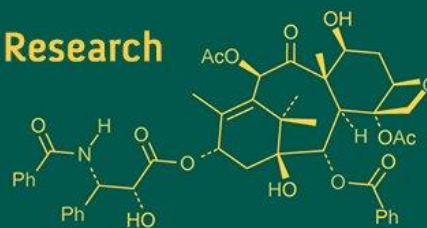
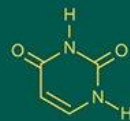


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Integrated nutrient management for enhanced growth, yield and economics of Brinjal (*Solanum melongena* L.) cv. white long F₁

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Abstract

A field experiment was conducted to study the effect of integrated nutrient management (INM) on the growth, yield, quality and economics of Brinjal (*Solanum melongena* L.). Ten treatments comprising different combinations of inorganic NPK fertilizers, farmyard manure (FYM) and poultry manure (PM) were evaluated under a randomized block design. The treatments ranged from an unfertilized control (T₁) to various proportions of chemical NPK supplemented with 25-50% nitrogen through FYM and/or poultry manure (T₂-T₈), and purely organic treatments with FYM and poultry manure combinations (T₉-T₁₀). Results revealed that treatment T₃ (75% NPK + 25% N through Poultry Manure) recorded the highest plant height (82.60 cm at 120 DAT), stem girth (3.53 cm), number of fruits plant⁻¹ (21.69), fruit girth (9.39 cm), fruit yield (1.03 kg plant⁻¹; 23.49 t ha⁻¹), carbohydrate content (3.92%) and protein content (1.82%) of the fruit, along with the earliest 50% flowering (47.45 days) and maximum number of flowers plant⁻¹ (88.36). Treatment T₂ (75% NPK + 25% N through FYM) closely followed T₃ in most growth, yield and quality parameters and recorded the highest benefit:cost ratio (2.87) with a net return of ₹1,28,623.70 ha⁻¹, making it the most economically efficient treatment. Purely organic treatments (T₉ and T₁₀) yielded significantly lower fruit yield (10.47 and 13.85 t ha⁻¹, respectively) and were economically unviable, with T₉ recording negative net returns (₹ -1,769.61 ha⁻¹). The unfertilized control recorded the lowest values for all parameters evaluated. The study conclusively demonstrates that integrated use of 75% recommended NPK with 25% nitrogen through poultry manure or FYM significantly enhances the productivity, nutritional quality and profitability of Brinjal cultivation over sole chemical or sole organic nutrient management approaches.

Keywords: Brinjal, *Solanum melongena* L., integrated nutrient management, poultry manure, FYM, NPK, fruit yield, benefit: cost ratio

1. Introduction

Brinjal (*Solanum melongena* L.), known locally as baingan, is one of the most widely cultivated and consumed vegetables in India. It belongs to the family Solanaceae (2n = 24), is believed to have originated in the Indo-Burma region, and is now grown extensively across tropical and subtropical climates worldwide.

Brinjal is valued for its nutritional, medicinal, and economic importance. Rich in vitamins, minerals, and bioactive compounds such as phenolics and antioxidants, Brinjal contributes significantly to human health and dietary diversification (Saha *et al*, 2023) [42]. The crop is adaptable to a wide range of environmental conditions, suitable for both irrigated and rain-fed cultivation, and valued for its nutritional and medicinal properties, including vitamins A, B6, C, and D, dietary fibre, potassium, and bioactive compounds with anti-inflammatory and antioxidant potential (Kumar *et al*, 2021; Rani *et al*, 2022) [14, 15, 20].

Nutrient management is a critical factor influencing crop growth and productivity. The conventional reliance on chemical fertilizers, although effective in achieving immediate yield gains, often leads to nutrient imbalance, soil degradation, and environmental pollution (Sharma *et al*, 2019) [47]. Integrated Nutrient Management (INM) has emerged as a sustainable strategy that combines organic manures, biofertilizers, and inorganic fertilizers in an optimized manner, enhancing nutrient use efficiency, soil fertility, and crop performance

(Singh *et al*, 2021) [57, 58]. INM has been reported to improve vegetative growth, flowering, fruiting, and quality attributes in solanaceous crops, including Brinjal, by providing balanced nutrition and improving soil microbial activity (Kumar *et al*, 2022; Verma and Choudhary, 2021) [16, 19, 20, 65].

Vegetative growth parameters such as plant height, leaf area, and stem girth, along with reproductive traits like flower initiation and fruit set, are strongly influenced by nutrient availability (Patel *et al*, 2020) [33, 35]. Furthermore, the integration of organic and inorganic nutrient sources not only enhances yield but also improves fruit quality parameters, including firmness, total soluble solids, and antioxidant content, which are important for marketability and consumer acceptance (Rani *et al*, 2019) [40]. Despite the recognized benefits of INM, crop responses are often influenced by local soil conditions, climate, and the nature of inputs, making site-specific evaluation essential.

