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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH CHARACTERISTICS OF CUCUMBER (*Cucumis sativus* L.) UNDER NATURALLY VENTILATED POLYHOUSE

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ABSTRACT

Cucumber (*Cucumis sativus* L.) is an important high-value vegetable crop that requires balanced nutrient management to achieve optimum growth and productivity under protected cultivation. In this context, integrated nutrient management (INM) has emerged as a sustainable approach for improving nutrient-use efficiency and supporting crop growth. The present investigation was conducted during Rabi 2025-26 to evaluate the effect of integrated nutrient management on the growth characteristics of cucumber grown under a naturally ventilated polyhouse. The experiment was laid out in a Randomised block design comprising eight treatments with three replications. Different combinations of the recommended dose of fertilisers, vermicompost, spent mushroom compost, microbial consortium and vermiwash were evaluated. Growth parameters, namely vine length, number of leaves, leaf area, chlorophyll content (SPAD) and dry matter production, were assessed at different growth stages and significant differences among the integrated nutrient management treatments were observed for all the growth parameters. The results revealed that T_6 (75% RDF + vermicompost @ 5 t ha^{-1} + microbial consortium (*Azotobacter* + PSB + KSB + ZnSB) @ 5 kg ha^{-1} + vermiwash @ 10 ml lit^{-1} spray application twice at 20 & 40 DAS) recorded the highest vine length (45.4, 175.2 and 282.5 cm), number of leaves (9.3, 37.7 and 47.8 plant^{-1}), leaf area (1565, 14390 and 17909 cm² plant^{-1}), chlorophyll content (38.4, 42.8 and 39.9 SPAD) and dry matter production (9.8, 115.1 and 130.3 g plant^{-1}) at 30 DAS, 60 DAS and harvest, respectively, and remained statistically on par with T_7 (75% RDF + spent mushroom compost @ 5 t ha^{-1} +microbial consortium (*Azotobacter* + PSB + KSB + ZnSB) @ 5 kg ha^{-1}) and T_5 (75% RDF + vermicompost @ 2.5 t ha^{-1} +microbial consortium (*Azotobacter* + PSB + KSB + ZnSB) @ 5 kg ha^{-1} + vermiwash @ 10 ml lit^{-1} spray application twice at 20 & 40 DAS). In contrast, T_2 (50% RDF + vermicompost @ 2.5 t ha^{-1} + microbial consortium (*Azotobacter* + PSB+ KSB + ZnSB) @ 5 kg ha^{-1} + vermiwash @ 10 ml lit^{-1} spray application twice at 20 & 40 DAS) recorded the lowest values for all the growth parameters. The findings suggest that the integrated application of 75% RDF, vermicompost, microbial consortium and vermiwash can be recommended as an effective nutrient management strategy for promoting vegetative growth of cucumber under protected cultivation.

Keywords **:** Integrated nutrient management, cucumber, naturally ventilated polyhouse, vermicompost, microbial consortium.

Introduction

Cucumber (*Cucumis sativus* L.) is one of the most widely cultivated vegetable crops belonging to the family Cucurbitaceae and is grown extensively across tropical and subtropical regions. The crop is highly valued for its refreshing taste, high moisture content, vitamins, minerals and dietary fibre, making it an important component of a healthy diet (Singh *et al*., 2018). Besides its nutritional value, cucumber has gained considerable commercial importance because of its short crop duration, high yield potential and continuous market demand. Its ability to produce quick returns has made it a preferred crop among vegetable growers under both open-field and protected cultivation systems (Subedi *et al*., 2024).

With the increasing demand for quality vegetables, protected cultivation has emerged as an efficient production technology that enables higher productivity and better resource-use efficiency (Ameta *et al*., 2019). Among the different protected cultivation systems, naturally ventilated polyhouses have become increasingly popular because they are relatively affordable and require lower operational costs than fully controlled and automated greenhouses. These structures create a favourable growing environment that supports better crop growth and productivity, making them particularly suitable for commercial cultivation of high-value vegetable crops such as cucumber (Arshad *et al*., 2014).

