RESEARCH ARTICLE

# Response of Organic and Inorganic Sources of Nutrients on growth, flowering and yield of strawberry *Fragaria x ananassa* Duch cv. Winter Dawn

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## Abstract

The present study was conducted during the academic year 2024–25 at the Horticultural Research Farm of the Narayan Institute of Agricultural Sciences, GNS University, Sasaram, Rohtas, Bihar to assess the influence of organic and inorganic nutrient sources, applied individually and in different combinations, on the growth, flowering and yield of strawberry (*Fragaria* × *ananassa Duch*.) cv. Winter Dawn. The experiment was arranged in a randomized block design with ten treatments and three replications. The treatments comprised a control, 100% recommended dose of NPK fertilizers, farmyard manure (FYM @ 20 t $ha^{-1}$), vermicompost (10 t $ha^{-1}$) and their respective combinations with graded levels of NPK. The results indicated that the combined application of vermicompost (10 t $ha^{-1}$) with 100% recommended NPK significantly improved vegetative growth attributes such as plant height, plant spread, number of leaves per plant and leaf area. This treatment also promoted earlier flowering, increased the number of flowers per plant, improved fruit set, prolonged the harvesting period and produced superior yield parameters including fruit size, fruit weight, fruit volume and total yield per plant. The treatment comprising FYM (20 t $ha^{-1}$) along with 100% NPK showed the next best performance. In contrast, the control treatment recorded the minimum values for all the growth, flowering and yield parameters. The findings suggest that integrated nutrient management achieved through the combined use of vermicompost and inorganic fertilizers, is a viable and sustainable approach for enhancing strawberry productivity, improving soil fertility, and increasing economic returns.


**Keywords:** Strawberry, Integrated Nutrient Management, Vermicompost, Farmyard Manure, NPK, Yield.

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## Introduction

Strawberry (*Fragaria* × *ananassa* Duch.) is a widely cultivated soft fruit crop valued globally for its appealing flavour, bright colour, pleasant aroma and high nutritive content. It is a member of the family Rosaceae and originated as a hybrid between Fragaria chiloensis and Fragaria virginiana. Strawberry fruits are an excellent source of essential nutrients, including vitamin C, vitamin A, folic acid, potassium, calcium and dietary fibre. In addition to these nutrients, strawberries are rich in bioactive compounds such as anthocyanins, flavonoids and ellagic acid, which are known for their antioxidant, anti-inflammatory and anticancer properties. Owing to these health benefits, strawberries are increasingly recognized as a functional food and are being promoted for regular consumption in human diets. Globally, strawberry production has exceeded about 10.5 million tones. In India, strawberry cultivation has expanded significantly in recent years due to increasing consumer awareness, growing market demand, spread of peri-urban farming and the availability of improved varieties adapted to diverse agro-climatic regions with area was about 3,031 hectares, producing roughly 19,840 metric tons. Commercial cultivation of strawberry is mainly concentrated in states such as Maharashtra, Himachal Pradesh, Uttarakhand, Jammu and Kashmir, Karnataka and in the context of Bihar, strawberry cultivation has emerged more recently compared to traditional fruit crops like litchi and mango. Because Bihar's climate includes cooler winter months in parts of the state and agricultural research support, farmers have begun adopting strawberries as a high-value, short-duration fruit crop. Despite its economic potential, successful strawberry production largely depends on efficient nutrient management practices, as the crop is shallow-rooted, nutritionally demanding and has a relatively short growth period. The indiscriminate and prolonged use of chemical fertilizers, although effective in boosting short-term yields, has resulted in several adverse consequences, including degradation of soil structure, depletion of soil organic matter, nutrient imbalances, environmental contamination and increased cost of cultivation. Conversely, the sole application of organic manures often fails to meet the nutrient requirements of high-yielding and intensive crops such as strawberry. In this context, integrated nutrient management (INM), which involves the balanced use of organic and inorganic nutrient sources, has gained importance as a sustainable strategy to enhance soil health, nutrient availability and crop productivity. Organic amendments like farmyard

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manure (FYM) and vermicompost contribute significantly to the improvement of soil physical properties such as soil structure, aeration, porosity and moisture retention, while also enhancing chemical characteristics including nutrient availability and buffering capacity. These organic inputs also stimulate soil microbial activity, thereby promoting nutrient mineralization and overall plant growth. Vermicompost, in particular, is considered superior to conventional organic manures due to its high content of macro- and micronutrients, enzymes, vitamins and naturally occurring plant growth regulators, which collectively support better crop performance. Inorganic fertilizers supply nutrients in readily available forms and play a crucial role in meeting the immediate nutritional demands of crops. When used in conjunction with organic sources, they help synchronize nutrient release with crop uptake, minimize nutrient losses and improve fertilizer use efficiency. Previous studies have demonstrated the positive influence of integrated use of organic manures and chemical fertilizers on growth, flowering, yield and fruit quality in strawberry and other horticultural crops. However, the effectiveness of integrated nutrient management practices may vary with location, soil type and climatic conditions, necessitating region-specific research. Therefore, the present investigation was undertaken to evaluate the effect of farmyard manure and vermicompost in combination with different levels of inorganic fertilizers on the growth, flowering and yield of strawberry cv. Winter Dawn under the agro-climatic conditions of South West Bihar.

