Impact of Integrated Nutrient Management (INM) on Growth Attributes of Strawberry (*Fragaria*× *ananassa*Duch.) cv. Winter Dawn

ABSTRACT

A studyentitled Impact of Integrated Nutrient Management (INM) on growth attributes of strawberry (*Fragaria* × *ananassa*Duch.*)* in district Banda, Uttar Pradeshwas carried out at the "Green shade Net house" located in the Department of Fruit Science, College of Horticulture, Banda University of Agriculture & Technology, Banda (U.P.), during the academic years of 2022-23 and 2023-24. Eleven treatments using various combinationsof N, P, K, nano urea, bio fertilizers, and organic manures were tested in a Randomised Block Design with three replicates. The experiment's primary objective was to determine the effect of nano technology on the vegetative growth traits of strawberry cv. Winter Dawn. According to the findings of 2 years study and pooled results, application of treatment T_4 [75% N (Nano Urea) + 75% PK (Basal) + 250 kg VC + AZO + PSB] proved to be most effective treatment to increase growth attributes of strawberry *i.e.*, plant height 9.09 cm, 13.61 cm and 17.78 cm at 30, 60 and 90 DAP, respectively; plant spread *i.e.*, 12.75 cm, 21.32 cm, and 23.44 cm at 30 ,60 and90 DAP,respectively;number of leaves *i.e.*, 5.75, 13.81 and 17.87 at30, 60 and 90 DAP,respectively;leaf length*i.e.*,4.70 cm, 5.80 cm and 8.29 cm at30, 60 and 90 DAP, respectively; leaf width *i.e.*,5.94 cm, 7.53 cm and 11.60 cm at30, 60 and 90 DAP, respectively;Leaf area (cm^2) *i.e.*,40.31cm^2, 51.93 cm^2,66.38cm^2number of runners per plant *i.e.*, 5.27, number of crowns per plant *i.e.*, 4.39, biomass of fresh weight (g)*i.e.*, 147.37 g and Biomass of dry weight (g)*i.e.*, 36.84 g. Therefore, application of 75%N (Nano Urea) + 75%PK (Basal) + 250 Kg VC + AZO + PSB] proved to be most effective treatment to increase growth attributes of strawberry and same can be recommended to the growers.

Keywords: Azotobacter, bio-fertilizer, nano urea, organic manure, phosphorus solubilizing bacteria, strawberry, winter dawn, etc.

INTRODUCTION:

The strawberry, scientifically known as *Fragaria × ananassa*Duch., belongs to the Rosaceae family (Gupta and Tripathi, 2012). It is classified as a "false fruit" and is renowned for being one of the most delectable, invigorating, and nourishing soft fruits in the world (Sparacino *et al*., 2024). Originally native to America, the strawberry has gained widespread popularity (Galletta *et al.*, 1990). The development of this particular hybrid took place in France during the seventeenth century. It is worth noting that this hybrid is a monoecious combination of two American octaploid species, namely *Fragariachiloensis*Duch. And *Fragariavirginiana*Duch (Galletta and Bringhust, 1990).This fruit thrives in temperate climates with temperatures below26°C, which is necessary for flowering to occur (Jackson *et al.*, 2011). According to Chattopadhyay (2013), it is possible to cultivate it in subtropical climates and at high altitudes in tropical regions. Currently, strawberries are cultivated in various climatic zones thanks to their diverse genotypes.

From a nutritional standpoint, strawberries are considered a low-calorie carbohydrate fruit. They are also packed with vitamin A, providing 60 International Unit per 100g of edible portion. Additionally, strawberries are a good source of fiber and contain a high amount of pectin, specifically calcium pectate (Singh and Saravanan, 2012). Strawberry fruit is rimarily composed of water, making up approximately 90% of its composition. The strawberry fruit contains a significant amount of vitamin C (40-120mg/100g fruit), protein, and various minerals such as phosphorus, potassium, calcium, and iron (Kanupriya, 2002). It also contains phenolics and flavonoids (Hakkinen and Torronen, 2000).Strawberries have gained popularity as a nutritious and delicious fruit enjoyed by millions worldwide (Sharma and Singh, 1999). Strawberries are known for their abundance of bioactive compounds, including anthocyanins, carotenoids, vitamins, flavonoids, and phenolics. These compounds have been found to possess strong antioxidant properties (Giampieri*et al.*, 2017).