India is the second-largest producer of Brinjal after China, with a cultivated area of approximately 730.4 thousand hectares, production of 12,800.8 thousand MT, and productivity of 17.5 MT ha⁻¹ (Horticultural Statistics at a Glance, 2019) [12]. Despite this, average productivity remains low due in part to suboptimal nutrient management. Brinjal is a heavy feeder that responds well to fertilization, and improving its nutrition can dramatically enhance both yield and quality (Patel *et al*, 2020) [33, 35].

The intensive use of synthetic chemical fertilizers, while initially boosting yields, has progressively degraded soil health reducing organic carbon, disrupting microbial communities, and lowering nutrient use efficiency (Sharma *et al*, 2019) [47]. Conversely, sole reliance on organic manures is limited by their relatively low nutrient content and slow mineralization rates. Integrated Nutrient Management (INM), which combines judicious use of inorganic fertilizers with organic manures and biofertilizers, offers a sustainable pathway to optimize crop nutrition while preserving soil health (Singh *et al*, 2021; Kumar *et al*, 2022) [57, 58, 16, 19, 20].

Farm Yard Manure (FYM) a well-decomposed mixture of cattle dung, urine, and crop residues containing approximately 0.5% N, 0.2% P₂O₅, and 0.5% K₂O and Poultry Manure (PM), which has a higher and more readily available nutrient content than FYM, represent practical organic inputs widely accessible to Indian farmers. The FAO-advocated Integrated Plant Nutrient Supply System (IPNS) recommends combining such sources to mitigate environmental harm and sustain productivity (FAO, 2020; Verma and Choudhary, 2021) [65, 7].

In addition to enhancing vegetative growth, integrated nutrient management has been shown to positively influence reproductive traits such as flowering, fruit set, and fruit retention, which are critical determinants of final yield (Kumar *et al*, 2022; Rani *et al*, 2022) [16, 19, 20]. Balanced nutrition through the combined application of organic and inorganic sources improves nutrient availability during key growth stages, resulting in higher fruit weight, increased total soluble solids, and improved antioxidant content (Patel *et al*, 2020; Verma and Choudhary, 2021) [33, 35, 65]. Moreover, INM has been reported to enhance soil microbial activity, which supports nutrient cycling and sustains crop productivity over multiple seasons (Singh *et al*, 2021; Sharma *et al*, 2021) [57, 58, 51, 53]. Despite these demonstrated benefits, region-specific studies evaluating the effects of

INM on both yield and quality traits of Brinjal under subtropical conditions are limited, particularly for hybrid cultivars such as White Long F1. Understanding these effects is crucial for developing location-specific nutrient management strategies that maximize economic returns while maintaining soil health.

Considering the importance of sustainable vegetable production and the potential of INM to enhance both yield and quality, this study aims to assess the effect of integrated nutrient management on the growth, flowering, yield, and quality of Brinjal (*Solanum melongena* L.). The findings are expected to inform practical nutrient management strategies that optimize productivity while maintaining soil health and environmental sustainability. Despite considerable research on INM in vegetable crops, region-specific information for Brinjal cultivation under the agro-climatic conditions of Uttar Pradesh remains limited. The present investigation was therefore designed to evaluate the effect of varying combinations of inorganic fertilizers, FYM and Poultry Manure on the growth, flowering, yield, quality and economics of Brinjal cv. White Long F1 under the subtropical conditions of Uttar Pradesh.

2. Materials and Methods

2.1 Experimental site and period

The field experiment was conducted during the rabi season of 2024-25 at the Main Experiment Station of Horticulture, National Post Graduate College, Barahalganj, Gorakhpur, Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur, Uttar Pradesh, India, which experiences a subtropical climate with a monsoon-driven rainy season from mid-June to early October and a dry season from mid-October to early June, with mean maximum and minimum temperatures ranging from 18.5-29.7°C and 6.7-14.0°C, seasonal rainfall of 64.2 m, and mean relative humidity of 59-95% during the crop growing season. Prior to the experiment, composite soil samples collected from five random sites at 0-30 cm depth revealed the soil to be sandy loam in texture, slightly alkaline in reaction, with EC within safe limits, low in organic carbon and available nitrogen, and medium in available phosphorus and potassium, representative of smallholder fields across the Indo-Gangetic plains. The experiment was laid out in a Randomized Block Design (RBD) with three replications and ten treatments on a gross plot of 4.0 m × 3.0 m and net plot of 3.6 m × 2.4 m, with crop spacing of 60 × 60 cm row-to-row and 45 × 45 cm plant-to-plant, where the recommended dose of 100:60:30 kg N:P₂O₅:K₂O ha⁻¹ was applied through Urea, SSP, and MOP, with full P and K and half N as basal dressing and the remaining N top-dressed in two equal splits at 30 and 45 DAT, while FYM and PM were incorporated before transplanting as per treatment allocation across ten treatments viz. (T₁) Control, (T₂) 75% NPK + 25% N through FYM, (T₃) 75% NPK + 25% N through Poultry Manure (PM), (T₄) 50% NPK + 50% N through FYM, (T₅) 50% NPK + 50% N through Poultry manure, (T₆) 50% NPK + 25% N through FYM + 25% through PM, (T₇) 25% NPK + 50% N through FYM + 25% through PM, (T₈) 25% NPK + 25% N through FYM + 50% N through PM, (T₉) 75% N through FYM + 25% N through PM and (T₁₀) 75% N through PM + 25% N through FYM. Seeds of Brinjal cv. White Long F1 at 700 g ha⁻¹ were sown in raised nursery beds in November 2024, and four-week-old seedlings (4-5 leaves; 6-8 cm height) were transplanted in December 2024,

