

# Evaluation of Different Levels of Nutrients on Strawberry Cv. Winter Dawn for Central Midlands of Kerala

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## Abstract

A research trial was carried out in the experimental field of Department of Fruit Science, College of Agriculture, Thrissur, Kerala during two seasons (2016- 2017 and 2017-2018) to study the effect of different levels of farmyard manure, nitrogen, phosphorus and potassium on growth and yield of strawberry cv. Winter Dawn. The experiment was laid out in randomized block design with 9 treatments in three replications on different levels of nitrogen, phosphorus, potassium and farmyard manure. The results revealed that maximum plant height (19.39 cm), number of leaves (47.76), plant spread (30.64 cm) and number of crowns per plant (8.10) were recorded in T<sub>8</sub> (75:20:100 kg N: P: K ha<sup>-1</sup> + 30 t ha<sup>-1</sup> FYM) followed by T<sub>9</sub> (100:40:50 kg N: P: K ha<sup>-1</sup> + 30 t ha<sup>-1</sup> FYM). Minimum number of days to first flowering was recorded by T<sub>2</sub> (75:40:75 kg N: P: K ha<sup>-1</sup> + 10 t ha<sup>-1</sup> FYM). Maximum flowering and yield attributes were obtained by T<sub>8</sub> (75:20:100 kg N: P: K ha<sup>-1</sup> + 30 t ha<sup>-1</sup> FYM) which was on par with T<sub>9</sub> (100:40:50 kg N: P: K ha<sup>-1</sup> + 30 t ha<sup>-1</sup> FYM). The fruit quality viz., TSS, lowest acidity, TSS/acidity were highest in fruits obtained from plants supplied with fertilizer recommendation of 30 t ha<sup>-1</sup> FYM + 75:20:100 kg ha<sup>-1</sup> N: P: K recording 7.68°Brix, 0.72% and 10.68 respectively. While maximum total sugars content (5.23%) and ascorbic acid (52.22 mg/100g) were recorded when fertilized with 30t ha<sup>-1</sup> of FYM along with 100:40:50 kg ha<sup>-1</sup> of NPK.

**Key words:** Strawberry, Winter Dawn, Nitrogen, Phosphorus, Potassium, Farmyard manure

Strawberry (*Fragaria × ananassa* Duch.) is one of the most popular and economically important berry crops cultivated throughout the world. It is highly appreciated for its attractive appearance, pleasant flavor, distinctive aroma, and excellent nutritional value. The fruit is considered one of the most delicious and refreshing soft fruits, commanding high consumer preference in both fresh and processed forms [1]. Botanically, strawberry belongs to the family Rosaceae and originated from North America. Owing to its wide adaptability, high genetic variability, and heterozygous nature, the crop is successfully cultivated under diverse agro-climatic conditions across temperate, subtropical, and tropical regions of the world. The commercial importance of strawberry has increased considerably in recent decades because of its high productivity, short gestation period, and attractive economic returns. Among fruit crops, strawberry is recognized for providing quick and substantial returns per unit area and investment, making it an ideal crop for small and marginal farmers as well as commercial horticultural enterprises [2]. The fruit has gained immense popularity in domestic and international markets due to its unique taste, attractive red color, and versatility in processing into jams, jellies, syrups, juices, ice creams, yogurts, and confectionery products.

From a nutritional perspective, strawberry is regarded as a functional food because of its rich composition of vitamins, minerals, dietary fiber, and bioactive compounds. The fruit is an

excellent source of vitamins A, B-complex, C, and niacin, while also containing significant amounts of potassium, calcium, phosphorus, and iron. Furthermore, strawberries are rich in pectin, organic acids, and phenolic compounds that contribute to their nutritional and medicinal value. The health-promoting properties of strawberry have attracted considerable scientific attention due to the presence of potent antioxidants, including ellagic acid, anthocyanins (particularly pelargonidin), flavonoids, and other phenolic compounds. These bioactive substances possess strong antioxidant activity and are associated with anticarcinogenic, antidiabetic, anti-inflammatory, anti-obesity, and cardioprotective effects [3]. Consequently, regular consumption of strawberries is increasingly recommended as part of a healthy diet aimed at reducing the risk of chronic diseases.