In recent years, the presence of unauthorized fertilizers, pesticides, and the results of biological monitoring have led to environmental contamination in strawberry agriculture (Galagarza *et al.*, 2021). Chemical fertilisers have been found to enhance crop productivity, but they also bring about the presence of detrimental residues that can have adverse effects on human health, compromise sustainability, and contribute to water pollution (Shukla *et al.*, 2022). Therefore, nanotechnologies offer a promising solution to enhance agricultural production and promote sustainability. In 1974, Professor Norio Taniguichi of Tokyo University of Science introduced the term 'nanotechnology' (Khan and Rizvi, 2014).Nanofertilizers are designed to release nutrients at the right time, preventing any early interaction with the soil, water, and microbes. The nutrients quickly come together and integrate into the plant system. According to a study conducted by DeRosa *et al.* (2010), certain traits have the potential to enhance crop nutrient efficiency.

Strawberry plants thrive in regions with optimal nutrition and carefully regulated nutrient supply, resulting in increased yield. Nano mixed foliar sprays, when integrated with bio fertilizers and organic manures, offer enhanced field usage production, superior sustainability, and reduced plant mobility. Foliar nano fertilizers have been found to reduce the toxicity of macro and micro engineered elements applied to the soil, as demonstrated by Abbasifar*et al.* (2020).Keeping in view the above facts this experiment titled Impact of Integrated Nutrient Management (INM) on growth attributes of strawberry *(Fragaria × ananassa*Duch.) in district Banda, Uttar Pradesh was designed and carried out.

MATERIALS AND METHODS:

The experiment mentioned above was conducted during the years 2022-23 and 2023-24 under net house conditions located in the Department of Fruit Science, College of Horticulture, Banda University of Agriculture and Technology, Banda (U.P.). The experimental site is situated within the latitudes of 24° 53°–24° 55° N and longitudes of 80° 07°-81° 34° E. District Banda is geographically surrounded by the Madhya Pradesh districts of Satna, Panna, and Chhatarpur to the south, and the districts of Fathepur to the north, Chitrakoot to the east, and Hamirpur and Mahoba to the west. The soil of the experimental site contains slightly alkaline pH of 7.91 and low organic matter of 0.49%, EC (1.41 dSm^{-1}), Available N (106 kg/ha), Available P (9.44 kg/ha) and Available K (302 kg/ha).

The plants were treated with different treatments, *i.e.*, T_1: 100% NPK Basal dose of fertilizers, T_2: 100% N (Nano Urea) + 100% PK Basal dose of fertilizers, T_3: 75% N (Nano Urea) + 75% PK (Basal) + 500 kg FYM + AZO + PSB, T_4: 75% N (Nano Urea) + 75% PK (Basal) + 250 kg VC + AZO + PSB, T_5: 75% N (Nano Urea) + 75% PK (Basal) + 100 kg NOC + AZO + PSB, T_6: 50% N (Nano Urea) + 50% PK (Basal) + 750 kg FYM + AZO + PSB, T_7: 50% N (Nano Urea) + 50% PK (Basal) + 500 kg VC + AZO + PSB, T_8: 50% N (Nano Urea) + 50% PK (Basal) + 150 kg NOC + AZO + PSB, T_9: 25% N (Nano Urea) + 25% PK (Basal) + 1000 kg FYM + AZO + PSB, T_{10}: 25% N (Nano Urea) + 25% PK (Basal) + 750 kg VC + AZO + PSB andT_{11}: 25% N (Nano Urea) + 25% PK (Basal) + 200 kg NOC + AZO + PSB.

Prepared bed with the help of spade and transplantingof runners in 45×30 cm spacing. Recommended dose of NPK @ 100:120:80 kg/ha along with FYM, Vermicompost (VC) & Neem oil cake(NOC) were applied as basal dose and rest doses were applied 15 days before planting of runners as per treatment combination.Bio-fertilizers AZO (Azotobacter) and PSB (phosphorus solubilizing bacteria) were used in the experimental field to fulfill the recommended dose of bio-fertilizers. Calculated amount of bio-fertilizers were applied before mulching of the beds according to various treatment combinations. The nano urea was given immediately after transplantation, followed by three more at 20-day intervals.The experiment conducted in RandomizedBlock Design as per method suggested byPanes and Sukhatme,1985with three replications.