established with daily irrigation for six days, followed by irrigations at 15-day intervals, weeding at 15 and 30 DAT, standard plant protection measures, and harvesting commencing at 60 DAT at tender maturity over twelve pickings at 6-8 day intervals.

2.5 Observations recorded

2.5.1 Growth parameters

Plant height (cm), number of branches plant⁻¹, stem girth (cm) measured at 5 cm above ground level, and fresh/dry weight of plants (g) were recorded at 30, 60, 90 and 120 DAT from five randomly tagged plants per plot.

2.5.2 Flowering characters

Days to 50% flowering (from transplanting) and number of flowers plant⁻¹ were recorded per plot.

2.5.3 Yield attributes and yield

Number of fruits plant⁻¹, fruit length (cm), fruit girth (cm), fruit weight (g), fruit yield per plant (kg), and total fruit yield (t ha⁻¹) were recorded from all pickings of the net plot.

2.5.4 Qualitative characters

Carbohydrate content (%) was estimated colorimetrically. Protein content (%) was calculated by multiplying nitrogen content by 6.25 (Fahey *et al.*, 2019) [6].

2.5.5 Economic analysis

Cost of cultivation, gross returns, net returns (₹ ha⁻¹), and Benefit:Cost (B:C) ratio were computed based on prevailing market prices of inputs and produce (₹ 8,000 t⁻¹ for Brinjal fruit).

$$\text{Benefit: Cost ratio} = \frac{\text{Net returns (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

2.6 Statistical analysis

Data were subjected to analysis of variance (ANOVA) as per RBD using the method of Cochran and Cox (1963) [4]. Treatment means were compared at the 5% level of significance ($P = 0.05$) using the Least Significant Difference (CD) test.

3. Results and Discussion

3.1 Plant height (cm)

Among the various growth parameters studied, plant height served as a sensitive indicator of the overall physiological response of Brinjal to different nutrient management strategies. Observations recorded at four intervals 30, 60, 90 and 120 days after transplanting (DAT) consistently showed significant variation across treatments (Table 1).

At the earliest observation (30 DAT), plants under T₃ (75% NPK + 25% N through Poultry Manure) attained a mean height of 26.26 cm, the tallest among all treatments, while the unfertilised control (T₁) lagged considerably at 15.06 cm. This pattern was sustained over the entire crop duration. By 120 DAT, T₃ recorded a final plant height of 82.60 cm, with T₂ (75% NPK + 25% N through FYM) and T₅ (50% NPK + 50% N through Poultry Manure) closely following at 75.61 cm and 75.56 cm, respectively. In contrast, the sole organic treatments (T₉ and T₁₀) despite being nutrient-supplemented showed a noticeably weaker growth response, attaining 60.71 cm and 66.58 cm, respectively, at 120 DAT. The marked advantage of T₃ and T₂ over other treatments can be linked to the complementary nature of combined

organic-inorganic nutrition. Inorganic NPK provides immediately available macronutrients that drive early vegetative establishment, while poultry manure with its lower C:N ratio relative to FYM mineralises rapidly, contributing to a more sustained and steady nitrogen supply. This dual mechanism promotes active meristematic cell division and internodal elongation, both of which translate into greater plant height. Mistry *et al.*, (2025) [26] noted a similar growth advantage in Brinjal when inorganic fertilizers were supplemented with organic manures, attributing it to enhanced root-level nutrient acquisition. Senthilkumar *et al.* (2024) [45] likewise found that joint application of NPK and FYM improved plant height, an effect they linked to heightened soil microbial activity and consequent improvement in nutrient bioavailability. The slower growth observed in Tand Taligns with what Patel *et al.* (2023) [32] described as a limitation of sole organic management: the inability to match the nitrogen release rate demanded by high-yielding, nutrientintensive crops like Brinjal, especially during the early growth window.

