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Impact of different sources of nutrition and Plant Growth Promoting Rhizobacteria (PGPR) on growth and yield of cucumber (*Cucumis sativus* L.) Under naturally ventilated polyhouse

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Abstract
An experiment was conducted during *Late kharif* 2025 at College of Agriculture, KSNUAHS, Shivamogga, to study the impact of different sources of nutrition and plant growth promoting rhizobacteria (PGPR) on growth and yield of cucumber under naturally ventilated polyhouse conditions. The experiment was laid out in Randomized Completely Block Design (RCBD) design by using KPCH-1 (F_1 Hybrid) with eleven treatments and replicated thrice. The results revealed that application of 80% RDN + 20% through Vermicompost on N equivalent basis + PGPR consortia (T_9) was recorded significantly higher growth parameters like maximum vine length (361.67 cm), vine girth (12.13 mm), number of nodes per vine (19.28), number of leaves per vine (37.73), internodal length (12.25 cm) and total number of branches per vine (11.97). Whereas, yield related traits such as like fruit length (15.35 cm), fruit width (4.33 cm), fruit weight (191.67 grams), number of fruits per vine (9.65), yield per vine (1.85 kg), yield per plot (36.96 kg), yield per 1000 m^2 (30.47 q) and yield per hectare (304.73 q) are also recorded as higher in T_9 treatment under polyhouse condition.

Keywords: Cucumber, Vermicompost, Areca husk compost and PGPR (Plant Growth Promoting Rhizobacteria) consortia

Introduction

Cucumber (*Cucumis sativus* L.) is an important crop belonging to Cucurbitaceae family, which is native to India. It has the diploid chromosome number of 2n=14 is a prominent and largely cultivated vegetable crop, locally known as "sauthekayi" in Kannada and extensively cultivated throughout Karnataka. It is commonly grown throughout the India in open condition as well as in green houses. Cucurbits, encompassing 118 genera and 825 species, are grown in various tropical and subtropical countries worldwide (Gopalkrishnan, 2007) [5]. Cucumber considered one of the oldest cultivated vegetable crops, with evidence of its cultivation in India dating back over 3,000 years (Tekale *et al*, 2014) [18]. It is a thermophilic plant that is sensitive to frost and grows best at temperatures above 20 °C. In Asia, cucumber ranks as the fourth most important vegetable crop, following tomato, cabbage and onion (Singh *et al*, 2017) [16]. The tender fruits of cucumber are a rich source of carbohydrates, vitamins, minerals and contain a high percentage of dietary fiber and water.

Cucumber fruits have many health benefits. They give a cooling effect to the body, help prevent constipation, and are useful in managing jaundice and indigestion. The fruit has ascorbic acid and caffeic acid, which help in reducing skin irritation. People commonly eat immature cucumbers as salad or in pickles. They are mixed with curd to make a dish called 'Rayata'. Around the world, cucumbers are mostly grown for salad use. As people understand their health benefits more, the demand is rising. Cucumber also has a natural compound called cucurbitacin. Among the advanced techniques developed to boost vegetable crop productivity, protected cultivation. Such as in greenhouses, glasshouses, or polyhouses has clearly demonstrated immense potential to significantly increase yields.

Among various crop-growing methods, the proper use of plant nutrients is a key factor in achieving higher crop yields. Most farmers commonly use inorganic fertilizers such as NPK due to the quick availability to plants. However, the continuous and indiscriminate use of synthetic fertilizers over time gradually leads to the depletion of soil fertility. The soil where cucumber is cultivated require moderate to high nutrient levels so as to achieve high yields. Poor soil fertility leads to misshapen and bitter fruits, which are usually rejected by consumers, ultimately lowering the farmer's income (Majeed *et al*). Therefore, there is an urgent need to direct research towards the efficient and judicious use of available nutrient resources to enhance production, productivity and profitability per unit area, to satisfy the rising demand for food and resources driven by a continuously growing population. Special emphasis should be placed on the management of natural resources such as vermicompost, areca husk compost and bio-fertilizers, all of which are organic in nature.

