub>6</sub>: soil + sand + vermicompost and T<sub>7</sub>: soil + sand + vermiculite as presented in table 1. Healthy runners of the cv. 'Winter Dawn' were planted in 10 × 10 inches polybags of 200 gauge thickness containing equal proportion of different media substrate (v/v) and irrigated 1-2 days interval depending on the moisture content.

The effects of the different growing media were observed on the average survival percentage of runners, plant height (cm), no. of leaves per plant, plant spread (N-S and E-W), no. of crowns per plant, no. of runners per plant and root length (cm) as per the standard practices. The survival percentage of runners was recorded at 10 DAP, using the formula

$$\text{Percentage survival of runners} = \frac{\text{Number of live runners}}{\text{Total number of planted runners}} \times 100$$

The other parameters like plant height and number of leaves per plant were recorded at 30 days interval i.e., 30 DAP, 60 DAP, 90 DAP and 120 DAP. The leaf area was recorded at 120 DAP through improved model for non destructive estimation of strawberry leaf area developed by Demirsoy *et al.*, 2005 [9]. Plant spread (N-S and E-W), no. of crowns per plant, no. of runners per plant and root length were recorded at 120 DAP following the standard practices.

| Prediction model                                                                                    | r <sup>2</sup> |
|-----------------------------------------------------------------------------------------------------|----------------|
| Leaf area = 1.89 + (2.145 x upper lobe length x left lobe width) Standard error : 0.396*** 0.006*** | 0.993          |
| ***Significant at a level of 0.1%                                                                   |                |



Model for non destructive estimation of strawberry leaf area

Statistical analysis of the data collected were carried out using OPSTAT and Ms-Excel and were subjected to the statistical analysis of variance by Completely Randomized Design (CRD). The significance and non-significance of the variance due to different treatments was determined by calculating the respective 'F' values as the method described by Gomez and Gomez (2010) [12].

## 3. Results and Discussion

### 3.1. Survival percentage of runners

The survival percentage of runners was recorded at 10 days after planting (DAP) results showed that different growing media combinations had significant variation as presented in Table 2. The maximum survival percentage of runners (96.67%) was recorded in treatment T<sub>6</sub> (Soil + Sand + Vermicompost) which was statistically *at par* with treatment T<sub>4</sub> at 93.33%, T<sub>2</sub> (90.00%), T<sub>7</sub> (90.00%) and T<sub>1</sub> (86.67%). The treatments amended with raw or rapid-mineralizing manures, specifically T<sub>3</sub> and T<sub>5</sub> exhibited a lower survival rate of 83.33%. The minimum runner survival percentage (80.00%) was observed in the control treatment T<sub>0</sub>.

The superior survival of runners in T<sub>6</sub> may be attributed to the favourable physical properties of vermicompost, such as high porosity and water-holding capacity, along with its rich microbial load and readily available nutrients, which together promote faster root initiation and establishment of runners. Similar findings were reported by Arancon *et al.* (2004) [3] and Wahlang and Joseph (2024) [26] in strawberry, who observed enhanced runner survival following vermicompost application, attributed to improved microbial activity and nutrient retention in the root zone.

### 3.2 Plant height (cm)

The data on plant height as influenced by different growing media, recorded at 30, 60, 90 and 120 days after planting (DAP), are presented in Table 2. Analysis of variance revealed significant variation among treatments at all the growth stages studied.