3.2 Number of branches plant⁻¹

Branching is a key structural trait in Brinjal as it determines the surface area available for photosynthesis, the number of nodes that bear flowers and, ultimately, the fruit load a plant can sustain. Data presented in Table.1 depict a steady increase in branches per plant from 30 DAT through 120 DAT, with treatment effects becoming more pronounced as the crop matured.

T₃ produced the greatest number of branches at 30 DAT (4.75), while T₅ (50% NPK + 50% N through Poultry Manure) edged ahead by 120 DAT (18.35), with T₂ (17.95) and T₃ (17.94) following in close succession. Notably, T₉ (75% N through FYM + 25% N through PM) recorded a relatively higher late-season branch count (17.60) compared to its early-season performance, suggesting a delayed but meaningful contribution of slow-releasing organic nitrogen to axillary bud development at later crop growth stages. Control plants remained at the bottom throughout, with only 13.73 branches at 120 DAT.

The promotion of branching under treatments combining inorganic and organic nutrient sources can be understood through the role of nitrogen in cytokinin biosynthesis. Cytokinins, synthesised primarily in root tips under adequate nitrogen supply, are translocated to shoot meristems where they overcome apical dominance and stimulate lateral bud activation. Phosphorus, supplied alongside nitrogen in INM treatments, further supports this process by enhancing energy availability for shoot differentiation. Maji *et al.* (2023) [21] documented higher axillary branch production in Brinjal when inorganic fertilizers were used alongside organic amendments, and attributed it to precisely these hormonal and nutritional interactions. Paramasivan *et al.* (2024) [31] similarly recorded more branches per plant in Brinjal under STCR-based NPK supplemented with vermicompost. The lateseason surge in branching under T₅, with its higher poultry manure proportion, corroborates findings by Osei *et al.* (2021) [30] in eggplant, where higher organic inputs appeared to exert a more sustained influence on vegetative development over the cropping season.

3.3 Stem girth (cm)

Stem girth, a measure of the mechanical robustness of the plant, was consistently and significantly influenced by the

nutrient management treatments across all observation intervals (Table 1). A sturdier stem is important not only for supporting the weight of fruits but also for efficient transport of water and assimilates between roots and aerial parts.

At 30 DAT, T₂, T₃ and T₄ each recorded the highest stem girth (0.71 cm), a threefold improvement over the control (T₁: 0.51 cm). At 120 DAT, T₃ retained its lead with 3.53 cm, followed by T₂ (3.22 cm) and T₆ (3.17 cm). The control recorded the narrowest stems (2.20 cm), while the purely organic treatments T₉ and T₁₀ showed intermediate but inferior values (2.43 and 2.98 cm, respectively) compared to INM combinations. The thicker stem observed under T₃ and T₂ reflects enhanced secondary growth driven by improved availability of nitrogen, phosphorus and potassium. Nitrogen supports active cambial cell division, phosphorus is integral to cell membrane integrity and energy transfer, and potassium maintains cell turgor all of which are essential for the expansion and lignification of stem tissue. Poultry manure in T₃, beyond its macronutrient contribution, also supplies trace elements that serve as cofactors in cell wall biosynthesis enzymes. These physiological explanations find support in the experimental evidence of Bana *et al.* (2022), who recorded significantly thicker stems in Brinjal under integrated NPK-organic manure treatments. Subramanian and Tamilmani (2023) ^[60] also reported superior stem girth in Brinjal when chemical nitrogen was partially replaced by organic sources, noting that such combinations ensure a more balanced and temporally stable nutrient profile throughout crop development.

3.4 Fresh and dry weight of plant (g)

Fresh and dry weight measurements at 30 and 100 DAT

offer a quantitative indication of the plant's biomass accumulation capacity, reflecting the net outcome of carbon assimilation and nutrient-driven growth (Table 1).

T₃ led in fresh weight at both time points, recording 193.71 g at 30 DAT and 902.37 g at 100 DAT. T₂ and T₅ followed in that order. The control registered the lowest values (125.68 g and 559.88 g), well below all nutrient-supplemented treatments. Dry weight trends mirrored those of fresh weight, with T₃ achieving 17.78 g and 49.61 g at 30 and 100 DAT, respectively, and T₁ remaining at the bottom (10.60 g and 32.06 g). Treatments with higher organic nitrogen substitution (T₇, T₈, T₉) consistently recorded lower biomass than those with a greater inorganic fraction, particularly at 30 DAT, indicating a lag in nutrient availability from slow-mineralising organic sources in the early crop phase.

