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Impact of Integrated Nutrient Management (INM) on flowering characteristics of strawberry (*Fragaria* × *ananassa* Duch.)

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Abstract
A study entitled Impact of Integrated Nutrient Management (INM) on flowering characteristics of strawberry (*Fragaria* × *ananassa* Duch.) was 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 combinations of N, P, K, nano urea, bio-fertilizers, and organic manures were tested in a randomized block Design with three replicates According to the findings of this study, application of treatment T_4 [75% N (Nano Urea) + 75% PK (Basal) + 250 Kg VC + AZO + PSB] proved to be a most effective treatment to flowering characteristics of strawberry i.e., Days to first flower (days) [23.04(2022-23), 22.03 (2023-24) and 22.54 (pooled)], Number of flowers per plant [23.04(2022-23), 22.03 (2023-24) and 22.54 (pooled)], Number of fruits per plant [16.16 (2022-23), 16.25 (2023-24) and 16.21 (pooled)] Percentage of fruit set per plant [70.12% (2022-23), 73.76% (2023-24) and 71.94% (pooled)], Days to first fruit harvest [57.97 (2022-23), 53.68 (2023-24) and 55.83 (pooled)] Duration of harvesting (days) [65.12 (2022-23), 67.07 (2023-24) and 66.10 (pooled)] days.

Keywords: Azotobacter, biofertilizer, flower characteristics, nano urea, organic manure, PSB, strawberry, winter dawn

Introduction
Strawberry (*Fragaria* × *ananassa*) is one of the world's most popular soft fruits. It belongs to the family Rosaceae, and the majority of cultivated forms of strawberry are octaploid (2n=56). The fruit is an achene attached to juicy enlarged receptacles. The cultivated strawberry is an interspecific hybridization between *Fragaria chiloensis* and *Fragaria virginiana* Darrow, G. M. (1966) [4] Its fruits are very nutritious with distinct pleasant aromas and flavour and are consumed as a dessert or processed as jam, syrup, ice cream, and for quick freezing and canning, etc. (Gupta and Tripathi, 2012) [8].

This fruit survives in temperate climates with temperatures below 26 °C, which is necessary for flowering in strawberry (Jackson *et al.*, 2011) [10]. According to Chattopadhyay (2013) [3], it is possible to cultivate it in subtropical climates and at high altitudes in tropical regions. China is the leading global producer, with 3 million tons of the world's production supply. In India, the cultivation of this product takes place on a 3000-hectare area, resulting in an annual production of 14000 metric tonnes (NHB, 2021) [13].

Fresh strawberry fruits are full with antioxidants, vitamins, and minerals. The berries are rich in vitamin-C (58 mg/100 g), potassium (153 mg/100 g), folate (24 µ g), dietary fibre (2%) and vitamin-B6 (0.047 mg/100 g). They are also low in fat and calories. In addition, it has 90.95 percent water, 32 kcal of energy, 7.68 percent carbohydrates, 4.89 percent sugars, and 0.67 percent protein (Giampieri *et al.*, 2012) [5].

Strawberries have gained popularity as a nutritious and delicious fruit enjoyed by millions worldwide (Sharma and Singh, 1999) [15]. Bioactive substances found in large quantities in strawberries include anthocyanins, carotenoids, vitamins, flavonoids, and phenolics. These substances have been shown to have potent antioxidant qualities. (Giampieri *et al.*, 2017) [6].

In recent years, Chemical fertilisers enable extremely high agricultural yields, but they also include a lot of hazardous leftovers that can harm human health, reduce crop sustainability, and contaminate water, which has an adverse impact on the ecosystem.

Integrated nutrient management (INM) involves utilizing a combination of inorganic, organic, and microbial nutrient sources. This approach ensures balanced nutrient proportions, enhances nutrient response efficiency, and maximizes the quality and productivity of crops. INM also helps reduce the gap between nutrient removal caused by continuous use of chemical fertilizers and nutrient supply provided by slow-release fertilizers. The extensive use of chemical fertilizers impacts soil health and negatively reduces crop productivity and quality (Macit et al., 2007) [12].

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) [1]. Keeping the above facts in mind, this experiment titled Effect of integrated nutrient management (INM) on flowering characteristics of strawberry (*Fragaria* × *ananassa* Duch) was designed and executed.

Materials and Methods

The experiment mentioned above was conducted during the years 2022-23 and 2023-24 at the "Green shade Net house" located in the Department of Fruit Science, College of Horticulture, Banda University of Agriculture & 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 and T_{11}: 25% N (Nano Urea) + 25% PK (Basal) + 200 Kg NOC + AZO + PSB.