At 30 DAP, the highest plant height (8.89 cm) was recorded in T<sub>6</sub> (Soil + Sand + Vermicompost) remained statistically *at par* with T<sub>3</sub> (8.66 cm), while the minimum (6.51 cm) was observed in T<sub>0</sub> (control). At 60 DAP, T<sub>6</sub> again showed the highest height (16.08 cm) remained statistically *at par* with T<sub>3</sub> (15.52 cm), with T<sub>0</sub> showing the lowest (11.18 cm). At 90 DAP, T<sub>6</sub> (20.18 cm) recorded the maximum height, closely followed by T<sub>3</sub> (19.66 cm), and T<sub>0</sub> remained the lowest (13.78 cm). At 120 DAP, the maximum height was recorded in T<sub>6</sub> (23.67 cm), followed by T<sub>3</sub> (22.59 cm), while T<sub>0</sub> had the minimum (17.42 cm). Overall, T<sub>6</sub> consistently resulted in the maximum plant height across all stages, whereas T<sub>0</sub> (control) recorded the minimum throughout the growth period.

The addition of organic manures like vermicompost and poultry manure in the treatment T<sub>6</sub> and T<sub>3</sub> increases the nutrient availability, which enhances the soil structure and microclimate of the media, thereby increasing the plant nutrient uptake leading to increase plant height. Similar findings were reported by Bai *et al.* (2025)<sup>[5]</sup>, who observed that cattle manure vermicompost significantly enhanced plant height. Comparable results were also reported by Lakshmikanth *et al.* (2020)<sup>[16]</sup> in strawberry cv. Winter Dawn under polyhouse condition.

### 3.3 Number of leaves per plant

The data on number of leaves per plant as influenced by different growing media, recorded at 30, 60, 90 and 120 DAP, are presented in Table 2. Analysis of variance revealed significant variation among treatments at all the growth stages studied.

At 30 DAP, the maximum number of leaves per plant (6.91) was recorded in T<sub>6</sub> (Soil + Sand + Vermicompost), which was statistically *at par* with T<sub>3</sub> (6.62), while the minimum (3.84) was observed in T<sub>0</sub> (control). At 60 DAP, T<sub>6</sub> recorded the maximum number of leaves (13.56) remaining statistically *at par* with T<sub>3</sub> (12.90), while T<sub>0</sub> had minimum number of leaves (8.33). At 90 DAP, T<sub>6</sub> (18.41) recorded the maximum, which was statistically *at par* with T<sub>3</sub> (17.81) and T<sub>0</sub> showed minimum number of leaves (11.28). At 120 DAP, the maximum number of leaves per plant was recorded in T<sub>6</sub> (24.06), followed by T<sub>3</sub> (23.41), while T<sub>0</sub> had the minimum (16.76). Overall, T<sub>6</sub> consistently produced the maximum number of leaves throughout the growth period, closely followed by T<sub>3</sub>, whereas T<sub>0</sub> (control) recorded the minimum at all stages.

These findings are in agreement with those of reported by Kumar *et al.* (2022)<sup>[15]</sup> and Rathore *et al.* (2023)<sup>[22]</sup> who observed higher leaf number in strawberry with vermicompost-based growing media/organic manure treatments as compared to the control.

### 3.4 Leaf area (cm<sup>2</sup>)

The data on leaf area (cm<sup>2</sup>) as influenced by different growing media, recorded at 120 DAP is presented in Table 3. The statistical analysis of variance indicated that the leaf area was significantly influenced by different growing media combinations.

The maximum leaf area (101.44 cm<sup>2</sup>) was recorded in treatment T<sub>6</sub> (Soil + Sand + Vermicompost), which was statistically *at par* with T<sub>3</sub> (100.67 cm<sup>2</sup>). These were closely followed by T<sub>5</sub> (99.22 cm<sup>2</sup>) and T<sub>1</sub> (98.56 cm<sup>2</sup>). The remaining treatments T<sub>4</sub>, T<sub>7</sub> and T<sub>2</sub> showed comparatively low leaf area at 96.75 cm<sup>2</sup>, 95.87 cm<sup>2</sup> and 95.28 cm<sup>2</sup> respectively. The minimum leaf area (92.66 cm<sup>2</sup>) was recorded in the control (T<sub>0</sub>), which remained significantly lower than all other treatments.