## Material and Methods

### Experimental Site and Climate

The investigation was carried out during the 2024–25 cropping season at the Horticultural Research Farm of the Narayan Institute of Agricultural Sciences, Gopal Narayan Singh University, Jamuhar, Sasaram, located in the Rohtas district of Bihar, India. The experimental field lies at approximately 26.47°N latitude and 82.12°E longitude, with an elevation of about 113 m above mean sea level. The area falls under a subtropical climatic zone, characterized by high temperatures during summer, mild to cool winters, and moderate rainfall. These climatic conditions are favorable for strawberry cultivation during the winter months. The soil of the experimental site was sandy loam in texture, well-drained, and adequately aerated, with moderate fertility. Prior to the commencement of the experiment, composite soil samples were collected and analyzed for physicochemical characteristics. The soil was observed to be slightly alkaline in reaction, medium in available nitrogen and phosphorus, and low to medium in available potassium content.

### Experimental Design and Treatment Details

The experiment was laid out in a randomized block design (RBD) consisting of ten treatment combinations with three replications. The study aimed to assess the effect of different organic and inorganic nutrient sources and their combinations on the growth and yield of strawberry. Uniform, healthy, and disease-free runners of strawberry were selected for planting at the recommended spacing. All standard agronomic and cultural practices were followed uniformly throughout the crop growth period. The treatments included different levels of farmyard manure (FYM), vermicompost, and recommended doses of inorganic fertilizers, as follows: $T_0$ (control, no nutrient application), $T_1$ (100% recommended dose of NPK fertilizers), $T_2$ (FYM @ 20 t ha$^{-1}$), $T_3$ (FYM @ 20 t ha$^{-1}$ + 100% recommended NPK), $T_4$ (FYM @ 20 t ha$^{-1}$ + 50% recommended NPK), $T_5$ (FYM @ 20 t ha$^{-1}$ + 25% recommended NPK), $T_6$ (vermicompost @ 10 t ha$^{-1}$), $T_7$ (vermicompost @ 10 t ha$^{-1}$ + 100% recommended NPK), $T_8$ (vermicompost @ 10 t ha$^{-1}$ + 50% recommended NPK), and $T_9$ (vermicompost @ 10 t ha$^{-1}$ + 25% recommended NPK). Organic manures were applied as basal doses and thoroughly mixed into the soil before planting. Inorganic fertilizers were supplied in split applications following the recommended package of practices to enhance nutrient use efficiency and plant uptake. All plots received uniform irrigation, weed control, plant protection measures, and intercultural operations to ensure consistency and reduce experimental variability.

### Data Collection and Observations

Observations were recorded on various growth, flowering and yield attributes to evaluate the response of strawberry plants to different nutrient treatments. Growth parameters such as plant height, plant spread, number of leaves per plant, and leaf area were measured at key growth stages to assess vegetative performance. Flowering characteristics, including days to first flowering and number of flowers per plant, were recorded to study reproductive development. Yield-related parameters included number of fruits per plant, fruit length and width, average fruit weight, fruit volume and total fruit yield per plant. These observations were taken at the time of harvest to determine the influence of organic and inorganic nutrient combinations on fruit development and overall productivity.

### *Statistical Analysis*

The experimental data were statistically analyzed using analysis of variance (ANOVA) appropriate for a randomized block design. Treatment effects were tested for significance at the 5% probability level, and comparisons among treatment means were made using suitable statistical methods to determine significant differences.

## Result and Discussion

The data pertaining to growth, flowering and yield parameters of strawberry were statistically analyzed and are discussed below with support from relevant literature.