Despite its high productivity, cucumber is a nutrient-demanding crop owing to its rapid vegetative growth, continuous flowering and prolonged fruiting habit. Maintaining an adequate and balanced nutrient supply throughout the crop growth period is therefore essential for achieving optimum growth and productivity (Ghayal *et al*., 2018). Under protected cultivation, where the same soil is often used for repeated cropping, continuous dependence on inorganic fertilisers alone may gradually reduce soil organic matter, impair beneficial microbial activity and lower nutrient-use efficiency. Over time, such practices can affect soil health and limit the sustainability of crop production (Chatterjee and Bandyopadhyay, 2014).

Integrated Nutrient Management, which integrates inorganic fertilisers with organic nutrient sources and beneficial microorganisms, has become an effective approach for sustaining crop productivity while maintaining soil health. The combined use of these nutrient sources helps provide balanced nutrition throughout the crop growth period, improves nutrient-use efficiency and creates favourable conditions for healthy plant growth. (Choudhary *et al.*, 2013) Organic amendments contribute to improved soil structure and organic matter, whereas beneficial microorganisms enhance nutrient availability and uptake by stimulating biological activity in the soil (Kumar *et al.*, 2017). Such an integrated approach is particularly important under protected cultivation, where repeated cropping can gradually reduce soil fertility. By maintaining soil health and reducing excessive dependence on chemical fertilisers, INM supports sustained crop productivity and the long-term sustainability of naturally ventilated polyhouse cultivation (Kharga *et al*., 2019).

Therefore, the present investigation was undertaken to evaluate the effect of integrated nutrient management on the growth characteristics of cucumber (*Cucumis sativus* L.) grown under a naturally ventilated polyhouse. The study aimed to identify an effective and sustainable nutrient management strategy for improving vegetative growth under protected cultivation.

Materials and Methods

The present investigation was conducted during *Rabi* 2025-26 under naturally ventilated polyhouse at the Horticulture Garden, College of Agriculture, Professor Jayashankar Telangana Agricultural University (PJTAU), Rajendranagar, Hyderabad, Telangana, India. The experimental site is situated at 17°19′12.93″ N latitude and 78°24′58.13″ E longitude, at an altitude of 545 m above mean sea level, and falls under the Southern Telangana Agro-climatic Zone. The study was carried out using the parthenocarpic cucumber (*Cucumis sativus* L.) F_1 hybrid 'Multistar RZ', which is well suited for protected cultivation because of its vigorous growth, multiple fruiting habit and excellent fruit quality.

Before sowing, composite soil samples were collected from the 0-30 cm soil profile layer and analysed using standard analytical procedures to determine the initial soil characteristics of the experimental site. The initial soil properties and the methods used to estimate them are presented in Table-1. The recommended fertiliser dose of 150:100:100 kg $N:P_2O_5:K_2O$ ha^{-1} was adopted for the crop, with urea, single superphosphate and muriate of potash serving as the sources of nitrogen, phosphorus and potassium, respectively.

The experiment was laid out in a Randomized Block Design (RBD) comprising eight nutrient management treatments with three replications and the treatment details are presented in Table-2. The experimental area inside the naturally ventilated polyhouse was prepared by thoroughly tilling the soil with a power tiller, after which raised beds measuring 5.2 × 1.0 m were prepared. Cucumber seeds were sown on 27th October 2025 at a spacing of 40 × 40 cm, with one seed placed in each hill. Vermicompost, spent mushroom compost and the microbial consortium were incorporated into the soil 15 days before sowing as per the treatment schedule. The recommended dose of fertilisers was applied in two splits, with half of the nitrogen and the entire quantities of phosphorus and potassium applied at sowing, while the remaining nitrogen was applied at 30 DAS. Vermiwash was sprayed twice, at 20 and 40 DAS, in the treatments where it was included. The crop was irrigated through a drip irrigation system and all intercultural operations, including trellising, weeding and plant protection measures, were carried out uniformly in all plots throughout the experiment.

Growth observations were recorded at 30 DAS, 60 DAS and at harvest. For non-destructive observations, five healthy plants were randomly selected and tagged in each treatment and the same plants were used throughout the study. Plant height was measured from the base of the stem to the growing tip and expressed in centimetres. The number of functional leaves plant^{-1} was recorded manually, while chlorophyll content was measured using a SPAD-502 chlorophyll meter. Leaf area and dry matter production were estimated through destructive sampling, wherein three representative plants from each treatment were randomly selected at each sampling stage. Leaf area was measured immediately after sampling using an LI-300 portable leaf area meter (LI-COR, USA) fitted with an LI-3050A transparent conveyor attachment and expressed as cm² plant^{-1}. The harvested plant samples were shade dried, followed by oven drying at 60°C until a constant weight was obtained. The oven-dry weight was used to estimate dry matter production and expressed as g plant^{-1}.