Globally, strawberry cultivation has expanded rapidly owing to increasing consumer demand and advances in production technologies. In India, commercial cultivation of strawberry has gained momentum over the past few decades and is concentrated in regions such as Mahabaleshwar in Maharashtra, Haryana, Punjab, Uttar Pradesh, Arunachal Pradesh, Jammu and Kashmir, Uttarakhand, and Himachal Pradesh. Favorable climatic conditions in these regions support optimum vegetative growth, flowering, fruit development, and quality production. However, achieving high yields and superior fruit quality requires the adoption of appropriate

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cultural and nutritional management practices. Among various agronomic factors, nutrient management plays a pivotal role in determining plant growth, flowering, fruit set, yield, and fruit quality in strawberry. As a shallow-rooted crop with a relatively high nutrient demand, strawberry requires a balanced and continuous supply of essential nutrients throughout its growth cycle. Nitrogen is crucial for vegetative growth and leaf development, phosphorus promotes root growth, flowering, and fruit set, while potassium improves fruit size, color, firmness, and shelf life. In addition to inorganic fertilizers, the use of organic manures and biofertilizers has gained increasing importance in modern horticulture due to their positive effects on soil health, nutrient availability, microbial activity, and environmental sustainability.

Integrated nutrient management (INM), which combines chemical fertilizers with organic and biological sources of nutrients, has emerged as an effective strategy for enhancing crop productivity while maintaining soil fertility. Several studies have reported significant improvements in plant growth, yield, fruit quality, and nutrient-use efficiency in strawberry through the combined application of inorganic fertilizers, farmyard manure, vermicompost, and biofertilizers [4-7]. Organic amendments improve soil physical properties, increase water-holding capacity, and provide a slow and steady release of nutrients, whereas biofertilizers facilitate nutrient mobilization and enhance microbial activity in the rhizosphere. Such integrated approaches not only improve crop performance but also reduce dependency on chemical fertilizers and promote sustainable strawberry production. Despite the recognized importance of nutrient management, information regarding the response of recently introduced strawberry cultivars to different nutrient combinations under specific agro-climatic conditions remains limited. The cultivar 'Winter Dawn' has shown considerable promise because of its adaptability, productivity, and fruit quality characteristics. However, optimizing nutrient requirements for this cultivar is essential to exploit its full yield potential and improve fruit quality under local growing conditions. Therefore, the present investigation was undertaken to evaluate the performance of strawberry cv. Winter Dawn under different nutrient combinations with the objective of identifying an efficient nutrient management strategy for enhancing vegetative growth, yield, and fruit quality while ensuring sustainable production.

## MATERIALS AND METHODS

The present investigation was conducted during two consecutive growing seasons, 2016-2017 and 2017-2018, at the open field experimental farm of the College of Agriculture, Thrissur, Kerala, India, situated at 10°31' N latitude and 76°03' E longitude with an elevation of 22.25 m above mean sea level. The region is characterized by a warm humid tropical climate, with temperatures ranging from 22.2°C to 33.5°C during the cropping period, providing favorable conditions for strawberry cultivation. The experimental soil was sandy loam in texture with good drainage and aeration. One-month-old healthy tissue culture plants of strawberry (*Fragaria × ananassa* Duch.) cv. Winter Dawn were used as planting material. The field was thoroughly prepared, and raised beds measuring 1.6 m × 2.1 m were formed. Planting was carried out during the last week of September in both years, with twenty-four plants accommodated in each bed and a spacing of 50 cm maintained between beds to facilitate proper growth and intercultural operations. The beds were mulched with black polyethylene to conserve soil moisture, suppress weed growth, regulate soil temperature, and improve fruit quality. The experiment was laid