Application of organic fertilizer increase cucumber production vitamin C, protein and decrease nitrate accumulation in cucumber fruit (Sood *et al*). Vermicompost helps to improve soil aeration, enriches soil with micro-organisms, increase water holding capacity of soil, enhance germination, plant growth and crop yield. Bio-fertilizers are substances containing beneficial living microorganisms that, when applied to seeds, plant surfaces, or soil, colonize the root zone or internal tissues of plants and enhance their growth by improving the availability of essential nutrients. Bio-fertilizers and organic fertilizers play a crucial role in enhancing nutrient availability for improved crop yields. Bio-fertilizers are environmentally friendly; help prevent soil pollution and serve as a low-cost and safe source of plant nutrition. These beneficial bacteria support the growth and development of crops by aiding in the synthesis of auxins, vitamins, growth-promoting substances, and antibiotics.

The use of organic, inorganic and biofertilizers has recently played a significant role in enhancing crop yields. The core principle of Integrated Nutrient Management (INM) is to maintain or improve soil fertility and ensure a balanced nutrient supply over the long term, aiming to optimize crop production by effectively utilizing all available sources including chemical fertilizers, organic manures and biological inputs. Additionally, protected cultivation technology offers the potential for year-round production of high-value, quality vegetable crops. Influence of various organic, inorganic and biofertilizer in vegetable crops. Therefore, keeping in view all the perspectives of protected cultivation, the present study was designed to evaluate the effect of Nutrients and biofertilizers on growth and yield of cucumber.

Materials and Methods

The experiment was conducted in a Naturally Ventilated Polyhouse (NVPH) at the Department of Horticulture, College of Agriculture, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, during the year 2025. The soil used for the field experiment was red sandy loam with a pH range of 5.76. The plot size measured 4.2 m by 0.9 m, with a spacing of 60 cm by 30 cm between plants. The study was designed as a Randomized Completely Block Design (RCBD) with three replications, involving eleven treatments: Absolute control (T_1), 100% Recommended Dose of Fertilizers (RDF) at 100:60:60 kg NPK per hectare (T_2), 80% Recommended Dose of Nitrogen (RDN) (T_3), 75% RDN (T_4), 70% RDN (T_5), 80% RDN + 20% N through Areca husk compost and PGPR consortia (T_6), 75% RDN + 25% N through Areca husk compost and PGPR consortia (T_7), 70% RDN + 30% N through Areca husk compost and PGPR consortia (T_8), 80% RDN + 20% N through vermicompost and PGPR consortia (T_9), 75% RDN + 25% N from vermicompost and PGPR consortia (T_{10}) and 70% RDN + 30% N through vermicompost and PGPR consortia (T_{11}). (Treatments T_6 to T_{11} were based on nitrogen equivalence for vermicompost and Areca husk compost applications). The cucumber hybrid variety used for the study was KPCH 1 (Kerala Parthenocarpic Hybrid).

'KPCH-1' is a parthenocarpic F_1 hybrid developed from a cross between parthenocarpic and gynoecious lines and relased by Department of Vegetable Science, College of Agriculture, Vellanikkara. The seeds were sown in field at a spacing of 60 × 30 cm. The organic manures like Liquid biofertilizers (*Azotobacter*, Phosphorus Solubilizing Bacteria (PSB), Potassium Solubilizing Bacteria (KSB), Zinc Solubilizing Bacteria (ZnSB), Silicon Solubilizing Bacteria (SiSB), *Trichoderma*, *Mycorrhiza*) were used along with Areca Husk compost and vermicompost and directly applied in experimental plots as per the treatments suggested prior to two weeks of seed sowing.

Nitrogen, phosphorus, and potassium were applied using urea, di-ammonium phosphate (DAP) and muriate of potash (MOP), respectively. Half of the nitrogen dose, along with the full doses of phosphorus and potassium, was applied at the time of seed sowing in the experimental plots. The remaining half of the nitrogen was split into two equal applications, given during the vining stage and at flower initiation. All cultural practices were carried out regularly according to the crop's needs throughout the study period. Data recorded for various parameters were statistically analyzed using analysis of variance (ANOVA), with the standard error of means (S.Em ±) and critical difference at 5% significance level, following the method described by Gomez and Gomez (1984) [4].

Results and Discussion

Impact of different sources of nutrition and PGPR on Growth parameters

The data presented in Table 1 indicate significant improvements in vegetative growth parameters when various combinations of organic and inorganic nutrient sources were applied. These parameters include vine length (cm), vine girth (mm), number of nodes per vine, number of leaves per vine, internodal length (cm) and total number of branches per vine.