Greater biomass production in T₃ and T₂ stems from a convergence of favourable factors: enhanced nitrogen drives photosynthetic pigment production and enzymatic activity, while improved soil physical properties better aggregation, porosity and water-holding capacity resulting from organic manure addition support deeper and more extensive root exploration. This synergy between soil chemistry and biology allows plants to access a wider pool of nutrients and moisture, amplifying carbon fixation and dry matter accumulation. Paramasivan *et al.* (2024) ^[31] reported significantly greater fresh and dry matter yield in Brinjal under combined STCR-NPK and vermicompost treatments, attributing the result to improved rhizosphere conditions. Batabyal *et al.* (2022) observed a similar pattern in eggplant, where combined organic-inorganic management outperformed either approach used alone for biomass production.

Table 1: Plant height, Number of branches, Stem girth, Fresh weight of plant and Dry weight of plant (g) of Brinjal at periodic intervals as influenced by INM treatments

Treatments	Plant height (cm)				Number of branches plant-1				Stem girth (cm)				Fresh weight of plant (g)		Dry weight of plant (g)	
	30 DAT	60 DAT	90 DAT	30 DAT	30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	100 DAT	30 DAT	100 DAT
T ₁	15.06	30.57	48.66	54.73	2.67	7.18	11.75	13.73	0.51	0.99	1.58	2.2	125.68	559.88	10.6	32.06
T ₂	22.39	44.06	68.57	75.61	4.22	9.32	14.16	17.95	0.71	1.25	2.23	3.22	190.15	889.85	16.26	46.55
T ₃	26.26	47.04	76.1	82.6	4.75	9.66	14.99	17.94	0.71	1.23	2.2	3.53	193.71	902.37	17.78	49.61
T ₄	21.83	41.37	64.64	71.87	3.99	8.75	13.45	17.31	0.71	1.08	2.08	3	173.66	836.91	15.19	45.35
T ₅	22.18	42.25	66.68	75.56	4.03	8.91	14.18	18.35	0.66	1.22	2.17	3.12	175.93	856.31	15.16	44.88
T ₆	20.05	40.72	63.04	68.89	3.49	7.94	12.52	16.32	0.67	1.18	2.12	3.17	167.45	784.3	14.33	44.35
T ₇	18.58	37.69	56.42	64.78	3.17	8.33	13.2	16.19	0.64	1.06	2.11	2.66	156.25	750.75	13.52	38.8
T ₈	17.92	36.97	56.89	62.91	3.22	7.94	13.4	16.49	0.64	1.1	2.06	2.73	158.09	714.39	13.24	38.57
T ₉	17.44	36.14	56.39	60.71	2.98	7.95	12.66	17.6	0.57	1.06	2.01	2.43	149.72	690.77	13.07	37
T ₁₀	19.58	39.5	59.25	66.58	3.54	8.55	13.19	17.03	0.65	1.03	2.05	2.98	167.88	758.76	12.79	38.22
SEm±	0.38	1.08	1.78	2.37	0.14	0.21	0.28	0.3	0.65	1.03	2.05	2.98	3.07	14.46	0.38	1.26
CD at 5%	1.15	3.24	5.37	7.12	0.44	0.65	0.87	0.91	0.04	0.09	0.14	0.19	9.23	43.44	1.16	3.78

3.5 Flowering characteristics

The transition from vegetative to reproductive growth, indicated by days to 50% flowering, and the intensity of flowering, measured as number of flowers per plant, are pivotal determinants of fruit yield potential. Data on these parameters are presented in Table 2.

T₃ reached 50% flowering earliest, at 47.45 days, followed by T₅ (48.57 days) and T₂ (49.61 days). The control (T₁) required 56.61 days, a delay of over nine days relative to T₃. For flower number, T₃ again led with 88.36 flowers plant⁻¹, compared to just 30.07 in T₁. Purely organic treatments T₉

and T₁₀ recorded 36.40 and 53.42 flowers respectively substantially fewer than any INM treatment pointing to the role of inorganic nutrients in accelerating floral induction. Earlier and more prolific flowering under INM treatments is rooted in the improved nutritional status of the plant. A well-nourished plant accumulates sufficient photosynthates and building blocks in vegetative organs to trigger the hormonal shift toward reproductive development ahead of nutrient-deficient plants. Phosphorus, especially, is known to stimulate floral initiation through its involvement in nucleic acid synthesis and signal transduction, while

potassium enhances assimilate loading into the phloem for transport to developing floral buds. Poultry manure also introduces trace amounts of boron and zinc, micronutrients directly implicated in pollen tube growth and floral retention. Kumar *et al.* (2022) [20] reported that INM treatments with organic manures significantly enhanced flower count in Brinjal, an observation also made by Paramasivan *et al.* (2024) [31] under field conditions in Alfisols. The delayed flowering under Tand Tlikely reflects slower early-season nitrogen mineralisation from organic sources, which postpones the physiological readiness for reproductive transition a constraint previously highlighted by Sujatha *et al.* (2021) [61] in similar cropping systems.