out in a Randomized Block Design (RBD) comprising ten nutrient management treatments with three replications. All recommended cultural and plant protection practices were followed uniformly for all treatments throughout the crop growth period. Observations on vegetative growth, flowering behaviour, and yield attributes were recorded from ten randomly selected and tagged plants in each experimental unit. Vegetative parameters such as plant height and number of leaves were recorded at monthly intervals from November to March, while flowering and yield parameters were recorded during the reproductive and harvesting stages. The data generated over the two years were pooled and subjected to statistical analysis using two-factor analysis of variance (ANOVA), considering treatments and seasons as factors. The significance of treatment effects was tested, and treatment means were compared using the Critical Difference (CD) test at the 5% level of significance following the procedures described by Gomez and Gomez [8], thereby ensuring reliable assessment of the influence of different nutrient combinations on the growth, flowering, and yield performance of strawberry cv. Winter Dawn under the agro-climatic conditions of Kerala.

## RESULTS AND DISCUSSION

### *Vegetative attributes*

#### *Plant height*

Different nutrient combinations had a significant influence on plant height. Among the different nutrient combinations, FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup> @ 30:75:20:100 recorded maximum plant height in the later stages of growth. Absolute control recorded minimum plant height during all stages of growth (Table 1). Earlier results suggested that N rates of 75 kg ha<sup>-1</sup> or less was sufficient for the vegetative growth of different genotypes. These results are in conformity with the findings of Arjun [9] where FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup> @ 30:75:20:100 recorded maximum plant height in cv. Winter Dawn. Lower plant height in absolute control may be due to the poor nitrogen content in the soil.

#### *Number of leaves*

Among the different nutrient combinations, FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup> @ 30:75:20:100 recorded maximum number of leaves per plant in later stages of growth. Absolute control recorded minimum number of leaves during all stages of growth (Table 1). This is in conformity with the findings of Simonne *et al.* [10]; Tworokoskia *et al.* [11]; Abu-Zahra and Tahboub [12]; Santos and Chandler [13]; Arjun [9]. Lower number of leaves in absolute control may be due to the poor nutrient content in the soil.

#### *Plant spread*

Among the nutrient combinations, FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup> @ 30:75:20:100 recorded maximum plant spread in the later stages of growth. Absolute control recorded minimum plant spread (Table 2). Earlier results showed that this nutrient combination had significant influence on plant height and number of leaves of strawberry. This may be the reason for increase in plant spread also. This was supported by the findings of Arjun [9].

he results demonstrated that nutrient management significantly influenced the vegetative growth of strawberry plants. The application of FYM @ 30 t ha<sup>-1</sup> along with N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O @ 75:20:100 kg ha<sup>-1</sup> resulted in the highest plant height, number of leaves, and plant spread, indicating enhanced vegetative vigor and overall plant growth. In contrast, the

absolute control consistently recorded the lowest values for all vegetative parameters, highlighting the importance of adequate

nutrient supply for optimum strawberry growth and development.

Table 1 Effect of different levels of nutrients on plant height and number of leaves of strawberry

Treatments	Plant height (cm)					Number of leaves				
	1MAP	2MAP	3MAP	4MAP	5MAP	1MAP	2MAP	3MAP	4MAP	5MAP
T <sub>1</sub>	9.26	12.86	14.95	16.71	18.1	7.28	13.61	20.51	27.16	26.49
T <sub>2</sub>	7.75	11.56	12.55	13.92	15.37	6.19	15.44	28.25	36.07	40.59
T <sub>3</sub>	5.85	9.89	13.82	15.22	16.93	7.37	14.80	20.70	25.19	27.39
T <sub>4</sub>	8.85	12.02	14.46	15.92	16.76	6.41	13.45	26.91	36.94	42.39
T <sub>5</sub>	7.27	10.65	12.86	13.99	15.82	7.15	16.44	24.53	32.79	33.12
T <sub>6</sub>	9.38	11.57	13.6	15.24	17.04	7.02	12.69	24.99	36.79	39.68
T <sub>7</sub>	8.2	11.61	14.34	15.88	16.84	6.40	16.28	22.00	26.34	29.36
T <sub>8</sub>	8.73	12.42	15.24	17.63	19.39	6.23	12.62	31.31	43.68	47.76
T <sub>9</sub>	8.88	12.08	15.22	17.72	18.65	6.30	19.70	32.18	42.36	44.03
T <sub>10</sub>	6.59	9.63	11.68	13.64	15.36	4.60	10.48	15.29	19.00	18.84
CD	<b>1.26</b>	<b>1.29</b>	<b>1.1</b>	<b>0.88</b>	<b>0.88</b>	<b>1.10</b>	<b>3.25</b>	<b>3.25</b>	<b>3.1</b>	<b>3.24</b>