1. Vine length and Internodal length

The maximum vine length (361.67 cm) and internodal length (12.25 cm) was observed in the treatment T_9 (80% RDN + 20% through VC on N equivalent basis + PGPR consortia), as compared with T_2 (330.50 cm) and (11.02 cm), which was statistically on par with T_{10} (359.27 cm) and (12.05 cm), T_6 (354.13 cm) and (11.73 cm), T_7 (349.93 cm) and (11.52 cm), T_{11} (343.57 cm) and (11.22 cm), while the minimum vine length (240.47 cm) and (9.76 cm) were observed in Absolute control (T_1). It might be due to the application of high doses of nitrogenous fertilizers led to increased nutrient uptake. An adequate nitrogen supply to the vines enhanced the synthesis of amino acids, building blocks of proteins, which in turn stimulated cell division and cell elongation in the apical regions. The additional supply of vermicompost in INM improved physical properties of soil, availability of NPK in soil and well-developed root system resulting in better absorption of nutrients and water, due to which vine length might be increased. Biofertilizers used in INM might have helped in production of growth promoting substances leading to increase in vine length. These findings are in line with Thriveni *et al.* (2015) [19], Kanaujia and Daniel (2016) [6] and Singh *et al.* (2018) [15].

2. Vine girth

Similarly, the plant which received 80% RDN + 20% through Vermicompost on N equivalent basis + PGPR consortia (T_9) had significantly maximum vine girth (12.13 mm), as compared with T_2 (10.63 mm), which was statistically on par with T_{10} (11.94 mm), T_6 (11.81 mm), T_7 (11.76 mm) and T_{11} (11.44 mm). Whereas, minimum vine girth of (8.84 mm) was recorded in Absolute control (T_1). The increase in vine girth positively contributes to plant strength, which is essential for effective trailing. This enhancement may be attributed to improved vegetative growth influenced by nitrogen, a key component of nucleic acids that supports vital metabolic processes. Similar findings are in line with Nayak and Mahapatra (2016) [12].

3. Number of nodes and leaves per vine

Maximum number of nodes and leaves per vine (19.28 and 37.73) was observed in the treatment T_9 (80% RDN + 20% through VC on N equivalent basis + PGPR consortia), as compared with T_2 (16.53 and 32.33), which was statistically on par with T_{10} (18.93 and 36.20), T_6 (80 (18.15 and 35.07), T_7 (18.04 and 34.45) and T_{11} (17.78 and 34.13), while the minimum number of nodes and leaves per vine (13.68 and 17.27) were observed in Absolute control (T_1). Leaves are the primary sites of photosynthesis; therefore, the number of functional leaves per plant is a crucial factor influencing crop growth and productivity. An increase in leaf number may result from the effective action of biofertilizers, which release bioactive compounds that function similarly to growth regulators. When used in combination with vermicompost and inorganic fertilizers, these biofertilizers can significantly enhance leaf development. Here, vermicompost provides micronutrients (Zn, Fe and Mn) supporting leaf expansion. These findings are in line with Kanaujia and Daniel (2016) [6].

4. Total number of branches per vine

The application of 80% RDN + 20% through VC on N equivalent basis + PGPR consortia (T_9) has resulted in significantly maximum number of branches per vine (11.97) as compared to T_2 (10.04) and which was on par with the treatment T_{10} (11.65), T_6 (11.59), T_7 (11.48) and T_{11} (10.53), while the minimum number of branches per vine was observed in absolute control (7.31). This improvement could be attributed to the combined use of organic and inorganic nutrient sources, which may act as a tonic or stimulant for plants, enhancing nutrient assimilation. Organic manures enriched with biofertilizers often contain various plant growth-promoting rhizobacteria (PGPR) that can support plant development through nitrogen fixation and the production of growth hormones. These findings are in line with Bindiya *et al.* (2014) [2], Sahu *et al.* (2020) [14] and Malo *et al.* (2022) [11].