RESULTS AND DISCUSSION:

A statistical analysis was conducted to study the growth characteristics of Strawberry (*Fragaria* × *ananassa*) cv. Winter Dawn based on the findings; the inclusion of different treatments led to a significant improvement in all the characteristics. Based on the comparison of F Cal. and F Tab, it can be concluded that the variances exhibited statistically significant differences.

GROWTH ATTRIBUTES:

Fruit weight (g): According to results pertaining to Table 1,it was found that the treatment T_4[75% N (Nano Urea) + 75% PK (Basal) + 250 kg VC + AZO + PSB]was found best compared to other treatments. Itwas found significantly the maximumplant height*i.e.*,[8.83 cm (2022-23), 9.36 cm (2023-24) and 9.09 cm(pooled)] cm at 30 DAP, [13.21 cm (2022-23), 14.00 cm (2023-24) and 13.61cm (pooled)] cm at 60 DAP and [17.43 cm (2022-23), 18.13 cm (2023-24) and 17.78 cm(pooled)] cm at 90 DAP whereas,leastplant height*i.e.*,[5.94 cm (2022-23), 6.30 cm (2023-24) and 6.12 cm(pooled)] cm at 30 DAP, [8.42 cm (2022-23), 8.93 cm (2023-24) and 8.67cm (pooled)] cm at 60 DAP and [12.91 cm (2022-23), 13.43 cm (2023-24) and 13.17 cm(pooled)] cm at 90 DAP was found under the effect of treatment T_1[100% NPK Basal dose of fertilizers]

Plant spread (cm): As per the data regarding plant spread(Table 2), effect of treatment T_4[75% N (Nano Urea) + 75% PK (Basal) + 250 kg VC + AZO + PSB]was found best with significantlymaximumplant spread*i.e.*,[12.44 cm (2022-23), 13.06 cm (2023-24) and 12.75 cm(pooled)] cm at 30 DAP, [20.21cm (2022-23), 22.43cm(2023-24) and 21.32cm (pooled)] cm at 60 DAP and [23.21cm (2022-23), 23.67 cm (2023-24) and 23.44 cm(pooled)] cm at 90 DAP whereas,least plant spread*i.e.*,[8.85 cm (2022-23), 9.29 cm (2023-24) and 9.07

cm(pooled)] cm at 30 DAP, [13.49 cm (2022-23), 14.97 cm (2023-24) and 14.23 cm(pooled)] cm at 60 DAP and [19.09 cm (2022-23), 19.47 cm (2023-24) and 19.28 cm(pooled)] cm at 90 DAP was found under the effect of treatment T_1[100% NPK Basal dose of fertilizers]

Number of leaves: The results indicating tonumber of leaves(Table 3) as effected by Integrated Nutrient Management shows thattreatment T_4[75% N (Nano Urea) + 75% PK (Basal) + 250 kg VC + AZO + PSB]was found best with significantlymaximumnumber of leaves i.e.,[5.45 (2022-23), 6.05 (2023-24) and 5.75(pooled)] at 30 DAP, [13.67 (2022-23), 13.94(2023-24) and 13.81(pooled)] at 60 DAP and [17.78 (2022-23), 17.96 (2023-24) and 17.87(pooled)] at 90 DAP whereasleast number of leaves*i.e.*,[4.15 (2022-23), 4.61 (2023-24) and 4.38(pooled)] at 30 DAP, [9.55 (2022-23), 9.74 (2023-24) and 9.65(pooled)] at 60 DAP and [14.04 (2022-23), 14.18 (2023-24) and 14.11(pooled)] at 90 DAP was found under the effect of treatment T_1[100% NPK Basal dose of fertilizers].