*Number of crowns*

Among the nutrient combinations, FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup> @ 30:75:20:100 recorded maximum number of crowns per plant. Absolute control recorded minimum number

of crowns per plant (Table 2). The nutrient combinations favoured for plant height, number of leaves and plant spread in earlier results which might have influenced the production of maximum number of crowns also.

Table 2 Effect of different levels of nutrients on plant spread and number of crowns of strawberry

Treatments	Plant spread (cm)					Number of crowns				
	1MAP	2MAP	3MAP	4MAP	5MAP	1MAP	2MAP	3MAP	4MAP	5MAP
T <sub>1</sub>	12.97	18.78	22.50	27.75	29.26	1.00	1.27	2.03	3.53	5.03
T <sub>2</sub>	11.64	15.00	17.66	19.71	21.48	1.00	1.23	2.50	3.85	5.20
T <sub>3</sub>	12.33	17.01	20.68	25.09	28.06	1.00	1.40	2.63	3.23	3.83
T <sub>4</sub>	11.85	17.78	22.69	29.96	30.24	1.00	1.33	2.10	4.73	7.37
T <sub>5</sub>	13.17	18.06	21.15	26.16	28.62	1.00	1.47	3.10	4.37	5.53
T <sub>6</sub>	12.29	17.51	21.16	25.47	27.59	1.00	1.47	2.40	4.22	5.80
T <sub>7</sub>	12.47	16.77	20.22	22.78	24.67	1.00	1.37	2.90	4.38	5.87
T <sub>8</sub>	12.03	18.03	23.76	27.78	30.64	1.00	1.43	2.17	5.13	8.10
T <sub>9</sub>	12.15	17.34	21.71	27.39	29.39	1.00	1.17	2.70	4.70	6.83
T <sub>10</sub>	8.88	11.58	14.83	18.87	20.48	1.00	1.20	1.60	2.47	3.40
CD	<b>1.36</b>	<b>1.98</b>	<b>2.11</b>	<b>1.94</b>	<b>1.74</b>	<b>NS</b>	<b>NS</b>	<b>0.43</b>	<b>0.39</b>	<b>0.77</b>

*Flowering*

*Days to first flowering*

In Central midlands, different nutrient combinations had no significant effect on the number of days to first flowering and number of days to first flowering ranges from 49.70 days to 50.60 days. Since the same variety Winter Dawn was used in all the treatments and it exhibited earliness in flowering (Table 3). This indicates that flowering initiation was primarily governed by the genetic characteristics of the variety rather than by variations in nutrient management.

*Number of flowers per plant*

Different nutrient combinations had a significant effect on the number of flowers per plant. Among the different nutrient combinations, the application of farmyard manure (t ha<sup>-1</sup>) along with N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O at 30:75:20:100 kg ha<sup>-1</sup> resulted in the highest number of flowers per plant (8.71). Absolute control recorded minimum number of flowers per plant (Table 3). Plants fertilized with the same nutrient combination also exhibited maximum plant height, number of leaves, plant spread and number of crowns per plant.

Table 3 Effect of different levels of nutrients on flowering and yield of strawberry

Treatments	Days to first flowering	Number of clusters	Number of flowers	Number of fruits	Yield per plant (g)
T <sub>1</sub>	50.43	3.65	5.52	3.45	44.63
T <sub>2</sub>	49.70	5.20	6.80	4.80	57.67
T <sub>3</sub>	50.60	4.87	5.72	3.75	43.74
T <sub>4</sub>	50.08	5.68	7.58	5.50	60.10
T <sub>5</sub>	50.43	5.40	6.25	4.25	43.11
T <sub>6</sub>	50.20	5.18	6.60	4.60	55.55
T <sub>7</sub>	49.90	4.77	5.79	5.25	62.33
T <sub>8</sub>	50.07	5.85	8.71	6.42	79.92
T <sub>9</sub>	50.30	5.94	8.29	6.18	75.90
T <sub>10</sub>	50.50	2.24	3.64	1.68	10.80
CD	<b>NS</b>	<b>0.17</b>	<b>0.19</b>	<b>0.25</b>	<b>8.09</b>