Table 1: Impact of different sources of nutrition and PGPR on growth characters of cucumber

Treatments	Vine length (cm)	Vine girth (mm)	No. of nodes per vine	No. of leaves per vine	Internodal length (cm)	Total number of branches per vine
T_1	240.47	8.84	13.68	17.27	9.76	7.31
T_2	330.50	10.63	16.53	32.33	11.02	10.04
T_3	307.07	9.96	15.84	29.87	10.64	9.12
T_4	299.50	9.72	15.22	28.93	10.35	8.94
T_5	283.64	9.08	14.66	26.47	10.19	8.43
T_6	354.13	11.81	18.15	35.07	11.73	11.59
T_7	349.93	11.76	18.04	34.45	11.52	11.48
T_8	338.40	10.83	16.80	33.52	11.07	10.32
T_9	361.67	12.13	19.28	37.73	12.25	11.97
T_{10}	359.27	11.94	18.93	36.20	12.05	11.65
T_{11}	343.57	11.44	17.78	34.13	11.22	10.53
S. Em ±	7.49	0.33	0.61	1.26	0.39	0.52
C.D@ 5%	22.29	0.96	1.81	3.73	1.16	1.54

Note: Treatment details are provided in materials and methods

Impact of different sources of nutrition and PGPR on yield and its attributing parameter.

Yield and yield-related traits such as number of fruits per vine, fruit length (cm), fruit diameter (cm), fruit weight (g), yield per vine (kg), yield per plot (kg) and yield per hectare (q ha^{-1}) showed statistically significant differences across all treatments involving integrated nutrient management whether organic, inorganic, or their combinations during the study period (Table 2).

1. Number of fruits per vine

The highest number of fruits per vine (9.65), was observed in plants supplied with a dose of 80% RDN + 20% through VC on N equivalent basis + PGPR consortia (T_9), as compared with T_2 (8.85), which was on par with T_{10} (9.35), T_6 (9.30), T_7 (9.10) and T_{11} (9.06). Whereas, the Absolute control had lowest number of fruits per vine (6.68) in T_1. Increased fruit number per cucumber vine is likely due to improved photosynthetic activity and nutrient uptake under Integrated Nutrient Management (INM). Biofertilizers improved rhizospheric conditions and macronutrient absorption, supporting chlorophyll synthesis and metabolic functions. Combined application of organic and inorganic fertilizers ensured sustained nutrient release, while phosphobacteria and Azospirillum enhanced phosphorus availability and hormonal balance, respectively. These synergistic effects improved soil health, microbial activity and reproductive growth, resulting in increased fruit set per vine. The results are confirmed with the findings given by

Eifediyi and Remison (2010) [3], Anjanappa *et al*. (2012) [1] and Sudeshna *et al.* (2019).

2. Fruit length

The highest length of fruit (15.35 cm) was observed in plants supplied with a dose of 80% RDN + 20% through VC on N equivalent basis + PGPR consortia (T_9), as compared with T_2 (13.70 cm), which was on par with T_{10} (15.10 cm), T_6 (15.10 cm), T_7 (14.60 cm) and T_{11} (14.45 cm). Whereas, the Absolute control had lowest length of fruit (11.85 cm) in T_1. The combined application of organic, inorganic and bio-fertilizer sources positively influenced cucumber fruit length by enhancing nutrient availability, photosynthesis and assimilate translocation. Improved chlorophyll synthesis and metabolic activity under optimal nutrient conditions led to increased carbohydrate production and allocation to developing fruits. This efficient source-to-sink relationship supported cell elongation and fruit development. Additionally, providing nutrients at critical growth stages enhanced vegetative vigor, resulting in fruits that were longer and broader. The findings are confirmed by Malo *et al*. (2022) [11] in cucumber and Saeed *et al*. (2015) [13].

3. Fruit diameter

The highest fruit diameter (4.33 cm) was observed in plants supplied with a dose of 80% RDN + 20% through VC on N equivalent basis + PGPR consortia (T_9), with compared to T_2 (3.25 cm), which was comparable with T_{10} (4.29 cm), T_6 (4.24 cm), T_7 (4.21 cm) and T_{11} (4.18 cm). Whereas, the Absolute control had lowest fruit diameter (2.54 cm) were observed in T_1. The increase in cucumber fruit diameter may be linked to enhance assimilate production and efficient translocation to developing fruits, facilitated by optimized nutrient management and plant spacing. Proper alignment of plant nutrition and geometry improved light interception, nutrient uptake, and overall physiological performance, supporting better reproductive growth and fruit enlargement. The findings are confirmed by Kumar *et al*. (2017) and Malo *et al*. (2022) [11].