The data generated from the experiment were subjected to analysis of variance appropriate for a Randomised block design. The significance of treatment effects was tested at the 5% probability level and the treatment means were compared using the Critical Difference (CD). The corresponding Standard Error of Mean [SE(m) ±] was also computed following the procedure described by Gomez and Gomez (1984).

Table 1 : Initial soil properties of the experimental field

Characteristics	Value	Method adopted
A. Physical properties		
Sand (%)	69.2	Bouyoucus hydrometer method (Piper, 1966)
Silt (%)	5.2	
Clay (%)	25.6	
Soil texture	Sandy clay loam	
B. Chemical properties		
Soil pH (1:2.5 soil-water suspension)	8.10	pH meter (Jackson, 1967)
EC (dS m^{-1} at 25ºC)	0.67	EC meter (Jackson, 1967)
Organic carbon (%)	0.35	Chromic acid wet digestion method (Walkley and Black’s 1934)
Available Nitrogen (kg ha^{-1})	220.3	Alkaline potassium permanganate method using KELPLUS SUPRA LX – analyser (Subbaiah and Asija., 1956)
Available Phosphorus (kg ha^{-1})	20.2	Olsen’s method for extraction and Ascorbic acid method for estimation by Spectrophotometer (Olsen’s *et al.*,1954)
Available Potassium (kg ha^{-1})	293.5	Neutral normal ammonium acetate method using ELICO CL361 Flame photometer (Jackson, 1967)
C. Biological properties		
Dehydrogenase (µg TPF g^{-1} 24 h^{-1})	12.8	(Casida *et al*., 1964)
Urease (µg N g^{-1} 24 h^{-1})	18.7	(Tabatabai and Bremner, 1972)

Table 2 : Details of the experimental treatments

T_1	100% RDF (150:100:100 kg N: P_2O_5: K_2O ha^{-1})
T_2	50% RDF + vermicompost @ 2.5 t ha^{-1} + microbial consortium (*Azotobacter* + PSB+ KSB + ZnSB) @ 5 kg ha^{-1} + vermiwash @ 10 ml lit^{-1} spray application twice at 20 & 40 DAS
T_3	50% RDF + vermicompost @ 5 t ha^{-1} + microbial consortium (*Azotobacter* + PSB + KSB + ZnSB) @ 5 kg ha^{-1} + vermiwash @ 10 ml lit^{-1} spray application twice at 20 & 40 DAS
T_4	50 % RDF + spent Mushroom compost @ 5 t ha^{-1} + microbial consortium (*Azotobacter* + PSB + KSB + ZnSB) @ 5 kg ha^{-1}
T_5	75% RDF + vermicompost @ 2.5 t ha^{-1} +microbial consortium (*Azotobacter* + PSB + KSB + ZnSB) @ 5 kg ha^{-1} + vermiwash @ 10 ml lit^{-1} spray application twice at 20 & 40 DAS
T_6	75% RDF + vermicompost @ 5 t ha^{-1} + microbial consortium (*Azotobacter* + PSB + KSB + ZnSB) @ 5 kg ha^{-1} + vermiwash @ 10 ml lit^{-1} spray application twice at 20 & 40 DAS
T_7	75% RDF + spent mushroom compost @ 5 t ha^{-1} +microbial consortium (*Azotobacter* + PSB + KSB + ZnSB) @ 5 kg ha^{-1}
T_8	100% RDF + microbial consortium (*Azotobacter* + PSB + KSB + ZnSB) @ 5 kg ha^{-1}

Results and Discussion

Vine length (cm)

Integrated nutrient management treatments significantly influenced vine length of cucumber at all the growth stages as depicted in Figure-1. Among different treatments, T_6 consistently recorded the highest vine length and remained statistically on par with T_7 and T_5, whereas T_2 recorded the lowest vine length throughout the crop growth period. Under T_6, vine length increased progressively from 45.4 cm at 30 DAS to 175.2 cm at 60 DAS and 282.5 cm at harvest, compared with 34.5, 140.0 and 232.0 cm, respectively, under T_2. The corresponding vine lengths recorded under the statistically comparable treatments were 44.2, 170.9 and 272.8 cm in T_7 and 42.8, 166.0 and 265.7 cm in T_5 at 30 DAS, 60 DAS and harvest, respectively.