Leaf length (cm): The experimental result regarding leaf length (Table 4) indicate that effect of treatment T_4[75% N (Nano Urea) + 75% PK (Basal) + 250 kg VC + AZO + PSB]was found best with significantlymaximumleaf length*i.e.*,[4.67 cm (2022-23), 4.72 cm (2023-24) and 4.70 cm(pooled)] cm at 30 DAP, [5.77 cm (2022-23), 5.83 cm(2023-24) and 5.80 cm(pooled)] cm at 60 DAP and [8.24 cm (2022-23), 8.35 cm (2023-24) and 8.29 cm (pooled)] cm at 90 DAP whereasleast leaf length*i.e.*,[3.39 cm (2022-23), 3.43 cm (2023-24) and 3.41cm(pooled)] cm at 30 DAP, [4.19 cm (2022-23), 4.23 cm(2023-24) and 4.21 cm(pooled)] cm at 60 DAP and [5.98 cm (2022-23), 6.06 cm (2023-24) and 6.02 cm(pooled)] cm at 90 DAP was found under the effect of treatment T_1[100% NPK Basal dose of fertilizers].

Leaf width (cm): Significant differences were observed regarding data indication leaf width (Table 5) of strawberry. Treatment T_4[75% N (Nano Urea) + 75% PK (Basal) + 250 kg VC + AZO + PSB]was found best with significantlymaximumleaf width*i.e.*,[5.93 cm (2022-23), 5.96 cm (2023-24) and 5.94cm (pooled)] cm at 30 DAP, [7.51cm (2022-23), 7.56 cm(2023-24) and 7.53 cm(pooled)] cm at 60 DAP and [11.55cm(2022-23), 11.65 cm (2023-24) and 11.60 cm (pooled)] cm at 90 DAP whereasleast leaf width (cm)*i.e.*,[4.09 cm (2022-23), 4.11cm (2023-24) and 4.10 cm(pooled)] cm at 30 DAP, [5.18 cm (2022-23), 5.22 cm(2023-24) and 5.20 cm(pooled)] cm at 60 DAP and [7.97cm(2022-23), 8.04 cm (2023-24) and 8.01 cm (pooled)] cm at 90 DAP was found under the effect of treatment T_1[100% NPK Basal dose of fertilizers].

Leaf area (cm^2): As per the data regarding leaf area(Table 6), effect of treatment T_4[75% N (Nano Urea) + 75% PK (Basal) + 250 kg VC + AZO + PSB]was found best with significantlymaximumleaf area*i.e.*,[40.24cm^2 (2022-23), 40.38cm^2 (2023-24) and 40.31cm^2(pooled)] cm^2 at 30 DAP, [51.51cm^2 (2022-23), 52.35cm^2 (2023-24) and 51.93cm^2(pooled)] cm^2 at 60 DAP and [65.52cm^2 (2022-23), 67.25cm^2 (2023-24) and 66.38cm^2(pooled)] cm^2 at 90 DAP whereasleast leaf area (cm^2)*i.e.*,[30.04cm^2 (2022-23), 30.14cm^2 (2023-24) and 30.09cm^2 (pooled)] cm^2 at 30 DAP, [41.37cm^2 (2022-23), 42.05cm^2 (2023-24) and 41.71cm^2 (pooled)] at 60 DAP and [49.44cm^2 (2022-23), 50.75cm^2 (2023-24) and 50.09cm^2 (pooled)] at 90 DAP was found under the effect of treatment T_1 [100% NPK Basal dose of fertilizers].

Number of runners per plant: The results indicating to number of runners per plant(Table 7) as effected by Integrated Nutrient Management shows thattreatment T_4 [75% N (Nano Urea) + 75% PK (Basal) + 250 kg VC + AZO + PSB]was found best with significantly maximum number of runners per plant*i.e.*,[5.05 (2022-23), 5.48 (2023-24) and 5.27 (pooled)] whereas least number of runners per plant*i.e.*,[1.12 (2022-23), 1.24 (2023-24) and 1.18 (pooled)] was found under the effect of treatment T_1 [100% NPK Basal dose of fertilizers].

Number of crowns per plant: According to results pertaining to Table 7, it was found that the treatment T_4[75% N (Nano Urea) + 75% PK (Basal) + 250 kg VC + AZO + PSB]was found best compared to other treatments. Itwas found significantly the maximumnumber of crowns per plant*i.e.*,[4.33 (2022-23), 4.46 (2023-24) and 4.39(pooled)] whereas least number of crowns per plant*i.e.*,[2.37 (2022-23), 2.44 (2023-24) and 2.41 (pooled)] was found under the effect of treatment T_1 [100% NPK Basal dose of fertilizers].