### Growth Parameters

*Plant Height*

Plant height of the strawberry cv. Winter Dawn exhibited significant variation under different organic and inorganic nutrient treatments at all recorded growth stages (Table 1 and Fig. 1), indicating a strong response of vegetative growth to nutrient management practices. Measurements taken at 30, 60, and 90 days after planting (DAP) revealed that the tallest plants were consistently obtained under the application of vermicompost at 10 t ha$^{-1}$ combined with 100% of the recommended dose of NPK fertilizers. This treatment proved

**Table 1:** Response of Organic and Inorganic Sources of Nutrients on plant height (cm) of strawberry *(Fragaria ananassa Duch)* cv. Winter Dawn

| *Treatments* | *30 DAP* | *60 DAP* | *90 DAP* |
|---|---|---|---|
| $T_0$ Control | 6.24 | 8.86 | 13.20 |
| $T_1$ 100 % NPK | 7.45 | 10.65 | 15.11 |
| $T_2$ FYM (20 t $ha^{-1}$) | 7.33 | 10.35 | 14.26 |
| $T_3$ FYM (20 t $ha^{-1}$) + 100 % NPK | 9.14 | 13.54 | 17.55 |
| $T_4$ FYM (20 t $ha^{-1}$) + 50% NPK | 8.58 | 12.23 | 16.38 |
| $T_5$ FYM (20 t $ha^{-1}$) + 25% NPK | 8.23 | 11.76 | 16.12 |
| $T_6$ Vermicompost (10 t $ha^{-1}$) | 6.45 | 9.28 | 13.57 |
| $T_7$ Vermicompost (10 t $ha^{-1}$) + 100 % NPK | 9.22 | 14.02 | 18.13 |
| $T_8$ Vermicompost (10 t $ha^{-1}$) + 50 % NPK | 9.04 | 12.79 | 17.25 |
| $T_9$ Vermicompost (10 t $ha^{-1}$) + 25 % NPK | 7.77 | 11.35 | 15.66 |
| SEm± | 0.05 | 0.07 | 0.07 |
| CD at 5% | 0.15 | 0.19 | 0.20 |

superior to all others, underscoring the beneficial effects of integrating organic amendments with inorganic fertilizers on plant growth. The treatment receiving farmyard manure at 20 t $ha^{-1}$ along with 100% recommended NPK ranked second in terms of plant height, suggesting that FYM, when supplemented with adequate inorganic nutrients, also plays an important role in enhancing vegetative development. Conversely, plants grown under the control recorded the lowest plant height at all stages, highlighting the necessity of external nutrient supply for optimal strawberry growth. The enhancement in plant height observed under integrated nutrient treatments may be attributed to the improved and balanced availability of essential nutrients, particularly nitrogen, which is known to stimulate cell division and elongation, leading to increased vegetative growth. Additionally, the incorporation of organic manures likely improved soil physical properties, increased organic matter content, and encouraged microbial activity, all of which contribute to better root proliferation and more efficient nutrient uptake. The present findings are in conformity with earlier studies in strawberry and other horticultural crops, where the combined use of organic and inorganic nutrient sources resulted in improved plant height and overall growth performance. For instance, Hazarika and Ansari (2010) reported similar improvements in banana, Tripathi *et al.,* (2010) in strawberry, Ingle et al., (2008) in okra and Marathe and Bharambe (2007) in sweet orange. Collectively, these results underscore the importance of integrated nutrient management in promoting vigorous vegetative growth, improving overall plant architecture, and potentially enhancing subsequent crop yield and productivity.

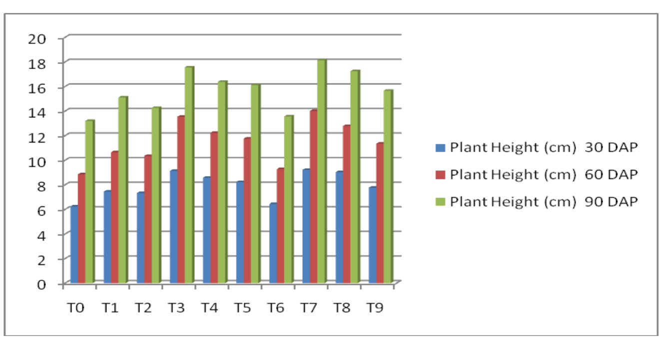


**Fig. 1:** Response of Organic and Inorganic Sources of Nutrients on plant height (cm) of strawberry (*Fragaria ananassa Duch*) cv. Winter Dawn

## Plant Spread

Plant spread varied significantly across the different nutrient management treatments (Table 2 and Fig. 2), demonstrating the strong influence of nutrient availability on vegetative growth and canopy development in strawberry. The magnitude of plant spread was clearly affected by both the source and combination of nutrients supplied. The maximum plant spread was recorded under the treatment receiving vermicompost at 10 t $ha^{-1}$ along with 100% of the recommended NPK dose. This response indicates that the combined application of organic and inorganic nutrients favors enhanced lateral growth and results in a more developed and uniform plant canopy. Such improvement in canopy expansion may be attributed to the supply of balanced nutrients, ensuring sufficient availability of essential macro- and micronutrients, which support vigorous vegetative growth. In addition, improved photosynthetic activity under optimal nutrient conditions likely contributed to greater production of assimilates, while efficient translocation of these photosynthates promoted leaf expansion and branching. On the other hand, the minimum plant spread was observed in the control reflecting restricted vegetative development due to nutrient deficiency. This finding clearly emphasizes the necessity of adequate and balanced fertilization for achieving optimal canopy growth and overall plant vigor in strawberry cultivation. These findings are consistent with previous research conducted by Nowsheen *et al.,* (2006), Singh and Singh (2009) and Rajbir *et al.,* (2010) in strawberry, where integrated nutrient management significantly improved plant canopy development, leading to more robust and well-formed plants. Overall, the results clearly demonstrate that the application of combined organic and inorganic nutrients not only enhances plant spread but also contributes to improved