The greater vine length recorded under T_6 may be attributed to the balanced nutrient supply from the integrated application of inorganic fertilisers, vermicompost, microbial consortium and vermiwash, which promoted vigorous vegetative growth. Improved nutrient availability likely enhanced the chlorophyll synthesis and photosynthetic efficiency, thereby resulting in greater assimilate production to support active vegetative growth. Furthermore, the enhanced availability of nutrients together with the activity of beneficial microorganisms and growth-promoting compounds present in vermiwash may have stimulated cell division and cell elongation, leading to increased vine elongation. Comparable results have been reported by Priya *et al*. (2026), Dekhane *et al*. (2024) and Patel *et al*. (2020), who also observed improved vegetative growth under integrated nutrient management practices.

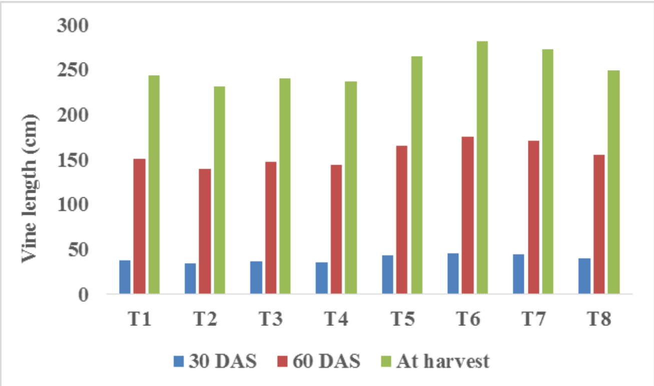

Fig. 1 : Effect of integrated nutrient management on vine length of cucumber.

Number of leaves plant^{-1}

Integrated nutrient management treatments significantly influenced the number of leaves plant^{-1} at 60 DAS and harvest, whereas the differences at 30 DAS were non-significant, as shown in Fig. 2. At 60 DAS and harvest, T_6 recorded the highest number of leaves plant^{-1} and was statistically on par with T_7 and T_5. Under T_6, the number of leaves increased from 9.3 at 30 DAS to 37.7 at 60 DAS and 47.8 at harvest, compared with 8.2, 31.4 and 38.7, respectively, under T_2. The corresponding values for T_7 were 9.1, 36.2 and 45.9, while T_5 recorded 8.9, 35.2 and 43.8 leaves plant^{-1} at 30 DAS, 60 DAS and harvest, respectively.

The higher number of leaves plant^{-1} recorded under T_6 may be attributed to the complementary effect of inorganic fertilisers, vermicompost, microbial consortium and vermiwash, which ensured a balanced and sustained supply of nutrients throughout the crop growth period. Adequate nutrient availability, particularly nitrogen, likely enhanced chlorophyll synthesis and photosynthetic activity, providing sufficient assimilates to support continuous leaf initiation and expansion. In addition, the beneficial microorganisms may have improved nutrient solubilization and uptake, while vermiwash supplied growth-promoting substances that favoured the development of a healthy canopy, resulting in a greater number of functional leaves plant^{-1}. A similar improvement in leaf production under integrated nutrient management has also been documented by Kumar *et al*. (2023), Singh *et al*. (2020) and Kanaujia and Daniel (2016)

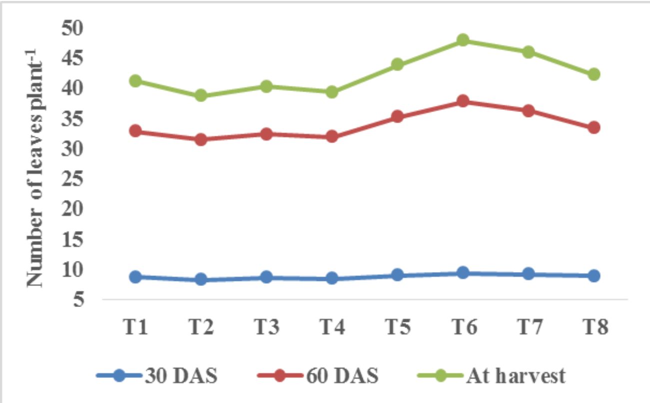

Fig. 2 : Effect of integrated nutrient management on number of leaves plant^{-1} of cucumber.