Biomass of fresh weight (g): The data regarding Biomass of fresh weight is shown in Table 8. From the data it was depicted that treatment T_4[75% N (Nano Urea) + 75% PK (Basal) + 250 kg VC + AZO + PSB]was found best compared to other treatments. Itwas found significantly the maximumbiomass of fresh weight (g)*i.e.*,[145.45g(2022-23), 149.29g (2023-24) and 147.37g(pooled)]whereas least biomass of fresh weight (g)*i.e.*,[118.74g (2022-23), 121.87g (2023-24) and 120.31g (pooled)]was found under the effect of treatment T_1 [100% NPK Basal dose of fertilizers].

Biomass of dry weight (g): As per the data regarding biomass of dry weight(Table 8), effect of treatment T_4[75% N (Nano Urea) + 75% PK (Basal) + 250 kg VC + AZO + PSB]was found best with significantlymaximumbiomass of dry weight*i.e.*,[36.36g (2022-23), 37.32g

(2023-24) and 36.84g(pooled)] g whereas least biomass of dry weight*i.e.*,[29.69g(2022-23),30.47g(2023-24) and 30.08 (pooled)] g was found under the effect of treatment T_1 [100% NPK Basal dose of fertilizers].

DISCUSSION:

Treatment T_4[75% N (Nano Urea) + 75% PK (Basal) + 250 kg VC + AZO + PSB]had the greatest effect and was the most significantin increasing vegetative growth of strawberry.There were significant differences in the impact of treatments on the height and spread of the plants, highest number of leaves, as well as the largest leaf size and leaf area. Maximum number of runners per plant, number of crowns per plant and biomass fresh and dry weight both in the individual years of observation and pooled data. It is possible that the presence of urea nanoparticles allows for easier penetration into leaf cells and stomata, resulting in an enhanced availability of nitrogen to the plant cells (Abdel-Aziz *et al.,* 2018). According to Sun *et al.* (2023), the rise in nitrogen availability could have resulted in the rapid synthesis of chlorophyll, crucial enzymes, and proteins. According to Gajbhiye*et al.* (2003), the heightened metabolic pathways could have resulted in accelerated cell elongation and multiplication, resulting in an overall increase in plant height and spread. Other studies have also documented similar results in guava (Bhatti *et al.,* 2023; Kumar *et al.,* 2024), (Singh *et al.,* 2016) and (Singh *et al.,* 2023) in strawberry. The increased availability of nutrients was attributed to the penetration of nano N through the stomata of leaves via gas uptake, as discussed by Rajasekar *et al.* (2017). In addition, the application of vermicompost with bio-fertilizers such as PSB and Azotobacter may have played a role in promoting plant growth. Studies conducted by Bhatti *et al.* (2023) on guava, Singh *et al.* (2016) and Kalil *et al.* (2022) on strawberry have reported a significant increase in the number of leaves and leaf area as a result of using nano urea.

The subsequent increase in the number of runners per plant can also be attributed to the enhanced plant growth in terms of height and leaf count. This leads to the accumulation of additional photosynthesis, resulting in an increase in both runners and leaf area per plant. The results align entirely with Upadhyay*et al.* (2023) study on strawberries, which reported the largest number of runners per plant when PM + Azotobacter + wood ash + vermicompost + oil cake were applied.Strawberry plant biomass might have increased due to the fact that synergistic effect of Nano Urea, Vermicompost, Azotobacter and PSB along with basal dose of P and K led to the sustained release of nutrients and in biovailable form to the plants. This leads to more biomass production of the strawberry plants. Similar results were reported by Singh *et al.* (2023), Singh *et al.* (2016) and Al-Aareji (2022) in strawberry**.**

Table 1:Impact of integrated nutrient management on plant height (cm) of strawberry (*Fragaria*× *ananassa*Duch.) cv. Winter Dawn