**Table 2:** Response of Organic and Inorganic Sources of Nutrients on plant spread (cm) of Strawberry (*Fragaria ananassa Duch*) cv. Winter Dawn

| Treatments | 30 DAP | 60 DAP | 90 DAP |
|---|---|---|---|
| $T_0$ Control | 9.32 | 14.78 | 19.41 |
| $T_1$ 100 % NPK | 10.64 | 17.61 | 20.74 |
| $T_2$ FYM (20 t $ha^{-1}$) | 10.61 | 17.11 | 20.57 |
| $T_3$ FYM (20 t $ha^{-1}$) + 100 % NPK | 12.56 | 21.61 | 23.27 |
| $T_4$ FYM (20 t $ha^{-1}$) + 50% NPK | 11.54 | 19.59 | 22.42 |
| $T_5$ FYM (20 t $ha^{-1}$) + 25% NPK | 11.30 | 19.22 | 21.62 |
| $T_6$ Vermicompost (10 t $ha^{-1}$) | 9.43 | 16.46 | 20.59 |
| $T_7$ Vermicompost (10 t $ha^{-1}$) + 100 % NPK | 13.32 | 22.35 | 23.44 |
| $T_8$ Vermicompost (10 t $ha^{-1}$) + 50 % NPK | 12.59 | 20.53 | 22.51 |
| $T_9$ Vermicompost (10 t $ha^{-1}$) + 25 % NPK | 10.78 | 18.53 | 21.41 |
| SEm± | 0.10 | 0.09 | 0.13 |
| CD at 5% | 0.28 | 0.27 | 0.38 |

plant architecture, which is likely to have positive effects on light interception, photosynthetic activity, and ultimately crop productivity.

## Number of Leaves per Plant

The number of leaves per plant differed significantly among the various nutrient management treatments (Table 3 and Fig. 3), reflecting the strong influence of nutrient availability on vegetative growth in strawberry. Leaf production showed noticeable variation across treatments, confirming that both the source and level of nutrients play a decisive role in leaf development. The highest leaf count per plant was recorded under the treatment receiving vermicompost at 10 t $ha^{-1}$ in combination with the full recommended dose of NPK fertilizers. This result highlights the advantage of integrated nutrient management in enhancing vegetative vigor. The treatment comprising farmyard manure at 20 t $ha^{-1}$ along with 100% recommended NPK ranked next, also showing a marked improvement in leaf production. Conversely, plants grown without any nutrient application (control) produced the fewest leaves, indicating suppressed vegetative growth under nutrient-deficient conditions. The increased number of leaves observed under organic and integrated nutrient treatments may be attributed mainly to improved nitrogen availability, which is vital for amino acid and protein synthesis and consequently supports active cell division and leaf formation. Furthermore, the decomposition of organic manures likely released growth-stimulating compounds such as hormones, vitamins, and enzymes, which enhance plant metabolism. Enhanced microbial activity and improved soil fertility resulting from organic amendments may have further facilitated nutrient uptake, thereby promoting sustained leaf initiation and expansion. These results are in close agreement with the findings of earlier researchers, including Rana and Chandel (2003), Gajbhiye *et al.,* (2003), Mohandas (1987) and Bambal *et al.,* (1998), who reported increased leaf production in different crops due to the combined effects of enhanced nitrogen fixation, microbial activity, and the application of integrated nutrient management strategies. Overall, these observations reinforce the importance of combining organic and inorganic nutrient sources to achieve optimal leaf development and improved plant vigor.

## Leaf Area

Leaf area per plant showed significant differences among the various nutrient management treatments (Table 4 and Fig. 4), indicating that leaf expansion in strawberry is highly responsive to nutrient supply. Among the treatments evaluated, the application of farmyard manure at 20 t $ha^{-1}$ in combination with the full recommended dose of NPK resulted in the