Leaf area (cm^2 plant^{-1})

Integrated nutrient management treatments significantly influenced the leaf area of cucumber at all the growth stages, as observed in Figure-3. Among the treatments, T₆ consistently recorded the highest leaf area and remained statistically on par with T_7 and T_5 throughout the crop growth period, whereas T_2 recorded the lowest values. Under T_6, leaf area increased progressively from 1565 cm² plant^{-1} at 30 DAS to 14390 cm² plant^{-1} at 60 DAS and 17909 cm² plant^{-1} at harvest, compared with 1055, 9622 and 12994 cm² plant^{-1}, respectively, under T_2. The corresponding leaf area recorded under the statistically comparable treatments was 1495, 13980 and 17689 cm² plant^{-1} in T_7 and 1415, 13215 and 16995 cm² plant^{-1} in T_5 at 30 DAS, 60 DAS and harvest, respectively.

The higher leaf area recorded under T_6 may be due to the integrated supply of nutrients from inorganic and organic sources, together with the beneficial effects of the microbial consortium and vermiwash. This favourable nutritional environment likely encouraged continuous leaf expansion and the development of a broader canopy, enabling the plants to intercept more light and efficiently convert it into photosynthates for sustained growth. The present findings are consistent with those of Muthukannan *et al*. (2024), Palve *et al*. (2024), and Yassen *et al*. (2020), who reported improved leaf area under integrated nutrient management practices.

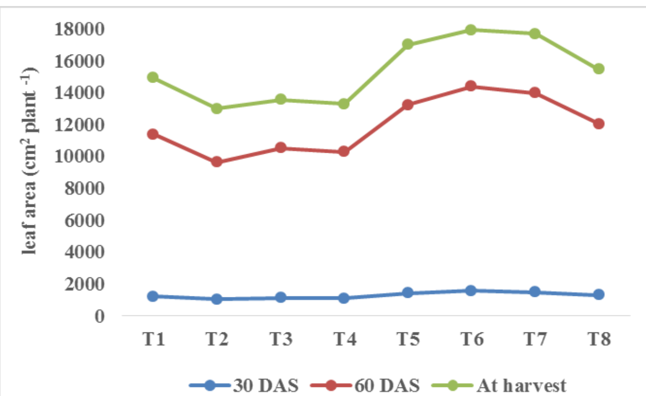

Fig. 3 : Effect of integrated nutrient management on leaf area of cucumber.

Chlorophyll content (SPAD units)

Integrated nutrient management treatments significantly influenced the chlorophyll content of cucumber at all the growth stages, as shown in Figure-4. Irrespective of the treatments, chlorophyll content increased from 30 DAS to 60 DAS and declined slightly at harvest. Among the treatments, T_6 consistently recorded the highest SPAD values and remained statistically on par with T_7 and T_5 throughout the crop growth period, whereas T_2 recorded the lowest chlorophyll content. Under T_6, chlorophyll content increased from 38.4 at 30 DAS to 42.8 at 60 DAS before declining slightly to 39.9 at harvest, compared with 29.4, 32.0 and 30.8, respectively, under T_2. The corresponding SPAD values recorded under the statistically comparable treatments were 36.3, 41.2 and 38.2 in T_7 and 35.4, 39.2 and 36.7 in T_5 at 30 DAS, 60 DAS and harvest, respectively.

The improved chlorophyll content recorded under T_6 could be attributed to the integrated application of inorganic fertilisers, vermicompost, microbial consortium and vermiwash, which ensured an adequate supply of nutrients required for chlorophyll formation. Enhanced nutrient uptake, particularly of nitrogen, along with the beneficial activity of soil microorganisms, likely helped maintain higher chlorophyll levels and improved photosynthetic efficiency during crop growth. Consequently, plants receiving integrated nutrient management maintained higher SPAD values than those supplied with inorganic fertilisers alone. Similar trends have also been reported by Gowda *et al*. (2022) Bahuguna and Pal (2020) and Gokul *et al*. (2020)