Treatments	plant height (cm)								
	30 DAP			60 DAP			90 DAP		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_{1}	5.94	6.30	6.12	8.42	8.93	8.67	12.91	13.43	13.17
T_{2}	6.02	6.38	6.20	8.81	9.34	9.07	13.21	13.74	13.47
T_{3}	8.71	9.23	8.97	12.81	13.58	13.19	17.09	17.77	17.43
T_{4}	8.83	9.36	9.09	13.21	14.00	13.61	17.43	18.13	17.78
T_{5}	8.09	8.58	8.33	11.64	12.34	11.99	15.94	16.58	16.26
T_{6}	7.84	8.31	8.08	11.26	11.94	11.60	15.58	16.20	15.89
T_{7}	8.57	9.08	8.83	12.19	12.92	12.56	16.51	17.17	16.84
T_{8}	7.42	7.87	7.64	10.87	11.52	11.20	15.01	15.61	15.31
T_{9}	7.18	7.61	7.40	9.86	10.45	10.16	14.09	14.65	14.37
T_{10}	7.31	7.75	7.53	10.26	10.88	10.57	14.42	15.00	14.71
T_{11}	6.19	6.56	6.38	9.43	10.00	9.71	13.77	14.32	14.05
S.E. (m) (±)	**0.11**	**0.13**	**0.09**	**0.16**	**0.17**	**0.12**	**0.16**	**0.17**	**0.12**
C.D. @ 5%	**0.34**	**0.37**	**0.24**	**0.48**	**0.52**	**0.34**	**0.46**	**0.52**	**0.34**

Table 2:Impact of integrated nutrient management on plant spread (cm) of strawberry (*Fragaria*× *ananassa*Duch.)cv. Winter Dawn

Treatments	plant spread (cm)								
	30 DAP			60 DAP			90 DAP		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_{1}	8.85	9.29	9.07	13.49	14.97	14.23	19.09	19.47	19.28
T_{2}	9.02	9.47	9.25	14.01	15.55	14.78	19.37	19.76	19.56
T_{3}	12.21	12.82	12.52	19.66	21.82	20.74	22.93	23.39	23.16
T_{4}	12.44	13.06	12.75	20.21	22.43	21.32	23.21	23.67	23.44
T_{5}	11.21	11.77	11.49	17.95	19.92	18.94	21.68	22.11	21.90
T_{6}	10.89	11.43	11.16	17.41	19.33	18.37	21.40	21.83	21.61
T_{7}	12.09	12.69	12.39	18.81	20.88	19.84	22.31	22.76	22.53
T_{8}	10.34	10.86	10.60	16.86	18.71	17.79	21.09	21.51	21.30
T_{9}	10.02	10.52	10.27	15.38	17.07	16.23	20.13	20.53	20.33
T_{10}	10.18	10.69	10.43	15.95	17.70	16.83	20.44	20.85	20.64
T_{11}	9.21	9.67	9.44	14.83	16.46	15.65	19.85	20.25	20.05
S.E. (m) (±)	**0.14**	**0.15**	**0.10**	**0.22**	**0.17**	**0.16**	**0.13**	**0.15**	**0.10**
C.D. @ 5%	**0.41**	**0.44**	**0.29**	**0.64**	**0.52**	**0.46**	**0.39**	**0.44**	**0.29**

Table 3:Impact of integrated nutrient management on number of leaves of strawberry (*Fragaria*× *ananassa*Duch.) cv. Winter Dawn

Treatments	number of leaves								
	30 DAP			60 DAP			90 DAP		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	4.15	4.61	4.38	9.55	9.74	9.65	14.04	14.18	14.11
T_2	4.22	4.68	4.45	9.86	10.06	9.96	14.43	14.57	14.50
T_3	5.38	5.97	5.68	13.38	13.65	13.51	17.42	17.59	17.51
T_4	5.45	6.05	5.75	13.67	13.94	13.81	17.78	17.96	17.87
T_5	4.94	5.48	5.21	12.20	12.44	12.32	16.20	16.36	16.28
T_6	4.87	5.41	5.14	11.91	12.15	12.03	15.81	15.97	15.89
T_7	5.16	5.73	5.44	12.79	13.05	12.92	16.76	16.93	16.84
T_8	4.80	5.33	5.06	11.62	11.85	11.74	16.36	16.52	16.44
T_9	4.51	5.01	4.76	10.74	10.95	10.85	15.28	15.43	15.36
T_{10}	4.58	5.08	4.83	11.03	11.25	11.14	15.64	15.80	15.72
T_{11}	4.44	4.93	4.68	10.45	10.66	10.55	14.90	15.05	14.97
S.E. (m) (±)	**0.04**	**0.05**	**0.03**	**0.14**	**0.16**	**0.11**	**0.16**	**0.17**	**0.12**
C.D. @ 5%	**0.12**	**0.16**	**0.10**	**0.41**	**0.48**	**0.31**	**0.46**	**0.50**	**0.33**