The addition of vermicompost in treatment T<sub>6</sub> improved soil aeration and water-holding capacity, facilitating better nutrient absorption. This enhanced nutrient uptake, particularly nitrogen, promotes cell elongation and multiplication, leading to increased leaf area and overall vegetative growth (Mandal *et al.* 2021)<sup>[19]</sup>. These findings are in alignment with those of Lakshmikanth *et al.* (2020)<sup>[16]</sup>.

### 3.5 Plant spread (cm) in N-S and E-W

The data on plant spread (N-S and E-W directions) as influenced by different growing media recorded at 120 DAP is presented in Table 3. Statistical analysis revealed significant variation among treatments in both directions.

The maximum plant spread was recorded in treatment T<sub>6</sub> (Soil + Sand + Vermicompost), with values of 25.81 cm (N-S) and 26.32 cm (E-W), which was statistically *at par* with T<sub>3</sub> (24.96 cm N-S and 25.71 cm E-W). These were closely followed by T<sub>5</sub> (23.87 cm N-S, 23.34 cm E-W) and T<sub>1</sub> (23.18 cm N-S, 23.96 cm E-W). The remaining treatments T<sub>4</sub>, T<sub>7</sub> and T<sub>2</sub> recorded comparatively lower plant spread 21.53, 18.71 and 18.44 cm in N-S direction and 22.18, 19.83 and 19.52 cm in E-W direction respectively. The minimum plant spread was recorded in the control (T<sub>0</sub>), with 17.22 cm (N-S) and 17.57 cm (E-W), which remained significantly lower than all other treatments.

Similar findings were reported by Rathore *et al.* (2023)<sup>[22]</sup> in strawberry cv. Winter Dawn, who observed the maximum plant spread in vermicompost and vermiwash-treated plants, attributed to improved nutrient availability and enhanced root development promoting lateral canopy growth.

### 3.6 Number of crowns per plant

The data on number of crowns per plant as influenced by different growing media are presented in Table 3. The statistical analysis of variance indicated that the number of crowns per plant was significantly influenced by different growing media combinations.

The maximum number of crowns per plant (4.54) was recorded in treatment T<sub>6</sub> (Soil + Sand + Vermicompost) which was statistically *at par* with T<sub>3</sub> (4.28). These were closely followed by T<sub>5</sub> (3.67), T<sub>1</sub> (3.31) and T<sub>4</sub> (3.15). The remaining treatments T<sub>7</sub> and T<sub>2</sub> recorded comparatively lower values 2.87 and 2.56 respectively. The minimum number of crowns per plant (2.23) was recorded in the control (T<sub>0</sub>), which remained significantly lower than all other treatments.

Similar findings were reported by Kumar *et al.* (2022)<sup>[15]</sup>, who observed a higher number of crowns per plant in strawberry with vermicompost and cocopeat-based potting substrates, attributed to improved nutrient availability and favourable physical properties of the growing medium.

### 3.7 Number of runners per plant

The data on number of runners per plant as influenced by different growing media are presented in Table 3. The statistical analysis of variance indicated that the number of runners per plant was significantly influenced by different growing media combinations.

The maximum number of runners per plant (6.18) was recorded in treatment T<sub>6</sub> (Soil + Sand + Vermicompost), which was statistically *at par* with T<sub>3</sub> (5.92). These were followed by T<sub>5</sub> (5.80) and T<sub>1</sub> (5.63). Treatments T<sub>4</sub> and T<sub>7</sub> recorded comparatively lower values 5.37 and 5.22 respectively, which were statistically *at par* with each other, while T<sub>2</sub> recorded 5.07 runners per plant. The minimum number of runners per plant (4.60) was recorded in the control (T<sub>0</sub>), which remained significantly lower than all other treatments.