4. Fruit weight

The highest fruit weight (191.67 g) was observed in plants supplied with a dose of 80% RDN + 20% through VC on N equivalent basis + PGPR consortia (T_9), as compared with T_2 (173.32 g), which was on par with T_{10} (188.87 g), T_6 (186.40 g), T_7 (184.93 g) and T_{11} (179.73 g). Whereas, the Absolute control had lowest fruit weight (142.93 g) were observed in T_1. The rise in average cucumber fruit weight is likely due to enhanced phosphorus availability and the steady nutrient release provided by organic manures, especially vermicompost. These inputs enhanced nutrient uptake, root development and microbial activity, creating favourable conditions for biomass accumulation. Additionally, efficient assimilate production and translocation to developing fruits further supported the gain in fruit mass. The findings are confirmed by Singh *et al.* (2018) [15] and Malo *et al*. (2022) [11].

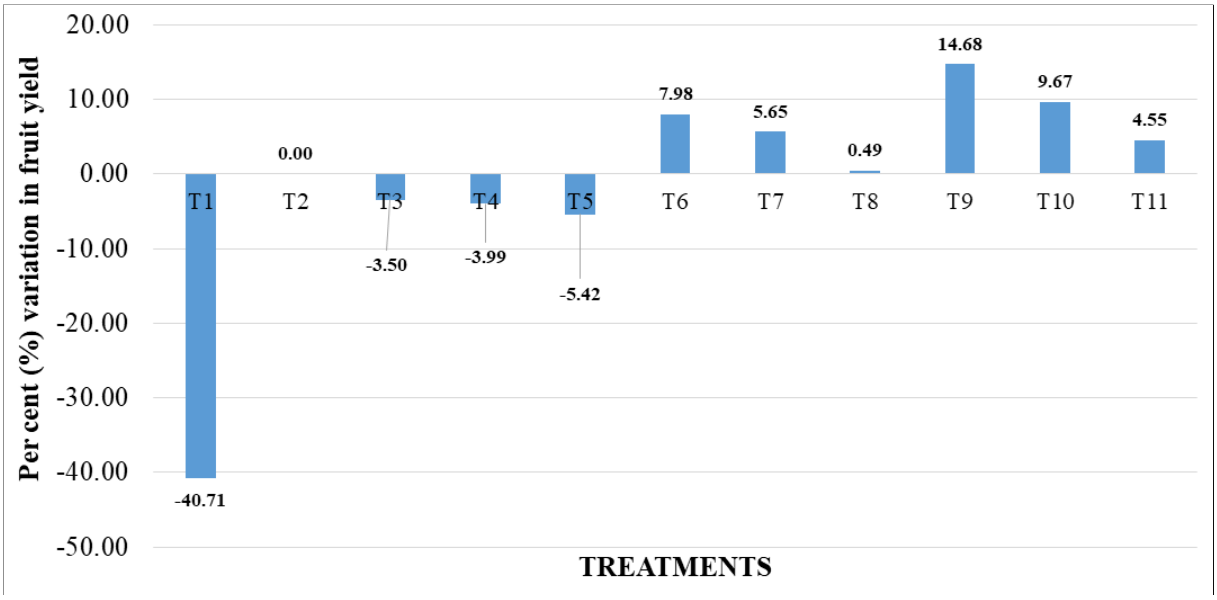
5. Fruit yield per vine, Fruit yield per plot, Fruit yield per 1000 m^2 and Fruit yield per hectare

