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A study on the impact of INM on yield and quality parameter of strawberry (*Fragaria x ananassa*) cv. sweet Charlie under protected cultivation

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Abstract
An experiment was conducted to study the "Impact of Integrated nutrient Management on growth, yield and quality of strawberry (*Fragaria x ananassa*)" at Department of Horticulture, Institute of Agriculture Sciences, Rama university Kanpur the experiment was laid out according to Randomized Blocks Design with eight treatments replicated thrice. The result reveals that the maximum plant height (21.38), plant spread (24.51 cm), number of leaves (18.69), leaf area (82.42cm2), marketable fruit (83.04%), number of harvest (5.87), yield/plant (227.74 g), TSS (9.62oBrix), TSS/acid ratio (14.77), ascorbic acid (61.25 mg/100 gm), were recorded in plants treated with treatment T_8(Integrated Nutrient + Azotobacter + other biofertilizers).The minimum days taken in flowering (54.77 days) and minimum titratable acidity (0.62%) were also recorded in treatment T_8 Azotobacter 50% + Aspergillum 50% + NPK 50%. Considering overall performances, the study revealed that the combined application of Integrated Nutrient could be a good source of plant nutrients for organic strawberry cultivation.

Keywords: Strawberry, sweet Charlie, INM, Azotobacter, PSB, aspergillums, organic

Introduction
The strawberry (*Fragaria x ananassa* Duch.), a member of the Rosaceae family,is a delicious fruit crop known for its bright color, taste and aroma.It is rich in Vitamin C, minerals, and antioxidants, making it an important source of human nutrition. (Kumar *et al.*, 2018) [6]. In India strawberry cultivation is increasing rapidly along with Maharashtra With increasing demand and health awareness, Its cultivation is growing in India. However, Higher dependency on chemical fertilizers harms the soil and enviormental economy. Integrated Nutrient Management (INM) involves the use of both organic and inorganic nutrients along with biofertilizers The cultivation of strawberries is experiencing rapid growth, particularly in regions such as Maharashtra, Himachal Pradesh, and Uttar Pradesh, attributed to the higher economic returns per unit area. To achieve successful strawberry cultivation, it is crucial to manage nutrients effectively. The overuse of chemical fertilizers results in environmental pollution and degradation of soil quality (Chadha *et al.*, 2018) [1]. Integrated Nutrient Management (INM) represents an environmentally friendly approach that integrates chemical fertilizers, organic manures such as FYM and vermicompost, along with biofertilizers like Azotobacter and Azospirillum. This method enhances nutrient availability, promotes soil health, and boosts microbial activity. Numerous studies have indicated that INM not only promotes vegetative growth but also enhances both the yield and quality of fruits. Biofertilizers are vital for nitrogen fixation, hormone production, and enhancing disease resistance. The application of organic amendments improves the soil's water retention capacity and nutrient levels, leading to superior plant performance. Consequently, this study was undertaken to assess the effects of various INM combinations on the growth, yield, and quality of strawberries (cv. Sweet Charlie) under conditions of protected cultivation.

Material and Methods
The study was conducted at the Department of Horticulture, Rama University, Kanpur,

during the Rabi season of 2024-25. Kanpur is located in central region of Uttar Pradesh which lies between 25°30"44" North latitude and 78°32"31" East longitude at an elevation of 285 meters above mean sea level. The experimental design employed was Randomized Block Design (RBD) featuring three replications and nine treatments.

The strawberry variety utilized for this research was Sweet Charlie. Each treatment plot comprised 16 plants with a spacing of 30 × 25 cm on raised beds within a polyhouse. Before transplanting the raised beds are covered with black polysheets to conserve moisture. And planting material of strawberry sweet Charlie were purchased from a private organization Pune by Amazon.

Replication 3

Plot size 2.0×1.2 m

Plant Population 240 plants (10 per treatment and 3 Replication)

The treatment combinations included

T_0: Control

T_1: Recommended dose of NPK

T_2: Azotobacter (100%)

T_3: Azospirillum (100%)

T_4: FYM @ 20 t/ha

T_5: Azotobacter (50%) + Azospirillum (50%)

T_6: Azotobacter (100%) + NPK (50%)

T_7: Azospirillum (100%) + NPK (50%)

T_8: Azotobacter (50%) + Azospirillum (50%) + NPK (50%)

Observations were made on various growth parameters at 30,60,90,120 days after planting growth characters (plant height, spread, number of leaves, leaf area), yield parameters (fruit number, average fruit weight, yield/plant), and quality parameters (TSS, acidity, and ascorbic acid content). The data gathered were analyzed using analysis of variance (ANOVA) at a 5% significance level.

Results and Discussion

The findings revealed notable variations among the treatments concerning all growth, yield, and quality traits. T_8 (Azotobacter 50% + Azospirillum 50% + NPK 50%) surpassed all other treatments.

Growth Parameters

At 120 days post-planting, T_8 achieved the greatest plant height (21.38 cm), followed by T_6 and T_7. The lowest plant height (18.07 cm) was recorded in T_0. Additionally, T_8 exhibited the largest plant spread (24.51 cm) and leaf area (118.2 cm²). The improved growth may be attributed to the balanced nutrient supply and the stimulation of plant hormones by biofertilizers.