Agricultural field was deep ploughed by the Disk harrow before one week of transplanting 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 solublizing bacteria) were used in the experimental field to fulfill the recommended dose of bio-fertilizers. Calculated amounts 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 utilized a Randomized Block Design (Panse and Sukhatme, 1985) [14] with three replications for each of the eleven treatment combinations. Flower characteristics like Days to first flower, Number of flowers per plant, Number of fruits per plant, Percentage of fruit set per plant, Days to first fruit harvest, Duration of harvesting (days).

Results and Discussion

A statistical analysis was conducted to study the flower 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.

Flower characteristics

Days to first flower: According to the results of Table 1, the effect of treatment T_4 [75% N (Nano Urea) + 75% PK (Basal) + 250 Kg VC + AZO + PSB] was found best compared to other treatments. It was found significantly the minimum days taken to the first flower i.e., [41.90 (2022-23), 38.89 days (2023-24) and 40.40 days (pooled)] whereas the maximum days taken to the first flower i.e., [48.74 days (2022-23), 45.24 days (2023-24) and 46.99 days (pooled)] was found under the effect of treatment T_1 [100% NPK Basal dose of fertilizers] This might be prolonged growth of plants in the presence of nano urea with bio fertilizer and vermicompost. The use of organic fertilizers and bio-fertilizers promoted robust plant growth and increased the production of cytokinins. Similar results have been reported by Hashemabadi *et al*. (2019) [9] in strawberry and Bhatti *et al*. (2023) [2] in guava.

Number of flowers per plant: As per the data regarding the number of flowers per plant (Table 1), the effect of treatment T_4 [75% N (Nano Urea) + 75% PK (Basal) + 250 Kg VC + AZO + PSB] was found best with significantly maximum number of flowers per plant i.e., [23.04(2022-23), 22.03 (2023-24) and 22.54 (pooled)] where as minimum number of flowers per plant i.e., [15.44 (2022-23), 14.76 (2023-24) and 15.10 (pooled)] was found under the effect of treatment T_1 [100% NPK Basal dose of fertilizers] It might be because the application of vermicompost and biofertilizers sped up the growth of inflorescence and leaf number in the autumn, which are positively connected with the quantity of flowers and fruits in the spring. An increase in the number of crowns per flower may have also contributed to the increase in blossoms. Similar observations were also reported by Tripathi *et al.* (2010) [18].

Number of fruits per plant: The results indicating to number of fruit per plant (Table 1) as effected by Integrated Nutrient Management shows that treatment T_4 [75% N (Nano Urea) + 75% PK (Basal) + 250 Kg VC + AZO +

PSB] was found best with significantly maximum number of fruit per plant i.e., [16.16 (2022-23), 16.25 (2023-24) and 16.21 (pooled)] where as least number of fruit per plant i.e., [9.26 (2022-23), 9.31 (2023-24) and 9.29 (pooled)] was observed in treatment T_1 [100% NPK Basal dose of fertilizers]. The availability of nutrients in optimal amount might have led the plant to slow down the time of its senescence (Gupta and Tripathi, 2012) [8], which might have led to increasing fruiting in the plants (Subramani *et al*., 2023) [16].

Percentage of fruit set per plant: The experimental result regarding percentage of fruit per plant (Table 2) indicate that effect of treatment T_4 [75% N (Nano Urea) + 75% PK (Basal) + 250 Kg VC + AZO + PSB] was found best with significantly maximum percentage of fruit set per plant i.e., [70.12% (2022-23), 73.76% (2023-24) and 71.94% (pooled)] where as least percentage of fruit set i.e., [59.98% (2022-23), 63.09% (2023-24) and 61.54% (pooled)] was found under the effect of treatment T_1 [100% NPK Basal dose of fertilizers]. Vermicompost, Azotobacter, and PSB are examples of biofertilizers that have been shown to promote vegetative development, increase leaf quantity and size, and ultimately improve flowering features, which most likely resulted in an increase in fruit setting. The results of this study are consistent with the findings of previous research conducted by Bhatti *et al*. (2023) [2] in guava.

Days to first fruit harvest: Significant differences were observed regarding data indication days taken to first fruit harvest (Table 2) of strawberry. Treatment T_4 [75% N (Nano Urea) + 75% PK (Basal) + 250 Kg VC + AZO + PSB] was found best with significantly least days taken to first fruit harvest i.e., [57.97 (2022-23), 53.68 (2023-24) and 55.83 (pooled)] where as maximum days taken to first fruit harvest i.e., [69.83 (2022-23), 64.66 (2023-24) and 67.25 (pooled)] was found under the effect of treatment T_1 [100% NPK Basal dose of fertilizers]. Nitrogen is responsible for maximum vegetative proliferation of the plant; as a result, during the reproductive phase there may be little bit deficiency of nutrients which leads to delayed ripening of fruits of strawberry (Gupta *et al*., 2023) [7]. The application of bio-fertilizers also led to prolonged supply of nutrients to plant in sustainable manner but most of it is utilized during the reproductive flower development process as a result the dry matter accumulation in fruits takes time (Kumar *et al*., 2018) [11].