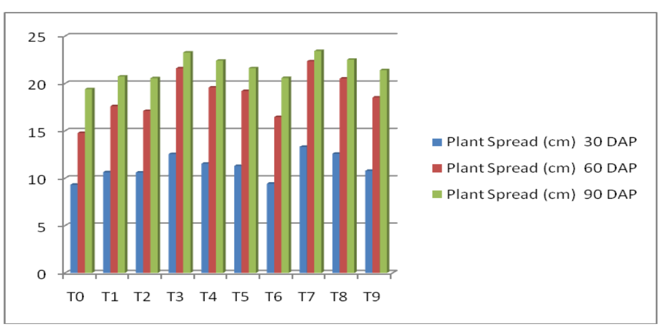


**Fig 2:** Response of Organic and Inorganic Sources of Nutrients on plant spread (cm) of Strawberry (*Fragaria ananassa Duch*) cv. Winter Dawn

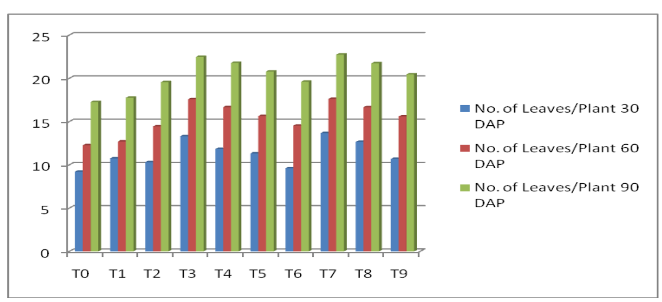


**Fig. 3:** Response of Organic and Inorganic Sources of Nutrients on Number of leaves per plant of Strawberry (*Fragaria ananassa Duch*) cv. Winter Dawn.

**Table 3:** Response of Organic and Inorganic Sources of Nutrients on Number of leaves per plant of Strawberry (*Fragaria ananassa Duch*) cv. Winter Dawn

| *Treatments* | *30 DAP* | *60 DAPS* | *90 DAP* |
|---|---|---|---|
| $T_0$ Control | 9.22 | 12.27 | 17.28 |
| $T_1$ 100 % NPK | 10.76 | 12.71 | 17.76 |
| $T_2$ FYM (20 t $ha^{-1}$) | 10.31 | 14.45 | 19.56 |
| $T_3$ FYM (20 t $ha^{-1}$) + 100 % NPK | 13.32 | 17.59 | 22.48 |
| $T_4$ FYM (20 t $ha^{-1}$) + 50% NPK | 11.84 | 16.68 | 21.79 |
| $T_5$ FYM (20 t $ha^{-1}$) + 25% NPK | 11.33 | 15.65 | 20.79 |
| $T_6$ Vermicompost (10 t $ha^{-1}$) | 9.62 | 14.54 | 19.62 |
| $T_7$ Vermicompost (10 t $ha^{-1}$) + 100 % NPK | 13.68 | 17.63 | 22.75 |
| $T_8$ Vermicompost (10 t $ha^{-1}$) + 50 % NPK | 12.66 | 16.67 | 21.75 |
| $T_9$ Vermicompost (10 t $ha^{-1}$) + 25 % NPK | 10.69 | 15.60 | 20.47 |
| SEm± | 0.10 | 0.12 | 0.09 |
| CD at 5% | 0.30 | 0.35 | 0.28 |

maximum leaf area, demonstrating the pronounced benefit of integrated nutrient use on vegetative development. This was followed by treatments involving vermicompost-based nutrient combinations, which also recorded considerable increases in leaf area compared to sole or no nutrient applications. The enhanced leaf expansion observed under integrated nutrient management practices may be associated with improved availability of essential nutrients, particularly nitrogen, which supports chlorophyll formation and leaf tissue development. In addition, better nutrient balance and improved soil conditions likely enhanced photosynthetic activity, leading to increased assimilate production and greater leaf growth. The present results align well with earlier findings in strawberry and other horticultural crops, where combined application of organic manures and inorganic fertilizers was reported to significantly increase leaf area and overall vegetative vigor. For instance, Rana and Chandel (2003) and Ghosh *et al.,* (2014) documented improved leaf growth in mosambi under integrated nutrient treatments, while Rajbir *et al.,* (2010) observed comparable increases in leaf area in strawberry plants. Such consistent results across different crops highlight the important role of integrated nutrient management in promoting optimal leaf development and overall plant productivity.

**Table 4:** Response of Organic and Inorganic Sources of Nutrients on leaf area (cm2) of Strawberry (*Fragaria ananassa Duch*) cv. Winter Dawn

| Treatments | Leaf area ($cm^2$) |
|---|---|
| $T_0$ Control | 40.38 |
| $T_1$ 100 % NPK | 42.10 |
| $T_2$ FYM (20 t $ha^{-1}$) | 40.39 |
| $T_3$ FYM (20 t $ha^{-1}$) + 100 % NPK | 42.83 |
| $T_4$ FYM (20 t $ha^{-1}$) + 50% NPK | 41.63 |
| $T_5$ FYM (20 t $ha^{-1}$) + 25% NPK | 41.57 |
| $T_6$ Vermicompost (10 t $ha^{-1}$) | 40.84 |
| $T_7$ Vermicompost (10 t $ha^{-1}$) + 100 % NPK | 43.38 |
| $T_8$ Vermicompost (10 t $ha^{-1}$) + 50 % NPK | 42.04 |
| $T_9$ Vermicompost (10 t $ha^{-1}$) + 25 % NPK | 41.60 |
| SEm± | 0.38 |
| CD at 5% | 1.13 |