3.6 Yield attributes

The yield attributes of Brinjal fruits plant⁻¹, fruit length, fruit girth and individual fruit weight represent the proximate drivers of final productivity. Data on these parameters are presented in Table 2.

T₃ recorded the highest fruits per plant (21.69) and fruit girth (9.39 cm). T₂ produced the longest fruits (9.42 cm), closely matched by T₃ (9.27 cm) and T₅ (9.26 cm). Individual fruit weight was greatest in T₆ (54.15 g) and T₄ (53.99 g), though differences among T₂, T₃, T₄, T₅ and T₆ were largely within the CD range (2.12 g), indicating statistical equivalence for this parameter. Control plants recorded the lowest values across all yield attributes.

The strong performance of T₃ in terms of fruit number and girth is a direct downstream consequence of the superior flowering documented in Section 4.5. Calcium and boron, both of which are supplied in appreciable amounts through poultry manure, play decisive roles in cell wall formation and fruit set, reducing the incidence of flower drop and premature fruit abortion. The somewhat higher individual fruit weight in T₆ compared to T₃ may reflect a source-sink effect: with fewer fruits competing for assimilates, each individual fruit receives a proportionally greater share, resulting in a heavier but fewer total yield. Senthilkumar *et al.* (2024) [45] and Mistry *et al.*, (2025) [26] both reported superior fruit dimensions and fruit set percentage in Brinjal under combined inorganic-organic treatments. Osei *et al.* (2021) [30], working with eggplant under similar management conditions, found that poultry manure-based INM significantly improved both fruit weight and volume

compared to treatments relying exclusively on either organic or inorganic nutrients.

3.7 Fruit yield

Fruit yield both per plant and per hectare is the ultimate integrated expression of all growth, developmental and reproductive processes in the crop. Data are presented in Table 2.

T₃ recorded the highest fruit yield of 1.03 kg plant⁻¹, equivalent to 23.49 t ha⁻¹, while T₂ followed at 0.97 kg plant⁻¹ (22.29 t ha⁻¹). T₅ and T₄ ranked third and fourth at 20.22 and 18.53 t ha⁻¹, respectively. The control recorded the lowest yield at 7.68 t ha⁻¹, barely one-third of T₃. Purely organic treatments T₉ and T₁₀, despite receiving substantial nutrient inputs, yielded only 10.47 and 13.85 t ha⁻¹ confirming that organic sources alone, at the substitution rates evaluated, were insufficient to realise the yield potential of the crop.

The yield advantage of T₃ over all other treatments is not attributable to any single factor but is rather the cumulative result of consistently superior performance across every growth stage and physiological process: more vigorous vegetative development, earlier and more abundant flowering, better fruit set and larger fruit dimensions. The inorganic component of T₃ meets the crop's immediate nutrient demand at critical growth phases, while poultry manure owing to its lower C:N ratio than FYM contributes a more timely secondary nutrient release compared to bulkier organic sources. The interaction between these two pools creates a nutrient environment that is both adequate in quantity and consistent in supply over the season. Patel *et al.* (2023) [32] and Mistry *et al.* (2025) [26] documented the highest Brinjal yield under 75% NPK with 25% N from organic sources, directly corroborating these findings. Sarangi *et al.* (2025) [43] noted that replacing 25% of chemical N with FYM-derived N improved yield over 100% inorganic N application, attributing the gain to improved soil microbial biomass carbon and nutrient use efficiency. The substantially lower output from purely organic treatments is in line with what Sujatha *et al.* (2021) [61] described as a structural limitation of organic-only systems: the inability to consistently match crop nitrogen demand during peak vegetative and reproductive phases, especially in low-to-medium fertility soils.

Table 2: Flowering characteristics, Yield attributes and fruit yield of Brinjal as influenced by INM treatments

Treatments	Days to 50% flowering	Number of flowers plant ⁻¹	Fruits plant ⁻¹	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Fruit yield (kg plant ⁻¹)	Fruit yield (t ha ⁻¹)
T ₁	56.61	30.07	7.07	7.56	7.42	38.27	0.35	7.68
T ₂	49.61	83.57	19.99	9.42	9.15	52.86	0.97	22.29
T ₃	47.45	88.36	21.69	9.27	9.39	52.44	1.03	23.49
T ₄	50.19	69.23	15.89	9.14	9.02	53.99	0.8	18.53
T ₅	48.57	76.04	17.26	9.26	8.9	52.82	0.87	20.22
T ₆	50.86	59.66	14.18	8.73	7.62	54.15	0.73	16.32
T ₇	52.87	46.66	10.21	8.57	8.34	49.11	0.54	12.11
T ₈	54.75	48.04	11.34	8.12	8.27	49.99	0.59	12.61
T ₉	53.78	36.4	9.12	8.3	7.95	50.27	0.46	10.47
T ₁₀	52.24	53.42	12.93	8.59	8.26	50.48	0.63	13.85
SEm±	0.41	1.15	0.72	0.1	0.1	0.7	0.05	0.7
CD at 5%	1.23	3.47	2.27	0.32	0.3	2.12	0.16	2.12

3.8 Carbohydrate and protein content of brinjal fruit

With consumer awareness of nutritional quality rising alongside productivity concerns, the effect of nutrient

management on the biochemical composition of Brinjal fruit was assessed in terms of carbohydrate and protein content per 100 g of fresh weight (Table 3).