Duration of harvesting (days): As per the data regarding duration of harvesting (days) (Table 2), The effect of treatment T_4 [75% N (Nano Urea) + 75% PK (Basal) + 250 Kg VC + AZO + PSB] was found best with significantly maximum duration of harvesting (Days) i.e., [65.12 (2022-23), 67.07 (2023-24) and 66.10 (pooled)] days where as minimum duration of harvesting i.e., [48.45 (2022-23), 49.90 (2023-24) and 49.18(pooled)] was found under the effect of treatment T_1 [100% NPK Basal dose of fertilizers]. The availability of nutrients in optimal amount might have led the plant to slow down the time of its senescence (Gupta and Tripathi, 2012) [8], which might have led to increasing fruiting and duration of harvesting in the plants (Subramani *et al*., 2023) [16].

Table 1: Effect of Integrated nutrient management on days to first flower, Number of flowers per plant, and number of fruits per plant of strawberry (*Fragaria* × *ananassa* Duch.)" cv Winter Dawn

Treatment	Days to first flower			Number of flowers per plant			Number of fruits per plant		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	48.74	45.24	46.99	15.44	14.76	15.10	9.26	9.31	9.29
T_2	48.26	44.79	46.52	16.60	15.87	16.23	10.10	10.16	10.13
T_3	42.46	39.41	40.94	22.54	21.55	22.05	15.62	15.71	15.67
T_4	41.90	38.89	40.40	23.04	22.03	22.54	16.16	16.25	16.21
T_5	44.26	41.08	42.67	20.79	19.88	20.34	13.94	14.02	13.98
T_6	44.82	41.60	43.21	20.24	19.35	19.80	13.40	13.48	13.44
T_7	43.34	40.23	41.79	21.68	20.73	21.21	14.78	14.87	14.82
T_8	45.38	42.12	43.75	19.67	18.81	19.24	12.86	12.93	12.90
T_9	46.88	43.51	45.19	18.10	17.31	17.71	11.48	11.55	11.51
T_{10}	46.37	43.04	44.71	18.71	17.89	18.30	12.02	12.09	12.05
T_{11}	47.42	44.01	45.71	17.48	16.71	17.10	10.94	11.00	10.97
S.E(m) (±)	0.22	0.21	0.15	0.25	0.26	0.18	0.22	0.24	0.16
C.D. @ 5%	0.90	0.85	0.44	1.01	1.05	0.69	0.90	0.97	0.63

Table 2: Effect of Integrated nutrient management on Percentage of fruits set per plant, day to first fruit harvest and Duration of harvesting of strawberry (*Fragaria* × *ananassa* Duch.)" cv Winter Dawn

Treatment	Percentage of fruits set per plant			Day to First Fruit Harvest			Duration of harvesting (Days)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	59.98	63.09	61.54	69.83	64.66	67.25	48.45	49.90	49.18
T_2	60.85	64.01	62.43	68.89	63.79	66.34	49.94	51.44	50.69
T_3	69.29	72.89	71.09	58.91	54.55	56.73	64.00	65.92	64.96
T_4	70.12	73.76	71.94	57.97	53.68	55.83	65.12	67.07	66.10
T_5	67.03	70.51	68.77	61.55	56.99	59.27	58.76	60.52	59.64
T_6	66.20	69.64	67.92	62.49	57.86	60.17	57.64	59.37	58.50
T_7	68.16	71.70	69.93	60.25	55.79	58.02	61.38	63.22	62.30
T_8	65.37	68.76	67.07	63.43	58.73	61.08	56.52	58.22	57.37
T_9	63.41	66.70	65.06	65.69	60.82	63.25	53.68	55.29	54.49
T_{10}	64.24	67.57	65.91	64.75	59.95	62.35	54.80	56.44	55.62
T_{11}	62.58	65.83	64.20	66.63	61.69	64.16	52.56	54.14	53.35
S.E(m) (±)	0.31	0.34	0.23	0.35	0.33	0.24	0.55	0.57	0.40
C.D. @ 5%	1.26	1.36	0.88	1.41	1.33	0.92	2.21	2.31	1.52

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 for boosting flower characteristics. This comprehensive method merges cutting-edge nano-urea technology, optimized basal nutrient application, and the enriching effects of vermicompost and beneficial microorganisms to maximize the benefits. The integration of these components probably created an ideal environment for nutrient absorption, encouraging plant growth and resulting in remarkable vegetative measurements. These findings underscore the significance of tailored nutrient management strategies in boosting plant growth, which can subsequently lead to higher crop yields and greater sustainability in strawberry farming. This approach can be communicated to strawberry farmers to help enhance their production and productivity.

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