Among all the treatments, maximum fruit yield per vine (1.85 kg), fruit yield per plot (36.93 kg), fruit yield per 1000 m^2 (30.47 q) and fruit yield per hectare (304.73 q ha^{-1}) was examined under the treatment (T_9) 80% RDN + 20% through VC on N equivalent basis + PGPR consortia, as compared with T_2 fruit yield per vine (1.67 kg), fruit yield per plot (32.20 kg), fruit yield per 1000 m^2 (26.57 q) and fruit yield per hectare (265.73 q ha^{-1}), which was on par with the treatment T_{10} fruit yield per vine (1.77 kg), fruit yield per plot (35.32 kg), fruit yield per 1000 m^2 (29.14 q) and fruit yield per hectare (291.43 q ha^{-1}), T_6 fruit yield per vine (1.74 kg), fruit yield per plot (34.78 kg), fruit yield per 1000 m^2 (28.69 q) and fruit yield per hectare (286.97 q ha^{-1}), T_7 fruit yield per vine (1.70 kg), fruit yield per plot (34.03 kg), fruit yield per 1000 m^2 (28.07 q) and fruit yield per hectare (280.77 q ha^{-1}) and T_{11} fruit yield per vine (1.68 kg), fruit yield per plot (33.67 kg), fruit yield per 1000 m^2 (27.78 q) and fruit yield per hectare (277.80 q ha^{-1}). However, fruit yield per vine (0.95 kg), fruit yield per plot (19.09 kg), fruit yield per 1000 m^2 (15.75 q) and fruit yield per hectare (157.50 q ha^{-1}) were found minimum under the Absolute control-T_1. Application of 80 per cent RDN + 20 per cent through Vermicompost on N equivalent basis + PGPR consortia (T_9) resulted in increasing the fruit yield to an extent of 14.68 per cent, respectively over application of 100 per cent RDN. (Fig.1). The results clearly demonstrate the importance of combining inorganic and organic nutrients with bio-fertilizers. The immediate nutrient availability from inorganic fertilizers, a balanced carbon-to-nitrogen (C/N) ratio and the production of auxins, growth-promoting substances and antifungal compounds through Azotobacter inoculation, along with the solubilization of phosphates by phosphate-solubilizing bacteria (PSB), likely contributed to the increased fruit yield observed in the T_9 treatment. Moreover, improvements in growth and yield-related traits may also have played a significant role in this outcome. Similar findings are line with Sudeshna *et al.* (2019) and Malo *et al.* (2022) [11].

Table 2: Impact of different sources of nutrition and PGPR on yield characters of cucumber

Treatments	No. of fruits per vine	Fruit length (cm)	Fruit Diameter (cm)	Fruit weight (g)	Fruit yield per vine (kg)	Fruit yield per plot (kg)	Fruit yield per 1000 m^2 (q)	Fruit yield per hectare (q)
T_1	6.68	11.85	2.54	142.93	0.95	19.09	15.75	157.50
T_2	8.85	13.70	3.25	173.32	1.61	32.20	26.57	265.73
T_3	8.59	13.10	3.09	160.98	1.47	29.31	24.18	241.82
T_4	8.52	12.80	2.97	155.51	1.44	28.71	23.69	236.90
T_5	8.49	12.55	2.73	151.08	1.39	27.89	23.01	230.15
T_6	9.30	15.10	4.24	186.40	1.74	34.78	28.69	286.97
T_7	9.10	14.60	4.21	184.93	1.70	34.03	28.07	280.77
T_8	8.89	14.30	3.56	176.01	1.62	32.37	26.70	267.07
T_9	9.65	15.35	4.33	191.67	1.85	36.93	30.47	304.73
T_{10}	9.35	15.10	4.29	188.87	1.77	35.32	29.14	291.43
T_{11}	9.06	14.45	4.18	179.73	1.68	33.67	27.78	277.80
S. Em ±	0.24	0.31	0.10	5.13	0.07	1.58	0.95	10.91
C.D@ 5%	0.71	0.92	0.31	15.14	0.21	4.69	2.82	32.68

Note: Treatment details are provided in materials and methods



Note: Treatment details are provided in materials and methods

Fig 1: Per cent (%) variation in fruit yield per 1000 m^2 over 100 per cent alone application of RDF as influenced by impact of different sources of nutrition and PGPR

Conclusion

From the current study, it can be concluded that, application of 80% RDN + 20% through Vermicompost on N equivalent basis + PGPR consortia is most effective way to improve growth and yield of cucumber. Application of 80 per cent RDN + 20 per cent through Vermicompost on N equivalent basis + PGPR consortia resulted in increase of fruit yield to an extent of 14.68% and 20% reduction of Nitrogen usage over application of 100% RDN. Integrating inorganic fertilizers with organic manures and biofertilizers enhances productivity and soil health, supporting sustainable yields and ecosystem balance. This approach is recommended for vegetable growers to maintain soil fertility without harming soil health.

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