Carbohydrate content was highest in T₃ (3.92%), followed by T₂ (3.84%) and T₅ (3.54%). Control fruits recorded just 2.71%, while intermediate values were obtained from treatments with a higher organic fraction (T₇: 3.04%, T₈: 3.12%, T₉: 2.92%). Protein content followed a broadly similar gradient, peaking in T₃ (1.82%) and T₂ (1.80%) and reaching its minimum in T₁ (1.22%). The narrow gap between T₂ and T₃ for both parameters well within the CD values of 0.22% and 0.13%, respectively indicates that either treatment produces nutritionally equivalent fruit quality.

The enrichment of carbohydrate and protein content in fruits of T₃ and T₂ plants is mechanistically tied to their superior vegetative development and photosynthetic capacity. A larger canopy area captures more radiation, channelling greater quantities of photoassimilates into fruit development. Nitrogen, abundantly and stably supplied under these INM treatments, is the foundational element for amino acid and protein biosynthesis, while phosphorus activates key enzymes of both the Calvin cycle and glycolytic pathways that produce simple sugars subsequently polymerised into storage carbohydrates. The contribution of organic manures to trace element supply particularly manganese and iron, which are cofactors in photosynthetic electron transport further strengthens the photosynthetic and metabolic machinery of the plant. Subramanian and Tamilmani (2023) [60] reported analogous improvements in carbohydrate and protein content in eggplant under INM treatments that combined inorganic nitrogen with organic amendments. Osei *et al.* (2021) [30], examining proximate composition of eggplant fruits, similarly found that poultry manure-enriched INM treatments produced fruits with measurably higher protein and total carbohydrate content than those grown under either sole inorganic fertilization or control conditions. Sujatha *et al.* (2021) [61] also documented improved sugar and protein levels in Brinjal fruit under integrated organic-inorganic management, attributing the gains to the holistic improvement in soil nutrient status and plant metabolic activity.

Table 3: Carbohydrate content (%) and protein content (%) in Brinjal fruit as influenced by integrated nutrient management (100 g fresh fruit)

Treatments	Carbohydrate content (%)	Protein content (%)
T ₁	2.71	1.22
T ₂	3.84	1.8
T ₃	3.92	1.82
T ₄	3.47	1.74
T ₅	3.54	1.77
T ₆	3.38	1.67
T ₇	3.04	1.52
T ₈	3.12	1.45
T ₉	2.92	1.48
T ₁₀	3.25	1.54
SEm±	0.07	0.04
CD at 5%	0.22	0.13

3.9 Economics of cultivation

The agronomic superiority of a treatment carries practical value only when it translates into favourable economic outcomes for the farmer. A comprehensive economic analysis was carried out for all treatments, encompassing cost of cultivation, gross returns, net returns and benefit:cost ratio (Table 4).

In terms of absolute monetary returns, T₃ outperformed all others with gross returns of Rs. 1,87,905.50 ha⁻¹ and net returns of Rs. 1,33,209.88 ha⁻¹. T₂ followed with gross returns of Rs. 1,78,350.32 ha⁻¹ and net returns of Rs. 1,28,623.70 ha⁻¹. However, when returns are assessed relative to investment, T₂ proved more efficient, recording a B:C ratio of 2.87 compared to T₃'s 2.23. The cost differential between the two Rs. 55,553.39 ha⁻¹ for T₃ versus Rs. 43,835.10 ha⁻¹ for T₂ stems primarily from the higher market price of poultry manure compared to FYM. At the other extreme, T₉ generated a net loss of Rs. 1,769.61 ha⁻¹, while T₁₀'s net return of Rs. 3,338.10 ha⁻¹ was negligible relative to the investment involved. T₅, despite containing only half the inorganic nitrogen component, returned a B:C ratio of just 0.99 a consequence of the steep cost of applying poultry manure at 50% N substitution levels.