## Flowering Parameters

### *Days to First Flowering*

The number of days taken to reach first flowering varied significantly among the different nutrient management treatments (Table 5 and Fig. 5), indicating a clear influence of nutrient supply on floral initiation in strawberry. Treatments involving the combined use of organic and inorganic nutrient sources resulted in a noticeable advancement of flowering compared to the untreated control. The earliest flowering was observed in plants supplied with vermicompost at 10 t

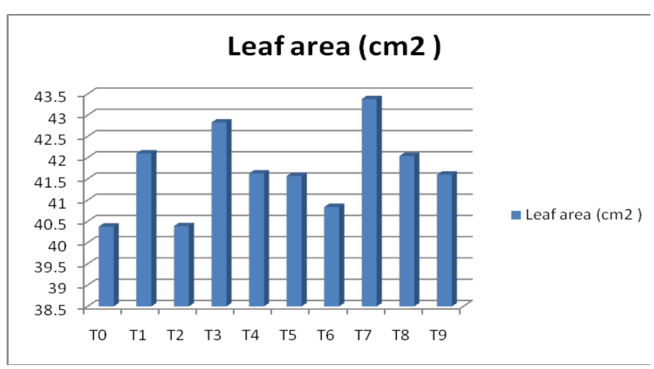


**Fig 4:** Response of Organic and Inorganic Sources of Nutrients on leaf area (cm2) of Strawberry (*Fragaria ananassa Duch*) cv. Winter Dawn.

**Table 5:** Response of Organic and Inorganic Sources of Nutrients on Days to first flowering (days) of Strawberry (*Fragaria ananassa Duch*) cv. Winter Dawn

| *Treatments* | *Days to first flowering (Days)* |
|---|---|
| $T_0$ Control | 61.16 |
| $T_1$ 100 % NPK | 55.60 |
| $T_2$ FYM (20 t ha$^{-1}$) | 58.19 |
| $T_3$ FYM (20 t ha$^{-1}$) + 100 % NPK | 50.02 |
| $T_4$ FYM (20 t ha$^{-1}$) + 50% NPK | 51.57 |
| $T_5$ FYM (20 t ha$^{-1}$) + 25% NPK | 53.30 |
| $T_6$ Vermicompost (10 t ha$^{-1}$) | 59.10 |
| $T_7$ Vermicompost (10 t ha$^{-1}$) + 100 % NPK | 49.04 |
| $T_8$ Vermicompost (10 t ha$^{-1}$) + 50 % NPK | 50.78 |
| $T_9$ Vermicompost (10 t ha$^{-1}$) + 25 % NPK | 57.54 |
| SEm± | 0.04 |
| CD at 5% | 0.13 |

ha$^{-1}$ along with the full recommended dose of NPK fertilizers. This was closely followed by the treatment receiving farmyard manure at 20 t ha$^{-1}$ in combination with 100% recommended NPK. In contrast, plants grown without any nutrient application required the longest duration to initiate flowering, reflecting delayed physiological development under nutrient-limited conditions. The promotion of early flowering under integrated nutrient management may be attributed to the balanced and continuous availability of essential macro- and micronutrients, which support enhanced metabolic activity and efficient enzymatic processes. Additionally, improved hormonal balance within the plants, along with better soil structure and increased microbial activity, resulting from organic manure application, likely facilitated improved nutrient uptake and utilization. These factors collectively contributed to accelerated plant growth and earlier transition from vegetative to reproductive stages. The present findings are in agreement with previous studies Shukla *et al.,* (2009), Kumar *et al.,* (2007), Singh *et al.,* (2008) and Umar *et al.,* (2009), which report that the combined use of organic and inorganic nutrient sources lead to earlier flowering in strawberry and other horticultural crops.

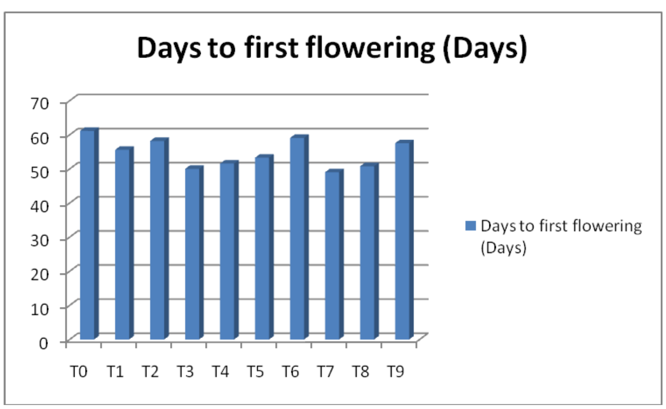


**Fig 5:** Response of Organic and Inorganic Sources of Nutrients on Days to first flowering (days) of Strawberry (*Fragaria ananassa Duch*) cv. Winter Dawn.