### Number of clusters

Different nutrient combinations had a significant effect on the number of clusters per plant. Among the nutrient combinations, FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 30:100:40:50 produced more number of clusters per plant (5.94) which was on par with nutrient combinations, FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 30:75:20:100 which produced 5.85 clusters per plant. Absolute control recorded minimum number of clusters per plant (Table 3). Earlier results reported that plants fertigated with FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 30:75:20:100 recorded maximum number of flowers and this might be the reason for maximum number of clusters per plant.

### Number of fruits per plant

Different nutrient combinations had a significant effect on the number of fruits per plant. Among the nutrient combinations, FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 30:75:20:100 produced more number of fruits per plant (6.42). Absolute control recorded minimum number of fruits per plant (Table 3). The plants applied with nutrient combination FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 30:75:20:100 exhibited maximum number of flowers per plant. This may be the reason for maximum number of fruits per plant by applying nutrient combination of FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 30:75:20:100.

Table 4 Effect of different levels of nutrients on yield attributes of strawberry

Treatments	Fruit length	Fruit breadth	Average fruit weight per plant (g)	Days to first harvest (days)	Days to final harvest (days)
T <sub>1</sub>	3.28	3.42	12.93	73.86	170.67
T <sub>2</sub>	2.97	2.92	12.02	73.70	176.17
T <sub>3</sub>	2.82	2.92	11.64	74.21	179.33
T <sub>4</sub>	3.15	3.13	10.91	74.33	174.00
T <sub>5</sub>	3.23	3.02	10.14	74.58	177.33
T <sub>6</sub>	2.88	3.10	12.06	73.37	169.17
T <sub>7</sub>	2.88	2.87	11.85	73.20	170.83
T <sub>8</sub>	3.07	3.30	12.41	71.25	174.50
T <sub>9</sub>	3.33	3.32	11.91	72.97	171.33
T <sub>10</sub>	2.37	2.30	6.35	76.61	165.67
CD	<b>0.38</b>	<b>0.26</b>	<b>1.51</b>	<b>0.83</b>	<b>0.62</b>

### Fruit length

Different nutrient combinations had a significant effect on fruit length. Among the nutrient combinations, FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 30:100:40:50 recorded maximum fruit length (3.33 cm) compared to other nutrient combinations. Absolute control recorded minimum fruit length (Table 4). Even though the number of flowers and fruits recorded are maximum in FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 30:75:20:100 nutrient combination, the fruit size is lesser. The increase in number of flowers in plants fertilized with FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 30:75:20:100 might aggravate internal competition, which in turn impairs flower development resulted in smaller fruits. This is in accordance with the findings of Rindom and Hansen [14] in strawberry.

### Fruit breadth

In Central midlands, different nutrient combinations had a significant effect on fruit breadth. Among the nutrient combinations, FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 10:50:20:50 recorded maximum fruit breadth (3.42 cm) compared to other nutrient combinations. Absolute control recorded minimum fruit breadth (Table 4). In nutrient combination, FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 10:50:20:50, the number of flowers and fruits are lesser and the photosynthates get accumulated in lesser number of fruits which ultimately resulted in increased fruit breadth. This is in accordance with the findings of Rindom and Hansen [14] in strawberry.

### Average fruit weight per plant

In Central midlands, different nutrient combinations had a significant effect on average fruit weight per plant. Among the nutrient combinations, FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 10:50:20:50 recorded maximum average fruit weight per plant (12.93 g) compared to other nutrient combinations. Absolute control recorded minimum average fruit weight per plant (Table 4). In plants fertilized with FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 10:50:20:50 nutrient combinations resulted in maximum

fruit breadth which might have resulted in maximum average fruit size and fruit weight per plant.