The maximum number of runners recorded in T<sub>6</sub> may be attributed to the higher nutrient availability, particularly nitrogen, along with growth-promoting substances such as auxins and gibberellins present in vermicompost, which stimulate lateral bud activity and promote runner initiation from the leaf axils of the crown. Similar findings were reported by Arancon *et al.* (2004) [3] in strawberry, who observed that vermicompost application significantly increased the number of runners per plant, attributed to enhanced microbial activity and improved nutrient retention

in the root zone. Comparable results were also reported by Lakshmikanth *et al.* (2020) [16] in strawberry cv. Winter Dawn under polyhouse conditions.

### 3.8 Root length (cm)

The data on root length as influenced by different growing media are presented in Table 3. The statistical analysis of variance indicated that root length was significantly influenced by different growing media combinations.

Among the evaluated treatments, the plants grown in T<sub>6</sub> (Soil + Sand + Vermicompost) produced the longest roots at 19.73 cm which was significantly *at par* with T<sub>3</sub> at 19.22 cm. Treatment T<sub>5</sub> also showed comparable results at 18.77 cm, while T<sub>1</sub> and T<sub>4</sub> were *at par* with each other producing a length of 18.08 cm and 17.67 cm respectively. The treatment T<sub>7</sub> averaged 16.78 cm which was closely followed by T<sub>2</sub> at 16.26 cm. Minimum root length was recorded in control (T<sub>0</sub>) at just 14.54 cm.

Similar findings of maximum root length under vermicompost-amended media were reported by Thakur and Shylla (2018) [25] and Apu *et al.* (2022) [2]. Preusch *et al.* (2004) [21] reported an increased root length of strawberries with fresh and composted poultry litter compost compared to control which was attributed to the role played by the potassium in proliferation of root.

**Table 1:** Details of treatment combinations

| S. No. | Treatments                           | Notations used |
|--------|--------------------------------------|----------------|
| 1      | Soil + Sand ( Control ) (1:1)        | T <sub>0</sub> |
| 2      | Soil + Sand + FYM (1:1:1)            | T <sub>1</sub> |
| 3      | Soil + Sand + Perlite (1:1:1)        | T <sub>2</sub> |
| 4      | Soil + Sand + Poultry manure (1:1:1) | T <sub>3</sub> |
| 5      | Soil + Sand + Peat moss (1:1:1)      | T <sub>4</sub> |
| 6      | Soil + Sand + Goat Manure (1:1:1)    | T <sub>5</sub> |
| 7      | Soil + Sand + Vermicompost (1:1:1)   | T <sub>6</sub> |
| 8      | Soil + Sand + Vermiculite (1:1:1)    | T <sub>7</sub> |

**Table 2:** Effect of growing media on survival percentage of runners, plant height and number of leaves per plant in strawberry cv. Winter Dawn under protected condition.