Table 4: Cost of cultivation, gross returns, net returns (zha⁻¹) and B: C ratio of Brinjal as influenced by integrated nutrient management

Treatments	Economics (₹ha ⁻¹)			
	Cost of cultivation	Gross returns	Net returns	B:C ratio
T ₁ : Control	27731.09	61454.87	36040.07	1.3
T ₂ : 75% NPK + 25% N through FYM	43835.1	178350.32	128623.7	2.87
T ₃ : 75% NPK + 25% N through Poultry Manure (PM)	55553.39	187905.5	133209.88	2.23
T ₄ : 50% NPK + 50% N through FYM	52003.7	148246.3	92054.67	1.74
T ₅ : 50% NPK + 50% N through Poultry manure	80369.72	158841.37	78316.36	0.99
T ₆ : 50% NPK + 25% N through FYM + 25% through PM	65245.51	130546.03	63544.52	1
T ₇ : 25% NPK + 50% N through FYM + 25% through PM	74723.89	96858.16	19081.74	0.25
T ₈ : 25% NPK + 25% N through FYM + 50% N through PM	86479.26	100901.04	17070.63	0.19
T ₉ : 75% N through FYM + 25% N through PM	82803.53	83784.87	-1769.61	-0.02
T ₁₀ : 75% N through PM + 25% N through FYM	107294.51	110801.87	3338.1	0.03

These economic outcomes reveal a clear pattern: the financial viability of a treatment is governed by the balance between the cost of organic inputs and the yield gain they generate. When poultry manure is used at modest supplementary doses, as in T₃ and T₂, it enhances yield sufficiently to offset its cost with a comfortable profit margin. At higher substitution rates or when used as the primary nutrient source, however, the cost of manure

application outpaces the marginal yield benefit, eroding profitability. Mistry *et al.* (2025) [26] similarly found that the combination of 75% NPK with 25% organic N gave the best economic efficiency among INM treatments for Brinjal, primarily because it holds cultivation costs in check while sustaining a high yield level. Kumar *et al.* (2022) [20], in their economic study of Brinjal cultivation in Mau district, Uttar Pradesh, found that integrating organic inputs with a

reduced chemical fertilizer dose consistently yielded higher B:C ratios than conventional full-dose chemical treatment. The poor economic performance of T_{and} T_{reflects} their fundamental limitation: organic manures at full N-substitution rates are expensive, release nutrients slowly leading to lower yields and provide relatively little phosphorus and potassium relative to crop demand, making them economically uncompetitive as standalone fertility sources. These findings collectively affirm that INM, with organic manures serving as strategic supplements rather than primary inputs, offers the most financially prudent path forward for Brinjal cultivation.

3.10 Summary

Examining the full dataset across growth, reproductive, yield and quality parameters alongside economic indicators, two treatments stand out consistently. T₃ (75% NPK + 25% N through Poultry Manure) demonstrated the strongest agronomic performance leading in plant height, stem girth, biomass, flower number, fruits per plant, fruit yield (23.49 t ha⁻¹) and nutritional quality, and generating the highest absolute net returns. T₂ (75% NPK + 25% N through FYM) closely matched T₃ across all measured parameters and proved to be the economically superior option, with the highest B:C ratio of 2.87. Treatments relying exclusively on organic nitrogen (T₉ and T₁₀) were consistently outperformed by INM combinations for both productivity and profitability. These results collectively underscore that integrating a modest proportion of well-chosen organic manure within a primarily inorganic fertilization framework is the most effective strategy for optimising Brinjal yield, quality and farm income under the conditions studied.

3.11 Conclusion

The present investigation on the effect of integrated nutrient management on growth, yield, quality and economics of Brinjal (*Solanum melongena* L.) clearly establishes the superiority of combined organic-inorganic nutrient management over either sole chemical fertilization or sole organic nutrient management approaches.

Treatment T₃ (75% NPK + 25% N through Poultry Manure) proved agronomically superior, recording the highest fruit yield (23.49 t ha⁻¹), carbohydrate (3.92%), and protein content (1.82%), attributed to the complementary roles of immediate and slow-release nutrient supply. Treatment T₂ (75% NPK + 25% N through FYM) was the most economically viable, with the highest B:C ratio of 2.87 and net return of ₹1,28,623.70 ha⁻¹, making it ideal for cost-conscious farmers.

Treatments with higher organic substitution (T₇-T₁₀) consistently underperformed, with T₉ recording negative net returns (₹ -1,769.61 ha⁻¹), confirming that complete replacement of chemical fertilizers with organics is neither agronomically adequate nor economically feasible for this nutrient-demanding crop. It is concluded that a minimum of 75% inorganic NPK must be retained in the nutrient schedule, supplemented with 25% N through poultry manure or FYM, for optimum yield and economic returns. Adoption of this INM strategy is recommended for Brinjal growers in Uttar Pradesh and comparable agro-climatic zones to enhance productivity, farm income, and long-term soil health.

The results of this study have direct practical implications for Brinjal growers in Uttar Pradesh and similar agro-

climatic regions. Adoption of the recommended INM practice 75% NPK supplemented with 25% N through either poultry manure or FYM can substantially increase farm income while simultaneously improving soil health through organic matter addition, contributing to the long-term sustainability of vegetable production systems.

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