Table 4:Impact of integrated nutrient management on leaf length (cm) of strawberry (*Fragaria*× *ananassa*Duch.) cv. Winter Dawn

Treatments	leaf length (cm)								
	30 DAP			60 DAP			90 DAP		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	3.39	3.43	3.41	4.19	4.23	4.21	5.98	6.06	6.02
T_2	3.49	3.53	3.51	4.31	4.35	4.33	6.15	6.23	6.19
T_3	4.58	4.63	4.61	5.66	5.72	5.69	8.08	8.18	8.13
T_4	4.67	4.72	4.70	5.77	5.83	5.80	8.24	8.35	8.29
T_5	4.23	4.28	4.25	5.22	5.28	5.25	7.46	7.56	7.51
T_6	4.14	4.19	4.16	5.11	5.17	5.14	7.30	7.39	7.35
T_7	4.41	4.45	4.43	5.44	5.50	5.47	7.77	7.87	7.82
T_8	4.05	4.09	4.07	5.00	5.05	5.03	7.14	7.23	7.19
T_9	3.78	3.82	3.80	4.67	4.72	4.69	6.67	6.76	6.71
T_{10}	3.87	3.92	3.89	4.78	4.83	4.81	6.83	6.92	6.87
T_{11}	3.69	3.73	3.71	4.56	4.61	4.58	6.51	6.59	6.55
S.E. (m) (±)	**0.01**	**0.02**	**0.01**	**0.03**	**0.04**	**0.03**	**0.07**	**0.08**	**0.06**
C.D. @ 5%	**0.04**	**0.05**	**0.03**	**0.09**	**0.12**	**0.07**	**0.21**	**0.25**	**0.16**

Table 5:Impact of integrated nutrient management on leaf width (cm) of strawberry (*Fragaria*× *ananassa*Duch.) cv. Winter Dawn

Treatments	leaf width (cm)								
	30 DAP			60 DAP			90 DAP		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	4.09	4.11	4.10	5.18	5.22	5.20	7.97	8.04	8.01
T_2	4.23	4.25	4.24	5.36	5.39	5.37	8.24	8.31	8.28
T_3	5.81	5.84	5.83	7.36	7.41	7.38	11.32	11.42	11.37
T_4	5.93	5.96	5.94	7.51	7.56	7.53	11.55	11.65	11.60
T_5	5.27	5.29	5.28	6.67	6.72	6.69	10.26	10.35	10.31
T_6	5.15	5.18	5.16	6.52	6.56	6.54	10.03	10.12	10.07
T_7	5.54	5.57	5.55	7.01	7.06	7.04	10.79	10.89	10.84
T_8	5.03	5.06	5.04	6.37	6.41	6.39	9.80	9.89	9.84
T_9	4.64	4.66	4.65	5.88	5.92	5.90	9.04	9.12	9.08
T_{10}	4.76	4.78	4.77	6.03	6.07	6.05	9.27	9.35	9.31
T_{11}	4.52	4.55	4.53	5.73	5.77	5.75	8.81	8.89	8.85
S.E. (m) (±)	**0.02**	**0.03**	**0.02**	**0.04**	**0.05**	**0.03**	**0.11**	**0.14**	**0.09**
C.D. @ 5%	**0.06**	**0.09**	**0.05**	**0.12**	**0.16**	**0.10**	**0.34**	**0.41**	**0.26**

Table 6:Impact of integrated nutrient management on leaf area (cm^2) of strawberry (*Fragaria*× *ananassa*Duch.) cv. Winter Dawn