| Notations      | Survival of runners (%) | Plant height(cm)    |                      |                      |                     | Number of leaves per plant |                     |                     |                     |
|----------------|-------------------------|---------------------|----------------------|----------------------|---------------------|----------------------------|---------------------|---------------------|---------------------|
|                |                         | 30 DAP              | 60 DAP               | 90 DAP               | 120 DAP             | 30 DAP                     | 60 DAP              | 90 DAP              | 120 DAP             |
| T <sub>0</sub> | 80.00 <sup>bcdef</sup>  | 6.51 <sup>fgh</sup> | 11.18 <sup>h</sup>   | 13.78 <sup>h</sup>   | 17.42 <sup>h</sup>  | 3.84 <sup>h</sup>          | 8.33 <sup>h</sup>   | 11.28 <sup>h</sup>  | 16.76 <sup>h</sup>  |
| T <sub>1</sub> | 86.67 <sup>abcde</sup>  | 7.75 <sup>cd</sup>  | 13.94 <sup>cd</sup>  | 17.86 <sup>cd</sup>  | 21.27 <sup>cd</sup> | 5.81 <sup>cd</sup>         | 11.78 <sup>cd</sup> | 15.64 <sup>cd</sup> | 21.35 <sup>cd</sup> |
| T <sub>2</sub> | 90.00 <sup>abcd</sup>   | 6.81 <sup>fg</sup>  | 11.98 <sup>fg</sup>  | 14.61 <sup>g</sup>   | 18.53 <sup>fg</sup> | 4.68 <sup>fg</sup>         | 9.86 <sup>fg</sup>  | 13.24 <sup>fg</sup> | 18.72 <sup>fg</sup> |
| T <sub>3</sub> | 83.33 <sup>abcdef</sup> | 8.66 <sup>ab</sup>  | 15.52 <sup>ab</sup>  | 19.66 <sup>ab</sup>  | 22.59 <sup>b</sup>  | 6.62 <sup>ab</sup>         | 12.90 <sup>ab</sup> | 17.81 <sup>ab</sup> | 23.41 <sup>ab</sup> |
| T <sub>4</sub> | 93.33 <sup>ab</sup>     | 7.59 <sup>cde</sup> | 13.63 <sup>cde</sup> | 17.68 <sup>cde</sup> | 20.32 <sup>e</sup>  | 5.58 <sup>cde</sup>        | 11.16 <sup>de</sup> | 14.39 <sup>de</sup> | 20.28 <sup>e</sup>  |
| T <sub>5</sub> | 83.33 <sup>abcdef</sup> | 7.78 <sup>c</sup>   | 14.22 <sup>c</sup>   | 18.32 <sup>c</sup>   | 21.68 <sup>bc</sup> | 6.09 <sup>c</sup>          | 11.98 <sup>c</sup>  | 15.86 <sup>c</sup>  | 21.56 <sup>c</sup>  |
| T <sub>6</sub> | 96.67 <sup>a</sup>      | 8.89 <sup>a</sup>   | 16.08 <sup>a</sup>   | 20.18 <sup>a</sup>   | 23.67 <sup>a</sup>  | 6.91 <sup>a</sup>          | 13.56 <sup>a</sup>  | 18.41 <sup>a</sup>  | 24.06 <sup>a</sup>  |
| T <sub>7</sub> | 90.00 <sup>abcd</sup>   | 7.10 <sup>ef</sup>  | 12.65 <sup>f</sup>   | 15.33 <sup>f</sup>   | 19.38 <sup>f</sup>  | 4.88 <sup>f</sup>          | 10.26 <sup>f</sup>  | 13.68 <sup>f</sup>  | 19.27 <sup>f</sup>  |
| SE.m ±         | 0.49                    | 0.21                | 0.25                 | 0.23                 | 0.31                | 0.17                       | 0.23                | 0.22                | 0.24                |
| CD @ 5%        | 1.47                    | 0.63                | 0.75                 | 0.68                 | 0.93                | 0.52                       | 0.70                | 0.66                | 0.72                |

1. C.D. = Critical Difference; SE(m) = Standard Error of mean; DAP = Days after Planting. Treatment notations (T<sub>0</sub>-T<sub>7</sub>) are as detailed in Table 1.

2. The superscript letters signifies that the treatment means with similar letters are *at par* at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

**Table 3:** Effect of growing media on leaf area, plant spread, number of crowns per plant, number of runners per plant and root length in strawberry cv. Winter Dawn under protected condition