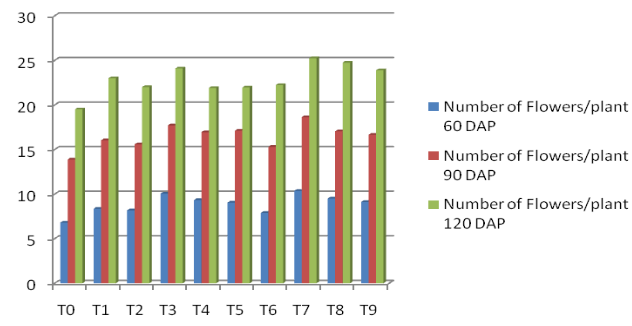


**Fig. 6:** Response of Organic and Inorganic Sources of Nutrients on number of flowers per plant of Strawberry (*Fragaria ananassa Duch*) cv. Winter Dawn.

## Number of Flowers per Plant

The number of flowers per plant differed significantly across the various nutrient management treatments at all stages of observation (Table 6 and Fig. 6), indicating that nutrient supply strongly influences reproductive development in strawberry. The highest flower count was recorded in plants treated with vermicompost at 10 t ha$^{-1}$ in combination with 100% recommended NPK fertilizers, followed closely by the treatment receiving farmyard manure at 20 t ha$^{-1}$ along with full NPK. In contrast, the control plants, which did not receive any nutrient inputs, consistently produced the fewest flowers. The increase in flower production under integrated nutrient management can be attributed to improved vegetative growth, greater assimilate availability, and more efficient translocation of photosynthates from source to sink tissues. Additionally, the combination of organic and inorganic fertilizers likely enhanced soil fertility, stimulated microbial activity, and increased the availability of essential nutrients, all of which support better floral initiation and development. These results are consistent with previous reports in strawberry and other horticultural crops, where the

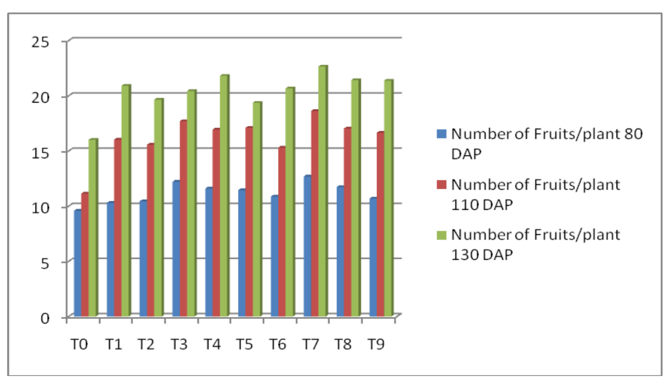


**Fig. 7:** Response of Organic and Inorganic Sources of Nutrients on number of fruits per plant of Strawberry (*Fragaria ananassa Duch*) cv. Winter Dawn.

**Table 6:** Response of Organic and Inorganic Sources of Nutrients on number of flowers per plant of Strawberry (*Fragaria ananassa Duch*) cv. Winter Dawn

| *Treatments* | *60 DAP* | *90 DAP* | *120 DAP* |
|---|---|---|---|
| $T_0$ Control | 6.80 | 13.88 | 19.51 |
| $T_1$ 100 % NPK | 8.36 | 16.04 | 23.00 |
| $T_2$ FYM (20 t $ha^{-1}$) | 8.18 | 15.58 | 22.01 |
| $T_3$ FYM (20 t $ha^{-1}$) + 100 % NPK | 10.06 | 17.71 | 24.10 |
| $T_4$ FYM (20 t $ha^{-1}$) + 50% NPK | 9.34 | 16.95 | 21.91 |
| $T_5$ FYM (20 t $ha^{-1}$) + 25% NPK | 9.05 | 17.11 | 21.97 |
| $T_6$ Vermicompost (10 t $ha^{-1}$) | 7.89 | 15.31 | 22.23 |
| $T_7$ Vermicompost (10 t $ha^{-1}$) + 100 % NPK | 10.37 | 18.63 | 25.25 |
| $T_8$ Vermicompost (10 t $ha^{-1}$) + 50 % NPK | 9.51 | 17.05 | 24.75 |
| $T_9$ Vermicompost (10 t $ha^{-1}$) + 25 % NPK | 9.12 | 16.66 | 23.89 |
| SEm± | 0.04 | 0.43 | 0.24 |
| CD at 5% | 0.12 | 1.29 | 0.70 |