### Days to first harvest

In Central midlands, different nutrient combinations had a significant effect on the number of days to first harvest. Among the nutrient combinations, FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 30:75:20:100 recorded the minimum number of days to first harvest (71.25 days). Absolute control recorded maximum number of days to first harvest (Table 4). Earlier results showed that nutrient combinations had no significant effect on earliness in flowering. So, the nutrient combinations influenced vegetative growth also influenced the fruit growth of strawberry and resulted in early harvesting.

### Days to final harvest

In Central midlands, different nutrient combinations had a significant effect on the number of days to final harvest. Among the nutrient combinations, FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 10:100:80:100 recorded the maximum number of days to final harvest (179.33 days), (Table 4). Compared to other nutrient combinations, plants fertilized with FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 10:100:80:100 had high levels of Nitrogen, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O and this might be the reason for maximum days to final harvest.

### Yield

In Central midlands, different nutrient combinations had a significant effect on the yield per plant. Among the nutrient combinations, farmyard manure (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 30:75:20:100 produced maximum yield per plant (79.92 g). Absolute control recorded lowest yield per plant (Table 3). Earlier results indicated that plant height, number of leaves, plant spread, number of crowns, number of clusters, number of flowers and number of fruits were maximum in plants fertilized with farmyard manure (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 30:75:20:100 nutrient combination. The nutrient potassium which favours fruit formation was found maximum in the

nutrient combination farmyard manure (30 t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O @ 75:20:100 kg ha<sup>-1</sup> (T<sub>8</sub>) which ultimately resulted in maximum yield per plant. These findings were in conformity

with the observations of Ali *et al.* [15]; Rana and Chandel [4]; Santos and Chandler [13]; Kumar *et al.* [16]; Karlidag and Yildirim [17].