| Notations      | Leaf area (cm <sup>2</sup> ) | Plant spread (cm)   |                     | Number of crowns per plant | Number of runners per plant | Root Length (cm)    |
|----------------|------------------------------|---------------------|---------------------|----------------------------|-----------------------------|---------------------|
|                |                              | N-S                 | E-W                 |                            |                             |                     |
| T <sub>0</sub> | 92.66 <sup>h</sup>           | 17.22 <sup>h</sup>  | 17.57 <sup>h</sup>  | 2.23 <sup>h</sup>          | 4.60 <sup>h</sup>           | 14.54 <sup>h</sup>  |
| T <sub>1</sub> | 98.56 <sup>cd</sup>          | 23.18 <sup>cd</sup> | 23.96 <sup>cd</sup> | 3.31 <sup>d</sup>          | 5.63 <sup>bcd</sup>         | 18.08 <sup>d</sup>  |
| T <sub>2</sub> | 95.28 <sup>fg</sup>          | 18.44 <sup>fg</sup> | 19.52 <sup>fg</sup> | 2.56 <sup>g</sup>          | 5.07 <sup>efg</sup>         | 16.26 <sup>fg</sup> |
| T <sub>3</sub> | 100.67 <sup>ab</sup>         | 24.96 <sup>ab</sup> | 25.71 <sup>ab</sup> | 4.28 <sup>b</sup>          | 5.92 <sup>ab</sup>          | 19.22 <sup>ab</sup> |
| T <sub>4</sub> | 96.75 <sup>e</sup>           | 21.53 <sup>e</sup>  | 22.18 <sup>e</sup>  | 3.15 <sup>de</sup>         | 5.37 <sup>de</sup>          | 17.67 <sup>de</sup> |
| T <sub>5</sub> | 99.22 <sup>c</sup>           | 23.87 <sup>c</sup>  | 23.34 <sup>c</sup>  | 3.67 <sup>c</sup>          | 5.80 <sup>bc</sup>          | 18.77 <sup>c</sup>  |
| T <sub>6</sub> | 101.44 <sup>a</sup>          | 25.81 <sup>a</sup>  | 26.32 <sup>a</sup>  | 4.54 <sup>a</sup>          | 6.18 <sup>a</sup>           | 19.73 <sup>a</sup>  |
| T <sub>7</sub> | 95.87 <sup>f</sup>           | 18.71 <sup>f</sup>  | 19.83 <sup>f</sup>  | 2.87 <sup>f</sup>          | 5.22 <sup>ef</sup>          | 16.78 <sup>f</sup>  |
| SE.m ±         | 0.28                         | 0.30                | 0.31                | 0.05                       | 0.12                        | 0.22                |
| CD @ 5%        | 0.84                         | .91                 | 0.93                | 0.15                       | 0.37                        | 0.67                |

1. C.D. = Critical Difference; SE(m) = Standard Error of mean; Treatment notations (T<sub>0</sub>–T<sub>7</sub>) are as detailed in Table 1.

2. The superscript letters signifies that the treatment means with similar letters are *at par* at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

#### 4. Conclusion

The present investigation revealed that different growing media significantly influenced the growth and propagation attributes of strawberry (*Fragaria × ananassa* Duch.) cv. Winter Dawn under protected condition. Among the treatments, T<sub>6</sub> (Soil + Sand + Vermicompost) consistently recorded the maximum values for survival percentage of runners, plant height, number of leaves, leaf area, plant spread, number of crowns, number of runners per plant and root length. Treatment T<sub>3</sub> (Soil + Sand + Poultry manure) remained statistically at par with T<sub>6</sub> throughout the study for most of the parameters. This superior performance may be attributed to the favourable physical properties, higher nutrient availability and growth-promoting substances present in vermicompost, which together supported vigorous vegetative growth and better establishment of runners. The control (T<sub>0</sub>) recorded the minimum values across all parameters. Based on these findings, amending the growing medium with vermicompost (Soil + Sand + Vermicompost, 1:1:1) can be recommended as the most effective combination for enhancing growth and runner production in strawberry cv. Winter Dawn under protected cultivation, followed by poultry manure as a suitable alternative.

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#### 6. Competing interests

The authors have no conflicts of interest to declare regarding this manuscript.

#### 7. Author's contributions

K.T. carried out the experimental work, data collection and manuscript preparation. P.P., A.K.R., D.K.S., and R.K. assisted with data collection, field observations and manuscript preparation. P.S. and G.D.S. provided supervision, technical guidance and critical revision of the manuscript. All authors read and approved the final manuscript.

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