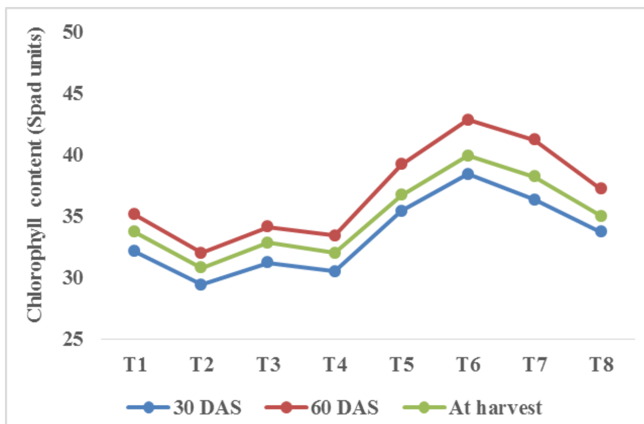

Fig. 4 : Effect of integrated nutrient management on chlorophyll content of cucumber.

Dry matter production (g plant^{-1})

Integrated nutrient management treatments significantly influenced dry matter production of cucumber at all the growth stages, as depicted in Figure-5. Across all treatments, dry matter production increased progressively from 30 DAS to harvest. Among the treatments, T_6 consistently recorded the highest dry matter production and remained statistically on par with T_7 and T_5 throughout the crop growth period, while T_2 recorded the lowest values. Under T_6, dry matter production increased from 9.8 g plant^{-1} at 30 DAS to 115.1 g plant^{-1} at 60 DAS and 130.3 g plant^{-1} at harvest, compared with 6.3, 87.1 and 100.2 g plant^{-1}, respectively, under T_2. The corresponding values recorded under T_7 were 9.3, 109.1 and 125.4 g plant^{-1}, while T_5 recorded 8.9, 104.6 and 119.7 g plant^{-1} at 30 DAS, 60 DAS and harvest, respectively.

The higher dry matter production recorded under T_6 may be attributed to improved nutrient acquisition resulting from the combined application of inorganic fertilisers, organic manures and beneficial microorganisms. Enhanced photosynthetic activity and efficient partitioning of assimilates to developing plant parts likely contributed to greater biomass accumulation throughout the crop growth period. A similar increase in dry matter production under integrated nutrient management has also been reported by Yogaraju *et al*. (2019) and Mahapatra *et al*. (2018).

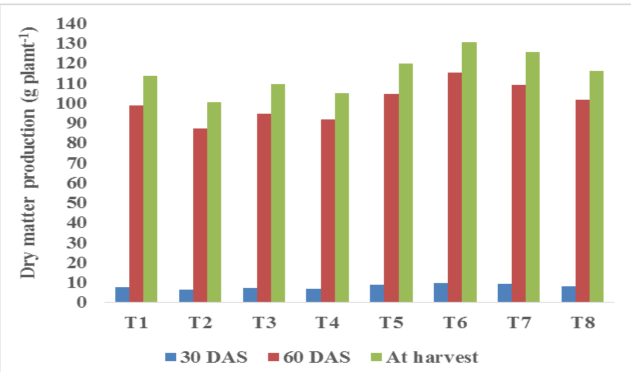

Fig. 5 : Effect of integrated nutrient management on dry matter production of cucumber.

Conclusion

The results of the present study clearly demonstrated that integrated nutrient management significantly improved the vegetative growth of cucumber grown under a naturally ventilated polyhouse. Among the different integrated nutrient management practices, the application of 75% RDF + vermicompost @ 5 t ha^{-1} + microbial consortium (*Azotobacter* + PSB + KSB + ZnSB) @ 5 kg ha^{-1} + vermiwash @ 10 ml lit^{-1} spray application twice at 20 & 40 DAS (T_6) consistently recorded superior vine length, number of leaves, leaf area, chlorophyll content and dry matter production, while remaining statistically on par with T_7 (75% RDF + spent mushroom compost @ 5 t ha^{-1} +microbial consortium (*Azotobacter* + PSB + KSB + ZnSB) @ 5 kg ha^{-1}) and T_5 (75% RDF + vermicompost @ 2.5 t ha^{-1} +microbial consortium (*Azotobacter* + PSB + KSB + ZnSB) @ 5 kg ha^{-1} + vermiwash @ 10 ml lit^{-1} spray application twice at 20 & 40 DAS) for all the growth parameters. Based on the findings of the present investigation, the integrated application of inorganic fertilisers, organic nutrient sources and beneficial microorganisms may be adopted as an effective and sustainable nutrient management approach for improving the vegetative growth of cucumber under naturally ventilated polyhouse conditions.

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