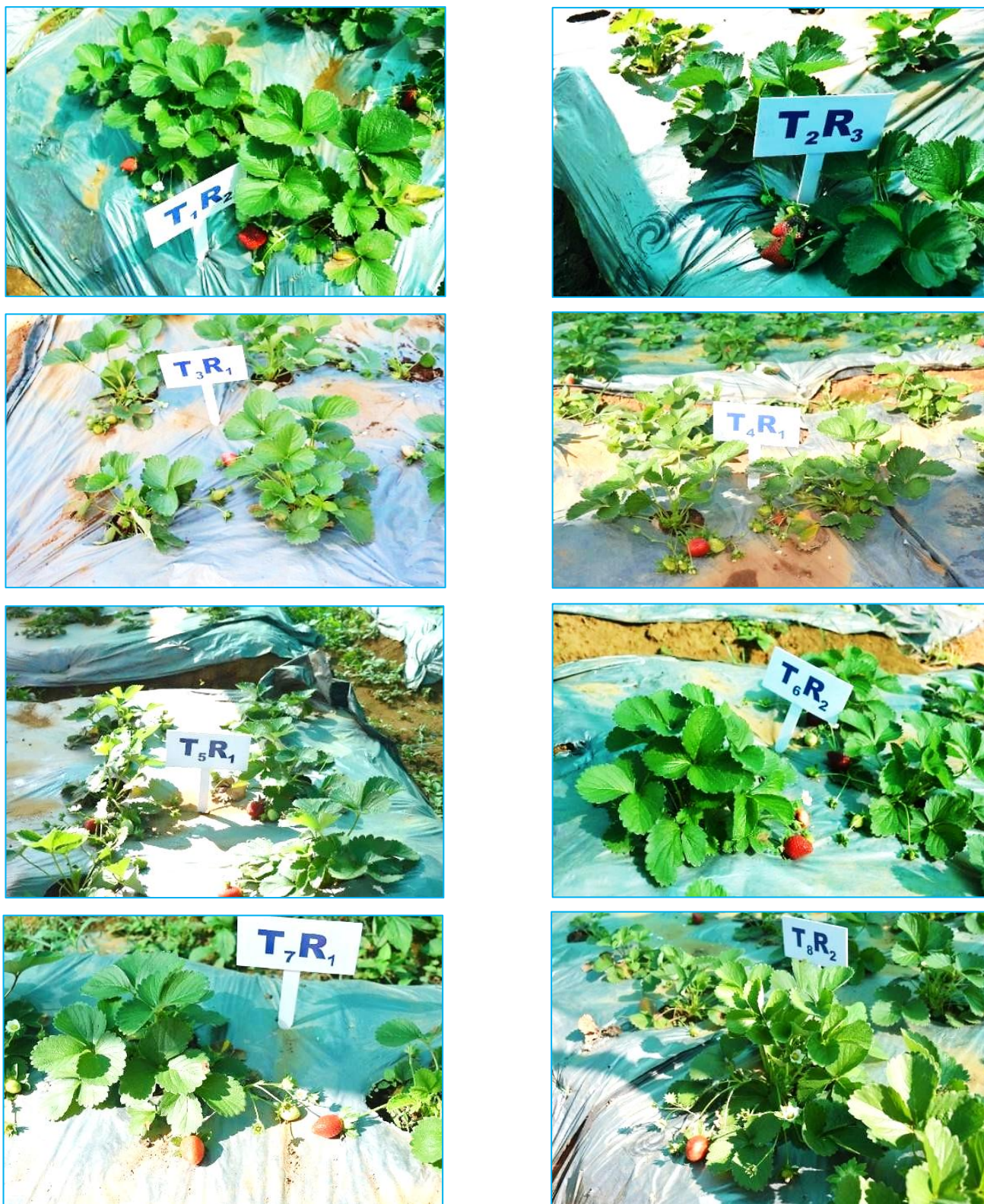


Fig 1 Strawberry field with different nutrient combinations

*Quality attributes*

Maximum TSS of 7.68<sup>0</sup>Brix and TSS/acidity ratio of fruits (10.83) was recorded in fruits harvested from plants fertilized with FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 30:75:20:100. Absolute control recorded lowest TSS (Table 5). FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup> @ 20:75:80:50 recorded minimum TSS/acidity ratio of fruits (Table 5). Increase in TSS might be due to the synergistic effect of differential

combination of organic and inorganic fertilizers applied in the treatment. This is in close conformity with the findings of Woznaik *et al.* [18]; Ali *et al.* [15]; Aracon *et al.* [19]; El-Hamid *et al.* [20]; Mahadeen [21]; Yadav *et al.* [5]; Shehata *et al.* [22]; Wani *et al.* [23] and Tripathi *et al.* [6]. Different nutrient combinations had no significant effect on the acidity of fruits (Table 5). Among the nutrient combinations, FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup>@ 30:100:40:50 recorded maximum total

sugars of fruits (5.23 %) and maximum ascorbic acid content of fruits (52.22 mg 100 g<sup>-1</sup>).

Absolute control recorded lowest total sugars and ascorbic acid content of fruits (Table 5-6). The maximum total

sugars and ascorbic acid content in fruits may be due to the combined effect of higher doses of FYM and nitrogen in the fertilizer application. These findings are in agreement with the observations of Odongo *et al.* [24]; Wani *et al.* [7], Arjun [9].



Fig 2 Strawberry fruits obtained from different nutrient combinations

Among the nutrient combinations, farmyard manure (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup> @ 30:50:80:75 recorded maximum anthocyanin content of fruits (48.15 mg 100 g<sup>-1</sup>) while FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup> @ 10:50:20:50 recorded lowest anthocyanin content (Table 6). Increasing the concentration of phosphorous content increases quality in strawberry [25]. FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup> @ 30:50:80:75 nutrient combinations have higher phosphorous content which might had a positive influence on higher anthocyanin content of fruits.

FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup> @ 10:50:20:50 applied plants produced fruits with maximum fruit breadth i.e., maximum fruit size. This may lead to dilution of anthocyanin pigments in the fruits. That may be reason for lower anthocyanin content. Among the nutrient combinations, FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup> @ 10:100:80:100 recorded maximum β - Carotene content of fruits (2.96 μg 100 g<sup>-1</sup>) while FYM (t ha<sup>-1</sup>), N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O kg ha<sup>-1</sup> @ 10:50:20:50 recorded lowest β - carotene content (Table 6). These findings were

supported by the observations of Odongo *et al.* [24] and Wani *et al.* [7] indicated that synergistic effect of differential

combinations of organic and inorganic fertilizers would influence the production of quality fruits.