Table 1: Impact of INM on Plant Height, Spread, Number of leaves per plant and Leaf Area

Treatments	Plant Height	Number of leaves per plant	Leaf Area	Plant Spread n-s direction
T_0	18.07	16.79	78.49	22.70
T_1	19.45	17.57	79.87	23.14
T_2	20.33	17.53	79.45	22.96
T_3	20.31	17.80	79.60	22.92
T_4	20.39	17.86	79.63	23.78
T_5	20.43	17.93	79.76	23.04
T_6	20.62	18.73	80.74	23.73
T_7	20.86	18.71	80.67	23.37
T_8	21.38	19.16	82.42	24.51

Yield Parameters

Treatment T_8 recorded the highest average marketable percentage (85.12%). the lowest unmarketable percentage (17.38%), fruit yield per plant (227.74g), Number of harvest per plant 5.87, The lowest yield (128.26 g/plant) and number of harvest of plant 4.04 was noted in the control (T_0). The combination of biofertilizers and partial NPK likely enhanced nutrient use efficiency and fruit development.

Table 2: Impact of INM on Yield Parameters:

Treatments	Marketable%	Unmarketable %	Yield per Plant	No. of Harvest
T_0	74.11	28.39	128.26	4.04
T_1	78.39	24.11	178.16	4.95
T_2	77.14	25.36	156.39	4.89
T_3	77.02	25.48	153.19	4.33
T_4	81.07	21.43	206.82	5.06
T_5	77.94	24.56	174.24	4.92
T_6	81.04	21.46	202.94	5.05
T_7	78.62	23.88	187.42	4.96
T_8	85.12	17.38	227.74	5.87
CD	0.13	0.14	0.02	0.42
Sem±	0.05	0.05	0.01	0.15

Quality Parameters

T_8 also demonstrated the best quality metrics with the highest TSS (9.65 °Brix), the lowest acidity (0.79%), and the highest ascorbic acid content (57.1 mg/100 g). This supports the beneficial impact of INM on enhancing fruit flavor and nutritional quality.

The integrated application of NPK with azotobacter and Azospirrilium likely enhanced nutrients availability and assimilation, thus improving overall crop production.

These Findings are consistent with previous research (Negi *et al.*, 2021,) [8], emphasizing the synergistic effects of organic and biological sources with chemical fertilizers.

Table 3: Impact of INM on Quality Parameters:

Treatment	TSS (° Brix)	Acidity (%)	AscorbicAcid (mg\100 g)
T_0	7.88	0.83	56.21
T_1	8.65	0.77	57.89
T_2	8.30	0.79	57.77
T_3	8.23	0.80	57.88
T_4	9.32	0.69	58.98
T_5	8.54	0.78	57.81
T_6	9.25	0.70	58.90
T_7	8.86	0.75	58.03
T_8	-	0.65	61.25
CD	0.74	0.46	0.88
Sem±	0.26	0.16	0.31

Summary

The study titled "Evaluation of Integrated Nutrient Management on Growth, Yield, and Quality of Strawberry (*Fragaria x ananassa* Duch.)" was conducted during 2024-2025 at the Department of Horticulture, Rama University, Kanpur, Uttar Pradesh. The key findings from this research are summarized below.

Plant Height: The tallest plants (21.38 cm) were observed in the treatment combining integrated nutrient management (INM) with Azotobacter and other biofertilizers, while the shortest (18.79 cm) were in the control treatment.

Plant Spread: The widest plant spread (24.51 cm) was recorded in the INM + Azotobacter + other biofertilizers treatment, with the narrowest (21.67 cm) in the control.

Number of Leaves: The highest leaf count (18.69) was achieved in the INM + Azotobacter + other biofertilizers treatment, compared to the lowest (15.67) in the control.

Leaf Area: The largest leaf area (82.42 cm^2) was recorded in the INM + Azotobacter + PSB treatment, while the smallest (78.49 cm^2) was in the control.

Yield per Plant: The highest yield per plant (227.74 g) was observed in the INM + Azotobacter + other biofertilizers treatment, with the lowest (128.26 g) in the control.

Marketable Fruit Percentage: The INM + Azotobacter + other biofertilizers treatment produced the highest percentage of marketable fruit, while the control had the highest percentage of unmarketable fruit.

Number of Harvests: The greatest number of harvests (5.87) was recorded in the INM + Azotobacter + other biofertilizers treatment, compared to the fewest (4.04) in the control.

Total Soluble Solids (TSS): The highest TSS (9.62 °Brix) was found in the Azospirillum + Azotobacter treatment, while the lowest (7.88 °Brix) was in the control.

TSS/Acid Ratio: The highest TSS/acid ratio (14.77) was observed in the INM + Azotobacter + other biofertilizers treatment, with the lowest (9.14) in the control.

Ascorbic Acid: The highest ascorbic acid content (61.25 mg/100 g) was recorded in the INM + Azotobacter + organic fertilizers treatment, while the lowest (56.21 mg/100 g) was in the control.

Conclusion

The results of this study indicate that the application of various organic nutrient sources significantly enhanced vegetative growth, yield, and quality parameters of strawberry crops. The treatment combining integrated nutrient management with Azotobacter and other biofertilizers yielded the best outcomes, including maximum plant height (21.38 cm), plant spread (24.51 cm), leaf count (18.69), leaf area (82.42 cm^2), marketable fruit percentage (83.04%), yield per plant (227.74 g), number of harvests (5.87), TSS (9.62 °Brix), TSS/acid ratio (14.77), ascorbic acid content (61.25 mg/100 g), and minimum titratable acidity (0.62%). Therefore, integrating INM with Azotobacter and other biofertilizers in strawberry cultivation can significantly improve yield and economic returns.

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