**Table 7:** Response of Organic and Inorganic Sources of Nutrients on number of fruits per plant of Strawberry *(Fragaria ananassa Duch)* cv. Winter Dawn.

| *Treatments* | *80 DAP* | *110 DAP* | *130 DAP* |
|---|---|---|---|
| $T_0$ Control | 9.60 | 11.15 | 16.02 |
| $T_1$ 100 % NPK | 10.31 | 16.04 | 20.91 |
| $T_2$ FYM (20 t $ha^{-1}$) | 10.45 | 15.58 | 19.66 |
| $T_3$ FYM (20 t $ha^{-1}$) + 100 % NPK | 12.22 | 17.71 | 20.44 |
| $T_4$ FYM (20 t $ha^{-1}$) + 50% NPK | 11.60 | 16.95 | 21.82 |
| $T_5$ FYM (20 t $ha^{-1}$) + 25% NPK | 11.46 | 17.11 | 19.37 |
| $T_6$ Vermicompost (10 t $ha^{-1}$) | 10.88 | 15.31 | 20.68 |
| $T_7$ Vermicompost (10 t $ha^{-1}$) + 100 % NPK | 12.70 | 18.63 | 22.66 |
| $T_8$ Vermicompost (10 t $ha^{-1}$) + 50 % NPK | 11.74 | 17.05 | 21.43 |
| $T_9$ Vermicompost (10 t $ha^{-1}$) + 25 % NPK | 10.70 | 16.66 | 21.38 |
| SEm± | 0.05 | 0.43 | 0.62 |
| CD at 5% | 0.15 | 1.29 | 1.84 |

use of both organic and inorganic nutrient sources was shown to significantly improve flower production. Similar results have been reported by Rana and Chandel (2003), Singh and Singh (2009), Zargar *et al.,* (2008) and Umar *et al.,* (2010).

## Yield Attributes

### *Number of Fruits per Plant*

The number of fruits per plant varied significantly across the different nutrient management treatments (Table 7 and Fig. 7), demonstrating the strong influence of nutrient supply on reproductive performance in strawberry. The highest fruit count was observed in plants receiving vermicompost at 10 t $ha^{-1}$ combined with 100% recommended NPK fertilizers, followed closely by the treatment with farmyard manure at 20 t $ha^{-1}$ along with full NPK. In contrast, the control treatment, which did not receive any nutrient inputs, recorded the lowest number of fruits per plant. The increased fruit production under integrated nutrient management may be attributed to improved vegetative growth, higher flower initiation and retention, enhanced pollination efficiency, and greater availability and uptake of essential nutrients during the crop growth period. The combined use of organic manures and inorganic fertilizers also likely improved soil physical conditions, stimulated microbial activity, and enhanced nutrient use efficiency, creating a more favorable environment for fruit set. These results are consistent with earlier studies in strawberry and other horticultural crops, where integrated nutrient management led to significant improvements in fruit set and overall yield. Similar results have been reported by Tripathi *et al.,* (2010), Umar *et al.,* (2009), Rajbir *et al.,* (2010) and Ghosh *et al*., (2014).

## Conclusion

The findings of this study indicate that combining organic and inorganic nutrient sources had a significant impact on the growth, flowering, and yield of strawberry cv. Winter Dawn. Among the treatments tested, the use of vermicompost at 10 t $ha^{-1}$ together with the full recommended dose of NPK fertilizers proved to be the most effective in improving overall crop performance. This integrated nutrient management strategy enhanced vegetative growth, as evidenced by increased plant height, plant spread, number of leaves per plant, and leaf area, reflecting improved plant vigor and canopy development. It also positively influenced reproductive traits by promoting earlier flowering, increasing flower numbers per plant, and improving fruit set, which extended the harvesting period. The observed improvements in flowering and fruiting may result from a balanced and sustained nutrient supply, better physiological efficiency, and increased metabolic activity. Additionally, this combination significantly enhanced fruit characteristics, including fruit length, width, volume, and average weight, leading to higher fruit numbers per plant and overall yield. The superior performance of this integrated approach can be attributed to vermicomposts ability to improve soil physical, chemical, and biological properties and stimulate beneficial microbial activity, while inorganic fertilizers provide an immediate and sufficient nutrient supply. In conclusion, integrating vermicompost with recommended doses of NPK fertilizers represents an effective, economically viable, and environmentally sustainable strategy for improving productivity, fruit quality, and soil health in strawberry cultivation, making it a suitable recommendation for growers under similar agro-climatic conditions.

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## Conflict of interest

The authors declare that there is no conflict of interest associated with this manuscript.

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