Table 5 Effect of different levels of nutrients on quality attributes of strawberry

Treatments	T.S.S (°Brix)	Acidity (%)	T.S.S/Acidity	Total sugars (%)
T <sub>1</sub>	6.50	0.90	7.36	3.94
T <sub>2</sub>	7.38	0.94	7.90	3.49
T <sub>3</sub>	7.52	0.85	9.28	4.80
T <sub>4</sub>	6.75	0.80	8.47	3.91
T <sub>5</sub>	6.47	0.99	6.82	4.50
T <sub>6</sub>	7.03	0.82	8.96	3.97
T <sub>7</sub>	7.33	0.74	10.19	5.07
T <sub>8</sub>	7.68	0.72	10.83	5.10
T <sub>9</sub>	7.23	0.77	9.72	5.23
T <sub>10</sub>	5.53	0.86	6.99	3.20
CD	<b>0.32</b>	<b>NS</b>	<b>1.72</b>	<b>0.20</b>

Table 6 Effect of different levels of nutrients on quality attributes of strawberry

Treatments	Ascorbic acid (mg/100g)	Anthocyanin content (mg/100g)	β – Carotene (µg/100g)
T <sub>1</sub>	19.88	18.00	1.96
T <sub>2</sub>	25.32	32.95	2.35
T <sub>3</sub>	38.00	18.45	2.96
T <sub>4</sub>	23.67	40.37	2.09
T <sub>5</sub>	28.18	30.97	2.18
T <sub>6</sub>	43.47	35.13	2.57
T <sub>7</sub>	25.21	48.15	2.18
T <sub>8</sub>	31.50	44.73	2.68
T <sub>9</sub>	52.22	42.88	2.48
T <sub>10</sub>	17.15	33.02	2.36
CD	<b>1.48</b>	<b>0.81</b>	<b>0.05</b>

## CONCLUSION

Based on the results obtained over two consecutive seasons, it can be concluded that nutrient management had a profound influence on the vegetative growth, flowering, yield, and fruit quality of strawberry (*Fragaria × ananassa* Duch.) cv. Winter Dawn under the humid tropical conditions of Kerala. Among the various nutrient combinations evaluated, the application of FYM @ 30 t ha<sup>-1</sup> in combination with N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O @ 75:20:100 kg ha<sup>-1</sup> proved to be the most effective treatment for enhancing overall crop performance. This nutrient combination significantly improved vegetative parameters such as plant height, number of leaves, plant spread, and number of crowns, which subsequently contributed to superior reproductive performance through increased number of flowers, clusters, and fruits per plant. The same treatment also resulted in the earliest harvest, highest fruit yield per plant (79.92 g), maximum total soluble solids (7.68°Brix), and the highest TSS:acid ratio, indicating improved fruit quality and consumer acceptability. Although certain quality attributes such as fruit size, total sugars, ascorbic acid, anthocyanin, and β-

carotene content were maximized under other specific nutrient combinations, the treatment comprising FYM @ 30 t ha<sup>-1</sup> along with N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O @ 75:20:100 kg ha<sup>-1</sup> provided the best balance between growth, yield, earliness, and fruit quality. In contrast, the absolute control consistently recorded the lowest values for most of the parameters studied, highlighting the critical role of balanced nutrient supply in strawberry cultivation. The findings of the present investigation demonstrate the synergistic effect of integrating organic manure with inorganic fertilizers and suggest that the application of FYM @ 30 t ha<sup>-1</sup> coupled with N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O @ 75:20:100 kg ha<sup>-1</sup> can be recommended as an efficient nutrient management strategy for achieving higher productivity and better fruit quality in strawberry cv. Winter Dawn under the agro-climatic conditions of Kerala and similar tropical regions.

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