Treatments	leaf area (cm^2)								
	30 DAP			60 DAP			90 DAP		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	30.04	30.14	30.09	41.37	42.05	41.71	49.44	50.75	50.09
T_2	31.27	31.38	31.32	42.69	43.39	43.04	51.24	52.59	51.92
T_3	39.71	39.85	39.78	50.89	51.72	51.31	64.84	66.55	65.70
T_4	40.24	40.38	40.31	51.51	52.35	51.93	65.52	67.25	66.38
T_5	37.25	37.38	37.31	48.23	49.02	48.63	60.48	62.08	61.28
T_6	36.72	36.84	36.78	47.61	48.39	48.00	59.80	61.38	60.59
T_7	38.48	38.61	38.55	49.55	50.36	49.96	62.66	64.31	63.49
T_8	35.49	35.61	35.55	46.29	47.05	46.67	57.62	59.14	58.38
T_9	33.73	33.84	33.79	44.35	45.08	44.71	54.76	56.21	55.48
T_{10}	34.26	34.38	34.32	44.97	45.71	45.34	55.44	56.90	56.17
T_{11}	32.50	32.61	32.56	43.01	43.72	43.36	52.58	53.97	53.27
S.E. (m) (±)	**0.25**	**0.25**	**0.18**	**0.28**	**0.30**	**0.20**	**0.40**	**0.43**	**0.29**
C.D. @ 5%	**0.73**	**0.75**	**0.51**	**0.82**	**0.87**	**0.58**	**1.17**	**1.26**	**0.84**

Table 7:Impact of integrated nutrient management on number of runners and number of crowns per plant of strawberry (*Fragaria*× *ananassa*Duch.) cv. Winter Dawn

Treatments	number of runners per plant			number of crowns per plant		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	1.12	1.24	1.18	2.37	2.44	2.41
T_2	1.53	1.66	1.59	2.49	2.56	2.53
T_3	4.80	5.23	5.02	4.19	4.32	4.25
T_4	5.05	5.48	5.27	4.33	4.46	4.39
T_5	3.70	4.04	3.87	3.66	3.77	3.71
T_6	3.45	3.74	3.60	3.52	3.63	3.57
T_7	4.25	4.64	4.44	3.91	4.03	3.97
T_8	2.90	3.15	3.02	3.38	3.48	3.43
T_9	2.10	2.30	2.20	2.96	3.05	3.00
T_{10}	2.38	2.58	2.48	3.09	3.18	3.14
T_{11}	1.98	2.17	2.08	2.82	2.90	2.86
S.E. (m) (±)	**0.14**	**0.14**	**0.10**	**0.07**	**0.08**	**0.05**
C.D. @ 5%	**0.41**	**0.42**	**0.29**	**0.20**	**0.23**	**0.15**

Table 8:Impact of integrated nutrient management on biomass of fresh plant (g) and biomass of dry plant (g) of strawberry (*Fragaria*× *ananassa*Duch.)cv. Winter Dawn

Treatments	biomass of fresh plant (g)			biomass of dry plant (g)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	118.74	121.87	120.31	29.69	30.47	30.08
T_2	121.85	125.07	123.46	30.46	31.27	30.86
T_3	143.84	147.64	145.74	35.96	36.91	36.43
T_4	145.45	149.29	147.37	36.36	37.32	36.84
T_5	137.62	141.25	139.44	34.41	35.31	34.86
T_6	136.00	139.59	137.80	34.00	34.90	34.45
T_7	140.73	144.45	142.59	35.18	36.11	35.65
T_8	132.89	136.40	134.64	33.22	34.10	33.66
T_9	128.07	131.45	129.76	32.02	32.86	32.44
T_{10}	129.78	133.21	131.49	32.45	33.30	32.87
T_{11}	124.96	128.26	126.61	31.24	32.06	31.65
S.E. (m) (±)	**0.68**	**0.73**	**0.50**	**0.21**	**0.23**	**0.16**
C.D. @ 5%	**1.99**	**2.15**	**1.42**	**0.62**	**0.68**	**0.45**

CONCLUSION

Based on the results, treatment T_4 [75% N (Nano Urea) + 75% PK (Basal) + 250 kg VC + AZO + PSB] was the most efficient treatment at boosting vegetative growth characteristics. This integrated approach combines advanced nano-urea technology, optimized basal nutrient provision, and the enriching properties of vermicompost and beneficial microorganisms to maximize the benefits. The combination of these components likely fostered an optimal environment for absorbing nutrients and promoting plant growth, leading to exceptional vegetative growth measurements. The results highlight the importance of customized nutrient management techniques in enhancing plant growth, leading to higher crop yields and increased sustainability in strawberry farming. This production practice can be shared with strawberry farmers to improve their production and productivity.

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Details of the AI usage are given below:

1.

2.

3.

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